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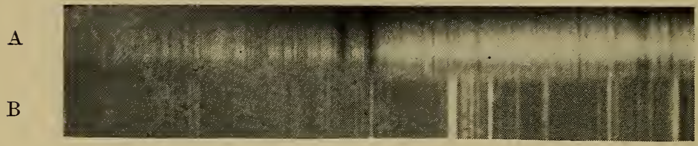

Fig. 1

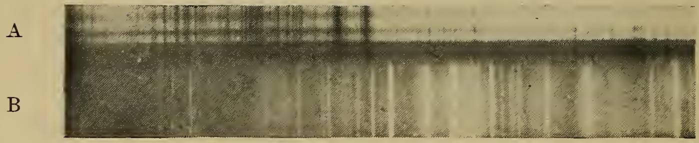

Fig. 2

Fig. 3

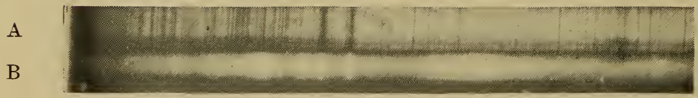

Fig. 4

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[FOURTH SERIES.]

ART. I.—*On Spectra Arising from the Dissociation of Water Vapor, and the Presence of Dark Lines in these Spectra;* by JOHN TROWBRIDGE. (With Plate I.)

IN passing from the study of the light emitted by gases under the effect of electrical discharges of comparatively small quantity to the investigation of the light produced by discharges of great quantity, a new field of research is entered. In previous papers on the spectra of hydrogen, I have stated my convictions of the importance of the role played by water vapor in spectrum tubes. The results of further study emphasize these convictions. With powerful discharges in hydrogen, oxygen, and rarified air, I always obtain the same spectrum, which I regard as that arising from the dissociation of rarified water vapor. The line spectrum, moreover, is accompanied by a faint continuous spectrum on which are dark lines, which indicate a selective reversibility in the silver salt, which is of great significance, it seems to me, in the applications of photography to astrophysics.

It has long been recognized that spectrum analysis is an extremely delicate method of recognizing the presence of a gas or the vapor of a metal under the excitation of heat; and when the improvements in photography enabled us to obtain permanent records of the spectra of gases, it was supposed that we had a means of escaping from the fallacies of eye observations which arose necessarily from personal idiosyncracies. If the photographic plate were a perfect instrument for recording the infinite number of vibrations which light can communicate to atoms of matter, we should certainly feel that we had made a great advance in physical science. When we reflect, however, on the belief that emulsions containing silver salts are capable of responding to all wave lengths of light in the portion of the spectrum considered most actinic, even when the light exceeds a certain intensity, we are conscious that we cannot rely upon an infinite range of photochemical action; and I shall show in this paper the existence of a selective reversibility produced on the photographic plate by powerful discharges of electricity through capillary tubes.

Realizing the importance of studying the behavior of gases under different forms of excitation, I have collected in the rooms devoted in the laboratory to spectrum analysis three forms of apparatus: an induction coil actuated by a very efficient liquid break, giving a spark of thirty inches in air; a step-up transformer excited by an alternating current, producing with glass condensers of about ·3 microfarad, discharges of an inch in length, of great body; and a storage battery of twenty thousand cells. A plant of this nature I conceive to be necessary in the present state of spectrum analysis, for molecular motions excited in rarified gases vary greatly with the kind of electrical discharge. In the application of photography to spectrum analysis, the investigator is immediately confronted with the necessity of submitting the gas to a comparatively long electrical stimulus in order to obtain a negative. Even with a concave grating of short focus several discharges are necessary with a narrow slit. Each discharge is capable of modifying the condition of the gas. This fact is well recognized by taking successive photographs of the light emitted by a spectrum tube under different strengths of current upon the same photographic plate. A simple form of plate holder enables this to be done. One obtains a striking example of the instability of the spectrum tube filled with apparently dry hydrogen when one subjects it first to very powerful discharges from a glass condenser of ·6 microfarad, charged by a storage battery of twenty thousand cells, with practically no self-induction in the circuit; and follows this excitation by the use of an alternating discharge of much less quantity. The powerful discharge gives what I term the water vapor spectrum; and after a certain number of these discharges one obtains with the alternating current discharges the spectra of argon. This results, I suppose, from the oxidization of traces of air in the tube. The hydrogen has disappeared momentarily; possibly the dissociation of the water vapor resulted in concealing its presence.

The period of the condenser discharges which I have employed varied from one five hundred thousandth of a second to one millionth. The practically instantaneous current varied from five thousand amperes to ten thousand. The revolving mirror method showed that the pilot spark was mainly effective, and that the subsidiary oscillations were feeble. The spectrum tube speedily became milk white from the sodium set free from the glass.

Lord Rayleigh* has shown how to demonstrate the presence of argon from very small quantities of air. My method is substantially his, except that I employ very powerful discharges which set free a sufficient amount of sodium vapor from the glass, and the oxygen is supplied from the dissociation of the water vapor, which is always in evidence when such powerful discharges are employed. The production of argon under these circumstances is a striking proof that I am dealing in this investigation with the spectrum of the dissociation of water vapor. From the same tube one can, by modifying the strength and character of the electrical discharges, obtain what is termed the four-line spectrum of hydrogen, the spectrum of sodium, the spectrum of argon, and the spectrum of the dissociation of water vapor. Doubtless one could also recognize the spectrum of helium; I am not yet sufficiently familiar with it.

In the course of a study of the water vapor spectrum one is naturally led to photograph the spectrum of the electric spark under water. It is possible to obtain powerful discharges of any suitable length under distilled water by enclosing the spark terminals in glass tubes, allowing only a small portion of the platinum terminals to project from the ends of the tubes. If the terminals are immersed more than an inch under water, the resulting explosion is apt to break the glass-containing vessel. The light of these discharges under distilled water is white and extraordinarily brilliant to the eye. When it is examined by the spectroscope one sees a continuous spectrum; and one obtains a continuous spectrum even by photography in the most actinic portion of the spectrum. On bringing the spark terminals to the surface of the water, leaving them barely immersed, one immediately obtains the so called four-line spectrum of hydrogen. To what is due the continuous spectrum under water? Does it result from the production of the water vapor spectrum under great pressure? That there is great pressure is shown by the sudden explosion, which is sufficient to blow the small tamping of water out of both ends of the containing tube. If the surface of the water is covered with a thin film of oil, this oil is immediately disseminated through the water, a milky white emulsion, which remains for days.

When we turn to powerful discharges through Geissler or Plucker tubes filled with hydrogen which has been dried with great care, we also obtain a continuous spectrum on which are superposed the bright lines of the water vapor spectrum, together with certain reversed lines, giving on the positive

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*Phil. Mag. (6), vol. i, 1901, p. 103.

dark lines instead of bright lines. Moreover, what are apparently the strongest bright lines of the water vapor spectrum are not reversed. There is a selective reversibility which arises with high temperatures, and is made evident by the faint background of the continuous spectrum.

This fact seems to me to be of great importance in the application of photography to the study of celestial phenomena, for reversal of spectrum lines do not necessarily indicate reversing layers of cooler gas, and may be a photochemical action of the silver plate.

One immediately thinks in this connection of the phenomenon of dark lightning or the Clayden effect, and of the suggestive experiments of Professor Nipher.* Spectrum analysis, however, reveals a selective reversibility, which shows that the subject of photochemistry must be carefully studied before we can interpret properly the records of photography in spectrum analysis.

There are doubtless many states of vibration even in the actinic portion of the spectrum which are not recorded by the silver salts, for a selective reversing action may obliterate or prevent a permanent record.

I have obtained this reversing action with different emulsions on glass and also on celluloid films. The strongest reversals are at wave lengths 4227, 3930, 3965. There is also a reversed band between wave lengths 4315 approximately and 4285, and a faint reversal at wave length 3953. Reversals are often seen on the negatives which disappear in the fixing bath.†

In this investigation ten thousand storage cells were employed to charge a glass condenser of ·60 microfarads. The charge was sent through Geissler tubes having an internal bore of one millimeter; the length of the capillary of this diameter was from eight to ten centimeters. The tubes were filled with apparently dry hydrogen at a pressure of approximately $·1^{mm}$.

I have reached a limit in submitting gases in glass tubes to powerful electric discharges, and am now turning my attention to the subject of quartz tubes in the hope of obtaining these in a suitable form for containing rarified gases.

In a previous paper,‡ I have expressed my conviction that the four-line spectrum observed in the protuberances of the sun is an evidence of the dissociation of water vapor in the sun's atmosphere, and an evidence therefore of the presence

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* Transactions Academy of St. Louis, vol. x, No. 6, On certain properties of light struck photographic plates.

† In this connection the following paper is significant: Disappearance of images on photographic plates. William J. S. Lockyer, Nature, Jan. 17, 1901.

‡ This Journal, vol. x, Sept. 1900.

of oxygen. In the spectrum one sees two reversed bands which coincide with the great H. H. lines in the solar spectrum; one also sees a reversed line at wave length 4227, closely coincident with a strong solar line; one has also a reversed band coinciding with a region of reversals in the sun between wave lengths 4315–4285. These regions in the sun are doubtless composite photographs of many reversals of different elements. I believe, however, that the basis of the reversals is the presence of dissociated water vapor.

The nomenclature, too, of the stars in relation to their spectra I believe should be changed to dissociation spectra; an excess of water vapor produces what is termed the hydrogen type, and the dissociation of this water vapor in the presence of other gases, nitrogen for instance, together with metallic vapors, may account for other types.

The intense light due to the dissociation of water vapor may, in some cases, mask the fainter light of the metallic lines in the stars which show only gaseous spectra, especially when we consider the varying distances of the stars. I have employed electrodes of platinum, copper, silver, aluminum, iron, and aluminum, and no trace of the lines of their vapor can be perceived in the photograph of the gaseous dissociation spectra; moreover, when sodium is present in the spectrum tubes, although it fills the tube with a brilliant yellow light at low voltage and strong currents, and exhibits the sodium lines very strongly, no trace is seen of it, with very powerful discharges. The tubes then show only the brilliant white light due to the dissociation of water vapor: a light which is the nearest approach to sunlight which I have been able to produce. Its actinic effect is greater than that of any of the metals, such as magnesium, aluminum or zinc. Possibly the varying amount of water vapor may be a factor in the variability of certain stars; and one is led to conjecture whether the light of the sun's atmosphere is not due to an electrical dissociation due to discharges of very high period.

The selective reversibility of the silver salts seems to me of momentous importance in the subject of astrophysics; for we have reversible actions on the photographic plate which are not due to the radiations of a gas passing through colder layers of the gas. In other words, we have actions recorded which are photochemical and are not in the heavens. It may be that certain reversals observed in the spectrum of Nova Persei may be of this nature. This selective reversibility serves to reveal certain lines which escape observation. Thus we see that there is a gaseous line at wave length 4227, and a line not shown on the reproductions but clearly seen on the negatives between the great H. H. lines, having a wave length of 3953.

The silver salt, therefore, does not respond to all rates of vibration; or if it does respond, the molecule is unstable and there is no resultant reaction which is evidenced by a photographic image. There may be spectra at very high instantaneous temperatures which we cannot photograph. It seems reasonable to suppose that the silver molecule is limited in its rates of vibration and that the photographic plate as well as the human eye is a limited instrument of research.

On Plate I, A represents the solar spectrum in the neighborhood of the great H. H. lines. B represents the gaseous spectra. The photographs were taken with a Rowland concave grating, and are not enlarged or touched in any way. Unfortunately the reproductions do not give many of the reversals, Figs. 1 and 2, B are spectra of air and oxygen taken with a comparatively low voltage and amperage at a pressure of about one millimeter. Fig. 3 is a spectra of hydrogen under the same conditions. Fig. 4 is the spectrum arising from the dissociation of water vapor with very powerful discharges. Fig. 5 shows a selective reversal line at approximately 4227. On the negative the two bright gaseous lines, which in fig. 4 closely coincide with the great H. H. lines, are seen to be reversed and appear as dark lines. This reversal is shown in fig. 7. B of fig. 7 closely resembles in general features the solar spectrum when the latter is photographed with a broad slit, so as to obliterate details and give broad characteristics.

My conclusions are as follows:

Dissociation of water vapor takes place in the atmosphere of the sun; oxygen, therefore, must be present. From a careful study of my negatives, I regard the evidence for the presence of water vapor as conclusive as that accepted for the presence of sodium in the sun.

The dissociation of water vapor, under the effect of powerful electric discharges in the presence of small amounts of atmospheric air, results in the production of argon even in tubes presumably filled with dry hydrogen.

The spectrum arising from the dissociation of water vapor contains dark lines as well as bright lines. These dark lines are due to a selective reversibility of the silver salt employed in the photographic emulsions, and are not due to the reversing action of a cooler layer of gas. The great brilliancy of the dissociation spectrum of water vapor, which obscures the spectra of metallic vapors: and the presence of dark lines due to photochemical reversals, make one cautious in accepting photographic evidence in regard to states of development of stars.

Jefferson Physical Laboratory,
Harvard University.

ART. II.—*Occurrence of Greenockite on Calcite from Joplin, Missouri;* by H. B. CORNWALL.

A YELLOW coating of greenockite on the sphalerite of the Joplin zinc district is no uncommon occurrence, and having received, through the kindness of Messrs. Geo. L. English & Co., of New York, specimens of calcite from this locality which showed a very distinct greenockite coating, the writer made tests upon the material, to determine what proportion of cadmium sulphide the coating might contain.

The greenockite occurs as a bright yellow, dust-like coating, which can be easily rubbed off with the finger. Beneath the greenockite coating, and often extending beyond it, there is, for the most part, a brown or yellowish brown, more adherent deposit, in a thin layer which can be easily scaled off with the knife-point. This seems to be sphalerite.

The greenockite was removed by very gentle scraping with the knife and subjected to the tests below. Although in places it is very distinct, the coating is also very light, and from an area nearly two centimeters square not more than 0·0014 grm. of the purest material could be obtained. Even this portion was found to be mixed with zinc compounds from the scale-like deposit below it.

Gently roasted on platinum foil over a Bunsen flame, the powder on cooling was brown in some parts, and nearly white (distinctly yellow while hot) in others, indicating cadmium and zinc oxides.* The roasted powder, mixed with an abundance of charcoal dust and heated to moderate redness in a closed glass tube, gave a brownish sublimate (cadmium oxide), and on stronger heating a less volatile sublimate, yellow while hot, white on cooling (zinc oxide).

On roasting 0·0014 grm. in a small platinum dish, dissolving the residue in sulphuric acid, evaporating and gently igniting, a residue was obtained which weighed 0·002 grm. Theory requires from pure cadmium sulphide 0·00202 grm. of cadmium sulphate; but as a mixture of sphalerite and calcite similarly treated might give the same figures, this result does not indicate with any certainty the proportion of cadmium in this lot of material.

A second lot, also weighing 0·0014 grm., was dissolved in nitric acid, evaporated to dryness with sulphuric acid, and heated to expel all free acid, the residue treated with a single drop of hydrochloric acid, sp. gr. 1·20, and dissolved in four

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* When not too strongly heated at first, the yellow coating assumes a transient dark brown or reddish-brown color, and becomes yellow again on cooling.

cubic centimeters of water. The whole was then saturated with hydrogen sulphide gas, giving very quickly a yellow precipitate, and this, after letting the gas act long enough, was filtered off, dissolved in strong hydrochloric acid, evaporated with sulphuric acid, ignited and weighed as sulphate. By this means the coating tested was found to contain 23·07 per cent of cadmium, or 29·66 of cadmium sulphide. It should be said that the coating yields sulphur dioxide when roasted.

By comparing the liquid holding in suspension this cadmium sulphide with another in which a known amount of cadmium sulphide had been precipitated, it had already been estimated that the yellow coating on the calcite contained not less than 15 per cent of cadmium.

Finally, although the Joplin sphalerite on which greenockite occurs will give a distinct reaction for cadmium when roasted and reduced with charcoal in the closed tube, in the manner already described, yet it was found that no precipitate could be obtained from it by hydrogen sulphide, even after thirty minutes action, the treatment being quantitatively, and in every other respect, exactly the same as described for the yellow coating on the calcite. A mixture corresponding to a sphalerite containing 5 per cent of cadmium yielded a precipitate of cadmium sulphide, under identical conditions, in a few minutes. Dana (System of Mineralogy, 6th ed.) states that the amount of cadmium present in any sphalerite thus far analyzed is less than 5 per cent.

It therefore appears certain that this yellow coating on the calcite, like that on the Joplin sphalerite, is greenockite.

John C. Green School of Science,
Princeton University.

ART. III.—*A Quantitative Study of Variation in the Fossil Brachiopod Platystrophia lynx*;[*] by EDGAR R. CUMINGS and ABRAM V. MAUCK. (With Plates II and III.)

DURING the year 1900–01 the authors made extensive collections of the brachiopod *Platystrophia lynx* from the Upper Ordovician rocks at Vevay, Indiana (Switzerland Co.).

Inasmuch as this species is extremely variable and at the same time exceptionally abundant and well preserved, a quantitative study of the variations presented at once suggested itself. Such an investigation is the more warranted because of the different opinions current as to the taxonomic importance of several of the forms under which *Platystrophia* presents itself.[†]

The specimens used in this investigation were collected from a zone which at Vevay extends from 240 ft. to 360 ft. above the level of the Ohio River. Part of the material was so collected that the precise layer is known from which a given specimen came; the object being to determine as accurately as possible the factor of range.[‡] The majority of the specimens used are from the upper 50 or 60 feet, and the upper 20 feet contains by far the most as well as the best of the material. Examples could not be obtained in sufficient abundance from the base of the *Platystrophia* zone to make a quantitative treatment possible; but we were able to ascertain that in the lower part of its range at Vevay, and in general throughout the Ohio Valley, *Platystrophia* presents less variation than at higher horizons; and that in the lower beds only the small pauci-plicate form is present.[§]

Beside the material collected layer by layer, a large collection was made from the upper beds wherever exposures could be found in the vicinity of Vevay.

The data taken for study are: Ratio of width to length of shell (equals shell index); ratio of depth to breadth of sinus

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[*] Presented before Section E at the Denver meeting of the American Association for the Advancement of Science, August, 1901.

[†] For synomony and bibliography of *Platystrophia* see Davidson, Silurian Brachiopoda, 1871, p. 268; Hall and Clarke, Pal. N. Y., vol. viii, pt. i, pp. 200, 201; Schuchert, Am. Foss. Brachiopoda, Bull. U. S. G. S., No. 87, pp. 308–310.

[‡] The Vevay section is published in the Am. Geol., vol. xxviii, Dec., 1901, pp. 361–381. By reference to page 373 of that paper it will be seen that the lowest specimens of *Platystrophia* (associated with *Dekayia ulrichi*) are small and of a type similar to var. *laticosta* or var. *dentata* Meek (*crassa* James). The form *lynx* does not come in till within 30 or 40 feet of the top of the section.

[§] Specimens have been examined from these lower zones at Cincinnati, Ohio, Lawrenceburg, Aurora, Rising Sun, Vevay and numerous points on Laughery Creek in Indiana.

(equals sinus·index); number of plications on ventral valve; number of plications on dorsal valve; number of plications in sinus; number of plications on fold.*

The width of the shell is in every case the greatest width, whether this occurs at the hinge line or farther forward. It was obtained by means of adjustable spring calipers. The width of the sinus was obtained by spreading the points of spring dividers between the anterior lateral angles of the sinus. The depth of the sinus was obtained by spreading the points of the dividers from one anterior lateral angle of the sinus to the anterior extremity of the first adjacent furrow in the bottom of the sinus. All measurements were read off on a millimeter scale and are correct to within 0·25^{mm}.

The number of shells used varies for the several characters indicated above, on account of imperfect material. Only entire shells were used for measurements; but the number of plications, especially the number in the sinus, may frequently be determined with accuracy on very poorly preserved specimens. The number of shells used in determining any one character is called a *group.*

Group I, Shell Index.

Width divided by length. Number of shells used, 679. Range of variation from 1·0 to 1·8. Mode† at 1·3, with frequency of 300·4.‡ Variation here is moderate in amount, and in the direction of greater width than length.

Group II, Sinus Index.

Width of sinus divided by depth of sinus. Number of shells used, 664. Range of variation from 0·9 to 3·0. Mode at 1·7 with a frequency of 112·2. Variation great in amount, and in the direction of a shallow sinus.

Group III, Number of Plications on Ventral Valve.

Number of shells used, 1173. Range of variation from 10 to 28. Mode at 17 with a frequency of 176·3. Variation large in amount, and in the direction of the greater number of plications.

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*Prof. Shaler has given (Foss. Brach., Ohio Valley, p. 43) a series of measurements of a limited number (20) of specimens of *Platystrophia.* His series includes also forms from Richmond, Indiana, and other American localities. In a forthcoming paper I shall take up the discussion of material from all the provinces both American and European, where *Platystrophia* is known to occur.—E. R. C.

† The term *mode* means the highest point of the curve, i. e., the class with the greatest frequency.

‡ For the purposes of comparison all frequencies were reduced to frequencies per thousand.

FREQUENCIES PER THOUSAND.

Classes	0·9	1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	3·0	Number of Shells used.	Constant for reduction to 1000s.
Group I		1·47	55·96	266·55	300·43	212·06	98·67	51·54	10·30	2·94														
Group II	4·5	9·03	9·03	33·13	51·20	60·24	70·78	106·92	112·95	103·91	90·36	78·31	73·79	57·22	39·15	31·62	30·12	19·57	12·04	3·01	1·50	1·50		

ABSOLUTE FREQUENCIES.

Group I		1	38	181	204	144	67	35	7	2													679	1·4727
Group II	3	6	6	32	34	40	47	71	75	69	60	52	49	38	26	21	20	13	8	2	1	1	664	1·5060

FREQUENCIES PER THOUSAND.

Classes	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29				
Group III	0·85	4·26	5·96	37·51	43·47	107·41	120·20	176·46	152·59	118·49	115·08	50·29	31·54	17·90	8·52	5·11	1·70	1·70	·85					
Group III*a*		2·21	13·30	24·39	55·43	93·12	110·86	119·73	199·55	133·03	104·21	57·64	35·47	17·73	13·30	6·65	4·43	4·43	2·21	2·21				

ABSOLUTE FREQUENCIES.

Group III	1	5	7	44	51	126	141	207	179	139	135	59	37	21	10	6	2	2	1				1173	0·8525
Group III*a*		1	6	11	25	42	50	54	90	60	47	26	16	8	6	3	2	2	1	1			451	2·2173

FREQUENCIES PER THOUSAND.

Classes	1	2	3	4	5	6	7	8																
Group IV	14·87	26·91	725·19	174·21	39·11	4·24	1·41																	
Group V		17·92	23·29	793·85	123·64	37·63	2·68	0·89																

ABSOLUTE FREQUENCIES.

Group IV	21	38	1024	246	75	6	2																1412	0·7082
Group V		20	26	886	138	42	3	1															1116	0·8960

Group IIIa, Plications on Dorsal Valve.

Number of shells used, 451. Range of variation from 11 to 29. Mode at 18 with frequency of 199·55. Variation correlated with that of Group III.

Group IV, Plications in Sinus.

Number of shells used, 1412. Range of variation from 1 to 7. Mode at 3 with frequency of 729·1. Variation in the direction of the larger number of plications.

Group V, Plications on Fold.

Number of shells used, 1116. Range of variation from 2 to 8. Mode at 4, with a frequency of 793·8. Variation precisely correlated with that of Group IV.*

The complete data are charted on page 11. The method of constructing the curves of fig. 1 is the usual one of laying off the classes along the axis of abscissas and the frequencies along corresponding ordinates.

The lack of correspondence between Groups III and III*a*, which should be exactly correlated, is due to the relatively small number of specimens used in Group III*a*. It forcibly emphasizes the necessity of using as large series of specimens as possible.

All the curves are skewed. None of them show more than one mode. They all rise abruptly and fall off less abruptly. This shows a certain correlation of the different variants.

An attempt was made to determine the relation of the number of plications in the sinus to the number on the entire valve. Hall says: "The prevailing number of lateral plications is seven on each side of the sinus or lobe; and so long as the mesial plications remain three and four, so long the lateral ones are seven. As soon as there is even an appearance of a departure from this number on the mesial lobe and sinus, and where the rudiment of an additional plait is visible, we then find the lateral plaits to be nine or ten."†

Our material does not bear out this statement. To test the point it was assumed that there is a precise correlation between number of plications in the sinus and number of plications on the whole valve. The area of the frequency polygon for any given number of plications in the sinus should then be equal to the sum of the areas of the frequency polygons of a definite number of plications on the valve. For example, the frequency polygon of three to four plications in the sinus has an area equal to that of the sum of the areas of the frequency

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* While there is necessarily one more plication on the fold than in the sinus, the fact that many specimens, owing to state of preservation, can be used for the determination of one group that are not available for the other, makes the two groups supplement each other.

† Hall, Pal. N. Y., vol. i, 1847, p. 134.

polygons of seventeen, eighteen, nineteen, and twenty plications on the ventral valve. Therefore any shell with four plications in the sinus should have between seventeen and twenty (both numbers inclusive) plications on the valve. It should have no more and no fewer.

An inspection of our material does not show this to be the case. In a series of 153 specimens with four plications in the sinus, the range is from 16 to 26 plications on the ventral valve. The average is 18·8 plications. The specimens with two plications in the sinus have from 11 to 22 plications on the valve. Those with one plication in the sinus have from 10 to 15 on the valve. The correlation is approximate rather than precise.

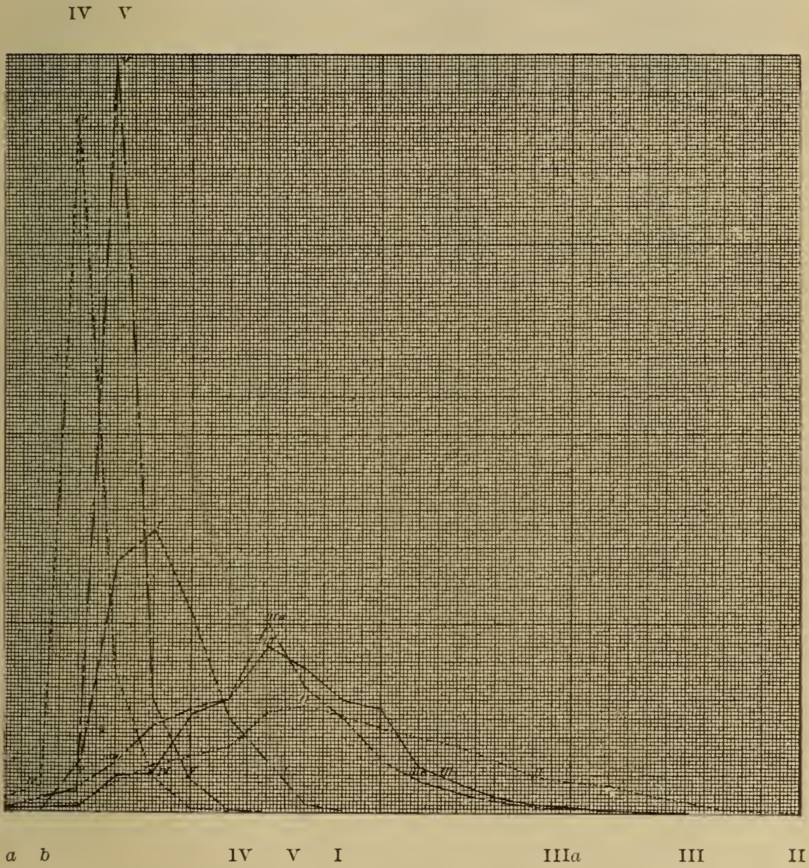

FIG 1. Curves of Groups I to V. On the axis of ordinates, each small division represents four individuals. On the axis of abscissas, each fifth (as from *a* to *b*) represents one class.

An inspection of Plates II and III shows the small size of the extreme forms, and conversely the large size and robust growth of those forms near the modes. The largest specimens will not be found exactly at the mode in any of the characters for which curves are plotted, but in classes to the right of the mode. That is, while it is true, for example, that by far the majority of specimens have three plications in the sinus, the largest specimens are more likely to be found in classes having more than three plications in the sinus. They will never be found in classes having less than three plications. When, however, the class falls some distance to the right of the mode it will again be found to contain small specimens. Smallness of size is, therefore, an accompaniment of the general extinction that prevails more and more, away from the mode. In the case of the number of plications on the valve, extinction does not become severe till the 20th is reached; and in the classes between 17 and 20 will be found the largest individuals.

In regard to the validity of the several species or varieties into which the *lynx* group of forms has been divided, namely, *Platystrophia lynx*, *P. laticosta*, *P. dentata* Meek (= *P. crassa* James), *there is absolutely no character or combination of characters* that can be relied upon to separate any large collection into distinct species. To a limited extent the above forms differ in range; although the authors have frequently seen all three represented on a single slab of limestone. It is well, however, to distinguish for stratigraphic purposes such varieties as *laticosta*, and *dentata* Meek.*

The following is a description of the modal form of *Platystrophia lynx:* shell three-tenths wider than long; greatest width about half-way from the hinge line to the front of the shell; width of sinus seven-tenths greater than its depth; seventeen angular plications on the ventral valve, three of which are in the sinus; eighteen on the dorsal valve, four of which are on the fold.

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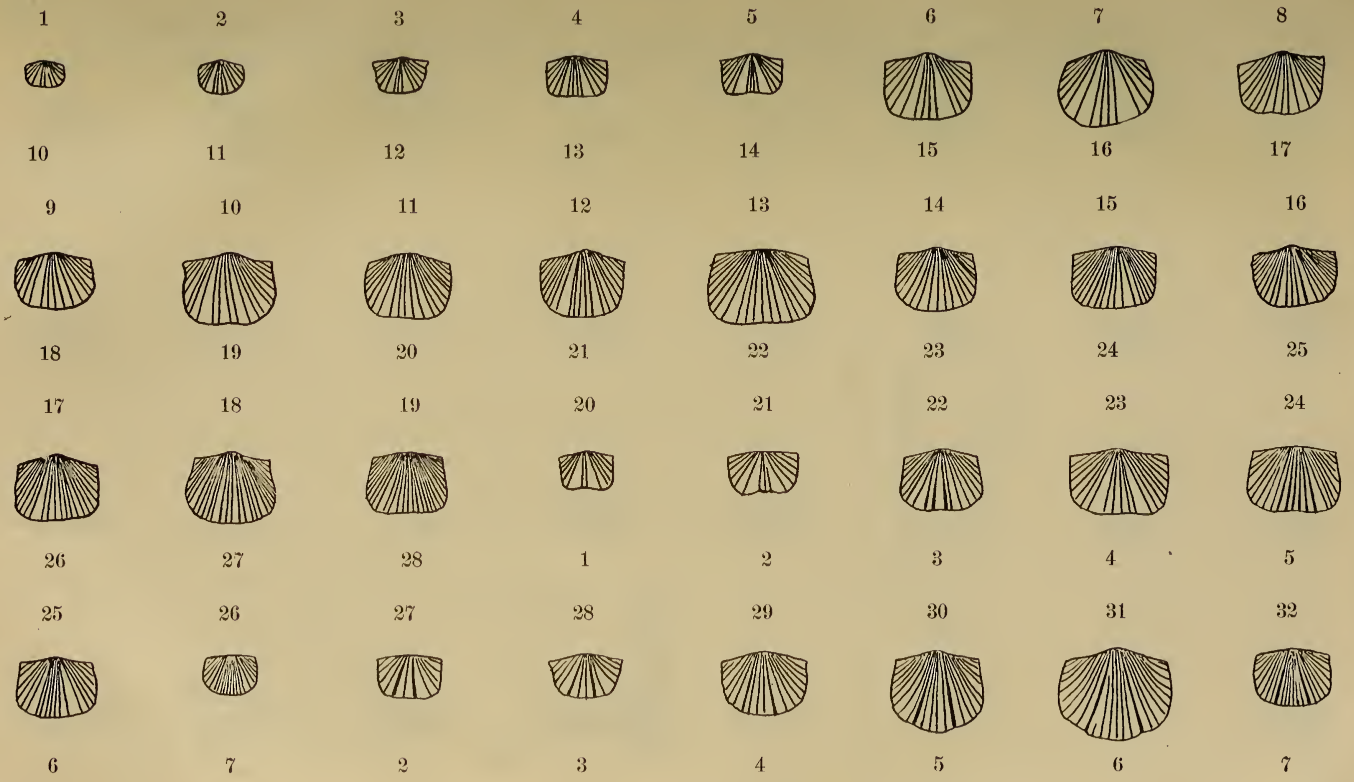
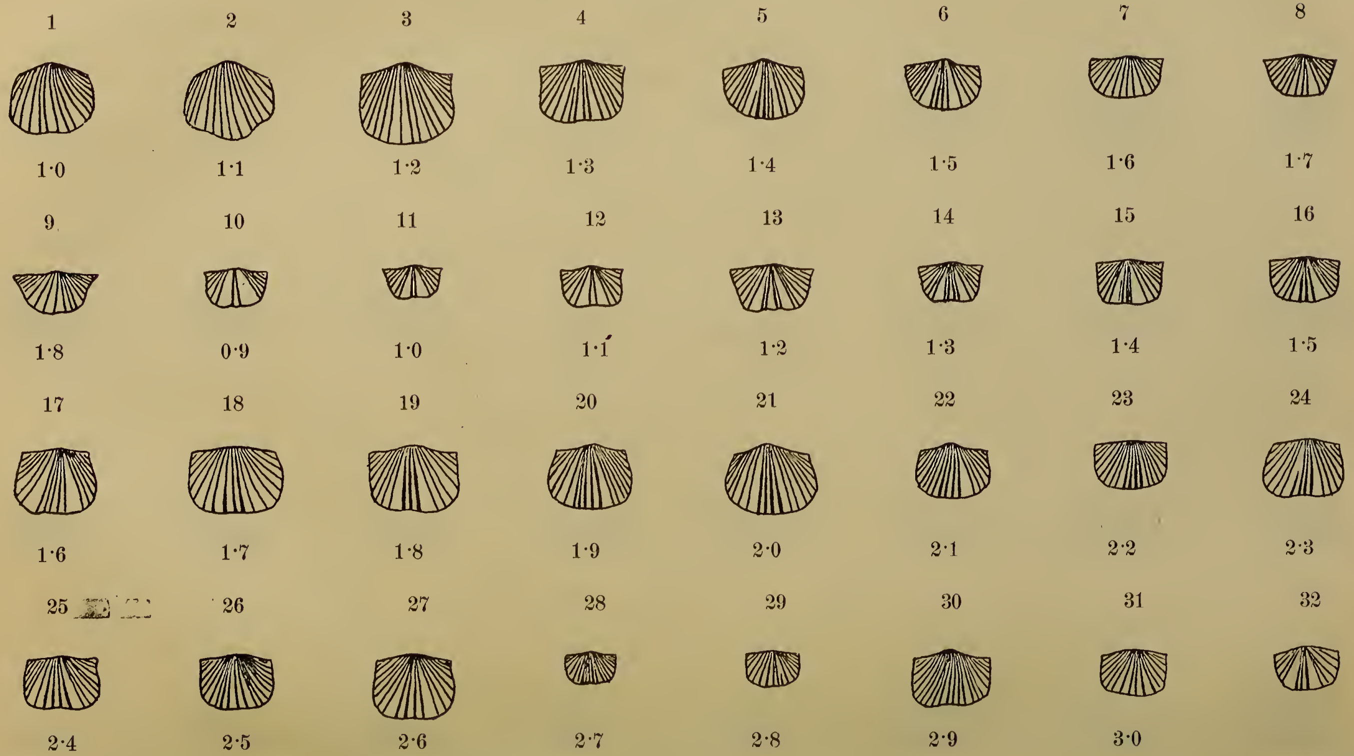
*As stated in a preceding footnote, the other forms, *acutilirata* Conrad, *biforata* Schl. and other foreign forms of *Platystrophia* are not considered in this paper. The form identified by Miller, and doubtfully by Meek, as *dentata* Pander is the *costata* of the latter author. Pander has figured *dentata* and *costata* (= *chama* Eichwald) side by side on pl. xi of his Beitrage zur Geog. Russ. *Dentata* has two plications in the sinus and three on the fold, while *costata* has one in the sinus and two on the fold. The name *chama* Eichwald cannot be retained for this variety, since the *Spirifer costatus* of Sowerby is a true *Spirifer*, and there is no other prior use of the name *costata* among the Orthidæ. See de Verneuil Geol. de la Russie, p. 140, and Sowerby, Tr. Geol. Soc. Lond., 2d ser., v, pl. lv, fig. 5–7. On the varieties of *Platystrophia* see especially Meek, Pal. Ohio, i, 1873, pp. 112–121; Hall, Pal. N. Y., i, 1847, pp. 133–134; Winchell and Schuchert, Minn. Geol. Surv., iii, 1893, pp. 454–457; Davidson, British Silurian Brachiopoda, 1871, p. 268 et seq.; Schuchert, Bull. 87, U. S. G. S., p. 308; Sardeson, Am. Geol., xix, p. 109.

PLATE II.



Figs. 1 to 19 inclusive, plications on ventral valve. Figs. 20 to 26 inclusive, plications in sinus. Figs. 27 to 32 inclusive, plications on fold. Numbers below the figures refer to number of plications in each case.

PLATE III.



Figs. 1 to 9 inclusive, shell index. Figs. 10 to 31 inclusive, sinus index. Numbers below the figures give the value of the index in each case.

ART. IV. — *Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. WORTMAN.

[Continued from vol. xiii, p. 448.]

Sinopa minor sp. nov.

A SMALLER species is represented in the Marsh collection by numerous remains, all in a somewhat fragmentary condition. Of these, I select as the type a considerable portion of a mandibular ramus of the right side, containing the three posterior premolars and the first and second molars in place, figure 96. There is also the anterior part of the opposite ramus, which contains the root of the canine and those of the anterior premolars. With this, I associate as a cotype a fragment of a right upper jaw bearing the fourth premolar and first molar, figure 97. The characters of this species, as exhibited by the type and cotype, are as follows: The size is much smaller than either *S. rapax* or *S. gracilis;* the canine is of the usual proportions; the small single-rooted first premolar is implanted some distance behind the canine, and is separated from it and the second premolar by considerable diastemata; the second premolar is two-rooted and separated from the third by a short interval, differing in this respect from both *S. rapax* and *S. gracilis;* the third and fourth premolars have the usual form; the first molar is relatively small, with low trigon and a large basin-shaped heel; the second molar is larger, with high trigon and large heel; the internal cusps are but little reduced, differing in this respect from *S. gracilis* and agreeing with *S. rapax;* the last molar is not preserved in the type; the fourth superior premolar is like that of *S. gracilis*, except that the internal cusp is more conical; the postero-external blade exhibits faint traces of a bilobed condition, which is not seen in *S. gracilis;* the two main external cusps of the first molar are well separated; there is a more distinct posterior intermediate, and an internal cingulum, all of which are different from *S. gracilis.*

96

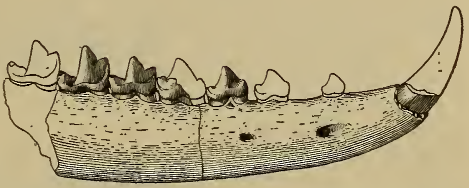


FIGURE 96.—Right lower jaw of *Sinopa minor* Wortman; side view; natural size. (Type.)

97

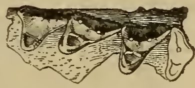


FIGURE 97.—Fragment of a right upper jaw of *Sinopa minor* Wortman; crown view; natural size. (Cotype.)

There are three or four individuals that agree perfectly with the type and cotype, but there are others that have a heavier build and are perceptibly larger. I cannot detect any further differences in the materials at hand, however, which would warrant referring the latter to another species. It may be that more complete specimens will necessitate their separation. Additional characters derived from these specimens are: Second lower molar equal to, or slightly larger than, third; last superior molar without postero-external cusp, and second superior molar, as well as first, with distinct internal cingula.

The measurements of the type are as follows:

Length of inferior dental series from base of canine, exclusive of last molar	42· mm
Length of premolars	30·
Length of first and second molars	12·
Length of entire inferior dental series (estimated)	48·5
Antero-posterior diameter of first molar	6·
Antero-posterior diameter of second molar	7·
Antero-posterior diameter of third molar (not type)	6·4

Measurements of Cotype.

Length of fourth premolar and first molar	13·
Antero-posterior diameter of fourth premolar	6·
Antero-posterior diameter of first molar	7·
Transverse diameter of fourth premolar	5·
Transverse diameter of first molar	4·6

The type specimen was found by Professor Marsh, at Grizzly Buttes, and the cotype, by Mr. Kinney, at the same locality. Other specimens are from Church Buttes, and one is doubtfully from Henry's Fork.

Sinopa major sp. nov.

The last species of this group to be considered is the largest yet found in the Bridger horizon. It is apparently undescribed, and the above name is proposed for it. Two reasonably complete mandibular rami, figures 98, 99, one of which contains nearly all the teeth in place, together with three or four other fragmentary pieces carrying various teeth, represent it in the collection. The type specimen has the three molars and the third and fourth premolars in place in the jaw, together with the roots and alveoli of the remaining premolars. The chief characters of the species, as exhibited by this specimen, may be stated as follows: It is much larger than *S. edax*, *S. gracilis*, or *S. minor;* the second premolar is separated but very slightly, if at all, from the third; the first is small, single-rooted, and placed about equidistant from the canine and second premolar; the second molar is slightly larger than the third; the heels of the molars are large and basin-shaped, that of the last being smaller than the other two; the shear is rather transverse, and the internal cusp is less reduced than in *S. gracilis;* the jaw is much more massive and deeper, and the distance from the posterior base of the canine to the third premolar is proportionally shorter than in the other species. This indicates a rather short-muzzled type. The specimens suggest an animal intermediate in size between a red fox and a prairie wolf.

98

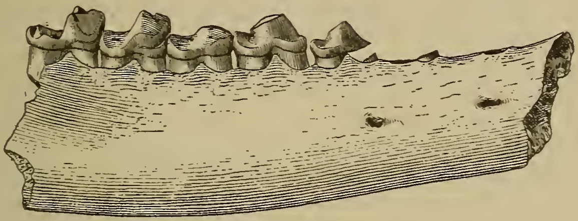


FIGURE 98.—Right lower jaw of *Sinopa major* Wortman; side view; natural size. (Type.)

99

FIGURE 99.—Left lower jaw of *Sinopa major* Wortman; side view; three-fourths natural size; restored from three specimens.

The principal measurements are:

Length of inferior dental series from posterior base of canine	70·^{mm}
Length of premolars	44·
Length of molars	26·
Antero-posterior diameter of first molar	8·
Antero-posterior diameter of second molar	10·
Antero-posterior diameter of third molar	9·
Depth of jaw at second molar	20·
Depth of jaw at second premolar	16·

The type specimen was found by Sam Smith at Church Buttes.

Discussion.—Two other species of this genus, *aculeata* and *insectivora*, were described by Cope from the Bridger, but Matthew has shown* that the types are unrecognizable, and he suggests that the names be dropped.

That the Bridger species should be more advanced than those of the Wind River and Wasatch is quite natural. At least three of them thus far known do not show any very great advance in structure over their older representatives, but still enough to separate them specifically. The remaining one, *S. gracilis*, exhibits very decided progress in the direction of the higher specialization of the family. This is seen in the disappearance of the posterior external cusp of the third superior molar, the more decidedly connate condition of the two main external cusps of the first and second superior molars, the development of a more sectorial structure of the fourth premolar, reduction in size of the heels of the lower molars, and reduction of the internal cusps of the trigon, with a more longitudinal shear. The internal cusps of the upper molars are also reduced.

There appears to be very good evidence of the specific descent of this species. Thus, *Sinopa hians* of the Wasatch, as far as its structure is known, answers with tolerable accuracy to the ancestral requirements. *Sinopa Whitiæ* of the intervening Wind River horizon appears to be intermediate in every feature of its osteology, as far as known, with the single exception that the second lower premolar is not spaced. If this character were variable in the Wasatch species, it may well prove to be the annectent form.

That *Hyænodon* and very probably *Pterodon*, also, were derived from this group, there appears to be very little doubt. The fundamental similarity in the structure of the skull, teeth, vertebræ, pelvic girdle, limb bones, and carpus, cannot be accidental parallelism, but on the contrary affords very strong presumptive proof of genetic affinity. The most specialized species of the genus, *Sinopa agilis*, however, cannot be in the line of direct descent because of the relatively small skull and the sharp, compressed, and slightly fissured, bony claws; whereas in *Hyænodon*, at least, the skull is large in proportion to the skeleton, and the claws are flat and deeply fissured.

It should be noted here that nearly every specimen of the genus *Sinopa* represented in the Marsh collection comes from the lower part of the Bridger beds, and that not more than one or two have been found in the upper part of the horizon. Their complete absence from the Uinta, as far as we now know, is, moreover, fairly satisfactory proof of their extinction

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*Bull. Amer. Mus. Nat. Hist., Jan., 1901, p. 24.

or migration from this country at the close of the Bridger. For this reason, I am persuaded that the evolution of the Oligocene types took place probably in Asia or the north, during later Eocene time, and that their subsequent appearance in this country during the Oligocene was due wholly to migration. It is highly probable that some generalized Wasatch species, such as *S. opisthotoma* of Matthew, was the ancestral type from which they were derived.

Further Observations upon the Marsupial or Metatherian Relationship of the Creodonts.

In the foregoing descriptions of the various characters of the Creodonts, frequent reference has been made to their relations with the Marsupials. Objections will doubtless be raised to the use of this term, since some writers restrict the term "Marsupial" to the living representatives of the group, which is perhaps, strictly speaking, correct. Huxley proposed the term Metatheria for a hypothetical group, which was meant to include both the modern Marsupials and the immediate Implacental forerunners of the Eutheria. The all-important distinction of such a group would consist in the implacental method of its reproduction—a character which would at once separate it from the Eutheria, in which an allantoic placenta is formed. In like manner, the absence of a distinct coracoid, the union of the odontoid process with the body of the axis, the lack of oviparous habits, and the more highly developed reproductive system would distinguish it from the Prototheria.

Unfortunately there are no known characters of the skeleton in this group which are constant associates or infallible correlatives of the implacental mode of reproduction, and since, among the fossils, we are compelled to depend solely upon osteological evidence, our judgments must of necessity rest very largely on analogy. When I have spoken of "Marsupial characters" and "Marsupial relationship," I have had constantly in mind the Implacental Metatheria of Huxley, preferring the use of the term "Marsupial," because the large number of primitive characters exhibited in the living members of this group undoubtedly furnish us the safest guide for a proper interpretation of similar characters in the fossils. By taking the more primitive members of the existing Marsupials as the basis of our comparisons, I am convinced that we shall be able to arrive at a very much clearer understanding of what the ancestors of the Creodonta were like, than by any other method of study. That they were derivatives or offshoots of any preexisting group of Placentals or Eutherians is exceedingly unlikely, and the strongest evidence of this fact is that they are practically as low in the scale of organization as any known

Eutheria. Moreover, evidence of the existence of such a group remains to be discovered. On the contrary, all the facts point very strongly to their origin, along with the Carnassidentia, from Implacental or Marsupial Metatherians. It is likewise conceivable that from this same general substratum the other Eutherian orders arose.

Some day, when our knowledge of these matters is vastly more extensive and accurate than at present, it will perhaps be necessary to abandon this horizontal system of classification, implied by the use of such terms as Prototheria, Metatheria, and Eutheria, and substitute for it the phyletic or linear system—the only one expressive of the genetic relationship which we seek to discover. It will then be determined, without much doubt, that these several ordinal groups have recognizable chains of ancestry, penetrating not only well down into the Metatherian substratum, but almost to the very bottom or beginnings of Mammalian existence. We shall then give names to these lines of descent rather than to successive stages of their development. But until this Utopia in the subject is realized, we must content ourselves with cruder methods, more in keeping with our ignorance.

Summary.

Having now completed a study of all the Eocene Carnivora in the Marsh collection, I append herewith a brief summary of the more important discoveries, opinions, discussions, etc., embodied in the foregoing paper. They are the following: The general organization of the order and the relationship of its more primitive members to the Metatherian Marsupials are discussed; the order is divided into three suborders, Creodonta, Carnassidentia, and Pinnipedia, and their relations are considered; of the Eocene Canidæ, the type of the genus *Vulpavus* is figured, a new species added, much of its osteology described, and the progressive modification of the family considered; a new related genus, *Neovulpavus*, is proposed; additional characters of *Uintacyon*, together with its position in the group, are given; *Prodaphænus* is considered to be the forerunner of the *Amphicyon* series, and four main lines of canine descent are pointed out; the Viverravidæ are defined, the type species of *Viverravus* is figured, and another species added; a new genus of this family, *Oödectes*, is proposed and a large part of its osteology described; the relations of the Viverravidæ to the living Viverridæ are examined, and the position is taken that the descent of the modern civets is probably traceable to this source; the type species of the three genera *Triacodon*, *Ziphacodon*, and *Harpalodon*, are figured, and the opinion expressed that they are not valid genera; the type of *Ælurotherium* is figured and described, a new species added, and its ancestral relationship to the Felidæ discussed and reaffirmed; the organization of the Creodonta and their relations to the Metatherian Marsupials are considered, a new classification is proposed, and the families are redefined; the Viverravidæ and Palæonictidæ are removed to the Carnassidentia; the family Mesonychidæ is considered, the genera of the Mesonychinæ are defined, a new genus, *Harpagolestes*, is proposed and defined, and the osteology of *Dromocyon vorax* given in full, with numerous illustrations; the small pelvic outlet may have indicated extreme helplessness of the young at the time of birth, like the Marsupials, and a possible cause for the extinction of the line; the evolution of the phylum is considered, and the progressive modifications of the teeth and limbs are pointed out; the origin and homologies of the mammalian tritubercular molar are fully discussed, and dissent is expressed from the theory of Migration or Rotation of Osborn; the family Oxyænidæ is considered, the arrangement of the genera discussed, and two subfamilies, Oxyæninæ and Limnocyoninæ, are proposed and defined; the genera of the Oxyæninæ are defined, the type specimen of *Patriofelis ferox* is figured and described in detail, and the probable habits of the species are rediscussed at length; the genera of the Limnocyoninæ are defined, one new species is added, and the synonymy of the others given; many new points are added to a knowledge of this group, its possible Insectivorous relationship is pointed out, and one species, at least, is thought to have been aquatic in habit; the family Hyænodontidæ is redefined, and the Bridger species of *Sinopa*, of which two are added, are described in detail; much of the osteology of *Sinopa agilis*, with illustrations of skull, fore foot, and limb bones, is given; the probable origin of the Hyænodonts and Pterodonts is considered, some further observations on the Marsupial or Metatherian relationship of the Creodonts are made, and their probable origin is considered.

Art. V.—*New Exposures of Eruptive Dikes in Syracuse, N. Y.*; by Philip F. Schneider.

Igneous rocks in the horizontally stratified Paleozoic beds of Central New York are too rare to pass unrecorded; and when, recently, excavations in Syracuse for the Butternut street trunk sewer disclosed another of these occurrences in a new locality and at so great a depth that ordinary excavations had not reached it because of the thickness of the overlying drift, it became important that some permanent and available record should be made of the same.

The eruptive rock was first noticed April 16, 1901, some three days after it was first penetrated. At this point, a short distance beyond the place where the sewer crosses Highland st., the eruptive rock occurred in the bottom of the trench and was dug into only to a depth of some two feet. It was overlaid by nearly three feet of decomposed peridotite, which had been entirely changed to a soft greenish-yellow earth. As the excavation progressed to the east of Highland st., the workmen penetrated deeper into the rock, which for some distance presented a slightly stratified appearance suggesting a sheet branching from the dike proper, which subsequent excavations proved to be the case.

The dike itself was first encountered 126 feet east of the center of Highland st., and was so hard and firm as to be removed with great difficulty. The width of the dike is 36 feet and it comes up to within ten feet of the natural surface. From its location in the trench, which was five feet in width, the strike of the dike appeared to be N. 5° E. There was scarcely any sheet to the east of the dike, but to the westward it extended over three hundred feet.

The rock in the main dike, with the exception of the upper two feet, is perfectly hard and firm. It is of a dark green color, some of it being almost black, and contains an abundance of apparently jet black crystals. The upper portion, immediately beneath the drift, had changed to a soft greenish-yellow earth, in some places to a yellowish earth. The fact that the lower portion of the drift contained much of the serpentinous earth mixed with it would suggest that a considerable area was covered with eruptive matter. The typical rock contained few inclusions as compared with that at DeWitt, N. Y., or even that in the Syracuse dikes at Green st. The softer rock of the sheet, however, contained many of them. No prominent fossils were found in any of these inclusions, whereas in the rock at De Witt they were very abundant. No traces of the enclosing walls of the dike could be found. Sheet material banked it on the west, and heavy Pleistocene clays with quicksand beyond them formed the eastern border. At Green st. the enclosing walls are perfectly shown, and it was hoped that further excavations would open up other exposures showing the contact phenomena, but this did not occur. The other excavations, where the strike of the dike would seem to indicate its existence, were all on higher ground with heavy mantles of drift which even this deep sewer did not penetrate.

One other opening occurred in a return sewer on Highland st. The excavations passed for 180 feet through rock which was thought at that time might be merely sheet material from the dike, but I am now convinced that it was another parallel dike. This rock, while almost as difficult to excavate as that of the first dike, decayed very rapidly after a few days exposure. It also had more or less of a massive wedged appearance in the trench like the first dike, and quite unlike the banded appearance of the sheet, and furthermore contained many inclusions. It also contained numerous small red crystals, the "rubies," which the neighboring school children collected in abundance. None of these peculiar forms were found in the De Witt, or in any of the Syracuse dikes at Green st. Some of them appeared to be perfectly crystallized garnets, but so rapidly did this rock break up, especially when dry, that they usually fractured soon after being exposed. A few crystals of greenish color were also obtained from this same rock, but none of either kind were noticed in the hard, firm variety. All of these facts would seem to indicate a second dike more or less parallel to the first and less than 250 feet away. Through this second dike the excavations must have passed very nearly longitudinally, while the sewer proper crossed the main dike at nearly right angles. As the return sewer stopped when connection had been made with the sewer proper, and as the excavations up to this point did not pass through to the farther side of the dike, no facts as to its width can be given. The proximity of these dikes to those at Green st., which are less than a mile away, suggests some underground connection, and inasmuch as their general direction is the same they may be merely a continuation of those dikes. The intervening space has frequently been trenched, and at such times the excavations have been carefully watched for evidence of the dikes without revealing any trace of them.

Syracuse, N. Y.

ART. VI.—*Petrography of Recently Discovered Dikes in Syracuse, N. Y.; with Note on the Presence of Melilite in the Green Street Dike;* by C. H. SMYTH, Jr.

THE freshest specimens of the dike rock from Butternut st., Syracuse, N. Y., are nearly black, but in the average material the color is gray, with a more or less decided greenish tinge. In texture, the rock is distinctly porphyritic, with phenocrysts ranging up to 15^{mm} or more in diameter, scattered somewhat unevenly through a moderately fine and even-grained groundmass. Occasional veinlets and small pockets of calcite appear, but these are exceptional, and the rock as a whole, aside from the "sheet" material mentioned below, is quite homogeneous. Of the specimens sent to the writer for examination, many appear to the unaided eye quite fresh and unchanged from their original condition; but they are very deceptive, as in most cases alteration has progressed to a considerable degree. Several sections cut from sound specimens of good color and with lustrous dark phenocrysts, under the microscope show little but a mass of alteration products, which, however, retain the original texture of the rock very well. In consequence of this alteration the following description of the petrography of the dikes is based upon only a few sections of fresh material, together with such data as are afforded by the altered specimens. But the petrography is comparatively simple, and the data at hand are sufficient to show a substantial agreement with the other dike rocks of the vicinity.

Sections of the least altered material show that the phenocrysts are olivine, as indicated megascopically. Crystal outline is generally lacking or at most quite imperfect, and the irregular grains show the customary alteration to serpentine along cracks and around the margin. In some grains this alteration is but slight, while in others the serpentine has wholly replaced the olivine. Between the two extremes there is complete gradation. Associated with the olivine there is a very little colorless monoclinic pyroxene. It occurs in irregular grains, and shows the usual high extinction angles. Though in very small amount, this pyroxene is a fairly constant constituent of the rock.

Biotite of a pale brown tint appears in large irregular plates and shreds of small size. The former are primary, but the appearance of the shreds and their relations to the other minerals suggest that they may be, in part, secondary. Perofskite is abundant, though varying considerably in quantity in different sections. It appears in minute crystals of sharp outline. In some cases, high powers show these crystals to be octahedra, and this is probably, as would be expected, the form of all of them. They are honey yellow, and decidedly translucent, so much so indeed as to show this property clearly with low powers. In this respect, the perofskite differs from that of the De Witt dike, in which Prof. Kemp* perceived the translucent character only with high powers. It would be difficult to find better microscopic specimens of perofskite than are shown in the rock here described.

Magnetite is another primary mineral, occurring in the usual small crystals and irregular grains. But it is far less abundant than is often the case in rocks of this general type. In some sections there is a small quantity of a granular, isotropic mineral with high index of refraction. While this may be garnet, no exact determination of the species could be made. In addition to the foregoing minerals there is present, even in the freshest specimens, a considerable amount of undeterminable alteration products mingled with the serpentine, carbonates, secondary magnetite, mica shreds and the minor primary constituents to make up the groundmass. While it is possible that there may have been glass in the unchanged rock, none is now recognizable.

Much of the foregoing description of the freshest parts of the dike applies equally well to the more altered parts. In these, the olivine has been almost wholly changed to serpentine, which is greenish or yellowish and shows the characteristic net texture to a marked degree. The double refraction of the serpentine is very low, and in the thinnest parts of sections, and often elsewhere as well, it is sensibly isotropic. Different specimens show great diversity in the amount of secondary magnetite in the serpentine. In some cases the former mineral is scantily sprinkled through the latter, while in other cases the serpentine is rendered nearly opaque by the powdery magnetite. The primary magnetite and perofskite are not affected by alteration, the latter in particular retaining all of its characteristic properties and showing in the sections of thoroughly altered specimens perhaps even better than in the fresher rock. All of the foregoing changes belong to the process of alteration rather than weathering, and do not affect the integrity of the dike as a whole, while modifying its composition, both mineralogical and chemical, to an unknown depth. Weathering on the other hand, though superficial, destroys the dike, as far as it goes, resulting in thorough disintegration.

The rock first called a sheet, but now regarded as probably a distinct dike, differs from that described above chiefly in containing abundant inclusions of the wall rocks together with

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* This Journal (3), xlix, p. 459.

occasional grains of garnet. The inclusions are so numerous as sometimes to equal or exceed the dike rock in quantity, and it is probably due to their presence that the rock goes to pieces very rapidly when exposed to the atmosphere. This may be due in part to the chemical effects of the inclusions, but more largely to mechanical influences, the homogeneity of the rock being destroyed, while it is filled with fragments, many of which disintegrate easily. The material is most unsatisfactory for study and affords very poor sections. The following description is, for this reason, quite incomplete.

The garnet appears rather scantily in irregular, rounded grains, sometimes reaching 4 or 5^{mm} in diameter. The color is bright red, becoming very pale in thin sections. Around most of the grains there is a very thin shell somewhat distinct from the rest of the rock, but the nature of the material is such that no good section of the shell could be obtained. Apparently mica (perhaps with hornblende) is the chief constituent. In one case the shell consists of decomposition products, through which are scattered great numbers of perofskite crystals. Somewhat analogous to this is the occurrence of a mass some 3^{mm} in diameter consisting largely of tiny crystals of perofskite, the whole surrounded by a shell of biotite.

In every case seen by the writer, the garnet occurs in that part of the rock which contains abundant inclusions, but never in the inclusions themselves. This relation to the inclusions, together with the scantiness and irregular distribution of the garnet, suggests that rather than a normal product of the dike magma like that of the Elliot Co., Ky. peridotite described by Diller* and that of many European occurrences, it may result from the fusion of parts of the wall rock in the molten dike, somewhat as in the case of the sapphires of Yogo Gulch, described by Pirsson.† However, conclusive evidence upon this point is lacking. That the garnets are themselves inclusions derived from the wall rocks is hardly possible. Were this the case, garnets should be found in some of the inclusions themselves, and even did this happen, it would be needful to prove that they were primary, and not formed by the contact action of the dike rock. Moreover, the only external source of garnets would be in the underlying pre-Cambrian rocks, and these are of such a nature that they would be most unlikely to fuse completely away from the garnets, leaving the latter free.

Embedded in one of the garnets was a bright green grain about $0{\cdot}5^{mm}$ in diameter. When broken and placed under the microscope it shows one cleavage, with which the extinction makes a high angle, while the green color is hardly perceptible.

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* Bull. 38, U. S. G. S.

† This Journal (4), iv, pp. 421-423.

The mineral is probably pyroxene, but the limited quantity hardly admits of accurate determination.

Aside from the variations described, this rock differs in no marked degree from the first dike rock described, except that one section shows tiny prismatic crystals of pyroxene in the groundmass. On account of its excessive alteration, sections of the rock are largely made up of secondary products, but these are essentially the same as those described above.

Of the two classes of inclusions, Paleozoic and pre-Cambrian, the former are naturally more abundant. The fragments are often angular and sometimes show a faint zonal coloration along the contacts. But there is no decided indication of new mineral growth. The pre-Cambrian fragments are usually more rounded, the result of the attrition involved in their upward journey of many hundred feet. They do not differ materially from inclusions described in other dikes of the region.

In comparing the rocks of this locality with specimens from DeWitt and from Green st., as might be expected, a strong family resemblance is apparent. There is perhaps less mica and rather more perofskite in the Butternut st. rocks, while only one section shows the tiny crystals of pyroxene that are so abundant in the groundmass of the DeWitt dike. But these differences are much too slight to be of any moment.

Melilite in the Green St. Dike.—The marked resemblance, both in petrography and geological relations, between the Syracuse rocks and the alnoite of Manheim has led the writer to expect, at any time, the discovery of melilite in the former. In studying the DeWitt rock, Prof. Kemp* searched carefully for this mineral but found none. The writer's study of the Butternut st. rock met with the same result; but in the examination of the rock of the original Green st. dike of Williams,† melilite was found. This seems at first sight surprising, as, doubtless, sections of the rock have been examined by many petrographers; but the fact that melilite has not been noted before simply illustrates the elusive nature of the mineral, resulting from its tendency to alteration. In the case of the original Manheim dike, the rock was first described by the writer‡ as a peridotite and its true nature was learned only when fresher material was procured;§ while in the largest dike of that locality no melilite could be determined with certainty, although there can hardly be a doubt of its original presence.‖

Some years ago a section was made from a specimen of the Green st. dike which very closely resembled the original

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* Loc. cit.

† This Journal (3), xxxiv, pp. 137–145.

‡ Ibid. (3), xliii, pp. 322–327.

§ Ibid., xlvi, pp. 104–107.

‖ Bull. Geol. Soc. Am., ix, pp. 257–268.

Manheim rock and, moreover, seemed fairly fresh. This was searched, with greatest care, for melilite, but to no purpose. In the present study, three sections of the rock have been examined, one from an old specimen and two from new material. In the first, a few very small individuals of melilite were found, so inconspicuous that their discovery can be regarded as little more than accidental. But in the other two sections, the melilite is present in some quantity. In habit and general appearance it is very like the Manheim melilite, though less abundant. Like the latter, it often shows abnormally high double refraction, possibly the result of alteration, and, as a rule, is optically positive, although the negative variety is also present.

From the foregoing, it is evident that in rocks as thoroughly serpentinized as are those of the Syracuse dikes, melilite may be nearly or quite obliterated; and it is extremely probable that perfectly fresh specimens would show melilite in all of these dikes. Perhaps an exception should be made in the case of the DeWitt dike, but even here there would seem to be sufficient alteration to mask the melilite if originally present in small quantities. Apparently, then, the petrographic affinities of this group of dikes is with the melilite rocks rather than with the peridotites, and this is interesting in bringing them into close relationship with the Manheim dikes, and in determining another occurrence of a rare variety of rock. Of course, incomparably the most important contribution to our knowledge of the Syracuse rocks was the establishment by Williams* of their igneous nature, but all new data in regard to the locality are worthy of record.

In a note appended to his description of the De Witt dike, Prof. Kemp† gives a brief resumé of the occurrences of igneous rocks in Central New York, including two instances of bowlders. Another case of the latter kind may be mentioned here.

In the Hamilton College collection are two specimens labelled "Hornblende Boulder, Syracuse, N. Y." The rock is coarsely porphyritic, with very little groundmass, and so peculiar in aspect that the writer had a section made from it some years since. Under the microscope this shows idiomorphic pyroxene of pale violet color, with a somewhat smaller amount of olivine. The individuals of both range up to 10–12^{mm} in diameter, and the two minerals make up perhaps 90 per cent of the rock, being held together by a scanty groundmass of minute laths of plagioclase. While it is quite possible that the rock is of Canadian origin, still it may well belong with the other bowlders referred to, in a group of basic eruptives breaking through the New York Paleozoic rocks.

Hamilton College, Clinton, N. Y.

* Op. cit. and Bull. Geol. Soc. Am., i, pp. 533–534.
† Op. cit., p. 462.

ART. VII. — *Preliminary Note on Silver Chabazite and Silver Analcite*; by GEORGE STEIGER.

IN an investigation upon the constitution of certain silicates an attempt was made to replace the alkaline metals by silver. This has been done with chabazite and analcite, the only two species upon which, so far, I have been able to test the reaction.

It will at once be seen that this work is analogous to that of Heumann* and others in the preparation of silver ultramarine. Heumann, by heating blue ultramarine in a sealed tube to 120° for fifteen hours, obtained a silver salt which was very nearly pure, and which upon fusion with various chlorides and iodides yielded corresponding compounds of barium, zinc, manganese, etc., and also compounds of some organic radicals.

The first experiment which I attempted was to heat ammonium chabazite† in a sealed tube with five times its weight of silver nitrate for four hours at 250° C., at which temperature the silver nitrate easily fused. After leaching with water, a determination of silver was made in the dried residue, 25·06 per cent Ag_2O being found.

Another portion was boiled for several hours in an open dish with a 10 per cent solution of silver nitrate; the residue from this gave 17·20 per cent Ag_2O. These results show that ammonium was at least in part replaced by silver. The experiments upon chabazite were only preliminary, and are to be carried farther.

More complete work was done in the case of analcite, and three portions of it were treated as follows:

"A." Natural analcite heated in an open tube with dry silver nitrate for four hours to 400° C.

"B." Natural analcite heated in a sealed tube with dry silver nitrate for four hours at 250°C.

"C." Ammonium analcite,‡ heated in a sealed tube with dry silver nitrate four hours at 250° C.

All were leached with water, and washed until the filtrates gave no test for silver; the residue was then dried on the water bath. The product in each case was a white powder not differing in appearance from the original material.

The analyses of the different portions are given below, together with the composition of the theoretical compound $Ag_2O{\cdot}Al_2O_3{\cdot}4SiO_2{\cdot}2H_2O$, which is found in column "D."

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* Liebig's Annalen, cxcix, 253 (1879).

† This Journal, vol. xiii, p. 27.

‡ This Journal, vol. ix, p. 117.

	A.	B.	C.	D.
Leach water				
Na_2O (calc. to analcite)	13·13	12·57	·60	
Dried residue				
SiO_2	41·31	40·08	42·69	39·35
Al_2O_3	16·44	16·29	18·22	16·72
Ag_2O	37·45	36·91	32·01	38·03
Na_2O	·85	·81	·68	----
H_2O	4·29	5·86	6·08	5·90
NH_3	----	----	·69	----
Nitrates	none	none	none	----
	100·34	99·95	100·37	100·00

It seems from the foregoing experiments that at least some of the natural silicates, which have been supposed to be very refractory bodies, are easily attacked and replacements effected by simple operations.

Work is now in progress on other minerals, along these same lines, and it is also proposed to study the action upon them of thallium and lead nitrates and other salts.

Chemical Laboratory, United States Geological Survey,
Washington, D. C.

Art. VIII—*The Significance of Certain Cretaceous Outliers in the Klamath Region, California*; by Oscar H. Hershey.

Cretaceous remnants occur in the southern part of Trinity County, California, in five very limited areas. They are distinguished from the Neocene deposits by their better lithification, by the gravel being almost exclusively of quartz and displaying the marine type of rounding, by their occupying structural basins and not valleys of erosion, and by their being identical lithologically with the Cretaceous deposits in the neighboring portion of the Sacramento Valley.

The principal Cretaceous outlier is in the valleys of Indian, Redding and Brown's Creeks, a few miles northwest of Bully Choop peak. It is about three square miles in area, and elongated in a direction west-southwest. It consists of several hundred feet of fine, well-stratified, yellowish sandstone and a little of the olive-colored shale so characteristic of the Upper Cretaceous in the Sacramento Valley. It rests unconformably on the Abrams mica schist.

The next area is at the junction of the North Fork of the East Fork of Hay Fork with the main East Fork Creek. It occupies less than a square mile in area, but dips distinctly toward the center of the small basin. The lower bed is a coarse, mixed breccia and conglomerate. The angular fragments were derived from the underlying Paleozoic slates and cherts. This bed differs from the usual basal conglomerate of the Cretaceous in the Sacramento Valley, but its identification is made certain by its being overlaid by the olive-colored shales, whose characters are unmistakable.

The third area occurs on the divide between Hay Fork and Salt Creeks, at the head of Dobbin Gulch. There is about a thousand feet of coarse conglomerates with some green sandstone, yet the deposit is only about one square mile in extent. On all sides it dips distinctly toward the center of the basin at angles between 20° and 30°. It rests on Paleozoic slates and cherts, the Clear Creek volcanic series and the Bragdon slate, the latter of very late Jurassic age. The pebbles, cobbles and occasional bowlders which compose the rock are, however, chiefly of white, yellow, brown, pink, blue and black quartz, derived from the rocks of the Klamath region but at some distance from their present position.

The fourth remnant occurs at the junction between Rattlesnake and Post Creeks and is about one and one-half square miles in area. It rests on the Clear Creek volcanic series, and consists of several hundred feet in thickness of a fine pebbly conglomerate, overlaid by a coarser conglomerate. The pebbles in the first are of quartz, have a remarkable uniformity in size and are perfectly rounded. They weather out and bestrew the surface as would a shower of marbles. They unmistakably indicate marine action.

Another supposed Cretaceous remnant is found at the Sweepstakes mine, a few miles southwest of Weaverville, but it has not been studied in detail and its extent is not known. It consists of a hard conglomerate of fine pebbles resting on the edges of the upturned Paleozoic slates and cherts.

The first four areas are Horsetown in age. The differences which are observed between them in going southwestward are exactly imitated by the basal beds of the Horsetown from the village of Horsetown along the foot of the mountains to Harrison Gulch and Good's Pass. At Horsetown the basal beds are shale and fine sandstone, as in the Indian Creek area. To make the identification complete, both Diller and Anderson have found the Horsetown fauna on Indian and Redding Creeks. Westward from Ono, the basal bed of the Horsetown is a heavy conglomerate like that of the Dobbin Gulch area; and near Harrison Gulch, there occurs in the Cretaceous the same peculiar pebble conglomerate as that of the Post Creek area.

Undoubtedly the sea of the Horsetown epoch transgressed on the southeastern border of the Klamath region and deposited probably several thousand feet in thickness of conglomerates, sandstones and shales over what is now a rough mountain area. At the time of the submergence it must have been comparatively even, but the heavy conglomerates tell of elevated and perhaps mountainous land in the interior of the Klamath region.

This country, that became covered by the Horsetown sediments, had previously suffered profound denudation. At the close of the Jurassic period, the stratified and already largely metamorphosed formations of Mesozoic, Paleozoic and perhaps earlier age, were intruded by three great series of batholiths, the first of peridotite, the second of gabbro and the last of granodiorite and allied plutonic rocks. These intrusions were accompanied by orographic activity of the greatest magnitude, for the whole area was thrown into a series of geosynclines, with many minor folds and faults. At the close of the disturbance the surface must have been very mountainous—a mountain system, in fact, made up of quite different and more massive ranges than those of to-day. Erosion slowly reduced these mountains. Most of their destruction was accomplished during the early Cretaceous time. Several thousand feet at least of Mesozoic slates and meta-andesites were removed and the rivers cut deeply into the Paleozoic slates beneath. The denudation reached even to the plutonic masses and laid bare the coarse-grained gabbro and granodiorite which must have solidified at a considerable depth beneath the surface. As products of this erosion and of that accomplished in the Sierra Nevadas at the same time, we have in the Coast Range region many thousands of feet of sandstone and shale, the first chiefly Franciscan and the latter Knoxville in age. Judging from the work performed, this "early Cretaceous" period must have been a very long one, perhaps equal to all the time since.

Base-leveling in the Klamath region continued through the Horsetown and Chico epochs. Northeastward from Horsetown the Chico formation laps past the Horsetown and from Clear Creek to far beyond the Sacramento River it is in contact with the metamorphic rocks as shown by Diller and others. The basal bed of the Chico is a fine sandstone, with no conglomerate whatever present in this area. Apparently the southeastern border of the Klamath region had been pretty thoroughly base-leveled before the opening of the Chico epoch, but the northeastern border seems to have still remained hilly, since the base of the Chico in Shasta Valley and the Siskiyou range is a heavy conglomerate. It is probable that even to the close of the Cretaceous, the central portion of the Klamath area remained elevated, but base-leveling had been affected around its borders, and a very slight depression was sufficient to cause the Upper Cretaceous strata to lap over on to it.

Subsequently to the Chico epoch there occurred another profound orographic disturbance of the Klamath region. It was characteristically different from that which closed the Jurassic period. Much of the area and perhaps all seems to have been deformed into a series of deep, elliptical basins. The four principal Cretaceous remnants in Trinity County mark the deepest portions of four of these structural basins, each of which was elongated in a direction west-southwest, adjoined each other and virtually constituted a syncline separated from the Sacramento Valley by a rather prominent anticline. Perhaps my meaning may be clearer if I state that the four Cretaceous remnants are separated from each other by tracts of metamorphic rock which rise about 2000 feet above the deepest portions of the basins, but that the ridge of metamorphic rocks which separates them from the Cretaceous in the Sacramento Valley is much higher.

The average altitude of the bottom of the Cretaceous in the center of each basin is about 2500 feet. The ridge which separates them from the Sacramento Valley rises from an altitude of about 4000 feet at Harrison Gulch to over 7000 feet in Bully Choop peak. On the south side of this range the Cretaceous strata dip away at an angle about the same as the general slope of the mountain, and Cretaceous remnants occur at a considerable height on its flank. Indeed, Cretaceous pebbles and the gold derived from the basal conglomerate are widely scattered over the slope and indicate that Cretaceous strata in place have but lately disappeared from it. Near Harrison Gulch and at Good's Pass, where the ridge is lowest, the Cretaceous strata reach to the very summit and curve over its top. A careful reconstruction of the plane of the base of the Cretaceous upon data furnished by the basins on the north of the ridge and the Cretaceous border on its southern slope shows that the summit and slopes of this range must correspond roughly with the Cretaceous base-level upon which, after submergence, the Horsetown was deposited. It is the Cretaceous base-level brought to light by erosion. This base-level was deformed near the close of the Cretaceous to just about the same extent as is the present surface. The northeast-southwest range of which Bully Choop is the principal peak is, in a certain sense, a structural range although its present topographic prominence is due entirely to erosion. It almost exactly coincides in position and form with a post-Chico range. The most remarkable thing about it is that this post-Chico mountain range was thrown up almost at right angles to the strike of the metamorphic formations forming its core and, hence, to the post-Jurassic mountain system. If the post-Chico Bully Choop range rose rapidly enough so that its summit was not materially reduced by erosion during the movement, at its completion it was a ridge with a base on the average 12 miles wide and rising in its highest peak over 7,000 feet above the lowlands on the south and 4500 feet above the deepest basin on the north. It became the main drainage divide and has continued so to the present.

We do not know whether the same sharp deformation of the surface in post-Chico time persisted over the entire Klamath region, but there are evidences that it did. Wherever the Cretaceous strata are found on the borders of the Klamath region, they are tilted at a considerable angle. On the northeastern flank of the mountains, in Shasta Valley, in the Siskiyou Mountains and in the Rogue River Valley in Oregon, the Cretaceous strata rest upon the metamorphic formations with their original contact, but are tilted toward the northeast at a high angle, in a few places nearly vertical. There is a general rise of the Klamath region toward the northeast and the highest portion of the upland occurs on the immediate border, just beyond which the surface abruptly falls away to the deep broad basin on the floor of which Mt. Shasta and the Cascade range have been built up. The phenomena are similar to those which characterize the Sierra Nevada region with its short steep slope on the east and a long gentle slope on the west, and suggest that the northeastern face of the Klamath Mountains marks the line of a great fault; but the relation between the steeply inclined Cretaceous strata and the older rocks shows that the structure is that of a sharp monocline rather than a fault.

The Sierra Costa Mountains rise abruptly above a supposed Cretaceous remnant near Weaverville and on the northeast they are terminated by the sharp monocline above-mentioned. They must have been one of the abnormally elevated portions of the post-Chico mountain system.

Berkeley, California.

Art. IX. — *The Action of Copper Sulphate upon Iron Meteorites;* by O. C. Farrington.

In 1852 Wöhler* announced the discovery that some iron meteorites, irrespective of their nickel content or structure, are passive to neutral solutions of copper sulphate, i. e., they do not reduce copper from such a solution. This passivity he stated could be overcome by introducing a piece of ordinary iron into the solution or by adding a few drops of acid.

No data were given as to temperature, length of time allowed for deposition or the strength of the solution. The following meteorites were reported by him to be passive: Bemdego, Bohumilitz, Braunau, Cape of Good Hope, Green County (undoubtedly Babb's Mill), Obernkirchen, the Pallas Iron, Red River (probably Cross Timbers), Schwetz, Toluca, and the terrestrial iron of Greenland. A number of other meteorites which need not here be enumerated he reported at the same time as "active," i. e., they reduced copper from the copper sulphate solution; while those of a third class were designated as "intermediate," i. e., they were nearly passive, but after remaining some length of time in the solution brought about a slow reduction of copper. That the passivity was a property of the entire mass of the meteorite seemed to be proved by the fact that when the surface of the meteorite had been made active and the coating of copper was removed by filing, it would again behave passive.

Since the publication of Wöhler's article several other investigators of iron meteorites have tested their behavior toward copper sulphate with the result usually of finding them active, but the following, as listed by Cohen,† have been reported passive: Toluca by Krantz, Knoxville by Smith, Misteca by Bergemann, Octibbeha County by Taylor, Ohaba by Bukeisen (this is a stone), Charcas by Meunier and Lexington Co. by Shepard. Two of these, however, were reported by other observers to be active, viz: Toluca by Pugh, Jordan and Taylor, and Charcas by Daubrée. The observers later than Wöhler also failed to give details regarding the conditions of their experiments. Wicke and Wöhler state that the Obernkirchen meteorite, after remaining a day, reduced no copper from its salts.‡ Smith states that Knoxville is passive with reference to the action of sulphate of copper, but when immersed in a solution of the latter and allowed to remain several hours the copper deposits itself in spots on the surface

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* Poggendorff's Annalen 1852, vol. lxxxv, pp. 448–9.

† Meteoritenkunde, Heft 1, p. 68.

‡ Ann. d. Chem. u. Pharm., 1864, vol. cxxix,, p. 123.

of the iron.* Meunier states that the section of Charcas was washed in alcohol and ether to remove grease and upon it a drop of solution of sulphate of copper was placed. At the end of some hours the drop had evaporated, leaving crystals of the salt but no copper.†

Viewed simply as a matter of reasoning, it would seem quite impossible, with our present knowledge, to account for a passive behavior of meteorites independent of their nickel content. As is probably generally known, nickel is less active to copper sulphate than iron, and it might be expected that the activity of alloys of iron and nickel would decrease in proportion as the percentage of nickel increased. But that some individuals of the same alloy (for iron meteorites are practically alloys of iron and nickel) should be entirely passive while others were normally active would be quite extraordinary. Wöhler's conclusion was that all iron meteorites were probably in their original state passive, but that through local terrestrial influences and the passage of time, some had since their arrival upon the earth become active. Meunier expressed the opinion that a peculiar molecular structure may be indicated by the passivity.‡ In view of the lack of details regarding the experiments upon which Wöhler based his conclusions and the results he obtained, it seemed to me desirable to reinvestigate the matter to some extent.

Of the meteorites listed above as passive, there are to be found in the collection of the Field Columbian Museum, specimens weighing from 10 to 1100 grams each, of the following: Babb's Mill, Bemdego, Braunau, Bohumilitz, Cape of Good Hope, Charcas, Cross Timbers, Knoxville, Lexington Co., Misteca, Pallas Iron, Toluca and the native iron of Greenland. These therefore were available for investigation. In order to test their activity each section was in turn immersed in a solution of 200 grams of Baker & Adamson's C. P. copper sulphate to a liter of distilled water. The temperature of this solution was about that of the room, or 18° C. In this test every meteorite gave an active reaction. A perceptible deposition of copper took place upon each section within one to four minutes after its immersion. The only exception to this general rule was Knoxville, which in some trials deposited in four minutes but in others required twelve or fifteen minutes. In the same solution and at the same temperature about thirty minutes was required before deposition took place upon a piece of ordinary cube nickel the surface of which had been rendered bright by filing. A specimen of josephinite, how-

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* This Journal (2). xix, 155.

† Ann. Chim. et Phys., 4th ser., vol. xvii, p. 92.

‡ Loc. cit.

ever, gave no deposit at all, though left twenty-four hours in the solution. With the exception of Knoxville and josephinite the period required for deposition seemed to correspond quite closely to the percentage of nickel. Thus ordinary iron would, as it is well known to do, take on a coating of copper almost instantly upon immersion in the solution. For the native iron of Greenland, which contains 2 or 3 per cent nickel, about thirty seconds were required. Irons like Charcas, Braunau, Bemdego and Lexington Co., which contain 4 to 6 per cent of nickel, required from one to two minutes, and Cape of Good Hope and Babb's Mill, which have about 15 per cent of nickel, three to four minutes. The somewhat eccentric Knoxville is a meteorite with a high percentage of nickel and josephinite contains 72 per cent nickel. Incidentally, therefore, the experiments indicated that immersion of an iron-nickel alloy in a solution of copper sulphate will afford a rough test of the percentage of nickel contained in the alloy, and, since a meteorite must contain nickel, a quick means of distinguishing meteoric from terrestrial iron.

To the experiments made in the above manner as compared with those of Wöhler, the objection may be made that Wöhler described his solution as a "*Lösung von neutralem schwefelsauren Kupferoxyd*," while a solution of copper sulphate has normally an acid reaction. In order to remove doubt on this point a solution was prepared according to the method given by Blair.* Such a solution is one of 200 grams to the liter, but to it sodium hydroxide is added until a slight precipitate appears and the latter is removed by filtration. The solution still has an acid reaction, but the possible presence of free acid is avoided.

The sections immersed in this solution gave, however, as far as could be observed, results exactly similar to those obtained with the simple solution. As no mention is made by Wöhler or other investigators of treatment to reduce the acidity of their solutions, it is highly probable that only the simple solution was used. Employment of solutions of different strengths was likewise without effect on the results obtained. Tests were made with a solution of 100 grams to the liter and some intermediate strengths, but the fact of the deposition of the copper and the period required for its deposition seemed unchanged.

Different temperatures were however of considerable influence in changing the time required for deposition. Thus the cube nickel, which required thirty minutes at 18° C., reduced copper in five minutes when the solution was heated to 63° C.

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* The Chemical Analysis of Iron, 3d ed., p. 63.

The specimen of josephinite which reduced no copper at 18° C. gave a deposit in twenty minutes at 63° C. At temperatures below 18° C. the time required for the deposit is greatly increased. Thus, Cañon Diablo, which reduces copper in one minute at 18° C., required sixty minutes at 10° C. and at 0° C. was kept twelve hours without producing a deposit. Toluca, which acquires a deposit in two minutes at 18° C., required eighty minutes at 10° C. and at 6° C. was kept for four hours without receiving a deposit. It was not tried longer at this temperature.

In these tests it was found necessary to immerse the sections in water of the temperature whose effect it was desired to study, for some minutes before transferring to the copper sulphate solution. Otherwise the heat of the section would cause deposition at an earlier period. Also a fresh section which had not been exposed to copper sulphate must be used, as traces of a previous deposit of copper would hasten deposition.

The periods named as sufficient for deposition are in all cases somewhat approximate and variable, since the exact moment at which deposition begins can be determined only roughly by the eye. The general results are however sufficiently accurate for the purpose. They show nothing to support Wöhler's belief that certain meteorites are inherently passive, but on the contrary point to the conclusion that meteorites act like any other iron-nickel alloy.

Daubree considers the deposition of copper due to the fact that the different alloys in a meteorite form electric couples,* but it hardly seems necessary to appeal to this force when deposition takes place so quickly upon a piece of iron not made up of different alloys.

It is hardly essential to the purposes of this article to try to account for the results reported by Wöhler and other observers, but one or two suggestions may be made in this connection. It is possible that some of the surfaces tested by these observers may have been rendered passive by treatment with nitric acid. This was quite probably the case with Misteca as treated by Bergemann, for he reports that upon freshly dissolved (*gelöst*) pieces he could get no deposit, while pieces from the outer surface of the meteorite without luster and of dark gray color were quickly coated.† Wöhler, however, expressly states that the sections which he tested had not come in contact with nitric acid.

Again a slight film of grease or oxide may have prevented deposition of copper. A substance so active to copper sulphate even as iron will be found to have become passive,

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* Comptes Rendus, 1867, vol. lxiv, p. 685.

† Pogg. Ann., 1857, vol. c, p. 246.

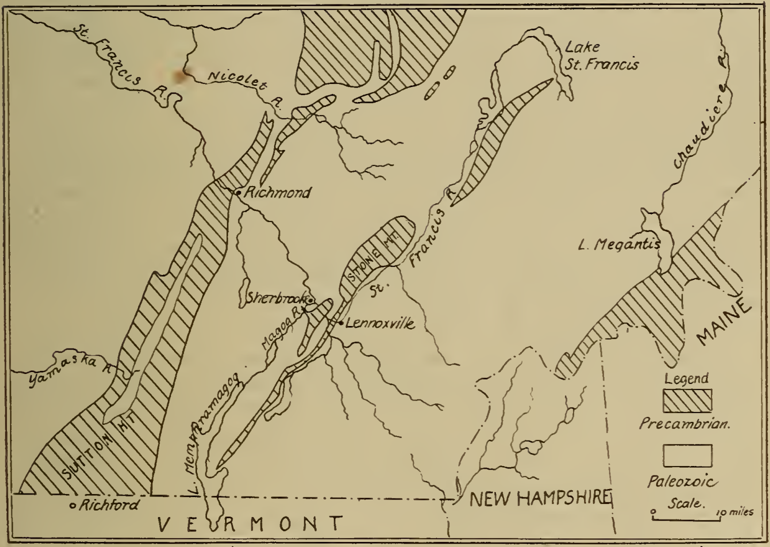
if heated a moment before immersion. This is probably on account of the film of oxide formed. The sections of Cape of Good Hope and Knoxville, which had an active behavior as treated ordinarily, I found to be thoroughly passive when reimmersed without rubbing after an interval of two weeks. No perceptible film of oxide could be detected, but on rubbing the surface with emery cloth deposition took place as before. There are some indications again that the molecular condition of the substance and especially of its surface may determine its degree of activity. For instance, a cube of nickel which was perfectly passive when treated in the ordinary way, no deposit being formed on it after standing 24 hours in the sulphate solution, although fresh surfaces were frequently exposed by abrasion, was made active by being heated to redness, cooled and again made bright by abrasion. A deposit of copper then formed within twenty minutes and the cube has shown active behavior since. The activity was the same both when the cube was cooled slowly and quickly. The specimen of josephinite previously mentioned as being passive at ordinary temperatures, was given a similar treatment, i. e., heated to redness, cooled and rubbed. It also became active under this treatment, reducing copper in a solution at the temperature of 18° C. at some time within a period of twelve hours, the exact time not having been noted. It was noticeable in this case, as in many others, that deposition began and was most active about capillary cracks and fissures. This would indicate that capillary tension was influential in effecting the reduction of the copper, and it is reasonable to suppose that such would be the case, since the molecules are probably brought into closer contact in such situations. It is evident that several conditions may affect the degree of activity of a meteorite or any other iron-nickel alloy, but I have found nothing to accord with Wöhler's observation that passive meteorites which had been made active by contact with iron, after the reduced copper was filed off became again passive. While several phases of the subject invite further investigation, enough evidence seems to be obtained to warrant classing all meteorites as active to copper sulphate and dropping the designation of passive meteorites.

I am indebted to my associate, Mr. H. W. Nichols, for a number of useful suggestions during the progress of the investigation.

Field Columbian Museum, Chicago, Ill.

Art. X.—*A Petrographical Contribution to the Geology of the Eastern Townships of the Province of Quebec;* by John A. Dresser.

That portion of the Province of Quebec which lies south of the St. Lawrence River comprises two physiographically distinct regions, viz.: The flat country of the St. Lawrence valley, and that part of the Appalachian mountain system which belongs to this province. The part of the latter which occupies the Gaspé peninsula is known as the Shickshock mountains, and that between the vicinity of Quebec city and the United States boundary line as the Notre Dame Hills. The district lying within the Notre Dame hills is commonly designated as the "Eastern Townships," the geological structure of which has furnished the theme of much well-known discussion during the past forty years. This has been chiefly connected with the question of the Quebec Group.*



A Part of the Eastern Townships of the Province of Quebec.

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* "Geology of Canada," 1863, pp. 225–297, by Sir W. E. Logan.
"The Quebec Group in Geology," Transactions of the Royal Society of Canada, vol. I, 1882, by A. R. C. Selwyn.
"Notes on the Microscopic Structure of Some Rocks of the Quebec Group." Ann. Rept. Geological Survey of Canada, for 1880–1–2, by F. W. Adams.
"The Quebec Group." Appendix A to Harrington's Life of Sir W. E. Logan, by Sir J. W. Dawson, 1883.
Reports of the Geological Survey of Canada for the years 1886, J; 1887–8, K; 1894, J, by R. W. Ells.

As originally defined by Logan and Billings, the Quebec Group embraced all the rocks of the Eastern Townships that are essential to the present investigation, and all were then regarded as of sedimentary origin. Subsequently, however, Hunt, on stratigraphical grounds, and Selwyn on stratigraphical and lithological evidences, distinguished certain older measures, which were referred by the latter to the early Cambrian and pre-Cambrian ages. The amplification of the views has been fully carried out by Ells in the reports of the geological survey of Canada for the years 1886 and 1894.

The only lithological changes embodied in these reports are in the recognition of the eruptive origin of the serpentines and the diorites, diabases, porphyrites and granites generally associated with them. These had been previously regarded as metamorphosed sediments. The silicates of magnesia were correlated with its carbonates, where dolomite occurred in the vicinity of the serpentine belt, and even in 1886, Dr. Selwyn, who had been the first to recognize the igneous origin of the serpentines, in a footnote appended to Dr. Ell's report, maintains that the hornblende granites are probably products of metamorphism in situ and not true intrusives through the serpentine, as the latter writer correctly considers them to be.

In respect to age, the serpentines and certain of the clastics were referred to the early Cambrian and the other eruptions to middle or late Silurian time, while three belts of supposed sedimentary rocks, running approximately parallel to the northeasterly trend of the Appalachians were classed as pre-Cambrian. One of these appears for only a relatively short distance along the boundary line between the province of Quebec and the State of Maine. The second crosses the St. Francis river between the city of Sherbrooke and the village of Lennoxville. This may be known as the Ascot or Stoke Mountain belt, while the third, which crosses the St. Francis river a little way north of the town of Richmond, twenty-five miles northwest of the second, is generally designated as the Sutton Mountain belt. The structure of these bands, especially of the last mentioned, was long a crucial point in the Quebec group controversy, they being interpreted as synclines by the earlier investigators, and as anticlines by the latter.

Petrography.—Recent petrographical investigations by the writer have, however, shown that both the second and third of these pre-Cambrian belts consist largely, and in places entirely, of altered volcanic rocks. These are so highly altered and consequently so much disguised, that they have been hitherto mistaken for sedimentaries, and have been accordingly treated on that assumption in all the stratigraphical discussions regarding them.

(a) In the *Stoke Mountain belt* the principal rocks examined were taken from the township of Ascot, on the west side of the St. Francis river, between Sherbrooke and Lennoxville. Others were taken from various points to the southeastward on the upper Belvidere road and from the vicinity of the Suffield, Sherbrooke and Clark copper mines. The rocks, which are generally fine in texture, are of various shades of green and gray in color, and many are in advanced stages of metamorphism. In the thin section, however, the microstructure remains sufficiently distinct to clearly establish the igneous origin of practically all of these rocks, and even to identify the specific characters of several on the merely preliminary examination of them that has yet been made.

Quartz-porphyry forms the hanging wall of the Silver Star mine at Suffield. It is of light gray in color, and from the prominence given the quartz phenocrysts by the bleaching of the base of the rock on weathered surfaces, it has been commonly regarded as a species of sandstone.

By the aid of the microscope the structure is found to be that typical of an effusive rock. A very finely crystalline base holds phenocrysts of quartz, which show in basal sections an uniaxial cross and positive sign ; and also of feldspar, which extinguished in several cases with its principal axes parallel to the planes of the crossed nicols and hence is orthoclase. A few feldspars are polysynthetically twinned and accordingly are plagioclase. Their extinction angles are small. Small rod-like individuals of colorless mica arranged in lines are presumably of secondary origin. They often occur within, or in association with, irregular areas of a rhombohedral carbonate, apparently dolomite.

Granite-porphyry occurs near Lennoxville on the line of the Canadian Pacific Railway. It differs from the quartz-porphyry chiefly in the more advanced character of its crystallization, both quartz and feldspar being distinguishable in the groundmass. A little chlorite, pyrite, brown iron oxide, and colorless mica are also present. An incipient cataclastic structure is beautifully shown in both of these rocks. The quartz-phenocrysts are sometimes reduced to mosaics of quartz grains, or at others are crossed by lines of crushed material, while the crystals on either side of the lines remain unchanged or show undulatory extinction. Being the largest single masses and of the most brittle material, the quartzes thus appear in every case to be the first constituents to show the effects of purely dynamic metamorphism. A much altered rock forming the hanging wall of the Clark mine was probably closely allied to the quartz-porphyry in its original composition. It rather closely resembles a specimen of "sheared felsite" from the Gettysburg Railway, south of Clermont House, Monterey, Pennsylvania, seen in the petrographical collection of McGill University.*

A greenish gray fine-textured massive rock is of large extent, especially in the southern part of this belt. In the thin section quartz is found in broken phenocrysts and also in smaller grains, presumably primary, in the rather fine holocrystalline groundmass. Under high power (x220) feldspar appears in the groundmass in small lath-shaped individuals which extinguish at low angles with the principal axes. Epidote and chlorite are abundant representatives of primary bisilicates. The rock would have originally been about of the character of a quartz porphyrite.

A large part of the central and southern portions of this belt in the township of Ascot is occupied by a highly foliated rock of green color and massive appearance. Under the microscope a little feldspar is found in an aggregate of colorless hornblende, chlorite, epidote, dolomite and sericite, all of which are secondary constituents.

This rock agrees essentially with the sheared greenstone from Jack's Mountain tunnel, near Monterey, Pennsylvania, as seen in the McGill University collection.

A similar but more dolomitized rock occurs in various parts of the belt, one occurrence of which is mapped as igneous on the map to accompany the Annual Report of the Geological Survey of Canada for 1886.

These rocks, though probably of several different ages of eruption, are generally much metamorphosed. But cutting them there are dikes of camptonite and olivine diabase, which are quite undisturbed in position and comparatively little altered in mineralogical composition. They also cut the Lower Trenton strata along the edges of the belt, while these overlie the other igneous rocks of the region. Whence it appears that the Stoke Mountain, or Ascot belt, has been the scene of volcanic activity at various periods through a long range of time, from pre-Cambrian to post-Trenton. A brief notice of the lithological character of those rocks has been recently given by the writer in a communication upon the copper-bearing rocks of the area,† and their general agreement in extent with the pre-Cambrian of the Geological Survey Map of 1886 pointed out.

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* Bulletin U. S. Geological Survey, No. 136, "Ancient Volcanic Rocks of South Mountain, Pennsylvania," by F. Bascom.

† Trans. Can. Min. Inst., Montreal, March, 1902.

(b) The igneous origin of a portion of the pre-Cambrian area, which forms the *Sutton Mountain belt*, was pointed out by the writer in a note to the Ottawa *Naturalist* of January, 1901. Since that time the extent of the igneous portion has been more fully examined, especially to the northeast of the St. Francis river, and its structural relations better ascertained. It is found to comprise the greater part of the pre-Cambrian of this area, as shown on the latest geological survey map of the region, that of 1886.

As far as examined, for a distance of some forty miles on either side of the St. Francis river the rock is an altered greenstone, very commonly amygdaloidal. In the microscopic section a little primary plagioclase sometimes remains, but in many sections the whole field consists of a secondary aggregate of chlorite, epidote, iron ore and leucoxene. The amygdules usually consist of quartz and zeolitic minerals. The rock is much foliated and has been generally described as a chloritic slate. Its resemblance to the basic rocks of the Ascot area is very close. It, too, is important as a copper-bearing rock.

In geographical position these volcanic belts form a link in the more westerly of the two chains of ancient volcanics designated by the late Prof. G. H. Williams,* while in their lithologic characters they agree with certain of the South Mountain rocks of Pennsylvania in all essential respects.† The Quebec rocks are, however, largely made up of the acid types, some of which agree essentially with rocks from Ascot. Most of the specimens are in less advanced stages of recrystallization than the rocks above described.

The basic phases from the Stoke Mountain area as well as those which comprise the Sutton Mountain belt are closely analogous to the greenstones from the vicinity of Monterey.

STRUCTURE.—As already stated, these rocks were formerly regarded as presenting synclinal structures, while the later investigators have believed them to form anticlines, the former view making them later in age than the adjacent rocks, the latter, earlier. With respect to relative age, the latter opinion is doubtless the correct one. The lowest sedimentary rock, dolomite, on the south side of Sutton Mountain belt in the township of Melbourne, for instance, contains fragments of the adjacent trap, and large areas of mica schists

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* The Journal of Geology, Jan.-Feb., 1894.

† A collection of rocks from this locality, which is in the petrographical laboratory of McGill University, has been examined for comparison through the courtesy of Prof. F. D. Adams, to whom my best thanks are also offered for valuable aid and advice in several matters connected with this subject.

in the vicinity are made up of its débris. Other evidences also point to the later age of the sedimentary rocks, which generally belong to the Trenton formation, and none to the reverse relation. The change of view in regard to the origin of these rocks, from sedimentary to igneous, does not, therefore, necessarily alter the recent determinations either of their relative or of their actual geological age. It would, however, be well that the evidence on which the latter determination was made should be carefully reviewed in the light of the present knowledge of their volcanic character.

On the other hand, the elimination of these volcanics leaves the stratigraphical structure of the sedimentary rocks a much simpler one than has hitherto been supposed.

A detailed study of the Sutton belt and adjacent formations in the vicinity of the St. Francis river shows the sedimentary rocks of the Quebec Group to occupy a trough between the volcanic ridge on the north and the serpentine belt at the south. Both these have apparently been covered by sediments which are now in part removed by denudation.

A *summary* of the results of this study, therefore, shows:

1. That at least the greater part of the pre-Cambrian or crystalline belts of the eastern townships of Quebec is of igneous, not sedimentary origin, as has been hitherto supposed.

2. That these rocks are allied to the volcanics of South Mountain, Pennsylvania, especially to the basic types, and indicate the continuance of this class of rocks throughout the Appalachians, as was suggested by Williams.

3. That the sediments of the region, which probably all belong to the Quebec Group, were deposited between and upon the preëxisting ridges of igneous material, which are now being uncovered by denudation, while the intervening valleys still remain deeply filled.

The pre-Cambrian area near the international boundary line, before referred to, and also the extension of the Sutton belt into the State of Vermont, would furnish subjects of investigation of especial interest in connection with the areas herein described.

Richmond, Quebec, Canada.

Art. XI. — *The Action of Carbon Dioxide on the Borates of Barium*; by Louis Cleveland Jones.

[Contributions from the Kent Chemical Laboratory of Yale University—CVIII.]

In 1888 Morse and Burton described "A Method for the Separation and Determination of Boric Acid."* I published an article in 1898 entitled "The Action of Carbon Dioxide on Soluble Borates,"† an account of certain results not in accord with those of Morse and Burton. More recently‡ Morse and Horn record at some length "preliminary experiments" made in an effort to substantiate the original analytical results of Morse and Burton.

I have waited for some time for the promised resumption of these experiments, and lest further silence be misunderstood, will show that the action of carbon dioxide and boric acid, in the presence of the one base—barium hydrate—both in the dry state and in solution, is that which I pointed out in my original paper, and, further, that these later experiments of Morse and Horn, correctly interpreted, completely substantiate this position.

The question is concerning the action of carbon dioxide gas upon a mixture containing boric acid and an excess of barium hydrate, viz: what part of the total barium is converted into carbonate and, upon evaporation and ignition, how much, if any, of this barium carbonate is reconverted into borate? Indirectly, and stated differently, it is: Can boric acid, when once separated, be brought into definite and weighable condition by the method recommended by Morse and Burton? (Loc. cit.) Despite the title of the contribution of Morse and Burton, Morse and Horn now regard the separation of the boric acid "as the most, and in fact the only, important feature of their contribution."

The following is the entire description of that part of the process relating to the determination of the boric acid as originally given by Morse and Burton: "The quantity of the dilute barium hydroxide solution" (about 25^{cc}) "which is equivalent to 25^{cc} of the standard sulphuric acid" ($N/10$) "is run into the flask, and the apparatus attached to a filter-pump." This is done preparatory to receiving the alcoholic solution of boric acid—a little over 75^{cc}. "*Finally, the excess of the barium hydroxide is precipitated by passing into it a current of carbon dioxide: the contents of the flask are transferred to*

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* Am. Chem. Jour., March, 1888, vol. x, pp. 154–158.

† This Journal, vol. v, pp. 442–446, June, 1898.

‡ Am. Chem. Jour., August, 1900, vol. xxiv.

a platinum dish, evaporated to dryness, and heated to a constant weight over a triple burner."*

In my original article I made three claims: 1st, that the metaborate of barium may be decomposed by gaseous carbon dioxide; 2d, that the boric acid thus "liberated" may be lost by volatilization; 3d, that the metaborate of barium and the carbonate may interact at high temperatures with the loss of carbon dioxide. These facts preclude the use of the method described by Morse and Burton for the determination of boric acid. The more recent experiments of Morse and Horn not only substantiate these facts but disclose a fourth objection to the use of this method for its original purpose, viz: the difficult dehydration of the metaborate of barium, concerning a mixture of which with barium carbonate, Morse and Burton originally said that it "being neither markedly hygroscopic nor capable of absorbing carbon dioxide, can be brought to a constant weight more readily than one containing oxide of calcium or magnesium."

The decomposition of barium metaborate.—That barium metaborate may be decomposed by carbon dioxide in aqueous solution, is proved by my original experiments; and now is corroborated by those of Morse and Horn. These authors, however, urge that, in alcoholic solutions—78 per cent—the boric acid would be in the form of metaborate of barium only and this should be unattacked to the extent of its insolubility. To test this point directly, carbon dioxide was passed into equivalent parts of barium hydrate and boric acid in 78 per cent alcoholic solution. The precipitate gave abundant evidence of the presence of carbonate, showing decomposition of the metaborate. The extent of this decomposition was determined quantitatively by determining the carbon dioxide in another similar precipitate. Barium hydrate and an excess of boric acid in a mixture consisting of 78 per cent alcohol, were treated in the cold for three hours with carbon dioxide. The precipitate was filtered, washed, and analyzed for carbon dioxide with the following result:

$Ba(OH)_2$ taken, 0·7883 grm.; B_2O_3 taken, 0·3576 grm.; excess B_2O_3, 0·0357 grm.; CO_2 found, 0·2042 grm.; CO_2 in total barium carbonate, 0·2024 grm.

Evidently the metaborate of barium in alcohol was completely decomposed by carbon dioxide and the boric acid *liberated.*

Another experiment was made as above, except that equivalents were taken and the treatment with carbon dioxide was discontinued after thirty minutes. After stopping the flow of carbon dioxide, the mixture was boiled for three minutes, to remove any excess of gas. The precipitate was filtered, washed

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* The italics, as in other quotations to follow, are mine.—L. C. J.

with 150^{cc} of hot water and analyzed for carbon dioxide. The result was as follows:

$Ba(OH)_2$ taken, 0·4379 grm.; B_2O_3 taken, 0·1788 grm.; alcohol, 76 per cent; CO_2 found, 0·1135 grm.; CO_2 in total barium carbonate, 0·1124 grm.

Upon evaporating to small volume the filtrate from this experiment, boric acid in abundance crystallized from the solution. Under these conditions, then, well within the limits of the recommendations of the Morse and Burton process, it is clear that barium metaborate is completely converted into carbonate with consequent *liberation* of boric acid, and that alcoholic solutions in no way prevent the action.

It might be argued that, in an evaporating mixture containing barium carbonate and boric acid in 78 per cent solution, the reaction would be reversed after the volatilization of the alcohol and the solutions became more concentrated. Indeed, Morse and Horn use this explanation (p. 110). To test this hypothesis, equivalent parts of barium hydrate and boric acid in alcohol were treated with carbon dioxide for two hours, the mixture evaporated to dryness and the carbon dioxide remaining in the dry residue determined. The following results were obtained:

$Ba(OH)_2$ taken, 0·4554 grm.: B_2O_3 taken, 0·1860 grm.; alcohol, 82 per cent; CO_2 found, 0·1018 grm.; CO_2 in total barium carbonate, 0·1169 grm. This shows that even with the very strong alcoholic solution, which was used by mistake, about 90 per cent of the metaborate was converted into carbonate and remained as carbonate after bringing to dryness.

To demonstrate, in another way, the presence of boric acid after the treatment recommended by Morse and Burton, I have used the methyl alcohol flame-test. Equivalents of barium hydrate and boric acid (I have used the word equivalents repeatedly, meaning quantities to form exactly the most important salt under discussion, viz: metaborate) were evaporated to dryness, methyl alcohol added and burned without getting the slightest indication of free boric acid. Again, equivalents of barium hydrate and boric acid were treated in alcoholic solution with carbon dioxide, the ethyl alcohol and water removed by evaporation, and methyl alcohol applied and burned with unmistakable indications of free boric acid—burning with a solid green flame.

Since free boric acid does not decompose barium carbonate upon evaporation, the question arises as to what is the temperature required to bring about this decomposition. The following experiment throws some light upon this point: finely divided anhydrous boric acid (0·1925 grm.) and barium carbonate (0·5177 grm.) were mixed in a platinum crucible, moistened with water and allowed to stand sixty hours. The contents of the crucible were then dried on a steam bath and afterwards heated for thirty minutes in an air bath at 350° C. The carbon dioxide remaining in the mixture was determined and found to be 0·0844 grm. Total CO_2 in $BaCO_3$ taken, 0·1154 grm.; CO_2 liberated by B_2O_3, 0·0310 grm.; CO_2 displaceable with formation of $Ba_2OB_2O_2$ by B_2O_3 taken, 0·1210 grm. Therefore, 74·38 per cent of the boric acid taken, if still unvolatilized, remains uncombined—at 350° C.

From the foregoing experiments, then, it is obvious that carbon dioxide decomposes the metaborate of barium in either aqueous or alcoholic solutions, and a portion, at least, of this boric acid liberated not only remains uncombined after evaporating to dryness but even upon heating to a high temperature.

Loss of boric acid by volatilization.—It is scarcely conceivable that a mixture of boric acid and barium carbonate in water should not lose an appreciable amount of boric acid on evaporation. Morse and Horn have found a detectable loss of boric acid from treating aqueous mixtures of barium hydrate and boric acid with carbon dioxide and evaporating. The carbon dioxide was stopped shortly after the alkaline coloration with phenolphthalein was destroyed. The quantity found by them is given, and varies from 0·0001 grm. to 0·00016 grm.; in one instance exactly 0·00012 on 0·0633 grm. of total boric acid present: $\left\{ \frac{0{\cdot}00636 + 0{\cdot}02538}{2} \times 13{\cdot}77 \right\} \div 3{\cdot}448 = 0{\cdot}0633$ grm. The decrease in weight should be even more noticeable in the presence of alcohol, though Morse and Horn did not detect more than 0·0040 grm. B_2O_3 $[(1/14200) \times 50 = 0{\cdot}0040]$ and this only when the concentration of alcohol arose above 92 per cent. Amounts below one part in 14,200 they were not able to discover.

The actual amount of boric acid volatilized on evaporating such mixtures to dryness is, of course, small, but certainly appreciable. Furthermore, under the analytical conditions described by Morse and Burton, the greater loss of boric acid doubtless occurs with the escape of water of combination between the temperature 100° C. and that at which the boric acid completely replaces its equivalent of carbon dioxide in barium carbonate. This temperature I have shown by experiment to be at least above 350° C. On the other hand, as was shown in my original paper, under extreme conditions, by the use of methyl alcohol and a continuous current of carbon dioxide, it is possible to volatilize all the boric acid from a mixture of barium hydrate and barium metaborate.

The interaction at high temperatures of the carbonates and borates of barium.—I have shown that the treatment recommended by Morse and Burton may result in a mixture containing barium carbonate and barium metaborate, or barium carbonate, barium metaborate and boric acid, or, indeed, barium carbonate and *free* boric acid. Of these compounds, both the barium metaborate and boric acid retain water considerably beyond 100° C.

Morse and Burton assumed that they had, after evaporation, a mixture containing only barium carbonate and barium metaborate. Morse and Horn explain it as follows: "It may be urged that even if Morse and Burton had the metaborate in insoluble condition, and it had been sensibly attacked during the treatment with carbon dioxide, nevertheless, in the subsequent attempt to heat the dried residue to constant weight, the metaborate must have attacked the carbonate. It has *since* then come to light that *some caution* must be exercised in this part of the manipulation. In the original description of the method, it was simply stated that the residue was heated to constant weight over a triple burner. The practice then, and on the few occasions when the process has since been used, was to hold the burner in the hand and rapidly play the flame over the platinum dish in order to secure as uniform a temperature of the contents as possible. The object in using a triple burner was not to obtain a *very high temperature*, which is not necessary, but, rather, to employ a flame large enough to keep the whole dish hot. No difficulty was experienced, when the heating was conducted in this manner, in *quickly* obtaining *constant and correct weights.* Nevertheless, it must be admitted, the authors of the method did not at that time suppose that the temperature at which the meta salt will attack the carbonate is so low as it has since been found to be. The temperatures employed by Jones were evidently *far* above those to which Morse and Burton heated their mixtures of metaborate and carbonate."

The use of a triple burner to secure gentle and uniform heating is unusual. Indeed, Morse and Horn use it in experiment XIV for a quite different purpose, i. e., to secure a temperature which decomposed the carbonate and borate mixture present. That the temperatures employed by me in my original experiments were *not* "*far* above those" used by Morse and Burton, can be answered best by the words of Morse and Horn: "At a *full red heat* the meta salt attacks the carbonate with expulsion of carbon dioxide" (page 130). "The temperature at which a mixture of the metaborate and the carbonate of barium is stable and which is still sufficiently high to insure the dehydration of the former, *appears* to be *just* under a red heat" (page 130). Morse and Horn do not, however, produce any evidence to show that the meta salt is dehydrated below red heat. In fact, their experimental evidence points the other way: "The experiment of heating the material, after treatment with carbon dioxide, until the weight fell below that calculated for a mixture of metaborate and carbonate, and then of exposing it in the air until the weight became very nearly constant, and finally, of removing the slight excess of weight by placing the material over calcium chloride or sulphuric acid, was many times repeated and always with a satisfactory degree of success except in two cases. In these it was *suspected* that, *while some portions of the material had been heated high enough to decompose the carbonate, other portions had not reached the temperature required for the complete dehydration of the metaborate;* for it was observed that the weights gained in the air on these occasions far exceeded the calculated deficits." Evidently, the temperatures at which decomposition of the carbonate and dehydration of the metaborate of barium takes place, cannot be *far* apart when both processes are going on in the same crucible.

I quote further (page 133): "In general, it was found difficult, by heating in our bath, to bring the too great initial weight of the material down to that calculated for a mixture of metaborate and carbonate, though in one case (No. XXX) this was accomplished by heating in the bath for three hours over three burners. The temperature on this occasion, however, rose so high that the thermometer was removed." The thermometer used registered as high as 550° C.

The conditions described above can only be accounted for in two ways, viz: (1) The metaborate has been decomposed by carbonate dioxide, though this treatment was stopped five minutes after the disappearance of alkalinity with phenolphthalein—and the barium carbonate has not at this temperature been decomposed; or (2) the metaborate still contains water. A combination of both these explanations, doubtless, more nearly expresses the truth. Morse and Horn, however (page 134), seem to prefer the latter explanation. "This," they say (i. e., the behavior of the ignited mixture in experiment XXX), "led us to *suspect* that the temperature at which complete dehydration occurs and that at which the metaborate begins to attack the carbonate cannot be very *far* apart."

The experiments made by Morse and Horn in an effort to show how these mixtures can be "quickly" brought to "constant and correct weights" are interesting, but not conclusive. They proposed (page 119) "to determine also the effect of exposing these mixtures, after heating, in an atmosphere containing carbon dioxide" with the object of finding "the temperature at which it was presumed a mixture of the metaborate and the carbonate of barium is stable, or rather the temperature at which it becomes stable." All these experiments, and those in which the mixtures were exposed to the air and dried in a dessicator, prove nothing; in fact, Morse and Horn only draw inferences from them (page 134): "From this it appears probable that the more basic borate which is formed at high temperatures, is decomposed at ordinary temperatures by the carbon dioxide of the air and reconverted into the borate and carbonate. A similar absorption of carbon dioxide takes place when material whose weight has been reduced below the normal amount, is reheated in the bath at temperatures under 500° C. From this it is *inferred* that normal weights could be *quickly* obtained by first heating to a high temperature and then at a lower one, but we have not yet tried the experiment."

Those final and satisfactory weights which are sometimes obtained may be due to the presence of an excess of carbon dioxide or water, or both, in an amount sufficient to replace any boric acid volatilized in evaporation and especially with the water of hydration. That Morse and Horn did have present in these experiments at the beginning of evaporation some free boric acid—or, if it is preferred, a more acid borate—and a corresponding increase in the amount of carbonate, is certain, because in all these experiments of which the results are recorded, carbon dioxide was passed for not less than fifteen minutes, or when phenolphthalein was used as an indicator, usually for five minutes after the disappearance of the alkaline reaction.

In my original paper I suggested the use of phenolphthalein to prevent too great an excess of carbon dioxide and corresponding decomposition of the metaborate. In a recent experiment I have tested the action of a metaborate in alcoholic solution upon this indicator, and find that exact equivalents of barium hydrate and boric acid in 78 per cent alcohol give a decided alkaline reaction, and that this alkaline coloration disappears only when about 36 per cent more boric acid is added. It is clear that phenolphthalein gives indication, not when the excess of barium hydrate is converted into carbonate, but at a point considerably beyond. Morse and Horn, then, were working with barium carbonate and an acid borate, and in many cases, most certainly, with barium carbonate and free boric acid.

If by accident—and I see no other way of doing it—the action of carbon dioxide is stopped just when the excess of barium hydrate has been converted into carbonate, still nothing is gained: for the experiments of Morse and Horn—if they show anything—make it clear that even these salts cannot be weighed with safety.

These experiments leave nothing more to be done to prove the impossibility of bringing to definite and constant weights the mixtures resulting from the method described by Morse and Burton. Furthermore, in the promised forthcoming continuation of this study by Morse and Horn, I see no possibility of any other deduction.

In conclusion, then, I reiterate:—First. Carbon dioxide decomposes the metaborate of barium in either aqueous or alcoholic solutions.

Second. The boric acid liberated may in part escape during evaporation to dryness and especially before reaching that temperature at which it has completely recombined with the barium, replacing carbon dioxide.

Third. A mixture, containing barium carbonate and hydrated boric acid, or barium carbonate with the hydrated metaborate and boric acid, or even barium carbonate and hydrated metaborate, cannot with safety be brought to definite composition for weighing.

Art. XII.—*Studies in the Cyperaceæ;* by Theo. Holm.

XVI. Carices (*C. genuinæ*) *physocephalæ and leucocephalæ.* (With figures in the text.)

The old section *Psyllophoræ* has generally been abandoned in later years as being too artificial, because it comprises both *Vigneæ* and *Carices genuinæ*, and several authors have striven to classify these monostachyous species in sections among higher developed types as "*formæ hebetatæ*" of these. But it is often a most difficult task to undertake such arrangements, inasmuch as there are not a few monostachyous species that seem to stand as isolated types so unlike the others, that in several cases one feels obliged to consider them as species with no immediate affinity to any section of the higher developed types.—This is, for instance, the case with the remarkable *Carex Fraseri* Andrews, with *C. Breweri* Boott and the puzzling *C. physodes* Bieb., which considered by themselves exhibit characters that are sufficient to make them represent groups of their own, in other words, "monotypic sections." Nevertheless, the only suggestion that has been made, so far, in regard to the classification of these three species was to refer them all together with a fourth species, *C. Engelmannii* Bailey, to one section: *Physocephalæ*, alluding to the inflated utricle. A critical examination of these species has, however, convinced us that they do not demonstrate any very close affinity to each other, hence that they ought to be regarded as constituting several sections instead of one; moreover *C. physodes* is truly a member of the *Vigneæ*. Having made a special study of monostachyous species for the purpose of connecting them with the higher types, *C. Fraseri* has actually been one of those whose possible affinity has aroused our curiosity more than most of the others. So far, we have been unable to trace any affinity to the other sections, as defined by Drejer,[*] near enough to unite it with any of these. And a consideration of its supposed allies, enumerated above, has not thrown any light upon the subject, but rather induced us to make a segregation. Let us examine each type of this section "*Physocephalæ*" by itself, and first of all *C. Fraseri*. In regard to the peculiarities of this species it is not necessary to present any long discussion, since we have already described the species in this Journal,[†] but we may recall a few of the facts to which we have called attention, viz: The monopodial ramification of the rhizome with its single assimilating leaf; that this leaf has no sheath or ligule differentiated, no midrib and no bulliform

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[*] Drejer S., Symbolæ Caricologicæ. Opus posthumum ab academia scient. Danica editum, 1844, p. 9.

[†] Vol. iii, 1897, p. 121.

cells, which is the more peculiar when we consider the unusual breadth of the leaf-blade in contrast to other broad-leaved species; furthermore that the stem above ground, the culm, is flat and hollow. These are features of such importance that the species may be well separated from all the other *Carices* as occupying a section of its own among the *Carices genuinæ.* Its snow-white inflorescence and broad, deep-green leaf gives to the plant a very singular aspect, yet the minor structure of the staminate and pistillate flowers is that of a true *Carex.*

The utricle is small for the size of the plant and the texture is very thin on account of the very delicate structure of the epidermis and the poorly developed mesophyll, besides that the very weakly developed mestome-bundles are only supported by a few strata of thin-walled stereome. None of these characters are mentioned by Professor Bailey, who established the section *Physocephalæ.**

In passing to describe the other species, formerly supposed to represent allies, *C. Breweri* Boott also shows, to some extent, a peculiar habit, though only in respect to the structure of utriculus. Boott† describes the utricle in this way: "perigyniis ovalibus amplis inflatis tenuissimis, leviter nervatis glabris fulvis rostellatis, ore albido oblique secto," and he compares the species, as far as concerns the large, inflated perigynium, with *C. Mertensii* and *C. Banksii;* the plant, however, shows no affinity to any of these two species. The utricle of *C. Breweri* is, thus, very large and inflated, altogether very unlike that of *C. Fraseri*, and we might state furthermore that the anatomical structure is, also, very different. Only the outer epidermis persists; it is very thin-walled and constitutes the only tissue between the two mestome-bundles, which are surrounded by a few layers of mesophyll, while no stereome was observed in our material. The leaves of *C. Breweri* are very narrow, almost filiform, with a shallow groove on the upper surface (fig. 5), and glabrous with exception of the margins, where short, prickle-like projections are developed in a few rows. The epidermis shows the outer cell-walls very much thickened, and the stomata, which are here restricted to the dorsal face of the blade, are slightly sunk below the outer cell-wall of epidermis; no bulliform cells are developed. The mesophyll consists of about six layers of palisades, arranged vertically on the leaf-face, partly surrounding the mestome-bundles and located close to the dorsal face of the blade. But the greater portion of the leaf is occupied by a colorless tissue, which soon breaks down and forms lacunes of quite considerable width. The stereome is thick-walled and accompanies the

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* A preliminary synopsis of North American Carices, 1886, p. 132.

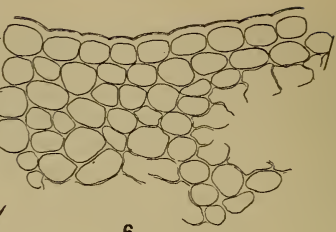
† Ill. genus Carex, vol. iv, p. 142.

larger mestome-bundles as hypodermal groups on the leptome-side of these, while it is much less developed on the hadrome-side; the smaller mestome-bundles have mostly only a few stereome-cells on the leptome-side; an isolated group of stereome is located in the leaf-margin. In regard to the mestome-bundles, these are all arranged in one band, large and oval in alternation with small, almost orbicular; they are surrounded by a thin-walled, green parenchyma-sheath, besides by a mestome-sheath of which only the inner cell-walls are thickened; no thick-walled mestome-parenchyma was observed.

Carex Breweri exhibits a leaf-structure, which corresponds in most respects with that of the two similarly narrow-leaved *Carices* from the dry rocks in the alpine and arctic regions: *C. nardina* Fr. and *C. elynoides* nob. besides with that of *Elyna Bellardi* Koch. When compared with the narrow-leaved species, which occur in wet places, for instance: *C. pulicaris* L., *gynocrates* Womskj., *dioica* L., *paralela* Læst. and *exilis* Dew., we noticed a prominent difference in the leaf-structure, depending upon the non-differentiation of the large colorless tissue, besides that the cross-section is more or less triangular in contrast to the almost hemicylindric outline, observed in *C. Breweri.*

In regard to the culm, this is cylindric, furrowed and glabrous; the internal structure corresponds with that of the leaf and the central portion is occupied by a large, thin-walled pith, separated from the narrow layers of mesophyll by wide lacunes. There is, thus, a very important difference from a morphological and anatomical viewpoint between *C. Fraseri* and *C. Breweri*, and no evidence of affinity, close enough to consider them as members of the same section is, so far, apparent.

The third species, which by Professor Bailey is enumerated as one of his *Physocephalæ*, is *C. Engelmannii* Bail., very briefly described in his preliminary synopsis (l. c.). This interesting species was first collected by Dr. Geo. Engelmann, in the upper Clear Creek region of Colorado, at an elevation of 12,000 ft., and it appears to be very rare, as it has only been found once since by Dr. P. A. Rydberg, who rediscovered it on the high mountains near Silverplume, Colorado, in the same region from where it was first recorded. Since the species is, thus, very little known, we have thought it worth while to present an illustration of it (fig. 1), showing one of the specimens, which Engelmann collected, and which was kindly loaned to the writer by Professor William Trelease. Furthermore we append a diagnosis, since, as stated above, the plant has hitherto only been briefly described, and since some of its more salient characters have been overlooked.



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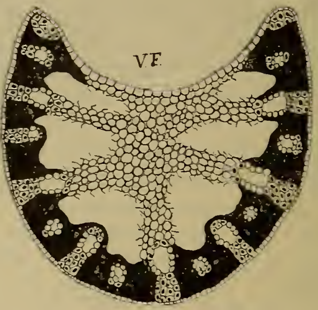

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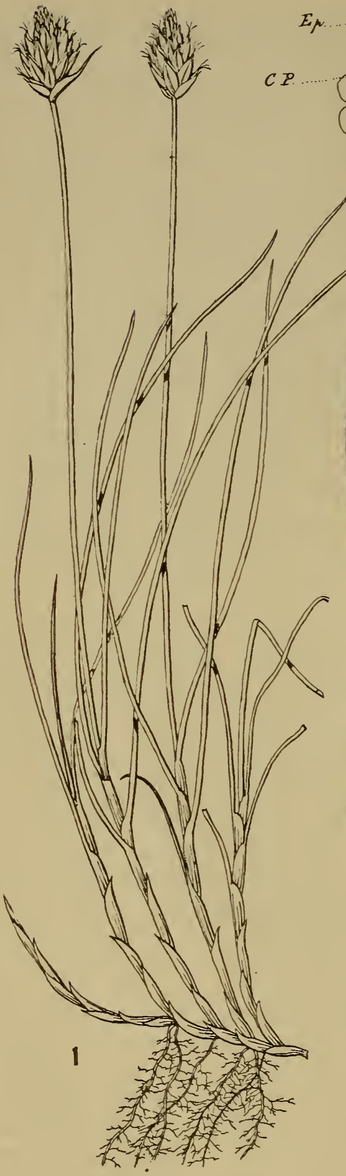

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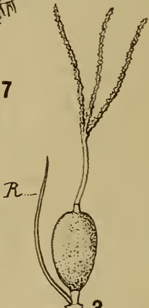

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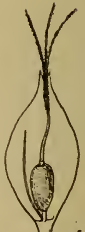

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Theo Holm ad nat. del.

Fig. 1. *Carex Engelmannii*, natural size.
Fig. 2. Scale of pistillate flower of same, magnified.
Fig. 3. Pistil of same; R = the rhacheola, magnified.
Fig. 4. Longitudinal section of utriculus with the pistil and rhacheola of same, magnified.
Fig. 5. Transverse section of leaf of *Carex Breweri;* V.F. = ventral face; magnified.
Fig. 6. Transverse section of same; Ep. = epidermis of the ventral face; C.P. = part of the colorless tissue; magnified.
Fig. 7. Inflorescence of *Carex physodes;* copied from Boott's plate; two-thirds natural size.

Carex Engelmannii: Rhizome stoloniferous, densely matted: culms numerous until 15^{cm} in height, erect, cylindric, sulculate, glabrous: leaves a little shorter than the culms, often curved, filiform, scabrous above, their sheaths light brown, persisting, not fibrillose: spike one, androgynous, globular, 1^{cm} in length: scale of staminate flower lanceolate, reddish brown with pale midrib: scale of pistillate flower (fig. 2), broader, acute, reddish brown with pale, excurrent midrib and membranaceous margins: utriculus (fig. 4) membranaceous, glabrous, tapering into a distinct bidentate-beak, at maturity not surpassing the scale, two-nerved, the nerves obsolete: caryopsis stipitate, obovate: rhacheola (R. in fig. 3) quite long: stigmas three.

The presence of the very distinct rhacheola was observed by Engelmann, who had made some sketches in lead-pencil representing the utricle and the pistil, which accompanied the specimens. In a pressed and dried state the species somewhat resembles *C. Breweri*, but when prepared in diluted alcohol the utricle shows a marked difference by being much narrower, much less inflated and especially by the beak being bidentate; but the anatomical structure of this organ, the utricle, agrees otherwise with that of *C. Breweri*.

In considering the leaf of *C. Engelmannii*, this is somewhat broader and distinctly conduplicate, with a larger ventral face; the outer cell-wall of epidermis is heavily thickened, and roundish papillæ abound on the upper surface; no bulliform cells are developed, and there are only two or three strata of colorless tissue on the upper face in the middle of the blade, separating epidermis from the green parenchyma. The mesophyll consists of very irregular palisades with large intercellular spaces and shows besides several lacunes of considerable width. The stereome and the mestome bundles show the same development as observed in *C. Breweri*.

The culm is very thin and furrowed, and exhibits a very open internal structure. The cortical parenchyma is traversed by wide lacunes separated from the pith only by a single or two layers of green parenchyma, and the pith itself is very thin-walled and broken down in the center.

The fourth member of Professor Bailey's *Physocephalæ* is *Carex physodes* Bieb., but it is hardly necessary to mention this species any further since it being a "*Vignea*" can not possibly be placed in this section of "*Carices genuinæ*." We have copied one of the inflorescences, figured by Boott (fig. 7), and it is at once noticed that the utricles exhibit a very anomalous structure, described by Treviranus in Flora Rossica as follows: "Utriculus maturescens magnitudine et forma fructuum *Corni masculæ* et *Taxi baccatæ*, angulis destitutus, multisulcus, glaberrimus, colore foliorum *Vitis* aridorum, rostro, quod ante maturitatem bifidum est, nunc obsoleto. Species nulli ceterarum affinis." Boott, in illustrating the species, reprints Bieberstein's diagnosis and declares himself unable to decide its affinity unless it be near *C. baccans* Nees, which, however, is one of the "*Indicæ*." It is a very rare plant, but has been recorded again by Meinshausen* from sandy soil on the Southern plains between Volga and the Caspian sea, and this author enumerates it among the *Homostachyæ* "spiculis homogeneis androgynis."

But neither Boott or Meinshausen have expressed any doubt as to the normal condition of this singular plant. However, Treviranus† himself, but several years after the publication of Ledebour's Flora Rossica, calls attention to the possibility of the utricles being abnormally developed, and the abnormality being evidently due to the puncture of some insect, as we are used to observe in other species of *Carex*, e. g. *C. vulpina*, *C. paniculata* and very commonly in *C. disticha.* And there are actually some points in Bieberstein's diagnosis which seem to confirm Treviranus' suspicion, namely, the structure of the anthers, "polline emisso, ad basin usque in lobos duos dehiscentes, ut tunc filamentum apice biantheriferum appareat," and the structure of the utricle, "dentibus oris duobus conniventibus exilibus, in maturo vix superstitibus," besides the comparison of the utricle with the fruit of *Cornus* or *Taxus.*

The section *Physocephalæ* as established by Prof. Bailey is thus, to say the least, an assemblage of incongruities and can not be maintained. *Carex physodes*, whether it be abnormal or not, must be placed among the "*Vigneæ*" on account of its inflorescence and two stigmas. *Carex Fraseri* can not by any means be regarded as an ally of *Carex Breweri* on account of its morphological and anatomical peculiarities, and we suggest to place it in a section of its own, to which we designate the name "*Leucocephalæ*," characterized as follows: Spike one, androgynous, snow-white; perigynium thin, glabrous, elliptic with the beak very short, obliquely cut; leaf broad and flat without sheath, ligule or midrib; culm flattened; stigmas 3. Only species *Carex Fraseri* Andrews.

Carex Engelmannii appears, on the other hand, well referable to Drejer's *Physocarpæ* as a "*forma hebetata*," and of which the diagnosis of the section is defined as follows: "Spicæ masculæ femineæque plures, breviter pedunculatæ. Bracteæ foliaceæ, evaginatæ. Perigynia membranacea, nervata, glabra, valde inflata, rostrata ore distincte bifido vel bicuspi-

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* Cyperaceen der Flora Russlands. (Acta hort. Petrop. vol. xviii, 1901.)
† Ad Caricographiam Rossicam, Moskow, 1863, p. 4.

dato. Stigmata terna, stylus plerumque intra perigynium flexuosus, caryopsis trigona vel triquetra."

In several respects the utricle of *C. Engelmannii* reminds of that of *C. pulla* Good. and its nearest allies, while we cannot agree with Drejer, that such types as *C. microglochin*, *C. pauciflora* and *C. pulicaris* should be looked upon as primordial types of this same section. *C. pulicaris*, for instance, differs greatly from any of these by the structure of its utricle alone, and we suggest the affinity of *C. microglochin* and *C. pauciflora* rather to be sought among the *Echinostachyæ* Drej.: "perigynia vix inflata, demum plus minus squarrosa" both of which characters are readily recognized in *C. pauciflora* and its allies. As regards *C. Breweri*, this may "ad interim" be retained as the only member of the *Physocephalæ*, and this section appears to be very near the *Physocarpæ*, evidently parallel with this; but at present we are unable to refer it to any of the already established sections in which higher developed types are represented.

Brookland, D. C., April, 1902.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Probable Source of the Heat of Chemical Combination, and a New Atomic Hypothesis.*—Professor T. W. Richards has brought forward the very suggestive generalization that the contraction exhibited during chemical combination is in many cases approximately proportional to the heat evolved; hence he believes that the chief source of heat of chemical combination is the work performed in compressing the material. He gives an explanation upon the same basis of the mechanism of the heat of adsorption, adhesion and change of allotropic form. He is led, from these considerations, to the interesting hypothesis of compressible atoms, for the details of which, with ingenious applications, reference must be made to the original article.—*Proc. Amer. Acad.*, xxxvii, 399, and *Zeitschr. physikal. Chem.*, xl, 597. H. L. W.

2. *Lithium Silicide.*—By heating silicon with metallic lithium in a nickel boat in an exhausted tube, Moissan has found that the two elements combine and that the excess of lithium used may be distilled off between 400 and 500°, leaving a bright indigo-blue product in the form of brilliant crystals. The compound has the composition represented by the formula Si_2Li_6 and corresponds to the spontaneously-inflammable hydride of silicon, Si_2H_6, which was recently described by Moissan and Smiles. The lithium silicide is very hygroscopic, is violently decomposed by water, acids and the halogens, and, as would be expected, has very powerful reducing properties. Thus, when heated with the oxides of iron, chromium, manganese and calcium it gives the metals or alloys, but it does not decompose alumina.—*Comptes Rendus*, cxxxiv, 1083. H. L. W.

3. *The Black Color of the Rocks in the Cataracts of the Nile.*—Lortet and Hugounenq state that the rocks in the Nile rapids at Wady-Halfa and at Assouan, which are covered at the time of high water, are very smoothly polished and present a deep black color when visible at low water. This is not due to the colors of the rocks themselves, which are eruptive rocks and sandstones of various colors, but to a thin black coating. When this surface is treated with strong hydrochloric acid a brown liquid is obtained which loses its color upon heating, chlorine is given off and the liquid gives reactions for manganese. This shows that the black coating is due to manganese dioxide. The rocks contain small quantities of manganese not in the form of dioxide, but the latter is produced upon their polished surfaces.—*Comptes Rendus*, cxxxiv, 1091. H. L. W.

4. *Bismuth-lead Sulphide-halides.*—Three compounds, made by fusing lead halides with bismuth sulphide, have been described by Ducatte. They form very small acicular crystals in the

cavities of the mass which has been fused. The formulas given are,

$$PbS \cdot Bi_2S_3 \cdot 2\,BiSCl,$$
$$PbS \cdot Bi_2S_3 \cdot 2BiSBr, \text{ and}$$
$$PbS \cdot Bi_2S_3 \cdot 2BiSI.$$

No evidence is given to show that the halogens are combined with bismuth rather than lead, hence it is not clear why the above formulas have been adopted instead of simpler ones which are perhaps more plausible on account of their less complicated form; for instance, $PbCl_2 \cdot 2Bi_2S_3$.—*Comptes Rendus*, cxxxiv, 1061. H. L. W.

5. *The Atomic Weight of Uranium.*—RICHARDS and MERIGOLD have made a new investigation upon the atomic weight of uranium by analyzing uranium bromide, UBr_4. The method differs essentially from any that has been used hitherto for the purpose, and apparently the results are more reliable than those of previous investigators. The results show that this atomic weight is about a unit lower than the value that has been previously accepted, the average of several closely agreeing determinations being 238·53.—*Proc. Amer. Acad.*, xxxvii, No. 14. H. L. W.

6. *First Book of Qualitative Chemistry;* by PRESCOTT and SULLIVAN. Eleventh Edition. 8vo, pp. 148. New York, 1902 (D. Van Nostrand Company, price $1.50). — This text-book, which has been in use since 1879, has now been entirely re-written in order to present the subject in the light of the modern theories of solution and of mass-action. Some attention is paid also to the classification of the Periodic System. The first 37 pages of the book are devoted to an introduction, chiefly of theoretical character, including concise presentations of the subjects of electrolytic dissociation, chemical equilibrium, solubility, etc. In the practical part of the book only a moderate amount of use is made of the ionic theory. The equations introduced are limited to the more difficult ones, and these are given without regard to ions. The book contains many satisfactory variations from the time-honored methods that have come down through Fresenius from Will and Rose, but it is surprising that the calcium sulphate method for testing for strontium, which was abandoned by Fresenius, is retained here, since the treatment of the nitrates with amyl alcohol is a much more satisfactory method.

The course outlined in this book is a rather extensive one, which is better adapted for beginners in college than for younger students. Abbreviated tables for analysis are adopted, but they are used in connection with many explanatory notes. Many teachers would prefer to have these aids to thoughtless laboratory work omitted altogether. H. L. W.

7. *Grundriss der qualitativen Analyse*, von Dr. WILH. BÖTTGER. 8vo, pp. xxii, 249. Leipzig, 1902 (Wilhelm Engelmann). —This text-book on qualitative analysis has been written from

the standpoint of the ionic theory, and comes from an assistant in Professor Ostwald's laboratory. It is evident that the work has been very carefully carried out on the proposed plan, and it will be useful to those who desire to employ the modern theories of solutions in teaching the subject. Perhaps it is doubtful if it is advisable to give as much prominence to the doctrine of ions and the law of mass-action as is given in this book, particularly with beginners in the study of chemical analysis, but the tendency of teachers seems to be in this direction.

The equations in the ionic form, which are extensively used in this book, appear more complicated and less easy to grasp than the usual equations, on account of the separation of the ionic symbols by the plus sign. For instance, the form of the usual equation,

$$2AgNO_3 + K_2CO_2 = Ag_2CO_3 + 2KNO_3,$$

is changed to

$$2Ag^{\cdot} + 2NO_3{}' + CO_3{}'' + 2K^{\cdot} = Ag_2CO_3 + 2K^{\cdot} + 2NO_3{}'.$$

This last equation does not represent the actual conditions with complete accuracy, because in moderately concentrated solutions ionization is not complete, and moreover it is not as easy to see, as in the first equation, what salts are mixed to produce the reaction. It would seem preferable, if ions are to be marked, to give equations some such form as the following one:

$$2Ag^{\cdot}NO_3{}' + Na_2{}^{\cdot\cdot}CO_3{}'' = Ag_2CO_3 + 2Na^{\cdot}NO_3{}'.$$

A somewhat loose statement is noticed in the explanation of ionization (S. 13) where it is stated that "always an equal number (eine gleiche Zahl) of positive and negative ions is formed or disappears." Of course these numbers vary according to valency.

The author has not used the results of the more recent investigations in all cases. If he had carefully consulted Fresenius's last edition, he would probably have pointed out the difficulty of detecting small quantities of silver chloride in the presence of mercurous chloride, and would have given a method for overcoming this trouble. He should have avoided the unreliable method of testing for strontium, in the presence of much calcium, with calcium sulphate solution. He should not have given the formula NH_2Hg_2Cl, but $NH_2HgCl + Hg$ for the familiar black substance produced by the action of ammonia upon mercurous chloride. The formula $SbCl_3 \cdot 5CsCl$ should have been $2SbCl_3 \cdot 3CsCl$, as has been shown by at least four different investigators, the first of whom published his results in 1882. H. L. W.

8. *Reflection Power of Metals for Ultra-violet and Ultra-red Rays.*—E. Hagen and H. Rubens extend their previous work on this subject, which extended from $\lambda = 450$ to 700 $\mu\mu$. They abandoned their previous photometric method and adopted a heat method, consisting of the use of a linear thermal element (H. Rubens, *Zeitschr. f. Instrumentenk.*, 18, p. 65, 1898). This heat method could be used as far as 221 $\mu\mu$; for the authors

discovered that an arc lamp gives carbon bands as far as this wave length in the ultra-violet which are of sufficient heating effect. Some of the results of the previous photometric work are corrected.

The reflection power of silver falls off quickly below 450 $\mu\mu$ and reaches a minimum of 4 per cent approximately at 320 $\mu\mu$. While silver for visible rays is the best reflecting of all metals, it is the poorest between 250–350 $\mu\mu$. Platinum, iron and nickel show approximately the same reflecting power. The reflecting power of speculum metal was investigated and is of especial interest in view of concave gratings. Magnalium shows an exceptionally high reflecting power. The reflecting power in the extreme ultra-red possesses far more regularity than in the visible and ultra-violet regions.—*Ann. der Physik*, 5, 1902, pp. 1–21.

J. T.

9. *Spark Discharge from Metallic Poles in Water.* — Dr. WILSING of Potsdam believes that the peculiarities of the spectrum of Novæ can be explained by pressure, and accordingly has studied spectra produced by the electric spark in water where it is presumable that great pressure results. He arrived at the conclusion that displacement of lines and double lines occurred which were in every way similar to those observed in the spectrum of Nova Aurigæ. Sir Norman Lockyer has repeated Dr. Wilsing's results and comes to the conclusion that shifts are obtained under water which are in opposite directions to those noticed in the dark lines of the spectra of Novæ and that the shift in the star does not arise from pressure.—*Nature*, May 22, 1902.

10. *Electrical Effect of Light.* — P. LENARD contributes an exhaustive paper on the effect of ultra-violet light in generating cathode rays, and the bearing of this phenomena on radio-active bodies. The velocity of the rays so excited is approximately $\frac{1}{1000}$ of the velocity of light. These rays show diffusiveness and must be absorbed in great measure by gases. The method of measure was by means of loss of charge.—*Ann. der Physik.*, 5, 1902, pp. 149–198. J. T.

11. *Interference Tubes for Electrical Waves.*—Various attempts have been made to employ Quincke's resonating tubes for the detection of electric waves. AUGUST BECKER has made a number of measurements with such tubes and with a coherer. The waves were propagated along the surface of the tubes and issued into the air with scarcely diminished energy. Their length within the tubes was 10^{cm} and in free air $7{\cdot}5^{cm}$. The tubes were filled with various liquids and the dielectric constants determined. A list of such constants is appended.—*Ann. der Physik*, 5, 1902, pp. 22–62. J. T.

12. *Law of Velocity which Cathode Rays suffer by Reflection.*—If there is such a law, the reflected rays should be more powerfully diverted by a magnet than the direct rays. E. GEHRCKE finds that this happens. As an exciter of the rays he employed

a static machine which gave a constant current. Different reflecting surfaces were investigated. The writer refers to the discovery of Hertz that thin metal films are penetrated by the cathode rays and draws the conclusion that the corpuscles can move within a metal without losing their charges. If one makes the further assumption, that the corpuscles also can lose in internal reflection, and that the loss of velocity of each corpuscle increases with the number of collisions with the particles of the reflectors, one comes to the conclusion that a strongly absorbing body like platinum will give forth fewer corpuscles than a weaker absorbing body like magnesium. The author's results seem to confirm this theory.—*Ann. der Physik*, 5, 1902, pp. 81–93. J. T.

13. *Role of Self-Induction in discharges of Electricity through Gases.*—Various observers have shown that certain spectral lines disappear when suitable self-induction is employed in oscillatory currents. M. B. EGINITIS studies the changes in heat effects produced in the spark terminals by varying self-induction. M. A. DE GRAMONT believes that the proper use of self-induction may lead in physical chemistry to a method of separating the spectra of dissociation of metalloids.—*Comptes Rendus*, May 5, 1902, pp. 1043, 1048. J. T.

14. *The Theory of Optics ;* by PAUL DRUDE. Translated from the German by C. Riborg Mann and Robert A. Millikan. Pp. 546+xxi. New York, 1902 (Longmans, Green, and Company).—Very nearly a half of the volume is devoted to a compendious treatment of geometrical and physical optics, written in a clear but very condensed style. The rigid deduction and application of the Principle of Huyghens, founded upon the theoretical investigations of Kirchhoff and of Voigt, will offer the most novel extensions to the familiar discussions of the current texts. It is difficult to conceive how a more admirable review of physical optics could be contained in so concise a form, and although it can hardly be regarded as a sufficient guide to a novice in this field, it is sure to give pleasure to every reader who possesses the requisite elementary knowledge.

Section II, of 220 pages, develops the electromagnetic theory of light and applies it to the explanations of the enormously varied optical properties of bodies. It is impossible to indicate in a brief review the surprising extent of the phenomena discussed with highly satisfactory completeness, or to point out the vast departure in style of treatment from the best known text-books on light. The last chapter of the section, however, in which the theory of Lorentz regarding the modifications which motion of the bodies in question introduces in optical phenomena, may fairly be cited as not the least interesting.

The final Section treats, in three chapters, of the energy of radiation ; of the application of the second law of thermodynamics to pure temperature radiation ; and of incandescent vapors and gases. These are broadly philosophical and illustrate the essential unity of all departments of physics.

As a whole, the book must be regarded as one of the most important recent contributions to scientific literature. The work of the translators appears to have been exceptionally well done.

C. S. H.

15. *Elementary Principles in Statistical Mechanics developed with special reference to the Rational Foundation of Thermodynamics;* by J. WILLARD GIBBS, Professor of Mathematical Physics in Yale University. Yale Bicentennial Publications. Pp. xviii + 207. New York, 1902 (Charles Scribner's Sons).—In this last volume by Professor Gibbs we have, as it were, the conclusion of his earlier papers published so many years ago on the subject of the Equilibrium of Heterogeneous Substances.

It rarely happens in science that there is one particular branch of it in which only one or two men can be considered as preëminent. To all intents and purposes this is the present condition in advanced study of thermodynamics. The scientific world, as a whole, owes a debt of gratitude to Professor Gibbs for at last giving in printed form such a clear and definite exposition of the Principles of Statistical Mechanics, with special reference to Thermodynamics. It is true that in this present volume the problem is treated as one of pure mechanics and not of thermodynamics; nevertheless, one's thoughts always turn to the latter to appreciate the physical meaning of the various equations.

The best description of the scope of the volume is contained in the preface written by Professor Gibbs himself, from which the following remarks are quoted more or less accurately. In the first chapter there is the general problem of which may be called the determination of the fundamental equation of statistical mechanics and its integration. In the second chapter certain principles proved in the first are applied to the "Theory of Errors"; while in the third chapter the same principles are applied to the "Integration of the Differential Equations of Motion." In the fourth and following chapters, making fifteen in all in the book, attention is directed to the consideration of statistical equilibrium of conservative systems, with special applications to Thermodynamic analogies, such as Entropy, Temperature, etc.

It cannot be denied that the present volume is extremely difficult reading, but one feels, as one masters it page by page, that there is obtained a deeper insight into the ultimate truths of Physics. It is not a book which a university student would in general find profitable reading, but it is one which every such student should add to his collection of choice volumes in order to have it at his disposal for reference or for consultation concerning many of the perplexing questions of Thermodynamics. J. S. A.

16. *Beiträge zur chemischen Physiologie und Pathologie,* herausgegeben von FR. HOFMEISTER. II, 5-6, 1902 (Vieweg u. Sohn).—In an earlier number of the Beiträge, Lewin concluded that indol and phenol may have their origin in metabolic processes in the animal body independent of putrefactive changes in the intestine. This view is now combatted by P. MAYER, as the result of an

experimental investigation of the excretory products found in phlorhizin diabetes. In the latter he finds no increase in the output of phenol, indol or glycuronic acid. LANGSTEIN has continued his study of the end-products of peptic digestion on crystallized egg-albumin. The compounds thus far definitely isolated include: leucin, tyrosin, phenylalanin, glutamic and aspartic acids, cystin, lysin, pentamethylendiamin, oxyphenylethylamin and a nitrogenous carbohydrate. The differences between peptic and tryptic digestion thus appear to be largely quantitative rather than qualitative in kind; although in peptic digestion the biuret reaction persists. NEUBERG and BLUMENTHAL report the formation of isovalerylaldehyde and acetone from gelatin. BIELFELD, in an investigation of the iron content of the liver, found that the liver cells of women are, as a rule, decidedly poorer in iron than those of men. These differences do not appear until the age of 20 to 25. MAGNUS-LEVY has published the results of a comprehensive and interesting investigation of acid formation during the autolysis of the liver, under aseptic and antiseptic conditions. The non-volatile acids thus obtained include two lactic acids and succinic acid; the non-volatile acids formed are: formic, acetic and butyric acids. The gases H, H_2S and CO_2 also arise. The application to our knowledge of certain pathological conditions is pointed out. L. B. M.

II. GEOLOGY AND NATURAL HISTORY.

1. *United States Geological Survey.* Examination of Forest Reserves and Adjacent Regions; by HENRY GANNETT. 21 Ann. Report, Pt. V, 711 pp.; 143 pls.; maps in accompanying portfolio. This report includes descriptions of seven reserves and wooded areas in different parts of the United States.

2. *Minéralogie de la France et de ses Colonies.* Description physique et chimique des Minéraux; Étude des Conditions géologiques de leurs Gisements; par A. LACROIX. Tome troisième, 1er fascicule, pp. 1–400. Paris, 1901 (Librairie Polytechnique, Ch. Beranger, Éditeur).—After an interval of nearly four years, the second volume of this most valuable work is now followed by the third. It contains the Oxides, Hydroxides, Nitrates, Plombates and Manganites. A fourth volume, which is promised soon, will complete the whole. To the mineralogist, who is acquainted with the admirable features of the preceding volumes, it is unnecessary to say more than that the part now issued is carried through on the same plan and with like success.

3. *Size of Grain in Igneous Rocks in relation to the distance from the Cooling Wall;* by AUGUSTIN L. QUENEAU. Contributions from Geol. Dept. Columbia University, vol. ix, No. 80, pp. 181–195.—The Palisades (Triassic Diabase) and the minette dike of Franklin Furnace, N. J., were chosen as fields for the study of the causes of variation in size of grain in igneous rock. The method used is based on Lane's work (Geol. Survey Mich., vol. vi), and the mathematical treatment upon the general theory of cooling presented by R. S. Woodward (Annals of Math., vol. iii).

4. *The Eparchæan Interval*—a Criticism of the use of the term Algonkian; by Andrew C. Lawson. Bulletin Dept. Geol., Univ. of Calif., vol. iii, No. 3, pp. 51–62.—In common with many geologists Professor Lawson believes that the term Algonkian has been used without sufficient regard for the accepted rules of nomenclature, and in such a way as to minimize the great interval of erosion between the Archæan and the Animikie series of Lake Superior. The *time* sequence of the important rock groups of the Lake Superior province is believed to be as follows:

- PALEOZOIC
  - Cambrian (Upper division or Potsdam only)
  - Unconformity.
  - Algonkian
    - Keweenawan.
    - Unconformity.
    - Animikie=Penokee=Upper Marquette.
- EPARCHÆAN INTERVAL.
- ARCHÆAN
  - Huronian=Upper Keewatin=Lower Marquette, etc.
  - Unconformity.
  - Laurentian, so called, granite gneisses, etc., (intrusive in the Ontarian) and the Carltonian anorthosites.
  - Ontarian
    - Keewatin=Lower Huronian=Crystalline schists of south shore invaded by [granite-gneisses
    - Unconformity.
    - Coutchiching.

5. *Former Extent of the Newark System*; by W. H. Hobbs. Bull. Geol. Soc., vol. xiii, pp. 139–148, 5 figs.—The prevalent opinion of geologists in regard to the Newark beds of the Atlantic border is that they were deposited in "local basins," and never extended far beyond their present boundaries. Professor Hobbs argues that the marginal faults favor the "broad terrane" hypothesis and that the distribution of the coarse conglomerates is not opposed to this theory. For a number of other reasons Professor Hobbs joins Russell in the belief that the Newark areas of the entire eastern border of the United States are remnants of one widespread formation.

6. *Quaternary History of Southern California*; by Oscar H. Hershey. Dept. Geol., Univ. California, vol. iii, No. I, pp. 1–30. 1 pl.—In his studies of the California Quaternary, Mr. Hershey has examined the evidence of earlier writers and has added much that is new in regard to the sedimentation and crustal movements during the Quaternary. A time scale divided into seven epochs has been constructed and the character of the erosion and deposition of each epoch is given.

7. *Plissements et Dislocations de l'écorce terrestre en Grèce*; by Ph. Negris. Pp. 210; 2 maps. (Athens: C. Beck; Paris: C. Béranger.)—Earth movements, principally foldings on a large scale, have affected Greece and parts of Turkey since Jurassic times; the first movement (the Olympic) was pre-Cretaceous, then followed movements during the Cretaceous and the Eocene. The last folding (the Tenarus), which runs from N. to S., began late in the Pliocene and affected all of Greece. The Tenarus folds are considered part of the world-wide crustal movements of late

Tertiary times. Outbursts of igneous rock—peridotite and trachyte—accompany the disturbances.

8. *The Old Tungsten Mine at Trumbull, Conn.;* by Wm. H. Hobbs. U. S. Geol. Survey, 22d Ann. Rept., Pt. II, pp. 13–22.—This report gives a short description of the geology of this mineral locality together with a detailed geological map of the region. The deposit is of interest chiefly on account of the occurrence of the rare tungsten minerals, scheelite and wolframite, the latter occurring as a pseudomorph of the former. Other characteristic contact minerals are found associated with them. These minerals are found at the contacts between a crystalline limestone and two beds of hornblende-gneiss, which lie, one above and the other below it. The hornblende-gneiss is of igneous origin having the characteristics of a hornblende diorite, which, however, becomes gneissoid and altered near its contacts with the limestone. Considerable work has been done at the locality in the effort to develop a paying tungsten mine, but with little success.

W. E. F.

9. *Peculiar Character of the Eruption of Mt. Pelee, May 8th.*—The writer, in a communication to the Connecticut Academy of Sciences, May 14, when only the first great eruption had occurred, maintained that the destruction of St. Pierre was due to the eruption of a great volume of exploding oxy-hydrogen gases, due to the decomposition of water by contact with the intensely heated lava deep within the volcano.*

Subsequent investigations of the nature of the destruction wrought there, and the character of the later eruptions, have fully confirmed this view.

At 2500° C. 50 per cent of the steam will be converted into these explosive gases at ordinary pressures, but at the enormous pressures within a volcano it would require a higher temperature to effect this. But there is no doubt whatever that temperatures above 3000° exist within many volcanoes.

It is, therefore, only necessary to suppose that the highly heated lava, by bursting through the intervening rock, came into sudden contact with a more or less extensive body of subterranean water, or even with porous rocks saturated with water, in order to explain the sudden generation of explosive gases.

If the subterranean waters thus converted into gases and steam were sea-water, the chlorine of the salt would also be dissociated from the sodium at the same or even lower temperatures, and this gas would also form an explosive mixture with a part of the hydrogen. By their union hydrochloric acid gas would be produced, which is a highly irritating, poisonous and suffocating gas, powerful enough, even when present in small quantities, to destroy animal and vegetable life, as has happened in several of the eruptions of Vesuvius and other volcanoes near the sea. However, in the case of St. Pierre, nearly all the people were probably killed instantaneously by the outburst of intensely hot

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* See Science, May 16, 1902.

flames, due to the oxy-hydrogen gas explosions, which must have penetrated to the interior of all buildings, scorching and burning everything within reach, while the force of the explosions, analagous to that of dynamite, was sufficient to demolish the strongest stone buildings, tear the branches from the trees and rend their trunks, dismount large cannon and transport them some distance, and produce scenes of indescribable ruin of all life and property, as is well shown in recent photographs. Probably there were several of these explosive outbursts, following in rapid succession, though a single one might have destroyed all life in St. Pierre.

The recent reports of Mr. George Kennan and of Professor Heilprin, who seem to have been the first to visit the new crater which destroyed St. Pierre, show that this crater is an oblique pit on the side of the mountain, facing St. Pierre, and with several tunnel-like openings in the perpendicular wall, pointing directly toward the city. Therefore, when the great eruption took place, the vast jets of explosive gases were ejected horizontally toward St. Pierre, which was thus swept by a "tornado of fire," as if it had been in the focus of an enormous blowpipe flame.

The burning gases and the very hot steam, resulting from this explosion, instantaneously spread out on all sides, far beyond the focus of the explosion, causing a wide zone of scorching and burning, but without the total destruction seen in St. Pierre itself. These hot and flaming gases caused the sudden burning of the upper works of the vessels and great loss of life, far beyond the limits of the more violent explosive action.

The explosive gases and flames evidently reached St. Pierre sooner than the cinders and stones thrown out by the same outburst of gases, but the oblique direction of the mouth of the crater was such as to produce a regular bombardment with hot missiles of this kind, which added to the destruction of the buildings and to the debris in the streets.

That the woodwork left on some of the buildings and the heaps of broken timber and trees in the streets were not burned up, was probably due to the heavy fall of rain that immediately followed the eruption, caused by the condensation of the steam in the upper regions of the atmosphere.

Professor R. T. Hill, who reached Morne Rouge and witnessed a late eruption (May 26) of Mt. Pelee from there, saw horizontal flashes of light in the midst of the vast column of steam and cinders emitted. These lightning-like flashes he attributed, no doubt correctly, to explosive gases. They were evidently due to the oxy-hydrogen gases, at that time greatly diluted with steam in the column of cinders, etc.

Had the openings of the new crater been directed vertically upward, as is usually the case, the loss of life and property would have been comparatively small, because the destructive energy would have been expended in the upper regions of the air.

This eruption, though of small volume, is of great scientific interest because of its rare and exceptional character. In fact, it is the only example of this highly explosive type of eruption that has occurred in modern times under circumstances that permitted scientific examination, or the testimony of intelligent observers. Eruptions of this kind might well be designated as the *oxy-hydrogen explosive type*, the principal destruction being caused by the explosion of vast volumes of these gases, while in the much more common type of eruptions the explosions are caused mainly by the escape of steam under very high pressures. Explosive eruptions of intermediate kinds, due to various mixtures of steam and the explosive gases, also occurred here. The later eruptions (as on May 26) from the summit crater of Mt. Pelee were evidently of this mixed kind, in which steam predominated.

A. E. VERRILL.

10. *The Fauna and Geography of the Maldive and Laccadive Archipelagoes.* Edited by J. STANLEY GARDINER. Vol. i, Part II, pp. 119–222, 7 plates, 16 figs.—The principal coral reefs of the Indian ocean were made the special object of study by an expedition headed by J. Stanley Gardiner in 1899 and 1900. The present paper is a continuation of a previous report (this Journal, vol. xiii, p. 321) and contains the following papers on fauna:

Amphibia and Reptilia, by F. F. Laidlow; Lepidoptera, by Ed. Meyrick; Echiuroidea, by A. E. Shipley; Sipunculoidea, by A. E. Shipley; Land and Freshwater Mollusca, by Edgar A. Smith; Pigments of Corals, by C. A. MacMunn; Marine Crustaceans, by L. A. Borrodaile; Chaetognatha, by Leonard Doncaster; Dragon Flies, by F. F. Laidlow.

Mr. Gardiner has continued his studies on the origin of the coral island groups (pp. 146–184) and finds that the subsidence theory is untenable for the great Maldive plateau. To quote the author: "My conclusion then is that an almost flat plateau at a depth of 160 fathoms was at one time formed, and that on this the banks severally arose." The details of the formation of the group are given graphically on page 183. Part III of vol. i is promised for October, 1902.

11. *Report on the Actinians of Porto Rico*; by J. E. DUERDEN. Bulletin U. S. Fish Commission for 1900, pp. 323–374, 13 plates. —This valuable paper is devoted largely to the anatomy and histology of the species treated, of which there were only thirteen in the collection. A single new species (*Bunadosoma spherulata*) is described. Two of the plates give general views of five species. The other plates are devoted to sections, and are well executed.

A. E. V.

✓ 12. *The Ascidians of the Bermuda Islands*; by W. G. VAN NAME. Trans. Conn. Acad. Sciences, vol. xi, pp. 325–411, 19 plates. Feb. 1902.—This is an excellent monographic work on the Bermudian Ascidians, which had previously received but little attention. The total number of species and marked varieties is 46, representing 23 genera. Four new genera are described and 21 new species, besides 11 subspecies or marked varieties.

Most of the new forms and all the new species are compound ascidians, which are unusually numerous at the Bermudas. Most of these were studied from living specimens, as well as from large series preserved in different media. Nearly all the species are illustrated by anatomical drawings, and most of the new ones by reproductions of photographs, showing the general appearance. Some of the photographs were made from living specimens, under water. It is altogether the most important work hitherto published on the ascidians belonging to the West Indian faunal area.

A. E. V.

13. *The Embryology of a Brachiopod* (*Terebratulina septentrionalis*); by E. G. Conklin. Proc. Amer. Phil. Soc., xli, No. 168, pp. 41–76. 10 plates. 1902.—This is, in many respects, one of the most complete accounts of the early stages of a Brachiopod that has been published. The author adds a discussion of the zoölogical affinities of the Brachiopods, concluding that from embryological data they are nearest to *Pharonis* and the Polyzoa.

A. E. V.

14. *Results obtained in Havana from the destruction of the Stegomyia fasciata infected by Yellow Fever; II. The Propagation of Yellow Fever*; by Major W. A. Gargas, Medical Corps, U. S. Army. Sanitary Dep., Havana, Ser. 4, 1902.—These two papers are of great interest and importance as demonstrating that yellow fever in Havana is transmitted by this particular mosquito, and in no other way. The disease was fully controlled simply by destroying these mosquitoes in various ways, and preventing them from gaining access to fewer patients, by the liberal use of screens. By these means, and without special disinfection of rooms or clothing, the fever was reduced to a minimum after March, 1901, when this method was commenced. No cases whatever occurred during the four months from October to January inclusive, which has not happened before in 150 years or more. The average number of deaths from yellow fever from April 1st to December 1st, since 1889, had been 410.54, but by the anti-mosquito methods it was reduced to 5, in 1901. Yet in 1900, with the most careful and elaborate methods of ordinary disinfection, very little impression was made on the yellow fever, for there were 1244 cases and 310 deaths in 1900, but in 1901 there were only 18 deaths, 12 of which occurred in January and February, before the destruction of the mosquitoes was commenced. Yet the conditions were in other respects very favorable for a bad epidemic in 1901, for about 40,000 non-immune emigrants had arrived,—a larger number than ever before. In view of such results there seems to be no doubt whatever that the true source of the yellow fever infection has been demonstrated and also that the disease can be easily and surely controlled in all cases, if suitable care be used to destroy this pernicious mosquito. Moreover, the same efforts will simultaneously eradicate the malarial fevers.

A. E. V.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Smithsonian Institution.*—The following papers have been recently issued from the Proceedings of the U. S. National Museum :

1269. The Mammals of the Andaman and Nicobar Islands ; by Gerrit S. Miller. Pp. 751–795.

1271. Review of the Larks of the genus Otocoris ; by Harry C. Oberholser. Pp. 801–884.

1272. New Decapod Crustaceans from the West Coast of North America ; by Mary J. Rathbun. Pp. 885–905.

1273. A newly found Meteorite from Admire, Kansas ; by George P. Merrill. Pp. 907–913.

1274. Distribution of three new Birds from the Southern United States ; by Edgar A. Mearns. Pp. 915–926.

Descriptive Catalogue of Meteorite collection in U. S. National Museum to Jan. 1, 1902 ; by Wirt Tassin. Rept. 1900, pp. 671–698. 3 pls.

2. *United States Weather Bureau:* Wind Velocity and Fluctuations of Water Level on Lake Erie ; by ALFRED J. HENRY. Dept. of Agriculture, Bulletin J. 22 pp., 13 plts.—The data collected by the Weather Bureau for many years has been tabulated and furnishes the basis for an interesting study of the "seiche" of Lake Erie.

3. *Scientia.*—The valuable series published in Paris by G. Carré and C. Naud under the above name has received the following additions :

Cryoscopie ; par F. M. Raoult. (Phys.-Mathèmatique, No. 13) pp. 106, 1901.

Franges d'interférence et leurs applications Métrologiques ; par J. Macé de Lépinay. (Phys.-Mathèmatique, No. 14) pp. 101, 1902.

La Géométrie non Euclidienne ; par P. Barbarin. (Phys.-Mathèmatique, No. 15) pp. 79, 1902.

Le Phénomène de Kerr et les phénomènes Électro-optiques ; par Eugène Néculcéa. (Phys.-Mathèmatique, No. 16) pp. 91, 1902.

Théorie de la Lune ; par H. Andoyer. (Phys.-Mathèmatique, No. 17) pp. 86, 1902.

Géométrographie ou Art des Constructions géométriques ; par Emile Lemoine. (Phys.-Mathèmatique, No. 18) pp. 87, 1902.

4. *Ostwald's Klassiker der Exakten Wissenschaften.* Leipzig, 1901–1902 (Wilhelm Engelmann). The following are recent additions to this valuable series:

Nr. 124. Abhandlungen zur Thermodynamik, chemischer Vorgänge ; von H. Helmholtz. Pp. 83.

Nr. 125. Untersuchungen über den Salpeter und den salpetrigen Luftgeist, das Brennen und das Athmen ; von John Mayow. Pp. 56.

Nr. 126. Experimental-Untersuchungen über Electricität (IX bis XI Reihe) ; von Michael Faraday. (London, 1835.) Pp. 106.

Nr. 127. Die Auflösung der bestimmten Gleichungen ; von Jean Baptiste Joseph Baron Fourier. (Paris, 1831.) Pp. 263.

Nr. 128. Experimental-Untersuchungen über Electricität, XII und XIII Reihe) ; von Michael Faraday. (London, 1838.) Pp. 133.

Plate IV.

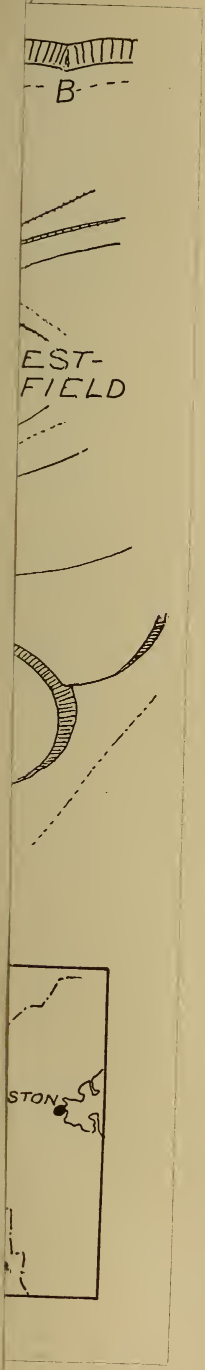
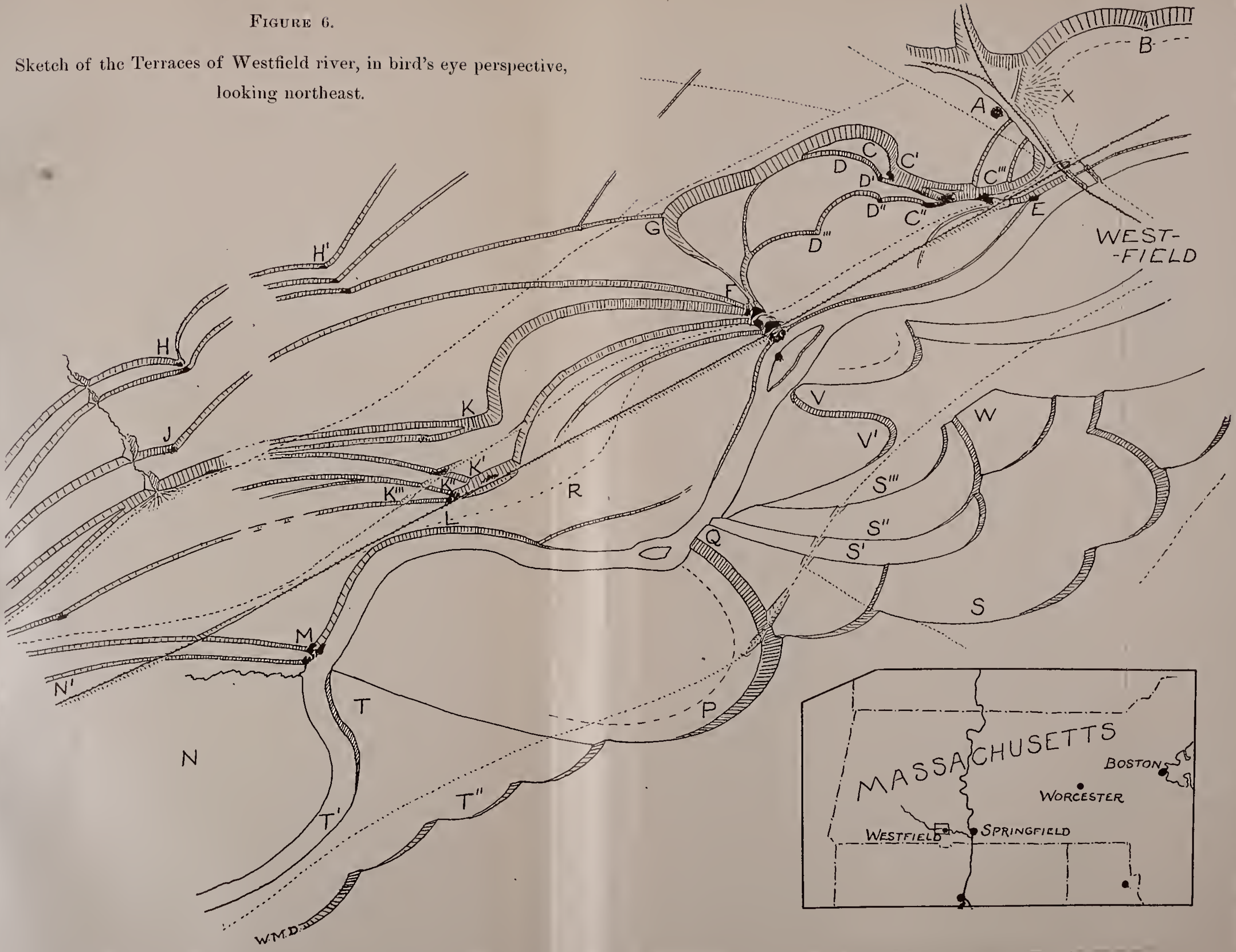


Figure 6.

Sketch of the Terraces of Westfield river, in bird's eye perspective, looking northeast.



THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XIII.—*The Terraces of the Westfield River, Mass.;* by W. M. Davis. (With Plate IV.)

1. *The several theories of river terraces.*—The river terraces that are so abundantly developed in the stratified drift of our New England valleys, receive scanty explanation in the text-books to which reference is ordinarily made for accounts of such forms, and are, indeed, not exhaustively treated in essays of a more advanced character. Their most significant feature is an arrangement in the form of a flight of steps, of unequal tread and rise, and usually of unlike sequence on the two sides of a valley, but necessarily exhibiting a less cross-valley breadth between the terraces at the bottom of two opposite flights than between those at the top. It is generally agreed that each terrace plain is the remnant of a flood plain, that was formed during the process of valley-carving by the river that now flows on the flood plain or "interval" between the lowest terraces of the series; and that the terrace fronts or scarps have been carved by the wandering river as it swung laterally on its successive flood plains. The slope of the terrace plains down the valley and the pattern of the terrace scarps in curves concave towards the river, frequently uniting in cusps, give convincing proof of these conclusions. It follows that our terracing rivers habitually had a greater breadth of swinging on the flood plains at high levels, when beginning the work of sweeping the drift from their valleys, than at the low levels on which they are now flowing. The special point that needs to be accounted for is, therefore, the restriction of the belt over which the river swings to a less and less breadth in passing from the initial to the present stage of terrace development.

There are three theories which offer an explanation for this restriction. The first and most popular postulates a decrease in river volume during and after the uplift of the region by which the erosion of the valley was prompted. The river is by this theory supposed to have been so large when terracing began that it needed a broad space on which to swing; now that the river has diminished in volume it is relatively enfeebled and is contented to swing over a narrower belt than formerly; so the later formed terraces do not undercut and destroy those of earlier date.

The second theory postulates successive uplifts of the region. The river, revived by each uplift, wears its channel beneath its previous flood plain and, on reaching grade, begins to swing laterally. It is then further postulated, sometimes tacitly, that the later uplifts have succeeded each other at shorter and shorter intervals, allowing less and less time for lateral swinging as the valley was worn deeper and deeper.

2. *Miller's theory of river terraces.*—The third theory, suggested in explanation of terraces in Scotland by Hugh Miller, the younger, in 1882,* recognizes slow regional uplift as the cause of valley erosion and then calls attention to the increase in the number of resistant obstacles—rock ledges, boulders, till—that the degrading river will encounter as it swings laterally while eroding the valley floor to lower and lower levels, and ascribes the decrease of interscarp breadth to this simple, effectual and observable cause.

As Miller's theory has not, to my knowledge, been quoted in this country, except in a brief note of my own,† a brief exposition of its merits may be made. I have found it very generally applicable to the terraced valleys of New England, and nowhere more so than in the valley of the Westfield river, between the eastern base of the Berkshire hills and the village of Westfield, Mass., a distance of about five miles, where I have repeatedly examined it. This district was the scene of an intercollegiate excursion in the autumn of 1901, in which Yale, Amherst, Williams, Wesleyan, Institute of Technology, and Harvard, together with six secondary schools, were represented by teachers and students to the number of forty-six; and it is not too much to say that at the end of the day's walk along the north side of the valley no doubt remained as to the competence of Miller's theory to explain the occurrence and the pattern of the terraces there seen. Decrease of volume and intermittent uplift seemed to be of altogether secondary importance, if indeed they had produced any recognizable effect.

The Westfield terraces.—The following pages give a brief account of the Westfield terraces, beginning with those on the

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* River terracing, its methods and their results, Proc. Roy. Phys. Soc. Edinb., 1883, 263–305.

† Bull. Geol. Soc. Amer., xii, 1900, 483–484.

north side of the valley near Westfield railroad station, thence going west about two miles to a little settlement known as Pochassic Street; and returning by the south side of the valley to the village again. The general pattern of the terraces is indicated in figure 6 (Plate IV), where the attempt is made to show them in bird's-eye view, as if looking northeast from a height of two or three thousand feet above a point about a mile south of Pochassic Street. The scale in the further part of the view is somewhat smaller than in the foreground. The vertical scale is significantly exaggerated. The Boston and Albany railroad is not so straight as it is here drawn through the valley; about a mile and a half of its length is shown. Defending ledges are drawn in black. Roads are dotted.

3. *The open Westfield plain.*—Just north of Westfield station, a good view is had from the terrace near Prospect hill schoolhouse, A, figure 6, over a broad plain that the river has excavated east of the village. The plain is limited on the north by a single high terrace, B, rising at once from the marshy abandoned river channels at its base to the level of the highest drift plain of the district. On the opposite side the flood plain of the Westfield is confluent with that of (Westfield) Little river (not shown in fig. 6), limited on the south by a single high terrace, to-day undercut by Little river at two places. The low plain thus gains the unusual breadth of a mile or more for a distance of about two miles eastward from our point of view. The two rivers here show no incompetence whatever in the process of lateral swinging. Whatever loss of volume they may have suffered—and some loss since the disappearance of the ice sheet is highly probable—and however recent the last uplift of the region may have been, these two streams are here sweeping over a broader valley floor to-day than they have opened at any earlier time; for whatever earlier flood plains they have formed at intermediate levels, during the process of excavating their valleys, are now completely undercut and destroyed (except for a few low terraces) by the opening of the present broad plain. The prime reason for so striking an exhibition of competence on the part of the streams is believed to be the absence of rock ledges in this section of the valley. No ledges have here been discovered by the degrading streams; their high terrace scarps consist of clays, sands and gravels (the latter near the top), very easily eroded wherever the streams flow against their base, as may be seen where Little river is now swinging against the terrace scarp on the southern side of the plain. A secondary reason for the competence of the river to swing so broadly at the present level is probably to be found in the delay of further valley-deepening and in the resulting detention of the streams

close to their present grade by the trap sheet which their united current has come upon in the notch in the trap ridge about two miles east of Westfield.

4. *Terrace diagrams.*—The single high terrace scarp, here so well developed and typified in figure 1, is of more general occurrence in the terraced valleys of New England than is generally supposed to be the case. It may indeed be taken as typical of many terraced valleys where no ledges have been discovered to prevent the free swinging of the rivers. A few lower terraces may still be unconsumed here and there, as in figure 2; this arrangement of terraces also being of common occurrence where ledges are wanting. The ordinary diagram of a terraced valley, such as is here reproduced in figure 3, is therefore misleading in implying that the stepping terraces have been carved in drift alone, without relation to the rock beneath. These many-stepped flights of terraces need for their preservation a number of ledges, as in figure 4; but this figure is very faulty in implying that ledges occur all along the base of the terrace scarps. As a matter of fact, the ledges do not occupy more than a small percentage of the terrace lengths, and far from all lying on the line of a single cross-section, as figure 4 implies, they are frequently distributed somewhat irregularly up and down the valley sides. The true relation of ledges and terraces is better shown in a block diagram, such as figure 5; and even here the area of the ledges exposed in the terrace cusps is exaggerated over that commonly observed.

5. *The Westfield spur (Prospect hill).*—If the terrace by Westfield station is now crossed to the west, it is soon found to be a spur of a high, but not of the highest plain, extending forward (southward on the north side of the valley) from the broad plain in the background. It is known as Prospect hill. The apex of the spur, E, figure 6, reaches the river; its breadth, east and west, is about a quarter of a mile. From its western side the valley floor again widens, making a recess or re-entrant in the high plain on the north; but here four subordinate terraces are found beneath a stronger scarp that rises to the highest level; they combine in a charming landscape, when seen from the western scarp of Prospect hill. As the river is thus found to have been competent to widen its valley both east and west of the terrace spur, some reason for the preservation of the spur should be looked for; and it is discovered clearly enough on descending the western scarp, which is found to be defended at various points along its bank by sandstone ledges, C′, C″, C‴. The sandstones are, to be sure, relatively friable; they are weak compared to the schists and gneisses of the Berkshire hills to the west; so weak, indeed, that while the Berkshires retain in the equable height of their uplands a

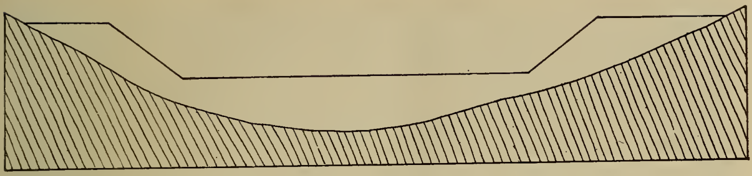


Fig. 1

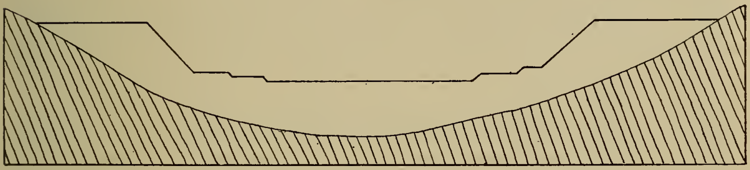


Fig. 2

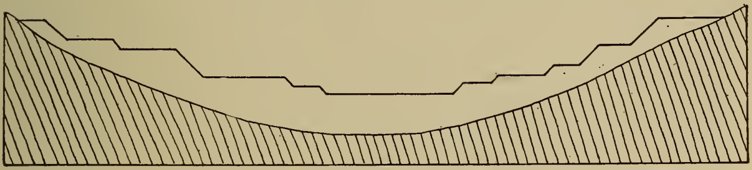


Fig. 3

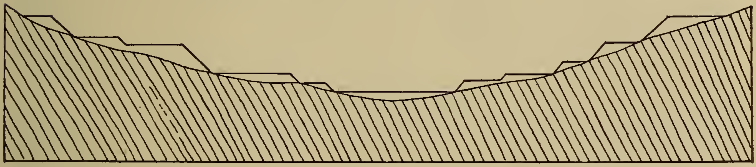


Fig. 4

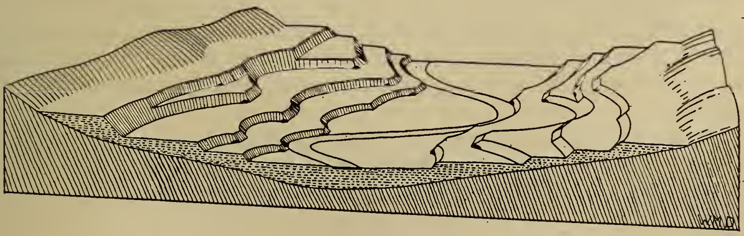


Fig. 5

fair indication of the altitude to which the Cretaceous peneplain of this region has been raised, the Triassic sandstones in this part of the Westfield valley (part of the greater Connecticut valley lowland) have been reduced by later Tertiary erosion to a lowland of a second (or $n+1$) generation. Yet compared to the silts and gravels of the terraces, the sandstones are very strong; whenever the river has, in the process of sweeping the drift from its valley, swung against a sandstone ledge, previously buried, further lateral swinging has been peremptorily stopped and the terrace behind the ledge has been preserved.

It is evidently because of the abundant defending ledges here that the Westfield spur has not been destroyed. The stream has made a most determined effort to destroy the spur by scouring out a hollow, C, at its back, sweeping around in so great a curve that its normal eastward course was locally turned back to the southwest; but the ledge, C′, on which the stream was caught, could not be removed, and hence the spur still stands there. The river seems to have been withdrawn from the deep recess, C, by taking a short-cut across a more axial part of the valley floor of that time, probably during a flood. When it again swung northward towards the recess, at a somewhat lower level than before, a lower part, D′, of the same ledge was encountered a little farther forward than the point, C′; and a small lunate area, C, of the earlier sweep was therefore preserved back of the new terrace, D. On the third return of the river into the same locality at a still lower level, it was caught by a small ledge, D″, several hundred feet farther forward, and again by larger ledges, C″, C‴, and hence a good stretch of the flood plain between D′ and D″ was preserved in a terrace.

The Westfield river is at present making still another effort to remove the spur, and it is now for at least the fourth time stopped by a member of this group of ledges, for a strong reef of sandstone is seen in the river bank at E in the. southern corner of the spur. The spur may in the distant future be somewhat sharpened by losing ground on its undefended southeast corner, should the river chance to swing that way; but such swinging will be for the present strongly resisted by the buttresses of two bridges and by artificial embankment where the Boston and Albany railroad follows the river; it will cost less to restrain the river than to remove the bridges and the tracks.

6. *No local evidence of decrease of volume in the Westfield river.*—Evidently the preservation of the spur of Prospect hill is not due to any incompetence or to any want of effort on the part of the river to remove the sands and gravels. The river has repeatedly and energetically attacked the spur; it has in

the most competent fashion swept away all the drift that could be reached. It was only upon encountering the stubborn resistance of an ambushed and impregnable ledge that the river first withdrew, and even then it withdrew only to renew the attack by returning bravely toward the spur on a later swing. Unfortunately for the reputation of the river, the ambushed ledges have been found entrenched farther and farther forward at every successive attack that has been made upon them ; hence the river, losing ground at every advance, has come to be looked upon as a weakened and shrinking stream that voluntarily abandons its earlier enterprises and accepts a narrower limit for its conquests to-day than when in a youth of (imagined) greater vigor and aggression ; but this is a most unjust interpretation of its behavior. The river is making a most determined and heroic effort to carry out its original plan of campaign. It is eminently successful in opening the valley east of Westfield, and if it is defeated at the spur, this is only because of the reinforcement of the unconsolidated drift by the invincible strength of the entrenched ledges. The river may be accused of want of foresight in not more carefully reconnoitering the ground that it originally proposed to excavate, but it is notorious that rivers are heedless of buried ledges, on which they often become inextricably superposed. The river may be thought headstrong to return to an attack, a forlorn hope, where defeat is inevitable. Heedless and headstrong it may be, but it does not deserve the reproach of being looked upon as enfeebled. Even if its volume is now less than formerly, the river is as competent to-day as it ever was to open a wide flood plain in drift, and it does so wherever free opportunity is offered of carrying out its original enterprise.

7. *Relation of ledges, terraces and river swings.*—It should be noted that the ledges of the Westfield spur have not in any case determined the depth to which the river has cut its valley. The ledges here were not encountered in the river bed but in the river bank, and hence have controlled only the breadth of lateral swinging at the point where they were by chance discovered. The depth at which the ledges were encountered was dependent simply on the amount of valley excavation that had been accomplished by the graded river at the time that the discovery was made. It is also important to note that while a ledge thus encountered in the bank of a swinging river will defend and preserve that part of any flood plain previously formed at a higher level, above and back of the ledge, it is not at all necessary that every former flood plain of the river should be thus recorded. If the successive northward swings of an east-flowing river have by chance less and less ampli-

tude, successive terraces will remain, even without defense by ledges. There can be no question that some of our terraces are of this accidental kind. But the undefended lower terraces will be undercut and destroyed if the river swings more strongly north again. If the river again swings north until it strikes a ledge, the uppermost terrace may alone be preserved, and that only back of the defending ledge. It thus becomes evident that in order to discover the number of times that a river has swung across its valley, making laterally sloping flood plains at lower and lower altitudes at every swing, we must not trust to the chance preservation of flood plain remnants in terraces here and there, but must seek a flight of terraces, systematically grouped on a long sloping ledge, which may preserve a lateral remnant of every flood plain that has been formed, as in figure 5. It is certainly a striking fact that the number of steps in a flight of valley terraces always reaches a maximum in just such situations. The preservation of numerous terraces of moderate height on long sloping ledges—however few such ledges there may be in the valley and however few terraces occur elsewhere on the valley sides—goes far towards excluding the theory of successive uplifts and pauses as a cause of terracing. It goes far also towards supporting the theory that the wandering river has been swinging from side to side across its valley, always degrading its channel but always acting as a graded river, during the whole period of terracing, whatever may have been the cause that determined the excavation of the valley drift. If uplift were the cause, the uplift must have been slow and relatively uniform.

In illustration of this conclusion, we may return for a moment to the broad basin east of Westfield. No terraces at intermediate levels are found here to prove that the river did repeatedly swing laterally while degrading its valley floor in this part of its course; yet there can be no reasonable doubt that the river really did swing back and forth here, for the remnants of four flood plains at intermediate altitudes are found in the terraces on the west side of Prospect hill, only half a mile away. Farther up the valley one may find a flight of nine defended terraces, described below, whose subequal heights range from ten to fifteen feet; thus proving that even the four terraces on the Westfield spur preserve a very incomplete record of the river's activity. Evidently the maximum number of steps observed in any terrace flight gives only the minimum number of swings that the river may have made during the whole period of degradation.

8. *Ledges outcrop on the up-valley side of terrace spurs.*—In the terrace spur here called Prospect hill, as in many others, it is noteworthy that the up-valley side of the defending ledges

has been clean swept by a swinging curve of the attacking river. This may be explained as a result of the normal progress of a river meander down the valley, until it is stopped by coming on a ledge, or abandoned by withdrawal of the current to a short-cut or cut-off course. The fact of the down-valley progress of a meander does not seem to have received much attention from physiographers, judging by the silence of text-books concerning it; but it must be a familiar matter to river engineers, so conspicuously is it exhibited on such maps as those prepared by the Mississippi River Commission. The cause of the down-valley progress is evidently to be found in the continued displacement of the thread of fastest current to the down-valley side of the channel on entering the tangent of inflexion between two meander curves.

9. *Brown's spur.*—On the other hand, a terrace may trail some distance down-valley from its defending ledge, unless the stream should by any chance swing in again and sweep it away. This chance has not happened in Prospect hill, the spur thus far considered; but it has in Brown's spur, F, half a mile farther west. This spur is well defended by a large sandstone ledge, at whose forward-reaching base the river is now flowing in a vain effort to widen its valley. Four terraces in the next up-valley reëntrant curve forward to the apex of the spur, and all agree in the most unanimous manner to sweep tangent to the slope of the defending ledge. The ledge is well exposed in the cuts made by the passing road and railroad. The scarp of the next higher terrace, G, is, however, pushed back a quarter of a mile farther north; evidently because when it was made the river was swinging at a slightly higher level than the summit of the defending ledges in the apex of Brown's spur. It seems undeniable, when one looks at these terraces on the ground, that the river would have pushed back the lower members of the series about as far as the higher member, if its lateral swinging had not been stopped by the ledge.

The peculiar feature of this spur is, however, the close trimming that it has suffered on its down-valley side. The river has at least three times swung northward so near the eastern side of the ledge as to narrow the spur into a sharp point. The normal down-valley progress of the meanders cannot be appealed to as a cause of this close trimming on the down-valley side of the ledge; some special cause must be looked for to direct the several northward swings of the river over so nearly the same course. It seems probable that some constraint has been exerted on the river further up its channel, whereby it has been repeatedly guided to the down-valley side of the ledge. A possible explanation of this peculiar feature will be suggested on a later page.

10. *The flight of terraces by Pochassic Street.*—The finest flight of terraces hereabouts is preserved a little east of a small settlement, known as Pochassic Street, on the southeastern slope of Pochassic hill, a drumlin, around whose base abundant ledges have been discovered. The settlement and drumlin are just to the left of the limit of figure 6. The highest terrace, H, shows waterworn cobbles and pebbles on its plain; the bouldery slope of Pochassic hill rises behind it. Terraces are usually counted upward from the valley floor in the reverse order from that of their production. It will be convenient here to follow the natural order and count downward, beginning with the plain and scarp of the highest terrace as number one. Thickets of small trees and bushes obscure many details here, and some of the terrace plains are inconveniently swampy near their back border, perhaps because of ledges farther forward by which the ground water is held up. Hence the correlation of some of the terraces in this locality is doubtful, as indicated by the blanks left in the figure. A flight of at least nine steps, H–M, may, however, be counted, all presenting characteristic concave fronts in what may be called the Pochassic reëntrant, all curving forward at their down-valley ends to defending ledges, and all of similar height, roughly from eight to fifteen feet. A later terrace occasionally undercuts an earlier one, so that the two scarps are locally united in a slope of more than the average height; such being the case with the fifth–sixth scarp, along whose base lies a narrow country road in the middle of the reëntrant; a little farther east and west the scarp is divided into two (or more) parts by a narrow terrace that comes forward at an intermediate level; thus what seem to be the fifth and sixth swings of the river may be identified.

The uppermost terrace may be followed along its scarped front through the second growth of bushes and trees past two defended cusps, H and H′, beyond which it turns to the northeast and at a distance of half a mile or so seems to run tangent to another drumlin. The second terrace is not identified on the first ledge, H, but appears on the second, H′; it seems to fade away on the broad plain a quarter of a mile to the northeast. The third terrace is caught on both ledges, H and H′; it then runs eastward half a mile and is undercut at G by the large reëntrant between Prospect hill (the Westfield spur) and Brown's spur. Shortly before it is cut away, a low terrace turns off northeastward from it and seems to continue some distance; hence what has just been called the third scarp might be taken to represent the fourth northward swing of the river.

It is important to note that the sharp curvature and large arc of the reëntrants in the first and third scarps in connection with the ledges at H and H′ are much more consistent with the behavior of a river similar in volume to that of the present Westfield than with the behavior of a much larger river.

The fourth terrace in the Pochassic reëntrant is caught on a ledge of loose-textured sandstone, J, that stands forward from the first small reëntrant in the higher terraces. The ledge is not directly exposed, but abundant angular fragments of pebbly sandstone are found in the apex of the blunt cusp on the terrace front. This terrace is believed to be the one that runs forward in a long sweeping curve to the apex of Brown's spur; but it has not been followed all through the bushes and some details of its form may not be shown in the figure.

The divergence between the eastward course of the third and fourth terraces, G and F, is highly significant. The third scarp was cut a quarter of a mile back of what is now the apex of Brown's spur, because at the time of the third northward swing of the river, its channel had not been worn deep enough to catch upon the summit of the ledges in the spur. But at the time of the fourth northward swing the river had eroded its plain to a lower level, so that it was held by the topmost ledge. The fourth terrace, therefore, could not be cut so far back as the third; it makes a long sweep forward from the Pochassic reëntrant to the apex of Brown's spur and leaves a rather broad plain between its scarp and that of the third terrace. It is perfectly evident that this arrangement of the two terraces was not due to any decreasing strength on the part of the river, but to the constraint imposed upon its wandering by the ledge at F.

11. *Perry's spur.*—Below the fourth terrace, J–F, come several others, which run forward to the rounded front of Perry's spur, K, K′, where several blunt cusps are determined by ledges of very friable sandstone that would hardly be seen but for cuts made by the road and the railroad. This item is of importance, for it shows that certain ledges which are strong enough to defend a terrace are not always bold enough to keep themselves in sight. After having done their duty in fending off the river, they strategically weather under cover and thus ambush themselves again beneath a thin sheet of their own waste mixed with creeping drift from the terrace they have protected. It is possible that another example of this kind may be found in the well defined cusp, D‴, of a low terrace in the reëntrant between Prospect hill and Brown's spur; it seems at first to be only the free intersection of two curves, for there is no sign of a ledge at its base and there are no angular fragments of sandstone by which the presence of an ambushed ledge is sometimes revealed. A little digging or a boring with a soil auger would suffice to determine this point.

The indefiniteness of some of the terraces in the Pochassic reëntrant may be due to the discovery there of till underlying the stratified drift. Till is seldom well carved by a swinging river; its texture is significantly firmer than that of stratified sands and clays. A small stream coming out from the north cuts little trenches in the terrace fronts and spreads its gravel fans on their plains, thus further obscuring their forms.

The eighth and ninth members of the Pochassic flight are well defined, but instead of conforming to the concave pattern of the higher members of the series, they spring forward to a defended cusp, M, nearly opposite the middle of the reëntrant. Here as elsewhere it is perfectly evident that the failure of the river to cut back these lower terraces is not due in the least to any loss of its original strength, but to the increase of resistance offered by the ledges. The river has now swung away from the northward meander that it followed while carving the lowest terrace, N′, to a correspondingly strong southward meander, T′, which is now cutting a low terrace, T, on the south side of the valley. A broad flood plain, N, has thus been opened. It happens curiously enough that the down-valley progress of this southward meander has just now brought it to such a position that it is impinging against a large exposure of the sandstones at M. The normal down-valley advance of the meander, T′, will soon carry it past the ledge, unless the caving bank at T is protected. For the present, the obstruction caused by the ledge in the normal flow of the river seems to have produced a slight bend in the channel a little farther up-stream. When the meander is sufficiently advanced the river will impinge directly on the unprotected bank between M and L, and consume it rapidly, leaving a sharp cusp at M. It is probably in some such way that the sharpening of Brown's spur, referred to above, has been accomplished. There has already been some undercutting of the low terrace east of M, for the main valley road was swept away by the northward swing of the river at L a few years ago. The road has been set back so as to cross Perry's spur, K′, north of the railroad, thus causing the desertion of several houses on the low plain, R, in front of the spur. The railroad itself is threatened by the river near L; the caving bank has been worn back dangerously near the track, and a quantity of coarse rock blocks has been thrown in there to stop the caving. But for this resistance the river would probably continue to swing northward until it encountered a low member of the group of ledges in the southwest base of Perry's spur, K′.

West of Pochassic Street another large reëntrant has been swept out on the north side of its valley; its down-valley side is well defended by ledges in the southwest base of Pochassic hill.

The flight of nine terraces in the Pochassic reëntrant, above described, constitutes the best series in the valley, as far as I have seen it. Closer study will probably increase the number of steps. The subequal height of the scarps suggests that these terraces record nearly every northward swing of the river in their locality. A similar number of swings has probably occurred elsewhere; the record of them is incomplete or wanting only because of the absence of defending ledges. It may therefore be concluded in general that it is only in localities well provided with ledges that one may expect to see preserved in terraces the lateral remnants of all the flood plains that were formed by the swinging river during the excavation of its valley; and that the maximum number of steps in a terrace flight is only the minimum number of lateral swings made by the river. All of these terraces testify to the graded condition of the degrading river at the time the terrace plains were made. The nine chance samples of river condition thus preserved may be fairly taken to show that the degrading river was meandering and swinging at grade during the whole period of terracing in this section of the valley. There is no indication that the individual terraces depend in any way whatever on individual uplifts.

12. *Terraces south of the river.*—The terraces on the south side of the valley may now be considered. No ledges are seen on this side of the river within the two-mile stretch included in figure 6. The first ledges are found half a mile further west; they defend the eastern or down-valley side of a strong reëntrant a little west of the town farm. Correlated with the prevailing absence of ledges is the absence of upper terraces. The high plain is habitually bordered by a strong scarp of forty or more feet, beneath which there may be several low terraces; but in one case the low flood plain of the present river enters a strong reëntrant, P, to the base of single scarp by which the whole descent is made from the high plain. Nowhere in this district is there a flight of low-scarped terraces from the top to the bottom level on the southern side of the valley. The reason for this contrast between the two sides of the valley may be with confidence ascribed to the general southward shifting of the belt within which the river swings, because of the southward slope of the ledges on the north side of the valley and the undefended condition of the terrace drift on the south side of the valley. It is a sort of monoclinal shifting of a river course. The several low terraces on the south might seem at first to contradict this explanation. They may, however, be reasonably explained as being not yet swept away. The river cannot attack the whole length of the southern side of the valley at once; it will swing against the southern

terraces only here and there, now and then; and hence the destruction of the lower southern terraces by the southward shifting of the belt of river-swinging can only be accomplished progressively. Thus viewed, it is no wonder that some of the lower southern terraces still remain. This corollary to the explanation above suggested receives much support when examination is made of the relation between the defended cusps of the terraces on the north and the concave reëntrants of the terraces on the south, to which we now proceed.

13. *Correlation of terraces on the two sides of the valley.*—It will be readily understood that, wherever a terrace scarp curves forward from a concave reëntrant to a defended cusp, the river must have once flowed along the base of the scarp and must have continued the line of the terrace curve past the cusp toward the opposite side of the valley, there to recurve toward the general valley axis. The farther forward the defended cusp reaches toward the axis of the valley, the more likely it is to direct the departing river strongly against the terraces on the opposite side of the valley. Thus the curved scarps, K′, K″, K‴, of the northern terraces, suggest that the river has formerly flowed on past the defending ledges of Perry's spur at these several levels and has thus entered the reversed curves of the southern scarps, S′, S″, S‴. The levels of the terraces concerned seem to correspond by pairs, but they have not yet been accurately measured. Of the three northern scarps, the one leading to K′ has the strongest curvature, for the middle of its reëntrant is cut farther back than the middle of the others. When the river flowed at the base of this scarp, its current must have departed from the defending ledge almost transversely to the general eastward course of the valley. Consequently the corresponding southern scarp, S′, makes a strong reëntrant on the south side of the valley. The second scarp, K″, of the northern group was more gently curved; the third scarp, K‴, still more gently curved; and the same relation is seen in S″ and S‴. It is possible that even the higher southern reëntrant, S, is indirectly related to the ledges of the northern valley-side about K; the general curvature of the river being determined by the ledges and a southward swing of the curving river there causing the excavation of the reëntrant, S. It is proposed to make a careful measurement of all these terraces in order to test their correspondences.

Another example of this cross-valley relation is found farther west. The curved scarp of the lowest northern terrace, N′, that sweeps out to the defending ledges at M, is the northern member of a double curve whose southern member made the strong concave sweep, P, already mentioned, under the high southern terrace plain. The ledges at M stand unusually far forward toward the valley axis; this southern sweep is therefore the only one that has consumed all the southern terraces at intermediate and low levels. The abandoned channel of the sweep is still swampy and the enclosing scarp is still uneven with landslides, so lately has the river been withdrawn. It is natural enough that the river should not have swung so far south at higher levels, for the guiding ledge, M, is rather low; it was not encountered until the river had cut down its flood plain nearly to the present level.

Inasmuch as the southern sweeps, S′ and P, seem to have been guided by the northern ledges, K′ and M, it is natural to find the unconsumed remnant of the terrace between the two sweeps in the form of a cusp, Q. This cusp is about forty-five feet high. It is entirely undefended and might, therefore, at first sight be classed with free cusps, and regarded as the consequence of a chance intersection of successive meander sweeps on the valley side. But the dependence of the sweeps, P and S′, upon the defended spurs on the northern side of the valley shows that the strong southern cusp, Q, is not altogether accidental. It is in reality a natural, although an indirect and temporary, product of the northern ledges at M and K′. Unlike the defended northern spurs, which are relatively permanent features, the indirectly defended cusp, Q, will not endure. Its apex is already truncated by a chance swing of the river against it; it will be more and more consumed as such swings are continued and repeated. It is safe only so long as the river flows on curves determined by the ledges at M. and K′.

The truncated free cusp, W, on the south side of the valley, is probably related to Brown's spur, F, in much the same way that the truncated spur, Q, is related to Perry's spur, K′.

Another southern cusp, T, is the remnant of a 15-foot terrace projecting far into the valley between the southern reëntrants, T′ and P. A strong scarp, T″, with blunt salients rises to the high plain back of T. The sharp apex of the cusp points directly to the ledges at M, yet it is entirely undefended south of the river. It is probable that there was something of up-valley carving on the eastern side of the cusp; a relatively unusual process, for, as has been stated above, river meanders normally progress down-valley. But in this case, the down-valley progress of a northern meander was stopped by the ledge at M. The ledge probably acted as a sort of fulcrum as soon as the river impinged upon it; the deeper the northern reëntrant, N′, was cut, the more nearly the river must have turned square across the valley at M, and the more it must have been turned against the down-valley side of the spur, T. Something of the same kind probably occurred when the reëntrants, S′, S″, S‴, were scoured out.

14. *Development of future meanders.*—The river is evidently tending to become more curved at its northward bend, L, and its southward bend, Q. It was formerly less curved; and it was probably then that it ran into the strongly concave reëntrant, V′. No immediately local cause is found for the preservation of the low spur, V, for no defending ledge is to be seen at its apex; but one may be there, buried in the flood plain deposits; the sandstone outcrops in the little island near by and in the cusp F nearly opposite. It is possible that these ledges held the river in the channel between them (on the north side of the present island) while the river scoured out the sharply concave reëntrant, V′; and that, as the river increased its curvature at L and Q, it withdrew from the curve of V′. Such a series of changes would not be inconsistent with what is known of the development of river meanders. Their greatest dimensions are attained only where the curves are well organized, and such organization requires time for its accomplishment. A limit is set to the size of the curves, less by an equilibrium between current and bank than by the abandonment of the curves when short cuts and cut-offs are made. The river course is thereby made nearly straight again, after which a new series of curves is gradually established. The Westfield river hereabouts is comparatively straight to-day. Its course for several miles eastward from T must be much less curved now than when the concave terrace fronts were carved at various earlier dates. But a strong curve is seen to-day at T′; the curves at L and Q are increasing and their maximum curvature is not yet reached, and hence it may be expected that another period of organized meandering is approaching. The restraint of the ledges at M will soon be avoided by the down-valley progress of the meander T. The northward curving at L will be resisted by the railroad. The southward curving at Q may be delayed by the abundant fall of gravels from the truncated end of the spur; and indeed there are already some indications that the river may bend southward into the low flood plain west of the spur. A stronger northward turn toward F would thus be induced and a stronger southward turn might then follow farther eastward. The latter item in this series of changes would be made more probable if the swinging river would again pass the ledges at F on a southeastward course, as it did when carving the up-valley side of Brown's spur.

All these details are relatively trifling, yet they have a value in that they unite in showing the competence of ordinary processes, appropriate to a meandering, swinging and slowly degrading river, to produce even the most minute forms of our terraces. There is no demand for an ancient river of great volume or for repeated movements of uplift in the terrace problem of the Westfield river.

15. *Southern terraces at Westfield.*— Nearer Westfield the complication of the southern terraces increases somewhat, and there is one member of the series at a higher level than elsewhere on the south side of the valley in this district. It may be therefore inferred that the river belt has hereabouts been shifting northward, and this would be confirmed by the high terrace of the opposite northern reëntrant. Yet no ledges are found on the south side of the valley as a cause of this shifting. The only explanation that I have thought of for it is that Little river once entered the Westfield from the south near the present site of Westfield village, and thus slowly. pushed the Westfield river northward from the course it had previously followed. Interference of one river with another in this way has been suspected in the eastern basin, beyond Westfield, and in several other localities in the Connecticut valley.

16. *Conclusions.*—The most manifest conclusion to be drawn from this study is the one already announced; namely, that Miller's theory of defending ledges gives a better explanation than any other for the terraces of our New England valleys. It is not desired to imply by this that all our terraces are defended, but that most of them are; and especially that all the many-stepped flights of terraces owe their preservation to defending ledges. Decrease of river volume and intermittent uplifts do not seem to have had any significant part to play in the restriction of the swinging rivers to narrower and narrower belts. Another conclusion is that the normal action of a meandering and swinging river suffices to account for practically all the details of terrace form; and hence that terraces, like other land forms, are susceptible of explanation, even down to their most minute elements. Following this there is a third conclusion, of interest to those who concern themselves especially with the study of land forms; namely, that in this division of the subject as well as elsewhere, observation is greatly aided by the discovery of a successful theory; for the essential facts are then quickly acquired by well directed search. It is also apparent that here as elsewhere description is greatly facilitated by explanation, for explanation enables the student to bring the local example into proper relation to the generalized type. There may seldom be necessity of giving minute description of forms so small and so ephemeral as drift terraces; but when that necessity arises it will be met better by characterizing terraces in terms explanatory of their origin than by an attempt at absolute or empirical description;

the defended and the free cusps, the high scarps without outcropping ledges, the flights of advancing terrace steps in association with groups of outcropping ledges, the correlations of the terraces on the opposite sides of a valley, all these items are best told by explaining them.

Finally it may be noted that even the geologist who is concerned only with the underlying rocks may well afford to give some heed to the pattern of drift terraces; for he will be most quickly guided to his desired outcrops if he examines the points and the up-valley sides of the terrace cusps.

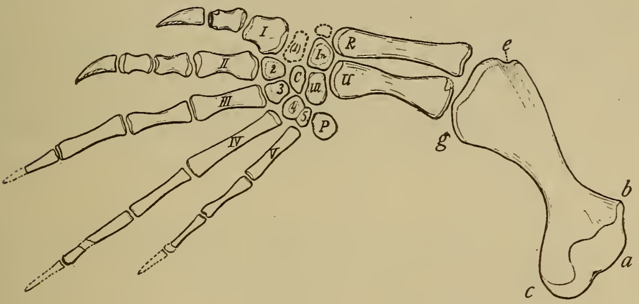
Cambridge, Mass., June, 1902.

Art. XIV.—*Notes on the Cretaceous Turtles, Toxochelys and Archelon, with a Classification of the Marine Testudinata;* by G. R. Wieland.

I. *The Front Flipper of Toxochelys latiremis.*

A fine specimen of *Toxochelys latiremis* Cope* from the Niobrara Cretaceous of Kansas (Accession No. 2491 of the Yale coll.) includes a well preserved skull and lower jaw, six cervical, and several dorsal vertebrae, anterior portions of the carapace and plastron, and two nearly complete front flippers. Although some of these bones are somewhat crushed, their preservation is in all other respects exceedingly good. The left of the front flippers is evidently the more complete, and apparently only lacks the radiale, first carpale, and some distal portions of the terminal phalanges of the third, fourth, and fifth digits. The various elements, with the exception of carpalia 4 and 5, were separated in collecting, or else had originally been more or less scattered. Nevertheless, the arrangement of the parts, as shown in figure 1, is given with considerable confidence as to the correctness of the main facts.

Figure 1. *Toxochelys latiremis* Cope. Dorsal view of the left front flipper, x¼.



a, b, c, e, g, respectively the head, radial and ulnar processes, ectepicondylar groove, and entocondyle of the humerus; R, radius; U, ulna; In, intermedium; Ul, ulnare; P, pisiform; C, centrale; 1–5, first–fifth carpalia; I–V, first–fifth metacarpalia.

Hitherto our knowledge of the front flipper of *Toxochelys* has been limited to the proximal half of the humerus and two fingers as described by Case,† although the phalanges are men-

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* E. D. Cope.—Vertebrata of the Cretaceous Formations of the West, vol. ii, Rep. U. S. Geol. Sur. of the Territories. Washington, 1875.

† E. C. Case.—University Geol. Sur. of Kansas, Paleontology, part iv, *Toxochelys.* Topeka, 1898.

tioned as "flattened" by Cope. Case figures as the first finger what is here denoted as the second, but, as is further mentioned below, there is a striking peculiarity in the strong resemblance of the second metacarpal to the first, which would lead one to err in this respect in the absence of the other digits.

Description. The humerus, rather broader in the fossil than in life as the result of crushing, is, as I have already pointed out on the basis of the proximal portion only, of the *thalassoid* type characteristic of various of the older Chelonidæ.* That is, while the general outline closely approaches that seen in typical oceanic turtles, certain persisting older characters are present, such in particular as the high position of the rather prominent radial crest. The most closely related humeral form is to be seen in *Lytoloma*† and in *Neptunochelys tuberosa* (Leidy, Cope) Wieland.*

The radius is somewhat longer than the ulna as in other Chelonidan forms, and also be it noted as in *Acichelys* (*Eurysternum*) *Wagleri*. (See figure in Zittel's Handbuch.)

The large *intermedium* is also of the same general outline as that of *Acichelys*.‡ The arrangement of the carpals is, however, mainly as in *Chelone*, etc., the first carpale not being excluded from contact with the centrale, while the first metacarpal is set high, and the small and thin *pisiform* is attached to the fifth carpale.

General Observations. The present is probably the first fairly complete restoration of the fore flipper of an ancient marine Chelonian which has been given, and as one might well expect in the case of a Cretaceous turtle presenting various primitive characters, no little light is shed upon the manner in which the evolution of the Testudinate flipper has proceeded. The most striking peculiarity is the flatness of metacarpal II. This bone presents characters distinctly intermediate to those of metacarpals I and III. As flattening is usually only present in the bones of the first finger, there is in *Toxochelys* a very marked use made of this means of adaptation for marine life. *Toxochelys* has two well developed claws, not noticeably differing in this respect from *Eretmochelys*, but the short and robust phalanges of the first and second fingers, all of which are exceedingly well preserved, are decidedly more suggestive of those seen in land forms than in the case of any other known distinctly marine turtle.

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* G. R. Wieland.—Some Observations on Certain Well-marked Stages in the Evolution of the Testudinate Humerus. This Journal, fourth series, vol. ix, June 1900.

† L. Dollo.—On the Humerus of *Euclastes*. Geol. Mag., vol. v, pp. 261–267. London. 1888.

‡ Zittel.—Handbuch der Paleontologie.

With respect to the distal phalanges of the fourth and fifth fingers, it should be stated that the present restoration is of necessity more or less generalized. These phalanges being more slender than those of the first and second fingers, have suffered crushing, and having been isolated also, one cannot be wholly sure of their exact order. Nevertheless, it is fully evident that fingers 3–5 are long, and have the structure seen in strictly marine turtles. In the appended table of measurements only those elements are given which may be determined with reasonable certainty, though the estimated lengths of fingers 3–5 are doubtless very near the truth.

At least we are enabled to deduce the principal variants in the evolution of the Testudinate flipper from some generalized type of foot like that of *Chelydra.* The humeral changes in general form I have already outlined at some length. In the case of the remaining elements it would of course be desirable to consider an approximately phyletic series, but in the absence of this, the general trend of change may best be made clear by considering the percentage of length of the elements of the flipper in *Chelydra*, *Toxochelys*, *Eretmochelys* and *Dermochelys.* These are, together with *Acichelys* of the Jurassic, and the known portions of *Archelon*, as follows:

	Humerus.	Radius.	Ulna.	1st finger.	2nd "	3rd "	4th "	5th "	Pisiform.
Dermochelys,	100	43	39	127	180	209	173	86	23
Eretmochelys,	100	53	44	49	89	128	105	44	12
Archelon,	100	54	51	—	—	—	—	—	21
Toxochelys,	100	58	50	51	73	100 ±	104 ±	70 ±	11
Chelydra,	100	52	53	50	72	73	55	50	(small)
Acichelys (=Eurysternum),	100	57	51	40	54	63	66	51	17

Inspection of the above table shows:

1. *Strongly marked radial and ulnar decrease in length.*
2. *Greater or less elongation of the radius as compared with the ulna.*
3. *Nearly static length of the first finger in the Chelonidan forms, with sharp increase in Dermochelys.*
4. *Persistent increase in the length of fingers 2–4.*
5. *More or less variable tendency to increase in length of the fifth finger.*
6. *Great pisiform increase, which began relatively early.*

Measurements of Toxochelys latiremis.

(All are from the same individual.)

The Skull.

	M.
Extreme length from beak to extremity of the supra-occipital process, which is complete	·152
Length from beak to occipital condyle	·114
Extreme width	·11
Width between articular surface of quadrates	·078
Length from beak to anterior border of internal nares	·025
Extreme length of ramus of lower jaw	·11

The Cervicals.

Length of 1st cervical centrum	·014
Length of 2d “ “	·025
Length of 3d “ “	—
Length of 4th “ “	·033
Length of 5th “ “	—
Length of 6th “ “	·032
Length of 7th “ “	·031
Length of 8th “ “	·03
Estimated total length of the eight cervicals	·226
Length of 1st dorsal centrum	·023

The Humerus.

	M.
Greatest length	·135
Depression of radial crest beneath proximal extremity	·02
Distance of ectepicondylar groove from distal anterior border	.005

Greatest length of the other elements of the front flipper:

Radius	·075	Metacarpale, III	·039
Ulna	·066	“ IV	·055
Intermedium	·018	“ V	·037
Ulnare	·017	Phalanx, I–1	·018
Centrale	·015	“ I–2 (claw)	·024
Carpale I	—	“ II–1	·02
“ II	·015	“ II–2	·019
“ III	·013	“ II–3 (claw)	·025
“ IV	·013	Phalanx III–1	·034
“ V	·011	“ III–2	·039
Pisiform	·015	“ IV–1	·036
Metacarpale, I	·023	“ V–1	·031
“ II	·035		

Total length, first finger	·65
“ “ second finger	·095
Estimated length, third finger	·13
“ “ fourth finger	·135
“ “ fifth finger	·09

II. *The Front Flipper of Archelon ischyros.*

In my first description of the gigantic turtle skeleton from the Fort Pierre Cretaceous of South Dakota which constitutes the type of *Archelon ischyros*,* I figured, in addition to other skeletal parts, the humerus, radius, ulna, femur, tibia, and fibula, and mentioned the fact that a number of carpals and tarsals with several phalanges were also present. This was practically the first contribution presenting the main features in the limb organization of the [Protosteginæ]. Hitherto our knowledge of the flippers of these great turtles had been limited solely to that given in Cope's original description of the first member of the group discovered, *Protostega gigas*.† In this form the humerus was described and figured together with the radius and ulna, although the latter were then supposed to be "metapodials" rather than bones of the forearm.

As there was at the time of my first publication an absolute dearth of information concerning the carpal and tarsal structure in marine turtles from the American Cretaceous, not one having been described, the fear that I might make some serious error prevented my publishing the restoration of the carpus which I then made, the various elements having been found only partly in position.

Now, however, Professor Williston‡ has just described the hind flipper of *Protostega*, and this enables me by exclusion to determine with a reasonable assurance of correctness that the elements I originally assigned to the carpus in my study of the closely related *Archelon* truly belong there. I am hence able to add some further facts concerning the skeletal organization and systematic position of these highly interesting Testudinates.

The partial restoration of the left fore flipper shown in figure 2 is based on the radius and ulna, with what are considered to be all of the carpals but two, together with the first and fifth metacarpals. Several phalanges are present, but as finger proportions may vary markedly it is not deemed advisable to attempt a complete restoration. The value to be attached to this preliminary restoration is provisional, as follows:

(a) The radius and ulna are simply drawn in a generalized position, but their orientation is based on that found in a second specimen where these bones were in an approximately normal position with respect to the humerus, only.

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* G. R. Wieland.—A New Gigantic Cryptodire Testudinate from the Fort Pierre Cretaceous of South Dakota. This Journal, fourth series, vol. ii, December 1896.

† Loc. cit.

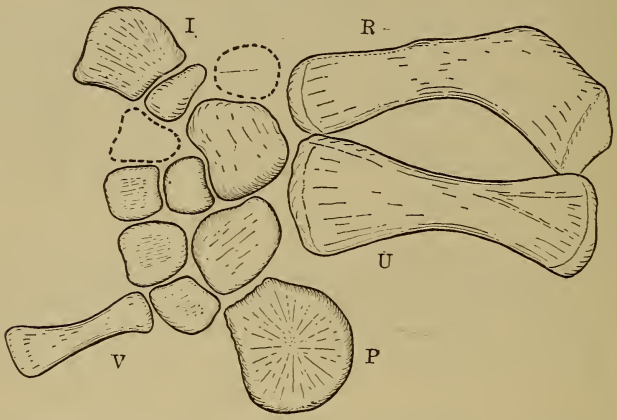
‡ S. W. Williston.—On the Hind Limb of *Protostega*. This Journal, fourth series, vol. xiii, April, 1902.

(b) Carpalia 3–5 were found in succession, and are doubtless correctly placed.

(c) There is little doubt but that the intermedium and ulnare are correctly determined, but their precise orientation is not so certain. Thus it may be that the intermedium should be rotated in a vertical arc of 90°. This, however, would not greatly alter its general contact outline, as it is a very robust and much rounded instead of flattened bone.

(d) Since metacarpal I and the pisiform are beautifully preserved, both as to form and surface markings, the possible remaining margin of error as to the identity of the several parts is slight.

Figure 2. *Archelon ischyros* Wieland. Partial restoration of left front flipper, x⅛.



R, radius; U, ulna; P, pisiform; I, carpale 1; V, carpale 5.

Description. Since the peculiarities of the *humerus* have been quite fully dealt with in my article on the Evolution of the Testudinate Humerus, this bone need not be further mentioned now, except to recall the fact that it resembles the humerus of *Dermochelys* more closely than any other, although differing in some very essential features.

The *radius* is only slightly longer than the ulna. Proximally it is triangular, and distally, rather elliptical in transverse section. The most marked characteristic whatsoever is the strong proximal bow, which recalls the lesser proximal bow seen in the radius of *Dermochelys.* Otherwise this form has a rounder, heavier head. The proximal articular face is only slightly concave, its general outline being that of an isosceles triangle, with the base in contact with the inner face of the ulna.

The *ulna* is short and massive. The proximal articular surface is slightly crescentic in general outline, and somewhat concave except for an oblique, low, saddle-shaped ridge which divides this face into subequal areas, the larger facing towards the radius. The distal articular surface is moderately convex antero-posteriorly, and rather flat in the dorso-ventral direction. The bone has a distinct broad and shallow grooving on the proximal ventral, and on the distal anterior side, marking the proximal and distal contact with the radius and producing the effect of a marked twist corresponding to the high angle between the general trend of the proximal and distal articular faces. As in the case of the humerus and radius, there is a certain correspondence with *Dermochelys*, but the ulna of the latter is more rounded.

The *intermedium* is much rounded and very robust. The *ulnare* is suboval in external outline, with the proximal edge much the thicker. The *pisiform* is very large, of subcrescentic outline, thick, and quite flat, but with a raised border on both faces.

The carpalia and metacarpals present have more the appearance seen in the Cheloninæ than in *Dermochelys*, in which respect there is in fact a wide difference, the pronouncedly marine appearance of the rounded subcylindrical and flat-ended metacarpal and phalangal bones of the latter being quite absent.

General Resemblances. In so far as now known, the manus and pes of *Protostega* and *Archelon* resemble those of *Dermochelys* rather more than any other form. Briefly pointed out, the more marked similarities of the manus are, the approximately equal length of the radius and ulna, the heavy proximal bow of the radius, the carpal organization with the centrale excluded from contact with carpale 1, and an enormous pisiform set high up near the ulna, and mainly on the ulnare. The point of most importance and necessarily of the greatest difficulty to settle with complete satisfaction is as to the assumed contact of the centrale with carpale I.

Professor Williston has, I think, omitted one of the tarsalia from his restoration of the hind limb of *Protostega*, so that there is likewise an even closer general correspondence between the hind limbs of these several forms than he suggests. The diminution of the fifth finger of the hind flipper, as he shows, to a single metatarsal is, I suppose, not to be regarded of as much importance as any reorganization of the carpalia or tarsalia (loc. cit.).

Measurements of Archelon ischyros.

(From the type specimen.)

The Radius.

	Meters.
Length	·35
Proximal diameters	·082 and ·114
Least diameters of shaft	·05 and ·067
Distal diameters	·049 and ·114

The Ulna.

Length	·33
Greatest and least proximal diameters	·093 and ·14
“ “ “ diameters of shaft	·054 and ·063
“ “ “ distal diameters	·088 and ·138

Measurements of carpals and metacarpals, viewed from dorsal surfaces:

	Greatest length.	Greatest width.
Intermedium	·8	·11
Ulnare	·11	·08
Pisiform	·14	·12
Centrale	·048	·06
Carpale I	·04	·07
“ II	—	—
“ III	·06	·056
“ IV	·068	·068
“ V	·06	·072
Metacarpale I	·09	·10
“ V	·156	·056

The extreme length of the accompanying humerus is ·65 meters.

III. *The Cervicals of Toxochelys and Archelon.*

(See Measurements, p. 98.)

The cervical formula has not hitherto been given for any of the Cretaceous marine turtles, so far as the writer is aware, our knowledge having been restricted to scattering or isolated vertebræ. I may hence give the formula for *Toxochelys*, and will show that that of *Archelon* may also be determined as quite similar, since we know the vertebræ most susceptible of change, the last three.

In the Yale specimen of *Toxochelys* (see Measurements), the first, second, fourth, sixth, seventh, and eighth cervical vertebræ are present. The nature of the other two, the third and the fifth, of course follows, as included arbitrarily in the subjoined table, in which are given the formulæ for the present forms and several others presenting interesting or im-

Cervical.	I *Archelon ischyros.*	II *Toxochelys latiremis.*	III *Dermochelys coriaceæ.*	IV *Eretmochelys imbricata.*	V *Chelydra serpentina.*	VI *Testudo polyphemus.*	VII *Erymnochelys Madagascariensis* (Grand).	VIII *Podocnemis Dumerilianus.*	IX. *Trionyx spinifer.*
1	Complex	Complex	Complex	Complex	Complex	Complex	Complex	Complex	Complex
2	Cyrtocœlian	Cyrtocœlian	Cyrtocœlian	Cyrtocœlian	Cyrtocœlian	Cyrtocœlian	Cyrtean	Cyrtean	Cyrtocœlian
3	"	"	"	"	"	"	Cœlocyrtean	Ephippic	"
4	Cyrtean	Cyrtean	Cyrtean	Cyrtean	Cyrtean	Cyrtean	"	"	"
5	Cœlocyrtean	Cœlocyrtean	Cœlocyrtean	Cœlocyrtean	Cœlocyrtean	Cœlocyrtean	"	"	"
6	"	"	"	Cœloplatyan	Cœlobicyrtean	Cœlobicyrtean	"	"	"
7	"	"	Cœlobicyrtean	Platybicyrtean	Bicœlobicyrtean	Bicœlobicœlian	"	Cœlocyrtean	Cyrtobicœlian
8	"	"	Bicœlocyrtean	Bicœlocyrtean	Bicœlocyrtean	Bicyrtobicyrtean	"	"	Bicyrtocyrtean

1. Cyrtean = double-convex; Cœlian = double-concave; Bicœlo-bicyrtean = doubly concave anteriorly, and doubly convex posteriorly, and so on. See this Journal for August, 1899, p. 163.

2. The last cervicals of *Toxochelys* are broad, but do not actually develop into double-concave, double-convex, or flatly terminated centra.

3. No. 7 of *Dermochelys* approaches platybicyrtean as in *Eretmochelys*.

4. The third–sixth cervicals of *Podocnemis* are quite as distinctly saddle-shaped as those of birds, doubtless as the result of the habit of retracting the neck laterally.

portant comparisons. All taken together display the great variations seen in particular in the last five Testudinate cervicals. I may explain that I have introduced a modified nomenclature I proposed in this Journal for August, 1899, p. 163, since the ordinary and incomplete terminology does not adequately express the complicated forms seen in Testudinate cervicals.

The cervicals of *Toxochelys* are distinctly intermediate in character between those of *Chelydra* and the *Chelonidæ*, being most like the former. The ends of the sixth, seventh and eighth broaden, but there are no distinctly biconcave, biconvex, or flat terminations, these vertebra still being procœlous (cœlocyrtean). Their centra have strongly marked elongate and thin or blade-like keels, quite similar to those of the sixth and seventh, but not the eighth centrum, of *Chelydra*. The total length falls far short of that seen in the *Chelydridæ*.

In *Archelon*, the sixth, seventh and eighth cervicals were found in place in the type specimen, as well as several others. All are characteristically procœlous (=cœlocyrtean), and none have their anterior ends markedly broadened as in *Toxochelys*. They are also relatively much shorter than in *Toxochelys*, and very robust (loc. cit.). I have estimated the cervicals of the type specimen of *Archelon* as having a length of ·72^{m}. The cranial length must be about the same. But in *Toxochelys* the total length of the cervicals is about one and a half times, and in *Chelydra* twice that of the cranium. We cannot doubt that the fourth cervical was biconvex (Cyrtean), since it is so in all known marine Testudinates. The vertebræ of *Archelon* are on the whole rather more primitive than in any other marine turtle, and it is certainly very interesting that there should be a closer agreement with *Toxochelys* than any other form.

IV. *Bearing of the Foregoing Data, and Classification.*

A phylogenetic classification of the marine Testudinates will still be held more or less difficult to deduce, according to the view that is taken of the much debated descent of *Dermochelys*. In weighing the evidence at present available, however, it needs to be borne in mind that the wide distribution of the turtles in latitude and time necessitates the consideration of slighter differences than in the case of more variant forms. While this must finally be a great advantage, it is a fact that at present brings home to us with force our imperfect, but happily rapidly increasing, knowledge of the fossil record. Again, there is a constant danger that in such a case one may regard evolution as having taken a far simpler course than has really been the fact. It would appear that several hypotheses yet require consideration, as follows:

(1) All the known marine Testudinates may be the descendants of a single littoral species.

(2) *Dermochelys* on the one hand, and all the other marine forms on the other hand, may have descended from two different littoral species of the same genus, or from different genera.

(3) *Dermochelys*, *Toxochelys*, *Protostega*, and the living *Chelonidæ* may represent the descendants of four genera of the same, or closely allied families.

(4) *Dermochelys* is of ancient descent, and stands phyletically and morphologically opposed to all other Testudinates.

Doubtless the final truth will be found to lie somewhere between the first and last extremes. Certainly it is difficult to overthrow the conclusion as to the general fact of descent as thus expressed and as defended with such signal ability by Baur:*

"Darüber aber ist kein Zweifel dass *Dermochelys* und *Psephophorous* keine urspünglichen Formen sind, sondern dass sie von wahren 'Thecophoren' und zwar von den 'Pinnaten' abstammen, um mich hier dieses Ausdrucks zu bedienen."

Dollo,† originally a strenuous opponent of this view, has recently adopted it. Taking up the question in further detail, he holds *Dermochelys* to be descended from a pelagic Thecophore with an extremely reduced carapace and plastron, but the descendant of a littoral Thecophore with a fully developed carapace, and a plastron without fontanelles. And this eminent scientist has proposed the ingenious hypothesis that such a Thecophore again acquired littoral habits, resulting in the formation of a heavy mosaic carapace, which, with a second resumption of pelagic habits, again began to disappear, and is still in process of reduction. The persistence of the nuchal is held to be due to its value as an attachment for the nuchal ligaments. However involved such an evolutionary process may appear, it is skilfully presented, and has much in its favor.

On the other hand, Hay‡ has presented at considerable length facts favoring a very early origin of the Dermochelan line.

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* G. Baur.—Biologisches Centralblatt, Band ix, 1889, p. 191 (Erlangen).

† L. Dollo.—Sur l'origine de la Tortue Luth (*Dermochelys coriaceæ*). Extrait, Bull. Soc. roy. des Sciences Med. et Nat. de Bruxelles, Seance 4 fevrier, 1901.

‡ O. P. Hay.—On Protostega, the Systematic Position of *Dermochelys*, and the Morphogeny of the Chelonian Carapace and Plastron. American Naturalist (Boston), Dec. 1898.

Presumably the evidence in favor of Baur's view is increasing. The writer so regards it. The fact that the cervicals of *Toxochelys* and *Archelon* agree in general, and at the same time differ most widely from the cervicals of *Dermochelys* and of the Cheloninæ, is, however, rather unexpected. Did the vertebræ of these Cretaceous forms tend to simplify, or has there been a more or less remote homoplastic parallelism in the course of complication in the case of the sixth, seventh and eighth vertebræ of the modern sea turtles, and such widely different forms, for instance, as the Testudinidæ?

The question at once arises, what is to be regarded as a very primitive Testudinate cervical, and what was the form in the species, genus, or group which made its way into the sea and gave rise to the marine group? We may most reasonably suggest as a very primitive cervical type, that of a turtle like the Pleurodiran *Erymnochelys*, in which there is a well-nigh complete agreement with the modern *Crocodilia*, the second, and not the fourth, centrum being biconvex. And we assume that some descendant of such a primitive type, with double convexity moved back to the fourth cervical centrum, the fifth–eighth centra remaining simply procœlous, stood in some common ancestral relationship to the sea turtles and most other existing Cryptodirans. It would at present, therefore, seem that even since the sea turtles split off from their littoral ancestry there has been a certain parallelism in the secondary cervical modifications undergone by them and the most nearly related land forms. This may hence prove, once we know the record more completely, to be another example of the fact that a course of evolution and change once established in a persistent group, may long continue, after the invasion of wholly new environments. There is in biologic, as in physical evolution, inertia.

As to the carpus of *Archelon*. It will certainly be very interesting if my surmise that there is no union between carpale 1 and the centrale should prove correct. This, although to be regarded as a secondarily acquired character, would indeed go far toward narrowing the gap between the extreme ends of the marine group. I may point out that the greatly accentuated bow of the radius of *Archelon* would make it probable, even in the absence of more direct evidence, that there was present some marked change in the order of the carpals.

Systematic Position of Archelon. While the data given in the preceding notes go far towards showing that *Protostega* and *Archelon* present more osteological resemblances to *Dermochelys* than any other turtles whatsoever, living or extinct, their structure is essentially that of the Chelonidae, of which they may best be regarded as a subfamily, the Protosteginæ. Moreover, these Dermochelan resemblances are only what we might well expect in Cretaceous turtles. There are likewise, as we see, certain Chelydran resemblances in the general type of skull, just as there are also Chelydran resemblances in *Toxochelys.* We are simply following convergent lines back sufficiently far to somewhat accentuate general relationships.

Position of Toxochelys. The fore flipper and cervicals of *Toxochelys* present some additional Chelydroid characters to those of the cranium and lower jaw, as already pointed out by Cope and Hay. *Toxochelys* hence proves to be one of the most interesting of turtles. Like *Protostega* and *Archelon*, it points with more or less distinctness toward a Chelydra-like ancestry. Baur has said that this genus should be placed in a distinct family, and in this has been followed by Hay and Case. But I think that *Toxochelys* may more conveniently be considered as representing a subfamily of the Chelonidæ, certainly if of common ancestry.

V. *Provisional classification of the marine Testudinates.*

CHELONIOIDEA (Baur).

(Superfamily of the Cryptodira.)

A parieto-squamosal arch; palatine foramen and free nasals sometimes present (Desmatochelydinæ); fourth cervical biconvex, with the centra of the sixth, seventh, and eighth usually greatly modified.

I. *Dermochelydidæ.*

No descending parietal processes; no palatine foramen; other cranial and limb characters not remote from those of the Chelonidæ; carapace represented by the nuchal only, and body enveloped in a leathery hide with an osteodermal mosaic; no claws. Genera: *Dermochelys, Psephophorous, Eosphargis.*

II. *Chelonidæ.*

Skull with descending processes of parietals, so far as known; palatine foramen sometimes present; vomero-premaxillar union often, but not constantly present; a normal, though often much reduced, carapace and plastron; nuchal with or without process on under side; claws, one or two.

1. Protosteginæ.—No free nasals; no palatine foramina; obturator foramen small and enclosed by ischiopubic contact on median line, as in many land forms.

Genera: *Protostega* and *Archelon; Protosphargis? Pseudosphargis?*

2. Toxochelydinæ. — No free nasals; palatine foramen, pterygoids, and lower jaw distinctly Chelydra-like; two strong claws.

Genera: *Toxochelys*, *Porthochelys*, *Cynocercus* (*?*), all of the Niobrara Cretaceous of Kansas, also *Neptunochelys* from the Cretaceous of Mississippi.

3. Desmatochelydinæ.—Free nasals; distinct palatine foramina (except *Rhinochelys?*).

Genera: *Desmatochelys*, *Rhinochelys*, *Atlantochelys*.

4. Cheloninæ.—No free nasals; no palatine foramina; vomero-premaxillar union often, but not constantly present; obturator foramen presumably not enclosed as in *Archelon* in any member of the group; claws, one or two.

Genera: *Osteopygis*, *Allopleuron*, *Lytoloma*, *Argillochelys*, *Eretmochelys*, *Chelone*, *Colpochelys*, *Thalassochelys*.

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Resume.—In the foregoing notes the following additions to the osteology of the marine Testudinates have been made:—

1. The elements and organization of the front flipper of *Toxochelys.*

2. The main elements of the wrist region of the front flipper of *Archelon ischyros.* (These are described from the type of the genus and species. The writer, in his first announcement of the discovery of this gigantic turtle, figured and described the accompanying humerus, with the radius and ulna, as well as the femur, tibia, and fibula,—this being the first instance in which all these limb bones were made known in the case of any extinct marine Testudinate.)

3. Important measurements for the coördination of various skeletal elements of *Toxochelys* and *Archelon.*

4. The deduction (with the exception of the secondary rearrangements of the carpals) of the principal lines of change in the evolution of the fore flipper from the foot of some primitive swamp, or littoral, *Chelydra*-like turtle.

5. The cervical organization of *Toxochelys* and *Archelon*, which is compared with that of living turtles.

6. A classification of the marine turtles.—This has chiefly been made possible by the description during the last few years of large portions of the skeleton of *Protostega* and of *Toxochelys*, and especially by the discovery of *Desmatochelys*, *Archelon*, and *Porthochelys.*

Yale Museum, New Haven, Conn.
April, 1902.

ART. XV.—*The Magnetic Effect of Electric Displacement;* by JOHN B. WHITEHEAD, JR.

HISTORICAL REVIEW.

IN the development of his theory of the electromagnetic field, Maxwell assumes that the phenomenon of polarization in a dielectric consists of an actual propagation or displacement of charge in the direction of the polarization; that in the case of the charging of a condenser, for instance, this act of displacement is equivalent to a current at any instant equal to the rate of change of the surface charge on one of the plates, i. e. $q=\frac{K}{4\pi}\frac{dF}{dt}$, q being the current density, K the specific inductive capacity and F the difference in potential per unit length, and that therefore the current is continuous throughout the circuit. He assumes further that the displacement current has the same magnetic effect as would be produced by a conduction current of density $q=\frac{K}{4\pi}\frac{dF}{dt}$, so that in the case of the condenser the magnetic effect in the neighborhood, incident upon any change of charge, would be due to the combined influence of the current in the charging wires and the displacement current in the dielectric.* "It appears, therefore, that at the same time that a quantity Q of electricity is being transferred along the wire by the electromotive force from B towards A, so as to cross every section of the wire, the same quantity of electricity crosses every section of the dielectric from A towards B by reason of the electric displacement." (Art. 60.) . . . . . .

"The variations of the electric displacement evidently constitute electric currents." (Art. 60.) . . . . . .

"One of the chief peculiarities of this treatise is the doctrine which it asserts, that the true electric current C, that on which the electromagnetic phenomena depend, is not the same thing as K, the current of conduction, but that the time variation of D, the electric displacement, must be taken into account in estimating the total movement of electricity." (Art. 610.)

The remarkable consequences of Maxwell's theory seem to justify his assumptions beyond all question. There need only be mentioned the finite velocity of propagation of electric and magnetic actions, this velocity being the same as that of light; the electromagnetic theory of light, which accounts for the results of experiment, practically without exception; the

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* Maxwell: Electricity and Magnetism, Art. 60, 75, 76, 111, 328–334, 608, 783, 791.

experiments of Hertz on electric waves showing them to be identical in behavior with light waves. The direct magnetic effect of the displacement current, however, has never been satisfactorily observed, if at all; published accounts of work in this direction seem to be limited to those of Röntgen, S. P. Thompson, Nicolaieff and Blondlot.

Röntgen.—The earliest attempt, apparently, was that of Röntgen in 1885.* He rotated a rubber disc between two stationary glass plates all in horizontal planes. The upper plate was coated with tin-foil which was grounded; the lower plate had on it a ring of tin-foil which was split along a diameter and the two halves oppositely charged. As the disc rotated there was a change in polarization at those portions of it passing over the opening in the tin-foil, and the resulting displacement current was in opposite directions at the two ends of this opening. Over the whole system and as close as possible to the upper plate, he suspended an astatic needle whose direction was along the line of the opening in the tin foil, and the line of suspension the continuation of that of the axis of the rotating disc. The length of the lower needle brought its ends to the center of the width of the tin-foil rings; any magnetic effect of the displacement current would thus tend to deflect the astatic system. On commutating the charges on the rings the deflection read by a mirror and scale was never over $1 \cdot 5^{mm}$, and the needle was subject to an oscillation of that amount due to disturbing influences. The observer, being ignorant of the direction of commutation, was supposed to take into account the motion already possessed by the needle in giving the direction of the resulting impulse. Röntgen states that after 1000 observations he acquired such practice as to be able to observe the proper direction nearly every time.

The results of this work can hardly be considered conclusive. That little importance is to be credited to it is evidenced by the small notice it has attracted. The genuineness of the observed deflection is particularly to be questioned in view of the fact that the poles of the needle were not in proper position to experience the full magnetic force of the displacement current. Each pole was entirely above the plane of the surface of the dielectric, and it may well be questioned what is the distribution of the magnetic field beyond the terminating surface of an "open current."

Thompson.—In 1889 S. P. Thompson† wound an iron ring with many turns of fine wire and imbedded it in a block of paraffin having on two sides parallel to the plane of the ring

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* Rep. der Physik, No. 21, 1885, p. 521.
† Proc. Roy. Soc., xlv, p. 392, 1889.

metal coatings which were connected to an induction coil. The winding on the ring being connected to a telephone receiver, sounds were obtained on charge and discharge of the coil. Very slight conductivity in the paraffin would have caused this.

Nicolaieff.—Nicolaieff in 1895* suspended a ring of paraffin between the two poles of an electromagnet, the plane of the ring being vertical and making an angle of 45° with the axis of the poles. The E.M.F. induced in the ring when the magnet is excited by an alternating current, sets up a displacement current which, by its magnetic reaction on the exciting field, creates a couple tending to make the ring turn and set itself perpendicular to the field. He excited the magnet first with direct current, getting a deflection due to the magnetic qualities of the ring, then with alternating current of the same intensity, causing a different deflection, the difference being due to the displacement current. The record of observations is not given in the paper, the author simply stating that the deflection was greater when the magnetic field was alternating than when direct; and was greater the greater the frequency. For 12 cycles per sec. the increase was 9% over the constant magnetic field, for 15 cycles 12%; in this case also conduction would cause the observed effect.

Blondlot.—Recently M. R. Blondlot† looked for an electric displacement in a mass of air moving in a magnetic field. He forced a blast of air through a rectangular passage, two sides of which were pole faces of a magnet, the other two a pair of condenser plates. The plates were connected by a wire which was broken at the instant the blast was at its maximum, so that the plates should be left charged if there was any electric displacement in the mass of air. He calculated the expected effect and calibrated his electrometer to read it; the results of a number of experiments were invariably negative. Making use of this experimental fact, he then proves theoretically the absence of any electromagnetic action of a magnetic field on a displacement current.

PRESENT RESEARCH.

General Theory.

The series of experiments herein described were undertaken in view of the continued uncertainty of the results of all effort to observe the magnetic effect of electric displacement, and in view of the fact that the method employed had certain advantages over those used heretofore.

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* Jour. Phys., vol. iv, 1895, pp. 245–254.

† Jour. Phys., Jan. 1902, p. 8.

In principle, the method is to subject a piece of dielectric to an alternating electric field and also to an alternating magnetic field, the directions of the two being at right angles in space; to adjust the phases of the two to give the maximum effect of the displacement current reaction against the magnetic field, and to look for motion of the dielectric in a direction perpendicular to the plane including the directions of the electric and magnetic fields. In this form the idea was suggested to the

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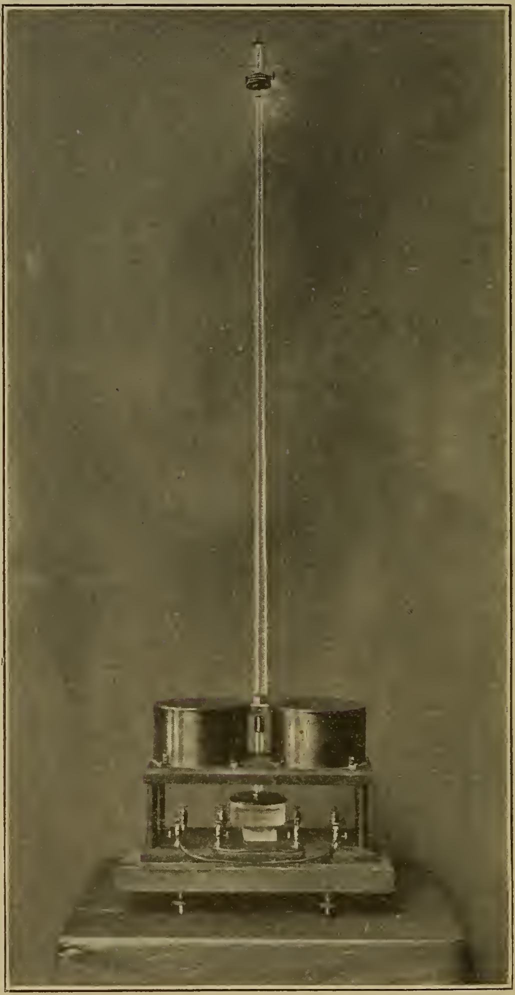

writer by Professor Rowland shortly before his death. Some twelve years before he made the same suggestion to Dr. Louis Duncan, who constructed a crude form of apparatus, but abandoned the work on account of the difficulty of obtaining a uniform field.

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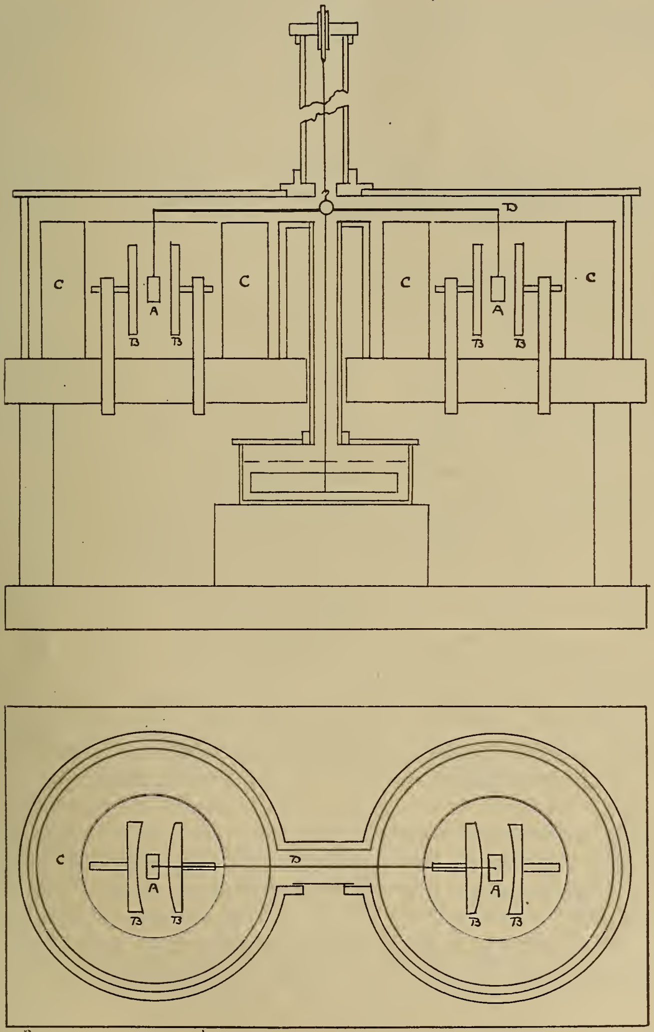

In each of four modifications of the form of the apparatus embodying the above principle, a block of dielectric was hung rigidly at each end of a light beam which was suspended horizontally on a quartz fiber attached at its center. The phase of either the electric or the magnetic field on one block being 180° from that on the other, the other field having the same phase for each block, the reaction of the displacement current on the magnetic field would be opposite at the two ends of the beam, causing a couple to act on the fiber suspension.

Apparatus.

First form.—The first form of the apparatus is shown in fig. 1, and fig. 2 gives a central section. AA are the rectangular blocks of dielectric, each attached to the beam D, which was constructed of bamboo or glass; B B B B are brass electrodes each turned so that its surface is a part of a circular cylinder with its axis coincident with the line of suspension of the beam; this was thought to give the best approximation to a uniform electric field between the electrodes. Each pair of electrodes was connected to the terminals of a transformer giving 8800 volts at 133 cycles per sec. C C are circular coils of wire, one surrounding each pair of electrodes, the planes of the turns being horizontal; they are supplied with alternating current from the same generator which excites the electrodes. The magnetic field is seen to be vertical, the electric field horizontal, so the resulting deflection of the beam should be out of the plane of the paper at one end and in at the other. The whole rested on a wooden base, and each half of the apparatus was enclosed in a brass case, there being between the two only a small connecting trough in which the beam could swing, thus making the interior as small as possible and so minimizing the disturbance due to air currents. A close fitting brass cylinder inside the coil, a ring on top, and tin foil on the floor, all connected to the case, which was grounded, protected the dielectric from any electric field due to the coil; all possible secondary circuits were split, the openings being closed with hard rubber or fibre. The damping vane shown in the sketch was a strip of mica immersed in water, attached to the deflecting beam by means of a fine glass rod. The quartz fiber used was approximately 102^{cm} (40″) long in all cases; it was enclosed in a glass tube fitted with a convenient torsion head permitting the adjustments of torsion and length independently; the fibre carried a small copper hook at its lower end which fitted into a corresponding hook sealed to the glass beam. Deflections of the beam were observed by means of the movements on a ground glass scale of the image of an incandescent lamp filament reflected from a small mirror on the center of the beam; during the later experiments the lamp was replaced by a Nernst filament, which is beautifully adapted to this purpose. The distance of the scale from the mirror was 140^{cm}. The connections are shown in fig. 3. The generator, G, was a Westinghouse "smooth-body," giving a pure sine wave, 1000 volts, 133 cycles; the transformers, T, T, T, were all Westinghouse make. The transformer T_0, giving the high voltage, was built privately; it was of closed magnetic type and had a ratio of 1 to 80. By a suitable arrangement of switches 110, 200, or 400 volts could be put on the coils. The two magnetizing coils were connected in multiple and so that they worked together; i. e., at any instant the fields were equal, parallel, and in the same direction. The electrodes were also in multiple, but worked in opposite directions, i. e., at any instant the fields were equal, parallel, but in opposite directions. In each circuit there was a reversing switch, R S.

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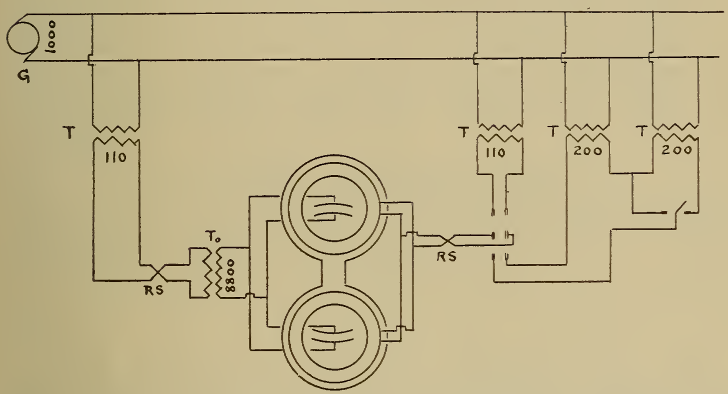

Calculation of Effect Expected.—Following is a calculation of the magnitude of the effect in the apparatus as constructed and experimented upon.

Each pair of electrodes were $1{\cdot}9^{cm}$ apart; the dielectrics were blocks of rock salt, glass or paraffin, $1^{cm} \times 1^{cm} \times {\cdot}63^{cm}$ and they were hung with their square faces parallel to the electrodes, so that one-third the length of a line of force was within the dielectric; thus $\sqrt{2}{\cdot}8800$ being the maximum E.M.F. between the electrodes the proportion of it active on the dielectric is given by:

$$V = \frac{\sqrt{2} \,.\, 8800}{2K+1}$$

the intensity of E.M.F. $F_m = \dfrac{dV}{dl}$

$$F_m = \frac{\sqrt{2} \,.\, 8800}{(2K+1) \times {\cdot}63} \quad \text{(maximum value in volts).}$$

The density of the displacement current is $q = \frac{K}{4\pi}\,\frac{dF}{dt}$; since the E.M.F. is alternating we have:

$$F = F_m \sin a$$

and

$$q = \frac{K}{4\pi}\, F_m \cos a\, \frac{da}{dt}$$

also, $\frac{da}{dt}$ = angular velocity $= 2\pi N = \pi\,.\,133$

$$\therefore q = \frac{K}{4\pi}\cdot\frac{\sqrt{2}\,.\,8800}{(2K+1)\times{\cdot}63}\cdot\frac{2\pi\,.\,133\,.\,10^8}{3\times10^{10}}\cos a \text{ in C.G.S. electrostatic units.}$$

$$= \frac{K}{4\pi}\cdot\frac{\sqrt{2}\,.\,8800}{(2K+1)\times{\cdot}63}\cdot\frac{2\pi\,.\,133\,.\,10^8}{(3\times10^{10})^2\times10^{-1}}\cos a, \text{ amperes}$$

$$= \frac{K}{2K+1}\;\frac{14{\cdot}6}{10^7}\cos a$$

$$\therefore\; = \frac{K}{2K+1}\;\frac{10{\cdot}3}{10^7} \text{ amperes, effective, per unit cross section.}$$

Each of the coils for the magnetic field contained 1200 turns of No. 18 B. & S. magnet wire; H, the intensity of the magnetic field at the center of these coils, as calculated with a neglect of the influence of the ends, was 200 i, i being the current in amperes; as measured by the electromotive force induced in an exploring coil of known area and number of turns, H was 166 i, (area of exploring coil 25^{cm^2}, 400 turns; observed E.M.F., with 2·4 amps. in coil, 33·5 volts, 133 cycles). The resistance of each coil was about 9 ohms, and the calculated value of the coefficient of self-induction was L = ·109 henry; at 114 volts, 133 cycles, each took 1·3 amperes which corresponds to a value ·104 for L. If θ be the difference in phase between the E.M.F. and current, i. e., the angle of lag, we have:

$$\tan\theta = \frac{2\pi NL}{R} = \frac{6{\cdot}28\times133\times{\cdot}104}{9} = 9{\cdot}3, \text{ whence } \theta = 83^\circ\ 52'$$

Now consider the phase relations between the displacement current and the alternating magnetic field from the sketch of the connections. Since the difference in phase between the primary and secondary E.M.F's of a transformer is approximately 180°, the E.M.F. on the electrodes having passed through two transformations has returned to coincidence of phase with the generator E.M.F. and may be indicated by sin a. The resulting displacement current has the phase cos a as shown above, i. e., differs by 90° from the generator E.M.F. The E.M.F. impressed on the coils has been transformed once, suffering retardation of 180°; owing to the self-induction of the coil the resulting current lags approximately 90°, and so, therefore, does the resulting magnetic field. Consequently, the displacement current and magnetic field are approximately 180° apart, that is, in the proper relation to give the electromagnetic reaction. Actually, since the angle of lag in the coil is 83° 52′ instead of 90°, the effect as calculated for coincidence must be multiplied by ·9942 = cos 6° 8′.

The current in the dielectric is thus acted on by a force:

$$\cdot 994 \frac{lq\,\mathrm{H}}{10} = \cdot 63 \cdot \frac{\mathrm{K}}{2\mathrm{K}+1} \cdot \frac{10\cdot 3}{10^7} \cdot \frac{166 \times 1\cdot 2}{10} \cdot \cdot 9942\,.$$

$$= \frac{\mathrm{K}}{2\mathrm{K}+1} \cdot \frac{12\cdot 8}{10^6} \text{ dynes.}$$

when 1·2 amperes flows in each coil, l being the thickness of the dielectric, or the length of the displacement current acted on by the field, and H the intensity of the magnetic field. This force is applied in opposite directions at the two ends of the suspended beam, which was $17\cdot 78^{\mathrm{cm}}$ long, giving thus a couple of

$$\frac{\mathrm{K}}{2\mathrm{K}+1} \cdot \frac{2\cdot 28}{10^4} \text{ dyne-centimeters.}$$

The angle of twist of a thread of length l, radius r, coefficient of rigidity n, acted on by a couple u is:

$$\Phi = \frac{2\,lu}{\pi r^4} \cdot \frac{1}{n}.$$

The length of the quartz fiber was $101\cdot 6^{\mathrm{cm}}$; its radius was estimated by comparison under a microscope with the spaces of a grating ruled on glass, the grating space of which was known, and did not differ greatly from $\cdot 0006^{\mathrm{cm}}$. The value of n being taken at 3×10^{11} for quartz,* we have

$$\Phi = \frac{\mathrm{K}}{2\mathrm{K}+1} \cdot \frac{2 \times 101\cdot 6 \times 2\cdot 28}{\pi \times \cdot 0006^4 \times 10^4 \times 3 \times 10^{11}} = \frac{\mathrm{K}}{2\mathrm{K}+1} \cdot 37 \text{ radians.}$$

Taking the value of K for rock salt as 5·8, we have $\Phi = \cdot 173$, which, since the distance from the mirror to scale was 140^{cm}, represents a deflection of $2 \times 1400 \times \cdot 173 = 485^{\mathrm{mm}}$, or more, since we have taken the tangent as equal to the arc.

The calculation above assumes that the electric and magnetic fields remain constant through the range of movement of the dielectrics. It was of course foreseen that the electric field would be most intense at the center of the space between the electrodes and so would tend to hold the dielectric within that region; nevertheless it was thought that a couple of the magni-

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* Threlfall and Boys.

tude above indicated would to a certain extent overcome this tendency. The test for the true effect seemed to lie in a reversal of the sense of the deflection when the phase of either the electric or the magnetic fields was changed by 180°.

Results.—When the electric field alone was applied, the beam, as was expected, found a stable zero position near the center of the electrodes. With a fiber 20^{cm} long this position could be upset by 10 to 20^{mm} on the scale, by a very small twist of the torsion head. This test was not so satisfactory when the long fiber was used, owing, apparently, to the large inertia of the suspended system, and to the arising of other disturbances within the time necessary for the torsion of the fiber to make itself felt. The zero point was always quite steady, having practically no oscillation, but was not always the same, varying within two centimeters. This indicated that near the center there was a region of fairly uniform electric field, and also that, owing to the mass and damping of the suspended system, the torsion of the fiber could not be depended on to give the zero position. The mass of the beam and dielectrics was from 2 to 3 grams, varying with the nature of the dielectric; of this the greater part was in the dielectrics. Fibers of the size here required broke if the mass were 3 grams or more.

The method of procedure was to allow the beam to come to rest under the influence of the electric field alone, the long time required for the oscillations about the central position to die out being another evidence that the field there was fairly uniform. Then the magnetic field was put on and the resulting deflection noted. Then either the electric or magnetic field was reversed, the deflection noted, and so on. The deflection was generally small and quite slow in all cases, requiring considerable time to become steady; in most of the observations only the sense of the deflection was noted. Proceeding in this way, several hundred observations were taken; they were generally negative in result, that is, the deflection did not change in either direction or amount when either field was reversed. At times, however, there were indications of the effect looked for, as is shown by the following description:

The electric field and then the magnetic field being put on, as described, with the values and conditions as given above, there resulted an uncertain deflection of about 1^{mm}, which did not reverse with a reversal of the magnetic field. The circuits were then arranged so that 200 or 400 volts might be impressed upon the coils. With 200 volts a deflection of from 5 to 10^{mm} was obtained, which, however, did not reverse with a reversal of the magnetic field; this deflection was towards a position which the beam tended to take when under the influence of the magnetic field alone. With paraffin as the dielectric the proper reversal was obtained to the extent of 4 or 5^{mm} on two occasions, one with a reversal of the electric field, the other with a reversal of the magnetic field. In both instances the deflections were from a zero position constant within 1^{mm}, and appeared as a slow motion immediately on closing the switch. The above mentioned disturbing effect of the magnetic field was always evident through all the experiments, but in this form of the apparatus in several instances there were distinct initial deflections in opposite sense to this tendency.

When the switches remained closed long enough, the above disturbing tendency seemed to predominate regardless of the direction of the field. The question at once arose as to whether it was a magnetic or an electric effect. Experiments with bits of iron filing on the dielectrics, with hard rubber known to be slightly magnetic, with rock salt which gave no trace of magnetic impurities, and with both direct and alternating currents, indicated that a part of this disturbing influence was due to the difference in the intensity of the magnetic field at the center and close to the side of the coil. For this reason only rock salt, glass and paraffin were used, as they appeared quite free from magnetic impurities; with them the disturbance was less than with sulphur and hard rubber, though it was still the predominating influence. Further experiments with rock salt several times gave evidences of the proper reversals to the extent of 2 or 3^{mm}; and with glass on one occasion the expected reversals of deflection were noticeable for six switch reversals; these deflections were only 2 to 3^{mm}. Very long waits between readings were necessary owing to the difficulty of obtaining a steady zero; this was probably due to air currents set up within the case caused by the heating of the coils when on the 200 volt circuit; the six readings mentioned required one afternoon. On the next day the proper reversals of deflection were observed for four reversals each of magnetic and electric fields; they were from 2 to 5^{mm}.

It must be stated, however, that these proper deflections were taken from among a mass of attempts which resulted sometimes in no deflection at all and at others in deflections in the wrong sense. While it was sometimes possible to account for these by a steady shifting of the zero position, I still questioned whether I had obtained the effect, and looked to the improvement of the apparatus.

Second and Third Form of Apparatus.—In the second form the air space was reduced and the electric screening made better by enclosing only the electrodes and suspended system within the case, the coils being outside. The case was entirely of brass, the posts of the electrodes being set in insulating bushings. To prevent secondary currents in the cylindrical cases, they were each split down an element of the cylinder; these splits were covered and were on the front of the case, i. e., diametral planes through them cut the beam, in its central position, at right angles. The conditions were not improved by the apparatus in this form; if anything, the disturbance due to the magnetic field alone was worse, and it always caused a movement of the dielectric towards the side of the casing to which it happened to be nearer. Still thinking it a magnetic effect due to the more intense field near the coils, a single large coil which would completely surround the entire case and have its center in the line of the fiber, was wound. The field due to this coil would be uniform around any circle concentric with the coil; the coil was $7{\cdot}62^{cm}$ high, had an internal diameter of $26{\cdot}6^{cm}$ and contained 360 turns of No. 15 wire. The conditions were not improved by the use of this coil, and it was still impossible to look for the true effect. This seemed to indicate that the disturbance was not magnetic, nor could it be due to electrostatic influence of the coil since the shielding was practically perfect. It was thought then that the electromotive force induced in the cylindrical metal case must set up a field in the slit down its side sufficient to cause the disturbances. To test this the slits were closed with solder, and new ones cut directly back of each of the outer electrodes; the disturbance disappeared almost entirely. Tests were then made with the single large coil and also with the two single coils; the constants for the large coil introduced no considerable difference in the calculated effect; the conditions in each of these series of tests were quite good; the electric field alone caused a good steady zero position; on closing the switch of the magnetic field there was usually no deflection at all, only a slight oscillation; sometimes there was a deflection of 1^{mm} or 2^{mm}, which, however, did not reverse on reversal of field and was probably a survival of the old disturbance.

Fourth Form of Apparatus.—As has been pointed out, the design of the electrodes in the experiments above described caused a position of stable equilibrium for the dielectrics, and it was thought that if the electric as well as the magnetic field were uniform and constant for all positions of the beam, the conditions would be greatly improved and practically as favorable as the method permits. To this end the final form of the apparatus was constructed: The large coil described above was used for the magnetic field; as shown in fig. 4, the electrodes were two complete rings of brass, set concentric with each other and with the coil. The surfaces were carefully turned and polished, and each ring was split in one place to prevent its becoming a short circuited secondary circuit. The true circular form of the ring was maintained by bridging the split with a strip of hard rubber; the splits in the two rings were in the same diametral plane. The rings were set on small, hard

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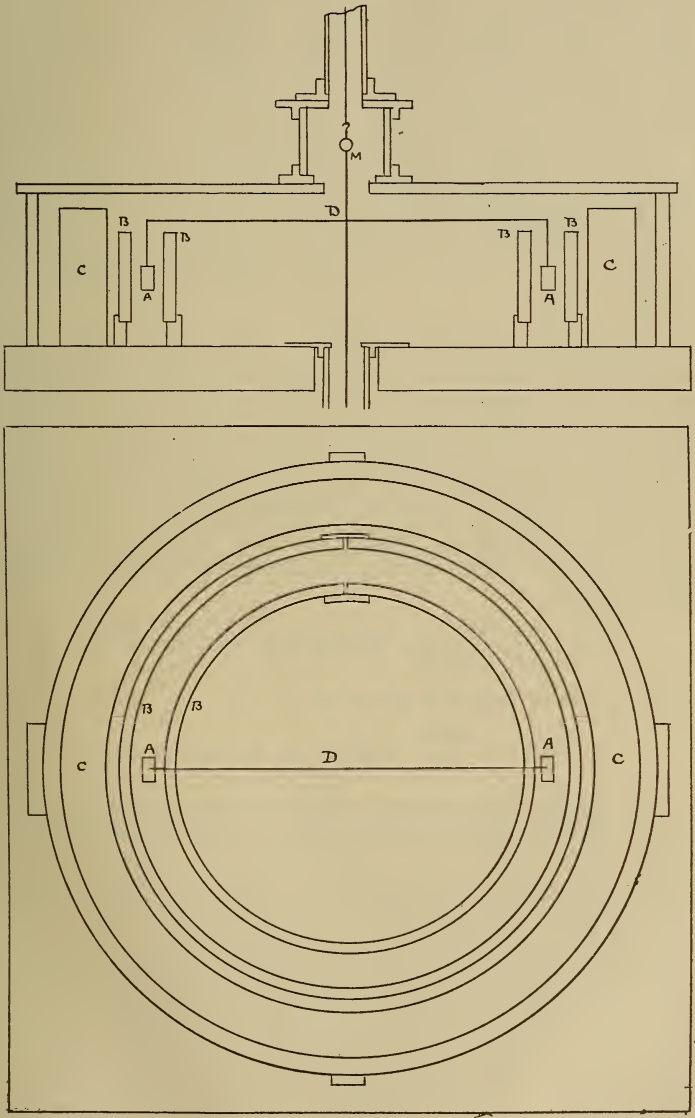

rubber chairs, and carefully levelled and spaced so as to be as nearly as possible the same radial distance apart at all points; this distance was 1·9^{cm} ($\frac{3}{4}''$). In the earlier experiments this distance was varied, and $1{\cdot}9^{cm}$ was found to be the minimum practicable separation, anything less resulting in the dielectrics receiving a charge which would draw it against the surface of one of the rings; for any distance between the electrodes this always happened in damp weather. The coil was carefully sheathed with tin-foil which was connected to earth. The suspension hook on the beam was lengthened so as to reach into a glass tube shown in the sketch at M and the mirror placed on it there. By moving the source of light and scale in a circle about the apparatus, it was thus possible to take observations in any position of the beam. The walls of the glass tube scattered the light somewhat, but the intensity of the Nernst filament was so great as to always give a well defined line on the scale. The whole deflecting apparatus was suitably enclosed so as to be free from disturbance by air drafts.

Calculation of Expected Effect.—With 8800 volts on the electrodes and with dielectrics of glass, paraffin and rock salt, the order of magnitude of the displacement current is not different from that already calculated. The angle of lag of the current in the coil, that is, the phase of the magnetic field, and also the intensity of the field, had also to be determined. The angle of lag was obtained by measuring the current taken by the coil at a known voltage and frequency. At 400 volts and 133 cycles this current was 10 amperes, the resistance being 4 ohms:

$$10 = \frac{400}{\sqrt{16 + 835\,L^2}}, \text{ whence } L = {\cdot}05 \text{ henry};$$

also the angle of lag, θ, is given by

$$\tan\theta = \frac{2\pi NL}{R} = 10{\cdot}45, \text{ or } \theta = 84^\circ\ 28'.$$

The intensity of the magnetic field at various positions within the coil was determined by sending a current through it and measuring the E.M.F. in an exploring coil of known area and number of turns. At 200 volts the current in the coil was 5·3 amperes. The exploring coil consisted of 400 turns of No. 33 wire, and had an effective area of about $25{\cdot}8^{cm}$. Moving the exploring coil along a radius by equal steps, the following readings give the curve, shown in fig. 5, of variation of the intensity of the magnetic field with the distance from the coil; ordinates are values of the intensity and abscissæ distances from the center, the coil having a radius of $13{\cdot}6^{cm}$. The deflecting beam was $22{\cdot}2^{cm}$ long, so that the dielectrics swing at a radius of $11{\cdot}1^{cm}$, and at this distance the field, with 5·3 amperes in the coil, had an intensity of approximately 220, or 42 per ampere, thus of the same order of magnitude as in the calculation for the first form of the apparatus. The suspension fiber was also the same, and so, therefore, the order of magnitude of the calculated deflection.

Position	Volts
Center	7·8
1	8·1
2	8·6
3	9·9
4 (near coil)	12·1

Results.—With this apparatus, when the electric field alone was put on, the beam after a sufficient time always found a position of equilibrium, in some places stable and at others unstable. The former seemed to be in a diameter which passed through the hard rubber supporting chairs of the rings, doubtless owing to a slight concentration into the chairs of the field of force; a slight departure from this line was sufficient to cause the beam to wander to some other position, and the indications seemed to certify a quite uniform electric field. On putting on the electric and then the magnetic fields, (5·3 amperes in coil) there was a deflection of from 2^{cm} to 3^{cm}, which, however, did not reverse or show any regular difference in amount when either field was reversed; it was found that the magnetic

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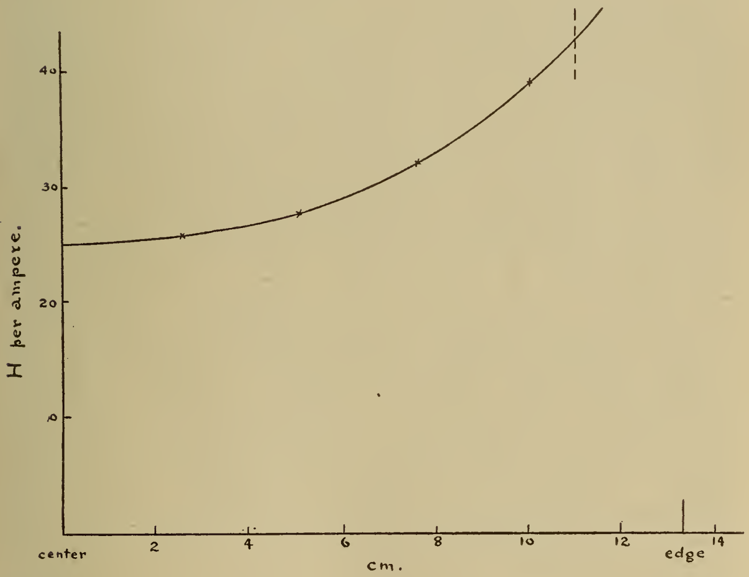

field when on alone gave a deflection in the same direction. Thus the magnetic field when on alone also had an effect on the position of the beam. With the beam at rest, when this field was made a slow drift away was generally seen, the beam coming to rest in some other position. Repeated efforts failed to locate single positions that it seemed to prefer, though in certain neighborhoods the direction of the deflection seemed the same. In some positions there was no deflection, though these were never the zero positions for the electric field alone; the problem then seemed to bring the two zero positions together.

Since the disturbance due to the magnetic field did not appear to be the influence of the splits in the ring as before, for it seemed independent of the distance of the dielectrics from them, and since the intensity of the magnetic field was uniform, it therefore seemed that direct electric influence of the coil or leading-in wires must be the cause, though the tin-foil screen seemed as perfect as possible. The attempt was then made to bring one of the positions in which the beam seemed unaffected by the magnetic field alone, into coincidence with a zero position for the electric field alone, by turning the coil into various positions about its center. This process was most tedious, involving as it did long waits for the beam to come to rest, and at its best it seemed only a hit-or-miss method. The condition sought, however, seemed so desirable, that repeated efforts were made to bring it about. One of them succeeded; and while the result obtained must be discredited in view of the failure of all attempts to repeat the proper conditions, and of other negative attempts, it is nevertheless thought that the following quotation from a note taken at the time should be inserted here: "this condition was obtained March 18th; the beam was allowed to come to rest under the electric field; this was then cut off and 400 volts put on the magnetic coil, which caused no deflection of the beam. On putting on both fields there was a slow deflection to the right of between 1^{cm} and 2^{cm}, about one minute being required. The magnetic field was then taken off and the beam allowed to move under the electric field alone; it resumed the former zero after one or two minutes. The magnetic field was then put on reversed; there resulted a much stronger deflection to the left which was allowed to continue several minutes, resulting in a deflection of 5^{cm}. Repetition could not be obtained, due to the fact that after the large deflection the beam did not return to the original zero position. (The heating of the apparatus due to the large current in the coil (10 amperes) when applied for any length of time frequently upset the equilibrium positions.) The conditions, however, of the above observations were so favorable that my belief in the presence of the effect was much strengthened after the many recent failures to detect any evidence of it."

Failing to repeat the condition as above described, a light strip of wood was placed along a diameter on top of the inner ring. This strip took up a sufficient charge to give the beam the position of delicate equilibrium when the beam was parallel to it, i. e., directly over it; it could be rotated to any position on the ring without opening the case, by means of a device not shown in the sketch; the rod of the damping vane passed through a hole at its center. A number of experiments were made with the following order; the beam was allowed to find a stationary position under the influence of the magnetic field alone. The interior being visible through the glass cover of the casing, the wooden strip was turned so as to be parallel to and directly under the beam, with the idea that the zero positions for the two fields would be brought into coincidence. It was found that in most cases any movement of the strip would upset the position of equilibrium due to the magnetic field. Frequently, however, the condition of coincidence was approached, and in all these instances when the effect was looked for the results were either spurious or negative. That is, if there was a deflection, as sometimes to the amount of 1^{mm} or 2^{mm}, neither its direction or amount changed with a reversal of field; or often there was no deflection at all for either phase of the field.

Differences in deflection for the two phases of either field were now looked for; the wooden strip was discarded and the beam allowed to find a stationary position under the action of both fields. That is, the electric field was put on and a steady state reached; then the magnetic field, resulting in a deflection of usually between one and two centimeters to a new position of equilibrium. The magnetic field was then quickly reversed and a change in the position of the beam looked for. In a series of observations in which the conditions seemed perfect, no change at all could be noted when the field was reversed, there being either no deflection at all, or less than 1^{mm} without regularity. In these experiments the coil only carried 2·6 amperes, giving a calculated effect one-half of that estimated above; 5·3 amperes, i. e., 200 volts on the coil, during the time required for the beam to come to rest, heated the interior to an extent sufficient, by reason of air currents or expansion of the ring electrodes, to cause erratic oscillations of the beam about its zero position.

While it was thought that at the comparatively low frequency of the alternating circuit, 133 cycles per second, a possible lag of the displacement current, owing to molecular friction or other cause, could hardly make itself felt, it nevertheless seemed worth while to shift the phase of either the electric or the magnetic field by a quarter of a period. For this purpose a two-phase machine was used, one phase being put on the primary of the high tension transformer, the other directly on the magnetizing coil. This separates the displacement current and magnetic field by one-quarter of a period, if there is a lag of one-quarter of a period in the coil due to its self-induction, as was approximately the case in the experiments already described. The machine operated at 38 cycles, and 85 volts per phase; the resulting displacement current is thus

$$\frac{38}{133} \times \frac{85}{110} = \cdot 23$$

of the value calculated for the first arrangement; at the lower frequency and voltage, however, the coil took 6·2 amperes, so that the magnetic field is $\frac{6 \cdot 2}{5 \cdot 3} = 1 \cdot 17$ times that in the first arrangement, so that the calculated magnitude of deflection is still appreciable; the angle of lag is given by

$$\tan \theta = \frac{2\pi \mathrm{NL}}{\mathrm{R}} = \frac{237 \times \cdot 05}{3 \cdot 9} = 3 \cdot 05, \therefore \theta = 72°.$$

The circuits were also arranged so that both electric and magnetic fields might be put on the same phase or one on each; this permitted, with the use of the reversing switches, a rapid change of phase of either approximately 90° or 180° between the displacement current and the magnetic field. In a series of observations with this arrangement there appeared to be no difference among the results of the several combinations of phase. The beam was allowed to come to rest under the electric field alone; on putting on the magnetic field there was the usual deflection, but there was no evidence of any change either in direction or amount of this deflection when the phase relations were altered at random.

Summary and Conclusions.

The mass of the evidence of this research is against the presence of the magnetic effect of electric displacement in an amount given by Maxwell's expression. The single positive result obtained with the final form of the apparatus must be questioned, for although the favorable conditions under which that result was observed could not be obtained a second time, it is thought that at times they were approached sufficiently to give traces of any effect as great as that noticed. The final form of the apparatus was undoubtedly that most likely to give results; in it there appear to be only two influences which might prevent the effect sought. The first is a variation in the intensity of the electric field from point to point and the tendency of the dielectric to remain in the region of greatest intensity; and the second, the presence of the damping vane. It is thought that neither influence was great enough to mask a couple of the value of that sought; as has been stated, the rings were carefully turned and adjusted in place so that their surfaces were the same distance apart at all points. Indications of any choice of position by the beam in the electric field were of the slightest, the stationary positions being very easily upset, and often changing by one or two centimeters between readings. The distribution of the electric field due to the coil, though uncertain, could not have departed greatly from symmetry about the center, and since the disturbance due to it manifested itself in deflections rarely exceeding 1^{cm}, it does not seem possible that the variations of intensity were great enough to account for the absence of visible effect when the displacement couple acting on the beam was reversed. In the earlier experiments several series of observations were made without the damping vane; no difference in the behavior or in the nature of the results was observed except the increase in time necessary for the beam to become stationary. Observations could not be made with the final form of the apparatus if the damper were taken off; the electric field was so nearly uniform that the beam would not retain a stationary position definite enough to be taken as a zero point.

The following arrangement, independently conceived, but afterwards discovered to be an improved modification of the apparatus used by S. P. Thompson, offers a possible means of detecting a magnetic effect of the displacement current. An Annulus $1{\cdot}9^{cm}$ thick, built up in laminations of sheet iron rings $3{\cdot}18^{cm}$ inside and $7{\cdot}6^{cm}$ outside diameter, was wound with a coil of several hundred turns of fine wire, which was connected with a telephone receiver. In the opening in this magnetic circuit was placed a cylinder of dielectric $2{\cdot}54^{cm}$ in diameter and $2{\cdot}54^{cm}$ in length. Flat electrodes were brought very close to the ends of the cylinder, but were not allowed to touch it. When now an alternating E.M.F. is applied to the electrodes the resulting displacement current should set up an alternating field in the surrounding magnetic circuit, and so induce a current in the telephone receiver. The space between the electrode and dielectric prevents in great measure a possible conduction current due to conductivity of the material of the dielectric. With 8800 volts at 133 cycles on the electrodes, neglecting the air gaps, and with paraffin ($K=2$) as the dielectric, the displacement current density is:

$$q = \frac{2}{4\pi} \cdot \frac{\sqrt{2} \, . \, 8800}{2 \, . \, 45} \cdot \frac{2\pi \, . \, 133 \, . \, 10^6}{(3 \times 10^{10})^2 10^{-1}} \cdot \frac{1}{\sqrt{2}}$$

and the total amount is

$$6{\cdot}45 \, q = 3{\cdot}34 \times 10^{-6} \text{ amperes.}$$

The experiment was tried with paraffin and with hard rubber and no sound could be detected in either case. The question whether the telephone receiver would respond to such a small current was of course still open, nor could it be completely answered. The following approximation was, however, made: a conductor was placed through the opening of the iron annulus and included in a circuit with an ammeter, a resistance, and a source of alternating electromotive force in low values; the lowest division on the ammeter scale was ·02 amperes, and the voltage was adjusted to give this reading, the telephone receiver giving a good note. Resistance was then inserted by steps up to about 100 ohms (inductive), apparently bringing the ammeter needle to zero; sound in the telephone receiver was still audible, though faint. The experiment was performed very roughly and hurriedly, and is susceptible of considerable improvement.

The writer's thanks are extended to Professor Ames for his interest and kindness in furnishing every facility needed in the course of the investigation.

The mechanical work was done by Mr. Charles Childs; for his skill and interest at all times the writer wishes to extend his appreciation.

It is proposed to carry this work further in both forms of apparatus.

Physical Laboratory,
Johns Hopkins University,
May, 1902.

ART. XVI.—*Certain Relations of Plant Growth to Ionization of the Soil;* by AMON B. PLOWMAN.

IN a series of experiments now in progress at the Harvard Botanic Garden, there have been observed some interesting phenomena in the relations of plants to electricity. The experiments have been of a widely varied nature, dealing with both static and kinetic charges, through a range of potential from 0·5 to 500 volts. Either platinum or high-grade carbon —usually the latter—was used for electrodes, and special care was taken to insure normal conditions of temperature, light, and moisture.

The experiments were of course checked off by controls, always using at least two different sets of controls in order to avoid accidental errors. In a well-lighted greenhouse it is not a difficult matter to locate the different plants in such a way as to give fairly uniform light to all. For soil-cultures, pots of the same size were used, filled with equal amounts of carefully prepared soil, and supplied with measured quantities of water.

The regulation of temperature presented serious difficulties whenever a considerable amount of current was used, for the resistance of the soil is very great and much heat is evolved in forcing the current through it. Thus a 500 volt circuit, joined through a body of soil 10×25^{cm} in cross-section and 40^{cm} long between electrodes, gave a current of 0·2 ampere, and in one hour raised the temperature of the soil from 16° to 44°C.

However, with a slight excess of moisture and a current not exceeding ·05 ampere, it has been possible to prevent a rise of temperature of more than 3° above the normal; and in most cases the temperature has been kept within a range of 1° above that of the control. In the matter of temperature-regulation the water-culture method possesses many advantages. Either by a slow circulation of the electrolyte, or by a more rapid circulation of water about the vessel containing the electrolyte, it is easy to maintain a constant temperature even when using currents of 2 amperes. In this way it is possible to introduce a very considerable electrical factor without seriously disturbing the other relations of the plants.

Among other facts recorded in the course of these experiments is the following: Seeds placed near the anode are always killed by current amounting to ·003 ampere or more, if continued for twenty hours or longer, while seeds placed near the cathode have in most cases been but little affected, and under some conditions have been apparently stimulated by such currents.

When the seeds were germinated in water this difference was most pronounced when a relatively heavy current was passed through the water for only a short time, in which case the seeds near the anode were killed, while those near the cathode were not apparently injured. If the current was allowed to flow for twenty hours or longer the ill effects were produced at all points between the electrodes, even when the current amounted to only ·003 ampere, at a voltage of 2 or more. When the current was passed through ordinary sandy soil in which the seeds were planted, the same results were obtained at the anode, but a much longer time was required to extend the injurious effects to the region of the cathode. Indeed, so long as the current does not exceed about ·08 amp. there is a considerable increase in the rate of growth of the seedlings near the cathode.

In explanation of these phenomena the following provisional theory is offered.

Whenever two points in any electrolyte are electrically charged to different potentials, the movement of the free ions in the solution[*] is given definite direction, and, if the difference of potential is sufficient, further dissociation of the electrolyte follows. The anions with their negative electrons move toward the anode, and the cations with their positive charges pass to the cathode. Since the movements of ions in solutions are relatively slow,[†] it is reasonable to suppose that in the region of the anodes there would be a slight excess of positive ions, due to the rapid neutralization of the negative ions by the positively charged electrode. In like manner the cathode removes the positive ions in its immediate vicinity, and is consequently surrounded by a slight excess of negative ions. The more slowly the ions move through the electrolyte the more marked will be the difference of conditions about the two electrodes.

How will seedlings respond to these differences of conditions? It is clearly indicated by the results of our experiments that vegetable protoplasm is paralyzed and quickly killed by the conditions existing about the anode, while within certain fairly broad limits it is stimulated by the conditions about the cathode. While the dissociation of the atoms and electrical separation of the ions must bring about slight differences of a purely chemical nature in the region of the electrodes, yet

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[*] Ostwald and Nernst. Ztschr. phys. Chem. iii, 120, 1889.

[†] Kohlrausch (Wied. Ann. l. 403, 1893) has shown that, in an electrolyte of unit potential gradient, the velocity in centimeters per second for certain ions is as follows:—

CATIONS				ANIONS.			
H	·00320	NH_3	·00066	OH	·00182	I	·00069
Na	·00045	Ag	·00057	Cl	·00069	Ni	·00064
Li	·00036	K	·00066				

these mere chemical differences can hardly account for the effects upon the plants, even *near* the electrodes, and certainly not for certain effects at points mid-way between the electrodes. This conclusion is borne out by the following facts :—

1. When seeds are germinated in distilled water through which a weak current is forced, the O ions are in excess in that part of the solution where stimulation occurs, and the H ions are in excess where the plants are killed. But it may be shown that small quantities of hydrogen are not markedly harmful to plants. And the quantity of oxygen set free in distilled water by a weak electric current is certainly no greater than that normally present in ordinary tap-water, such as was used for the controls; yet germination is often more rapid near the cathode than in the case of the control.

Apparently, the effects are produced by the *electrical charges* of the ions, rather than by any mere chemical activity of the atoms.

2. When seeds are placed in solutions of various acids, bases, or salts, of a degree of concentration far below the "killing point," they will germinate quite as well as in ordinary distilled water. But when a current of electricity of sufficient strength to propel the ions is passed through the solution, that part about the anode becomes destructive to plant life.

From these and other facts we conclude that *negative charges stimulate*, and *positive charges paralyze*, the embryonic protoplasm of these plants. This is strikingly in accord with the conclusions reached by Matthews* in his experiments on the nature of nerve stimulation, in which he shows that the sciatic nerve of the frog is stimulated by negative ions, and rendered less irritable by positive ions.

In support of the theory here advanced the following facts may be mentioned :—

1. When a flower-pot containing several lupines of about four weeks growth is charged to relatively high potential (500v.) with positive electricity, the plants cease to grow, gradually lose their turgidity and finally die. On the other hand, when a *negative* charge is used these effects are *not* produced, but the plants are actually stimulated.

It is evident that, in the first case, the negative ions in the soil are drawn to the positive terminal, while the positive ions are driven to the plant. In the second case, the positive ions are drawn to the negative electrode, and negative ions are driven to the plants.

2. When seedlings are grown in an aqueous culture-medium through which a weak current of electricity is flowing, the

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* Science, vol. xv, No. 378, 1902.

root-tips turn toward the anode. An attempt has been made to show an analogy between this movement and a similar turning of root-tips "up stream" against a water current. However, the analogy is of little value, owing to the fact that in the electrolyte there is a streaming of ions in *both* directions. Hence, the question is not so much a matter of the direction of the electric current as it is of the difference in effects of the two streams of ions.

Upon examination of the conditions which prevail about roots growing in an active electrolyte, we find that the side of the root toward the anode is being bombarded by a stream of *positive* ions moving toward the negative electrode, while the side toward the cathode is exposed to the stream of *negative* ions on their way to the anode. Consequently the side of the root toward the cathode is stimulated, and that toward the anode is retarded, in its growth, and of necessity the root-tip curves toward the anode.

Seedlings grown in ordinary soil show this curvature even more strikingly. The main axis of the plant is frequently curved almost 90° just below the surface of the soil. The curvature is toward the anode and away from the cathode, whether these be in circuit or isolated.

3. Normally, the plant body is electro-positive to the soil in which it grows. The potential difference appears to be a function of the physiological activity of the plant. The positive charge of the plant attracts the negative ions of the soil to its roots. Thus it seems that negative electrons are being constantly discharged to the plant as a natural condition of its life-activity. Any circumstance which would facilitate this electrical interchange we should naturally expect to be beneficial to the plant, while the reverse condition would be detrimental.

It must be borne in mind that the phenomena with which we have been dealing are conditioned not only by temperature, light, aeration and moisture, but also by the nature of the electric current used, the solution-tension of the electrodes, the osmotic pressure of the electrolyte, the degree of dissociation of the electrolyte, the valence of the ions, the physical state of the ions, the chemical relations of the ions to metabolic processes in the plant, besides certain peculiarities of the living protoplasm with which we are working, and which should doubtless be taken into account in connection with each of the conditions named above.

Evidently, any theory which may be advanced in explanation of the various phenomena of plant-growth in the electrical field, must stand the most exacting tests of physical chemistry, in order to be worthy of serious consideration.

Harvard University.

ART. XVII.—*Demagnetizing Effects of Electromagnetically Compensated Alternating Currents;* by ZENO E. CROOK.

THE effect on the hysteresis cycle of passing an alternating current longitudinally through an iron wire, was given in a paper published in 1891, by Dr. G. Fienzi and Professor G. Gerosia.* At a later date, Ignas Klemenicic published a paper on the relation of circular to longitudinal magnetism in iron and steel wires. He made a very brief mention of the effect due to alternating current. In the first named paper the writers found a very evident reduction of the area of the hysteresis cycle, and that a current of three amperes per sq. mm. was sufficient to totally destroy the hysteresis. When in this condition, the ascending and descending magnetization curves coincide and the effect of the magnetizing force approaches the theoretical condition expressed by Fröhlich's formula

$$I = \frac{\alpha H}{1 + \beta H}$$

in which α and β are constants for a given specimen of iron, and $\frac{\alpha}{\beta}$ is the saturation value of I. The writers thought the effect observed was due only to the demagnetizing power of the rapidly oscillating circular magnetic field. Their reason for this was that there was no perceptible jarring or vibration in the iron.

An attempt will be made in this paper to go still further into the study of the effects of alternating current on the magnetic properties of iron and steel. The main object of the study will be to discover *if there is an effect due to the current independent of that producéd by the circular magnetism.*

The first question to be solved was how to eliminate the electromagnetic action, so that the effect of the current alone could be studied. This was done, approximately, by making use of the principle discovered by Ampère, that when two adjacent currents in parallel conductors flow in opposite directions, the external field of force of the one tends to destroy that of the other. In order to be effective in destroying the internal as well as the external magnetic actions of the current, it was necessary to build up the iron from very thin laminæ, and send the current in opposite directions in each alternate layer.

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*Rendiconti de Instituto Lombardo, vol. xxiv, fasc. x, April, 1891; Electrician, April 3, 1891; Ewing, Magnetic Induction in Iron and Other Metals, page 319; Wiedemann's Annalen, vol. lvi, page 530.

Two methods of studying the hysteresis were adopted, so that the results of the one might be a check on those of the other.

First Method.

The first method was a modification of the apparatus used in the Hopkinson's bar and yoke method. The bar of iron, fig. 1, was made up of eighteen strips of sheet iron, each 40^{cm} long, $1{\cdot}9^{\mathrm{cm}}$ wide and ${\cdot}045^{\mathrm{cm}}$ thick. These were joined at the ends, and insulated from each other by strips of shellacked paper so that a current would flow through each successive strip in the opposite direction. Allowing a small amount for the effect due to insulation between the iron strips, it was estimated that the internal magnetic action of a current flowing through the iron in the manner described above, was approximately one-

Fig. 1.

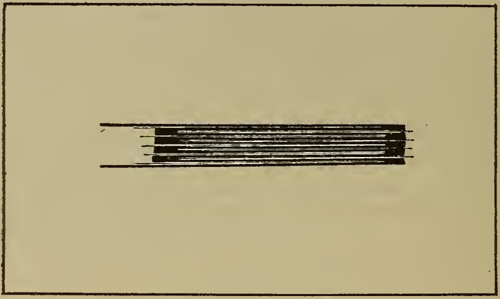
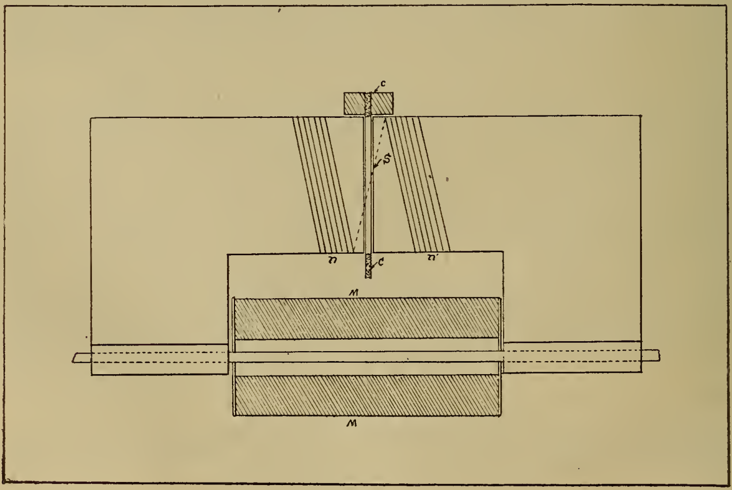


Fig. 2.

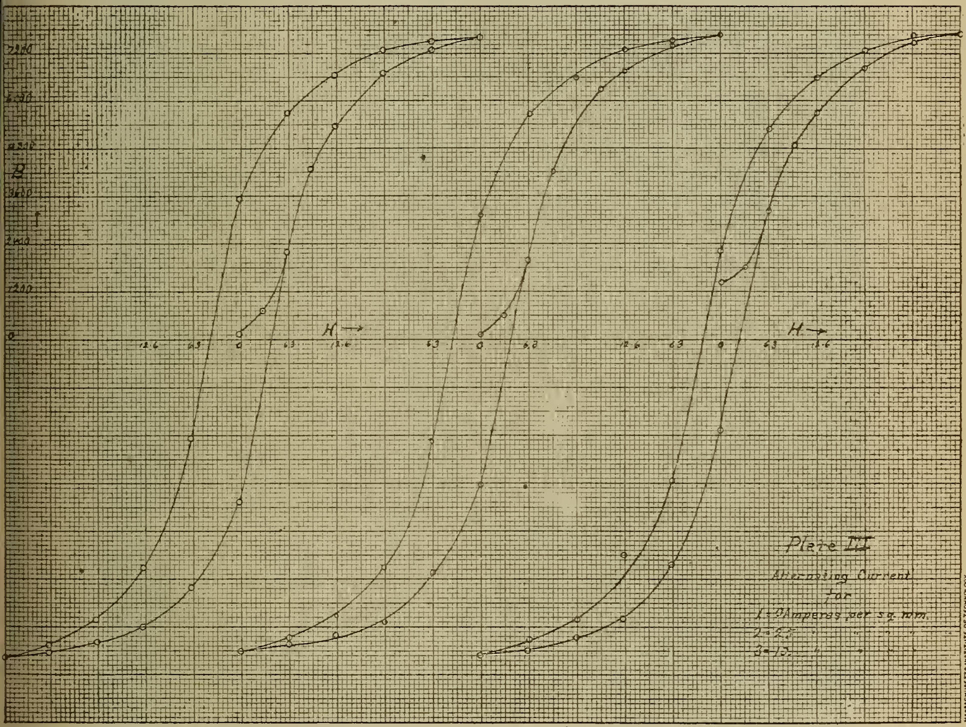


eighth of that due to a current of the same current density flowing directly through the iron strips in multiple.

The yoke, fig. 2, used was one designed by Prof. D. B. Brace and already described.*

The advantage of this apparatus over the old form of yoke is that at all times during the hysteresis test the total induction can be measured without changing the susceptibility of the magnetic circuit, and the only change in the induction is that caused by a change of current in the magnetizing solenoid.

Diagram I.



The alternating current used for demagnetization was obtained from a 50-volt circuit, transformed from a 1000 volt, 40 h. p. Westinghouse dynamo. The frequency of the alternating current was 133 periods per second.

The three hysteresis cycles given on Diagram I were all taken the same evening and under practically the same conditions.

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* This Journal, vol. xi, p. 365, May, 1901.

The curves were taken in the order in which they occur on the plate and were plotted from the readings given in Table I.

Curve 1 is the normal hysteresis cycle.

Curve 2 is a cycle taken with an alternating current density in the iron to 10 amperes per sq. mm.

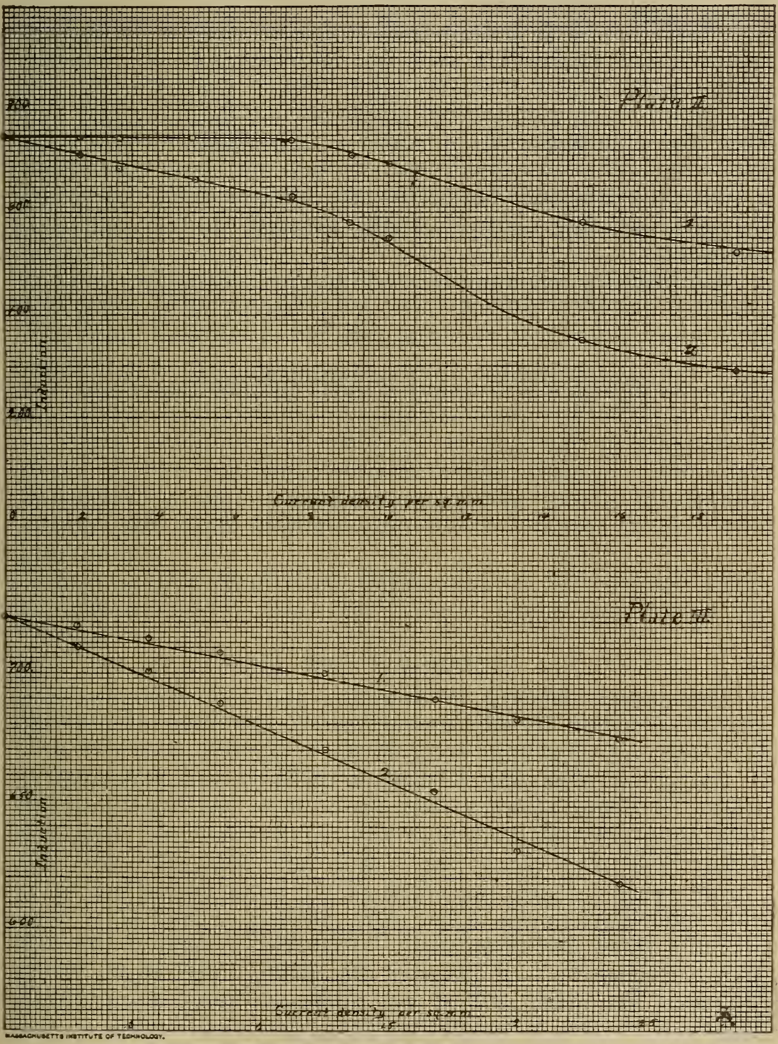
TABLE I.

		B.	
H.	Cycle 1.	Cycle 2.	Cycle 3.
0	174	120	1443
3·15	846	600	1815
6·3	2447	2010	3252
9·45	4329	4245	4890
12·6	5400	5415	5706
15·75		6279	
18·9	6765	6750	6939
25·2	7500	7440	7703
31·5	7590	7686	7740
25·2	7594	7604	7689
18·9	7311	7275	7320
12·6	6675	6630	6600
6·3	5730	5655	5331
0	3285	3128	2232
6·3	−2418	−2550	−3525
12·6	−5750	−5750	−6600
18·9	−6999	−6747	−7011
25·2	−7677	−7446	−7560
31·5	−7983	−7800	−7920
25·2	−7794	−7650	−7776
18·9	−7560	−7360	−7440
12·6	−7215	−6086	−6981
6·3	−6204	−5765	−5607
0	−4050	−3666	−2265
6·3	1863	2100	3249

A close inspection of the curves will show that the reduction of the area of the cycle is directly proportional to the reduction of the width and also to the reduction of the residual magnetism remaining in the iron when the magnetizing force is reduced to zero. This being the case, the problem can be considerably simplified by studying the effects of the alternating current on the residual magnetism from a constant magnetizing force, assuming that the effect on the hysteresis cycle is directly proportional to this effect on the residual magnetism.

The curves in Diagram II were taken to show the effect on the residual magnetism of varying current density in the iron strips in series. They were plotted from the readings given in Table II. Ordinates represent total induction and abscissae represent current density per sq. mm. Curve 1 shows the effect due to a constant current; curve 2, that due to an alternating current.

Diagrams II and III.



Curve 1 (Diagram III) shows the reduction of the residual magnetism due to an alternating current of varying density passing through the iron strips in series.

TABLE II.

Current density per sq. mm.	Total residual induction. For curve 1.	For curve 2.
0	745	745
2	740	712
3	743	684
5	743	665
7·5	740	630
9	710	580
10	695	550
15	580	360
19·2	520	290

Curve 2 (Diagram III) shows the corresponding effect due to an alternating current passing through the iron strips in multiple.

Readings for these curves are found in Table III.

TABLE III.

Current density per sq. mm.	Total residual induction. For curve 1.	For curve 2.
·0	722	722
·28	719	710
·56	714	701
·84	708	689
1·25	700	670
1·68	690	654
2·2	682	631
2·5	675	618

Second Method.

The second method of studying the alternating current effect on hysteresis was carried out in the same way as the first, the only difference being in the apparatus used.

Instead of a number of narrow strips of iron connected in series, the iron specimen was made from two thin sheets of iron, separated by shellacked paper and rolled into a compact tube. The iron sheets were each 56^{cm} long, 50^{cm} wide and $·018^{cm}$ thick. Along the edges of the plates corresponding to the upper end of the tube were soldered "leading-in" conductors, short distances apart. This was to insure a uniform current density in all parts of the plate. The edges of the plates at the other end of the tube were bared and soldered together, so that a current entering the upper edge of one plate would flow down, across the soldered junction, back on the other plate and out by the leading-in conductors soldered to its edge.

The tube was 50^{cm} long and had an inside diameter of $2{\cdot}5^{cm}$. Inside of the tube was a core of wood with a copper wire running along its cylindrical axis. This system is practically equivalent to sixteen concentric iron tubes $\cdot018^{cm}$ thick, with their ends so connected that a current of equal current density flows through each alternate one in the opposite direction or through all of them in multiple, according as the experimenter desires. The magnetizing coil was of the same length as the iron cylinder and wound with 300 turns No. 16 copper wire. The test coil used for measuring the magnetic flux was wound on a wooden spool made to slip over the magnetizing coil and sufficiently large and heavy to fall freely and uniformly when liberated. The cylinder was mounted inside the magnetizing coil in a vertical position, about five feet from the floor, and so arranged that the test coil would fall from the center of the cylinder to about two feet from its lower end. In this way it was possible to measure the total magnetic flux in the iron. The other apparatus was the same as that used in the first method.

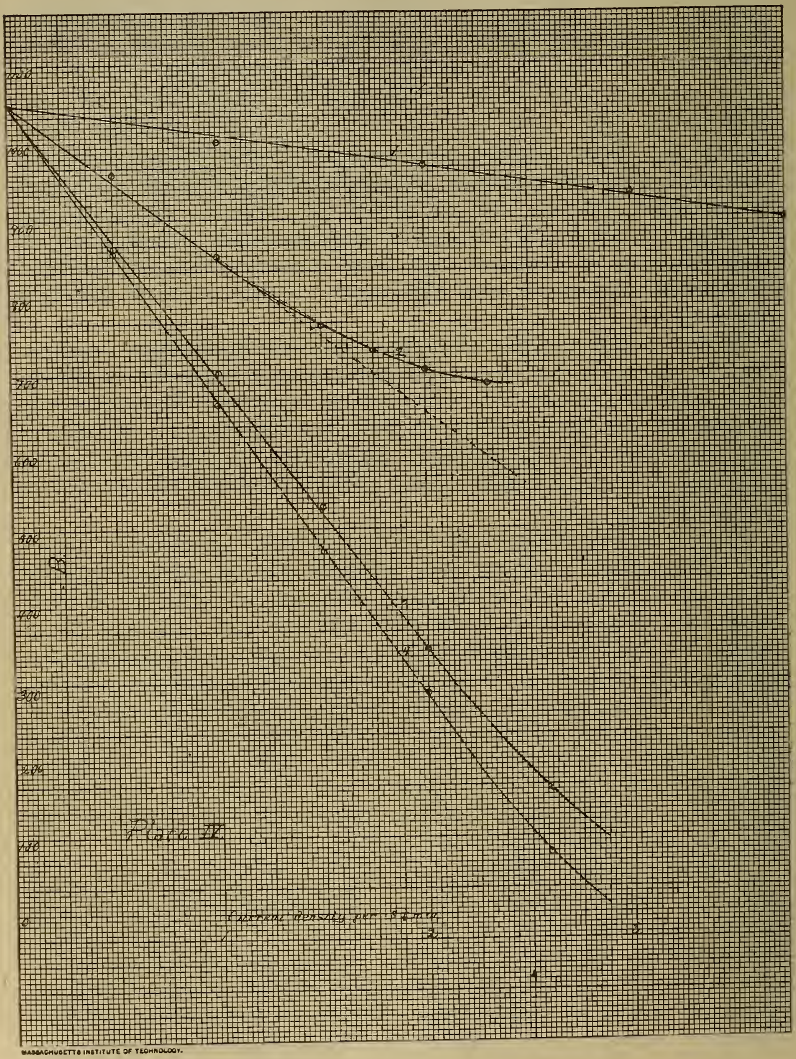
It was found that the amount of residual magnetism remaining in the cylinder after applying a strong magnetizing force, was very small, and all attempts to show the demagnetizing effects on the hysteresis cycle were unsatisfactory. However, the reduction of the residual magnetism by the alternating current was quite satisfactorily shown and the results are as given below.

The residual magnetism left in the iron was stronger when an alternating current was present during magnetization. Because of this, the alternating current was thrown off each time the magnetizing force was applied, and readings were taken to find the residual induction before again applying the alternating current. These all gave almost constant results. The readings were all reduced to the mean value. Readings taken while the alternating current was flowing and those taken after it was thrown off were nearly always the same. However, in curve 2 the values of the residual magnetism after the alternating current was thrown off were different and are represented by the dotted portion of the curve.

The alternating current was applied in four different ways and the effects studied. First, it was passed through the iron plates in series, so as to get the effect of the magnetically compensated current. Second, it was passed through the plates in multiple so as to get the combined effect of the current and circular magnetism. Third, it was passed through the iron plates in multiple and back through the copper rod. Fourth, it was passed directly through the copper rod. The curves, plotted from the values given in Table IV, are given on Diagram IV and are numbered to correspond to the order in which they are here mentioned.

Ordinates represent total induction, and abscissae, current densities per sq. mm.

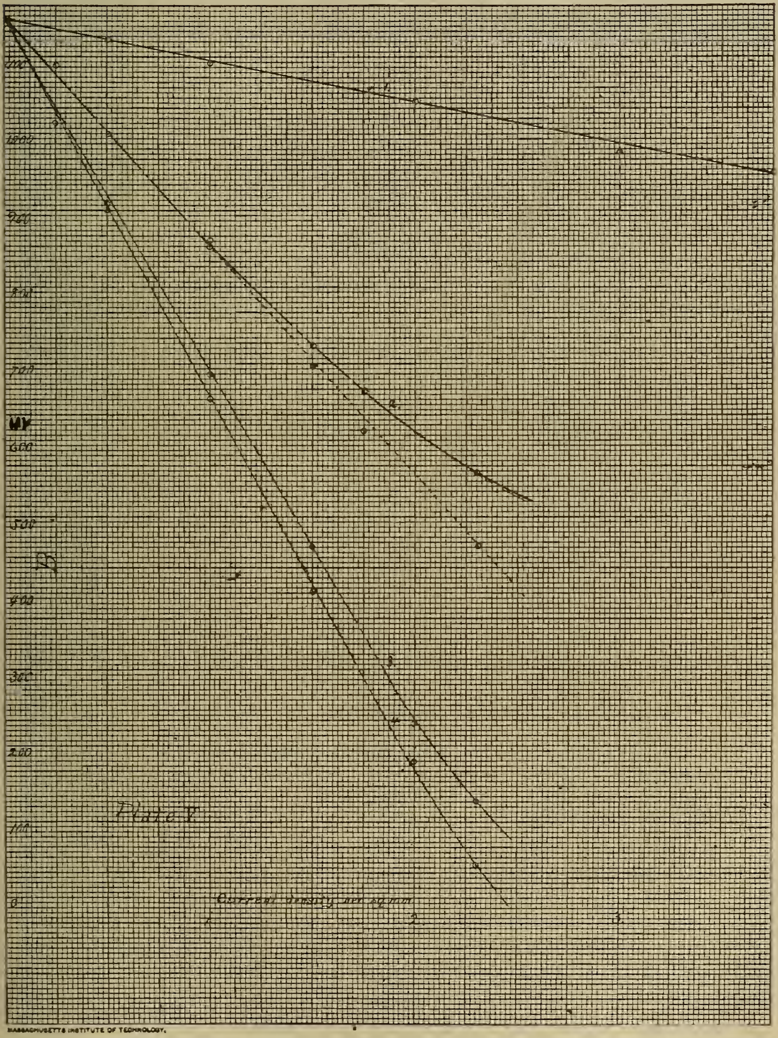
Diagram IV.



Curves similar to those given on Diagram IV were taken with the frequency of the alternating current reduced one half. They are given in Table V, and plotted on Diagram V.

The effect due to a direct current of varying current density is shown in Diagram VI. The direct current was applied by suddenly closing the circuit through the iron. A slow building up of the current had no effect on the residual magnetism.

Diagram V.



This shows that the effect was due to the sudden impulse of the current through the copper rod or through the iron. Readings for these curves are given in Table 6.

TABLE IV.

Current density per sq. mm.	Iron in multiple.	Iron and rod in series.	Rod alone.	Iron in series.
0·	1051	1051	1045	1055
·5	962	863	861	----
1·	856	660	702	1003
1·5	760	492	533	----
1·75	728	286	340	----
2·	705	----	----	970
2·29	681	----	----	----
2·6	----	80	163	----
3·	----	----	----	935
4·	----	----	----	903
4·58	----	----	----	870

TABLE V.

Current density in iron.	Total residual induction.			
	Iron in multiple.	Iron and rod in series.	Rod alone.	Iron in series.
·0	1150	1146	1150	1150
·25	1090	----	----	----
·5	1004	1012	1010	1125
1·	865 and 855	900	908	1095
1·5	725 and 695	----	----	----
2·75	665 and 610	----	----	----
2·	--- ---	658	686	1045
2·31	560 and 465	----	----	----
3·	--- ---	400	460	975
3·5	--- ---	----	----	945
4·	--- ---	179	230	----
4·62	--- ---	45	132	870

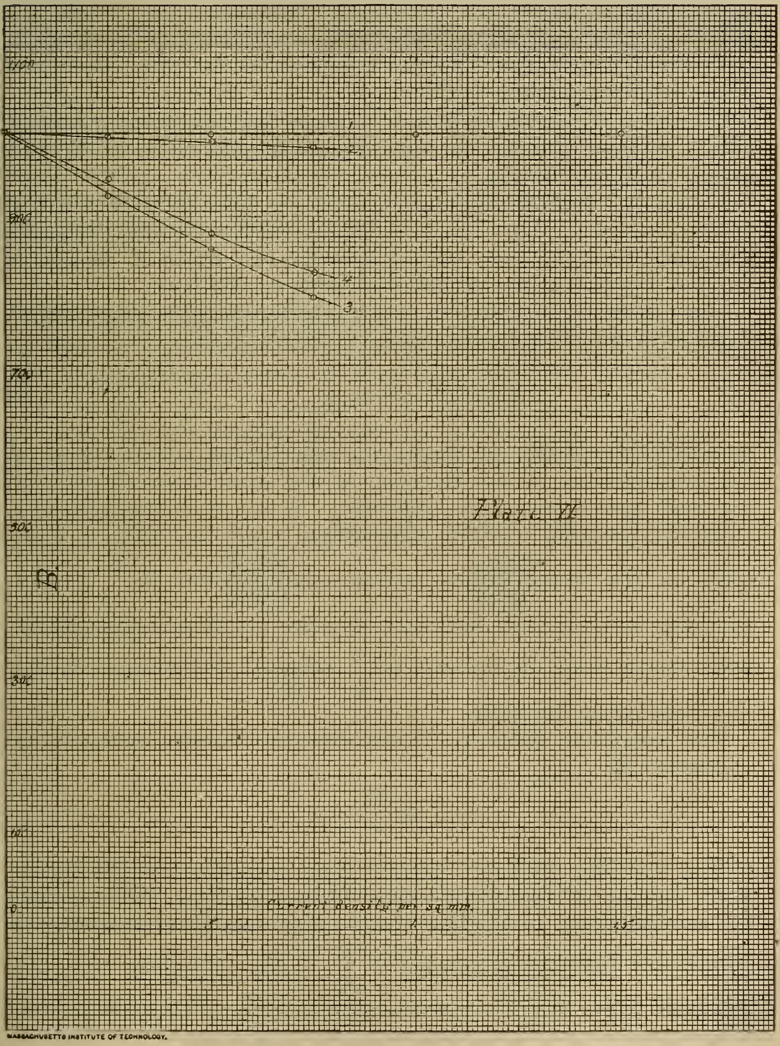
TABLE VI.

Current density in iron.	Total residual induction.			
	Iron in multiple.	Iron and rod in series.	Rod alone.	Iron in series.
0·	1000	1001	1000	1004
·25	996	----	----	----
·5	990	940	920	1000
·75	980	----	----	----
1·	----	875	850	1003
1·5	----	820	792	1003

The hysteresis cycles given on Diagram I shows that the alternating current as magnetically compensated has an effect on the magnetic induction in iron.

The curves on Diagram II show that for low current densities, the reduction of the residual magnetism in iron, or the reduction of the area of the hysteresis cycle, is proportioned to

Diagram VI.



the strength of the current. Above 7·5 amperes per sq. mm. this relation does not hold, but heating effects and the effect of the residual magnetism in the yoke come in to affect the induction measurements. If the values of curve 1 are subtracted from those of curve 2, the result is nearly a continuation of the straight line which gives the effect at low current densities.

The similar curves on Diagrams IV and V taken by the second method, and at different frequencies, show that the effects of the alternating current on the residual magnetism in iron are different for different frequencies, that for the lower frequency being the greater.

Curves 3, Diagrams IV and V, show that the total reducing effect of the current is approximately proportional to the strength of the current.

Curve 3, Diagrams IV and V, show the reducing effect of the external circular magnetic field from a current flowing through the central copper rod. Curve 4 shows the effect of passing a current down the central rod and back on the iron.

The force at a point in a metal tube due to a longitudinal current in the tube is expressed by the formula

$$F = \frac{2\pi w}{r}(r^2 - r_1^2)$$

in which F is the force, w the current density per unit area of the cross section, r the distance of the point from the axis of the tube, and r_1 the inside diameter. From this it is seen that at the inner surface of the tube, where $r = r_1$, the force is zero, while at the outer surface, where $r = r_2$, the force is $\frac{2i}{r_2}$. The average force in the tube due to a current flowing longitudinally along it is proportional to $\frac{i}{r_3}$ where r_3 is the mean radius of all points in the tube.

The magnetic force at a point outside a linear conductor is expressed by

$$F = \frac{2i}{r}$$

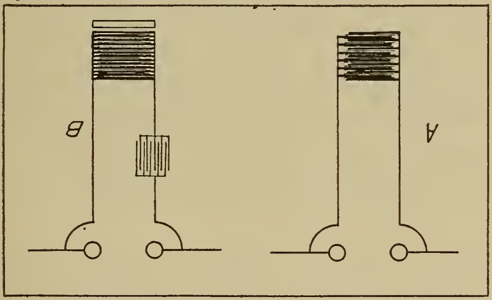
where i is the total current and r is the distance of the point from the axis of the conductor. It is, therefore, evident that the average force in the iron due to a current flowing along its cylindrical axis is proportional to $\frac{2i}{r_3}$. The magnetic force in the iron when the system was connected for taking curves 4, Diagrams IV and V, was therefore one-half what it was when it was connected for curve 3, and if the reduction of the residual magnetism was due to the circular magnetic flux alone, we should expect the values of any point on curve 4 to be one-half that of a similar point on curve 3. Any added effect caused by the presence of the electric flow in the iron would tend to make curve 3 approach curve 4, and in fact it is found that the latter falls below the former.

If the apparatus used in the second method was as effectual in reducing the circular magnetic effects as was expected, curve 1, Diagram IV, can be taken as giving an approximate measure of the reduction of the residual magnetism by an alternating current flux, with a frequency of 133 alternations per second; and curve 1, Diagram V, a similar measure when the frequency is at 66 alternations per second. The effect of the magnetically compensated current as given by these curves is about one-fourth of the total effect of the current and circular magnetic effect together.

Other Methods.

The following experiments were made to study the effects of electric oscillations on magnetized plates (fig. 3 A) placed in a magnetizing solenoid of very thin sheet iron (trunk covering) cut into strips 7 inches ×3/4 inch and separated by sheets of mica made to project past the edges of the iron an eighth of an inch. This system was connected to a Holtz machine and the spark gap adjusted so as to get a rapidly oscillating discharge. The magnet, after being magnetized to a maximum amount of residual magnetism, was placed carefully in the field of a sensitive magnetometer. This magnetometer was made of an astatic magnetic system suspended by a silk fiber in a glass tube. The magnet was so placed that the magnetometer was deflected a few degrees from the meridian. The system was carefully tested to prove the effect produced was not due to conditions external to the iron. Any disturbance in the magnetic field of force thus produced could be

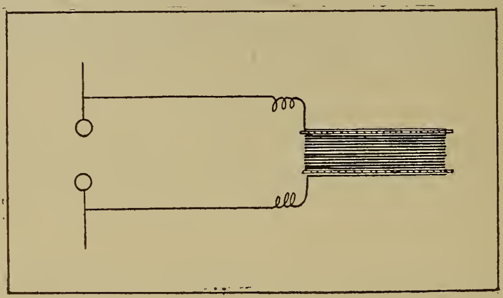
Fig. 3.



readily detected with a telescope and scale. It was found that an oscillation of the static charge in the "magnetic condenser" produced a demagnetizing effect which could be readily detected with the magnetometer. The effects were lacking when a thin foil condenser was substituted for the iron one.

The residual magnetism of the laminated electro-magnet was also found to be affected by the oscillating electric charges, when connected in series, fig. 3 B, with a condenser to the terminals of the static machine. The amount of this effect was approximately equal to the effect when the magnet was used as a condenser.

Fig. 4.



Another test, fig. 4, was made by placing a pile of these japanned iron sheets between terminals of tinfoil which were insulated from the iron by mica. This proved to be just as effective in producing results as the other method. The frequency of oscillation was an indeterminate factor and did not seem to affect the results, as the demagnetizing effect was apparently produced during the first oscillations. A single spark between the terminals of the machine, in most cases, proved to be as effective as a continuation of the oscillatory discharges.

Note.—This work was done at the University of Nebraska under the immediate direction of Dr. D. B. Brace, and much of the success of the investigation was due to suggestions offered by Dr. Brace and by Professor B. E. Moore.

Physical Laboratory, University of Nebraska,
Lincoln, Nebr.

ART. XVIII.—*Nepheline and other Syenites near Port Coldwell, Ontario;* by A. P. COLEMAN.

A FEW years ago some very interesting dikes of a rock containing analcite named "heronite" or analcite tinguaite were described by the writer from the north shore of Lake Superior between Heron Bay and Peninsula on the Canadian Pacific railway;* and the opinion was expressed that nepheline rocks should be found connected with them somewhere in the region. Dr. Adams also has suggested the same idea, basing his belief on some rock specimens from the region of Peninsula in the Geological Survey collection. They are augite syenites of an unusual kind often associated with nepheline syenites.†

In connection with an excursion to the iron range of the Slate Islands an opportunity was taken to examine the railway and shore near Port Coldwell, and it was intended to visit Pic Island a few miles off shore, where Professor Pirsson and others have suggested that nepheline rocks would probably be found, but unfortunately no suitable boat could be got at that little harbor, and this had to be given up.

No syenites of any kind were found between Heron Bay and a point three miles east of Peninsula, where augite syenite had been obtained a few years before; but west of Peninsula, more than half way to Port Coldwell, considerable stretches of nepheline syenite were discovered. So far as the study of the specimens has gone one can say that a great area of syenites and associated rocks rich in alkalies, derivatives of a magma differentiated into a whole series of related species, like those so elaborately described by Brögger in the Christiania region of Norway, occurs in this region.

The first rock of the group, going west, is the dark augite syenite which commences three miles east of Peninsula, and with some interruptions of red syenite and more basic rocks extends to a long trestle at mile 818, a distance of nine or ten miles, with an unknown width. From the trestle west to a cutting beyond Peninsula, the prevalent rock is a gray or purplish gray nepheline syenite, having an extent of about four miles. It is probable that detailed mapping of this little explored region would show large areas of this syenitic group of rocks, including Pic Island, and it is hoped that in the future these interesting eruptives may be studied more at length.

The only previous references to this group of syenites are to

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* Bureau Mines, Ontario, 1899, pp. 172–174; and 1900, pp. 186–191.

† Jour. Geol., vol. viii, No. 4, pp. 322–325.

be found in the reports of the Geological Survey of Canada,* where rocks containing red and white feldspar, some grains of orange-red elaeolite, and a few zircons, are said to occur in Pic Island and the mainland to the north; and of the Bureau of Mines,† where the occurrence of augite syenite and other associated rocks is referred to, though the nepheline rocks were overlooked. Acknowledgments must be made to Professor L. V. Pirsson and Dr. H. S. Washington for having been good enough to send chips and larger specimens of various nepheline syenites and related rocks from other localities which have proved most useful for comparison; and to Professor Pirsson for suggestions as to rock relationships.

Nepheline Syenites.

The syenites and associated rocks are very well exposed between miles 818 and 822 in the numerous rock cuts and cliffs where the railway winds along the rugged shore of Lake Superior, so that an almost continuous section is presented. The first nepheline syenite observed is just east of the long trestle at Red Sucker lake, where it forms irregular dikes and larger masses in gabbro, which appears to be the older rock of the two; and similar relations are found at the rock cut west of the trestle, though red syenite interrupts it at the third cutting. Beyond this, toward the west, hills of nepheline syenite rise 200 or 300 feet above the lake and continue with few interruptions to Port Coldwell station and the next cutting beyond it, the last point where it was observed being a little beyond mile 822. The second cutting west of the station is in red syenite. The rock varies from almost compact to very coarse-grained kinds having crystals an inch or more long; and in color from pale to dark gray, sometimes running into purplish tones or having brillant red spots. The black hornblende and augite crystals stand out sharply giving a fresh look to the rock, which unfortunately is not borne out in thin sections. In some specimens the hornblende crystals are long slender prisms, but in others they are short and stout. The different textures are often mixed intimately, fine-grained parts enclosing coarser grained ones or the opposite; and large or small blocks of the gabbro mentioned above are enclosed in the nepheline syenite. Dikes of a fine-grained purplish gray rock, sometimes with the look of an amygdaloid, cut the syenite; and last of all, there are sharply defined dikes of black diabase.

In general appearance the nepheline syenites are very different from those of Eastern Ontario, never showing the

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* 1846-7; also 1863, p. 80.

† 1897, p. 147.

gneissoid structure so common there, nor having dikes of pegmatitic rock consisting of large individuals of nepheline and muscovite. Nor are they like specimens from Barkevig, Norway, nor Litchfield, Maine, but some of them have much the appearance of specimens sent by Professor Pirsson from Highwood Mts., Montana, and Red Hill, Moultonborough, New Hampshire, having a tendency to flat plate-like forms of the feldspars, and long prisms of the darker minerals. These would apparently be classed by Professor Brögger as foyaites, though unlike a specimen of foyaite from Lougenthal, Norway, sent me by Dr. Washington.

In the considerable number of specimens collected near Port Coldwell four fairly well marked types may be distinguished, so far as megascopic structure is concerned:

1. Medium to coarse-grained gray rocks having a dioritic appearance with light and dark minerals in about equal amounts and the grains isodiametric.
2. Medium-grained, reddish, purplish or violet-gray rocks, with about twice as much of the lighter colored minerals as of the darker ones, and with a tendency to plate-like or elongated forms in the minerals.
3. Violet-gray, fine-grained rocks with porphyritic feldspars and other minerals.
4. Narrow veins of coarse-grained rocks, often mottled with red, gray and black.

There are, however, many intermediate varieties between the four here mentioned, illustrating the usual variability of the nepheline rocks.

1. The first variety occurs as fresh looking material about two miles east of Port Coldwell, and was supposed to be diorite when collected. The white minerals are nepheline, orthoclase, and a less amount of finely striated plagioclase having a very small extinction angle, probably oligoclase; all badly weathered and turbid, the nepheline sometimes changed into a brownish substance having aggregate polarization, perhaps a zeolite. The dark minerals include hornblende in fairly well formed crystals having a pleochroism of dark green, brownish green and brown, and an extinction angle of 23°; and also augite in about equal amounts, sometimes enclosed in the hornblende. The augite has a slight pleochroism, sea-green, gray-green and brownish green, but its extinction angle is normal and the nearly rectangular cleavages in cross sections show that it is really a pyroxene. The only accessory minerals noticed are magnetite and apatite, both in considerable quantities.

A very similar but duller rock occurs in the first railway cut west of Port Coldwell, with the difference, as seen under the microscope, that the hornblende is dark brown and the augite grayer and not pleochroic. One or two large masses of magnetite and serpentine probably represent olivines completely decomposed.

2. The gray or purplish gray variety, with relatively small amounts of the dark ingredients, contains all the minerals mentioned as belonging to No. 1, with the exception of the probable olivine; but the ferro-magnesian minerals are, of course, less in amount, and occasionally a little brown biotite occurs, in addition to the hornblende and augite. The red color of spots in the rock is due to infiltration of iron oxide in portions of nepheline completely changed to zeolites, and the usual reddish or purplish tone of the rock is due to the general diffusion of the same oxide. As distinguished from the previous variety this one is leucocratic. In some examples the minerals have plate-like or long prismatic forms with a suggestion of the trachytic structure. In one section the augite is almost entirely replaced by hornblende, often dark brown in the middle and green at the edge with very deep colors but not strongly pleochroic, perhaps barkevitic in character.

3. The porphyritic varieties of the nepheline syenite occur partly a mile or two east of Port Coldwell and partly to the south of the station near the harbor. Specimens from the former locality are dark bluish gray, fine-grained, with porphyritic feldspar, nepheline (rarely) and hornblende crystals.

One thin section from mile 819 shows very small crystals of nepheline having the prism and basal planes, enclosed in orthoclase and possibly oligoclase, as well as in hornblende, the latter mineral forming sieve-like structures, the holes being filled with lighter minerals, a good example of poecilitic intergrowths. The other minerals are augite, magnetite and apatite. A second specimen shows less of the poecilitic intergrowths but contains one or two long porphyritic prisms of nepheline.

Porphyritic examples from south of the station have a purplish gray ground in which bluish crystals of feldspar and black crystals of biotite are embedded. The groundmass does not differ much from the former rock, but the numerous phenocrysts are orthoclase, oligoclose and brown biotite, having strong dichroism.

4. The fourth variety forms narrow pegmatitic veins in the other varieties, and consists of the same minerals but of larger dimensions, sometimes more than an inch in length, though never rivaling the giant nepheline pegmatites of Eastern Ontario, as described by Dr. Adams, with crystals more than a foot long. The nepheline in the Port Coldwell specimens is often changed to a turbid orange-red material, mentioned by Sir William Logan as elaeolite,* the feldspars (orthoclase) are

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* Geol. Can., 1863, p. 81.

pale gray, and the hornblende prisms black, making a very showy rock. In spite of the striking differences in appearance of the varieties mentioned above, the range of minerals found in the thin sections examined is not great, much less, for instance, than in the nepheline rocks of Dungannon and York branch in Eastern Ontario,* and none of the rarer minerals have been found by myself, though zircon is mentioned in the 1863 report. The absence of muscovite, scapolite, sodalite, and of the usual microcline and microperthite is peculiar; though in some cases weathering has gone so far as perhaps to obscure the structures of the feldspars.

Augite Syenites.

The other important group of rocks in the region includes the augite syenites, which occur in two well marked varieties, one dark brownish gray to black in color, coarse-grained and with more or less of a plate-like character in the feldspars; the other red or reddish gray, finer grained and usually granitic in texture. The first variety is much the more extensive of the two and will be described first.

In the dark variety, which is no doubt the trap that Logan reports from the region, the feldspars are the prominent ingredient, forming broad plates or narrow shining strips, often carlsbad twins, attracting the eye in the sun; while the relatively small amounts of ferro-magnesian minerals escape notice. While dark brownish gray to black is the prevalent color, there are phases of a dull brown or a dull red; and weathered glaciated surfaces may even be white by the bleaching of the feldspar, when the augite and magnetite show as angular or black filling material between the feldspar crystals, which tend to be idiomorphic.

The syenite is always coarse-grained, the crystals averaging about a quarter of an inch in length, and also in breadth when seen broadside, but often only a tenth of an inch in cross section. There are coarse pegmatitic veins in the finer grained rock having individuals of feldspar an inch or two in diameter, and often fairly well built out in occasional cavities.

As this rock has been quarried by the railway for bridge construction, etc., it is easy to get fresh material.

Thin sections consist of feldspar in more or less idiomorphic forms with augite wedged in between, resembling, so far as one can tell from a description, Brögger's laurvikite.† The feldspars show no twin striations but have partly the appearance of microperthite and partly of microcline. They are

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* See Bureau Mines, 1899, Corundum and Other Minerals, p. 205, etc.; and Corundiferous Nepheline Syenite, p. 250, etc.

† Zeitschrift für Kryst. u. Min., Band 16, 1890, pp. 29, 30.

fairly fresh and in some directions have a handsome bluish shimmer. No nepheline nor sodalite nor quartz was observed. The dark minerals are chiefly augite with brown interior and dark green exterior, but some dark green and brown hornblende, and some magnetite occur also, as well as apatite.

An analysis of this rock made by Mr. A. H. A. Robinson of the Chemical Department of the School of Practical Science, Toronto University, gives the following results in column I:

	I.	II.	III.
SiO_2	58·81	58·88	·980
Al_2O_3	13·37	20·30	·131
Fe_2O_3	3·88	3·63	·024
FeO	6·97	2·58	·097
MnO	0·20	----	
MgO	0·51	0·79	·012
CaO	3·89	3·03	·069
Na_2O	4·96	5·73	·080
K_2O	5·42	4·50	·056
H_2O at 100° C.	0·29	1·01	
H_2O above 100° C.	0·75		
TiO_2	0·75		
P_2O_5	0·31	0·54	
Total	100·06	100·99	

Specific gravity at 17°·5 C., 2·75.

For comparison an analysis of Norwegian laurvikite from Byskoven, Laurvik, by A. Merian is given in column II.* The two analyses agree fairly closely except for the relative proportions of alumina and of ferrous iron oxide, which differ greatly. The analysis shows the rock consists largely of microcline and microperthite, the small amount of magnesia and large amount of ferrous oxide that the augite must consist mostly of the hedenbergite molecule. The amount of alumina, though smaller than in the laurvikite, is that which is required by the soda and potash to turn them into feldspars and is therefore correct, as shown in the molecular ratios given in column III.

Associated with the dark augite syenites with plate-like feldspars are numerous other varieties in much smaller amounts, some merely having the red color of the ordinary syenite, due to diffused hematite particles, but with the same ingredients and the same shape of the feldspars; others differing more widely in appearance and composition, but all more weathered and less satisfactory for study with the microscope. It will be sufficient to refer to the kinds having granitic structures,

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* Ibid., p. 30.

grains with equal diameters. These are on the average finer grained than the Laurvikitic syenite, and may be divided into leucocratic red syenites with comparatively little of the ferromagnesian minerals; and melanocratic varieties containing more than half dark minerals. It must be admitted that the term leucocratic syenites is not happy for the less basic varieties, since they are strong red and not white or pale colored. Several specimens from east of Port Coldwell are in reality quartz syenite consisting of feldspar pegmatitically intergrown with quartz, and small quantities of hornblende, augite, magnetite and apatite. The feldspars, which tend to be porphyritic, so far as their weathered condition permits one to decide, are orthoclase, microcline and oligoclase. These rocks seem to have the same composition as Brögger's nordmarkites, though no mention is made of pegmatitic intergrowths in the latter rocks.* Aegirite has not been recognised in the rocks from Port Coldwell, another point of distinction.

The melanocratic syenites, consisting to the extent of at least half of dark colored minerals, are dark gray rocks, usually with a red tinge, not very coarse-grained, with about equal diameters to the grains. The light colored minerals are orthoclase, some plagioclase and occasionally nepheline; the dark ones hornblende, pale blue-green augite and brown biotite in not far from equal amounts: while magnetite and apatite are always present, the latter often as numerous large prisms. They appear by analogy to be related to the essexites.

Plagioclase Rocks.

Three kinds of plagioclase rocks accompany the syenites of the Port Coldwell region, coarse-grained gabbro-like rocks older than the syenite and penetrated or carried off as blocks by the nepheline syenite; fine-grained gray-brown rocks occurring as dikes without well defined edges, in the nepheline syenite; and green-black dikes of diabase or diabase porphyrite, which are latest of all,

The gabbro is a speckled gray, coarse-textured rock showing plates of mica and often a few porphyritic plates of plagioclase megascopically. Thin sections are made up of half or less than half of a plagioclase having the extinction angle of andesine or sometimes labradorite; of pale bluish green augite, often idiomorphic, and brown biotite in about equal amounts, while brown hornblende and olivine are in smaller quantities. Magnetite and apatite in thick prisms are the chief accessories; and serpentine, chlorite and iron oxides occur as secondary products. In one section the biotite surrounding

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* Ibid., p. 55.

a weathered olivine crystal is modified so that the parts nearest the olivine are more strongly dichroic than the rest, bright green and orange-brown in the two directions.

The fine-grained dikes of brownish plagioclase rock are not very sharply defined as a rule, perhaps because they were erupted before the mass as a whole had completely cooled down. In many cases these rocks are specked with white or pale flesh-colored spots as if amygdaloidal, and they often contain what seem to be fragments of an older, fine-grained reddish rock.

The general mass of these rocks consists of some greatly weathered, lath-shaped plagioclase, partly with a radiating arrangement, enclosing biotite, augite, and magnetite in larger amounts. In this groundmass are often well-formed crystals of augite, sometimes in groups, pale green or brown, somewhat dichroic and with a zonal structure; and of dark brown hornblende. The lighter patches, suggesting amygdaloids, are composed chiefly of plagioclase, often with well-shaped prisms projecting inwards, the center being of some transparent mineral having low double refraction, perhaps a zeolite. There are a few prisms with parallel extinction, probably nepheline, though so badly weathered as to leave their character uncertain. Without an analysis it would be difficult to place this rock with certainty, so for the present it will be left unnamed.

The dikes of dark gray or black diabase and diabase porphyrite have been little studied. The only one of which thin sections have been made is an olivine diabase with comparatively little augite, often in slender fibers or prisms having the usual extinction angle, but sometimes as broader portions between feldspar laths. The magnetite, too, has elongated rod-like forms, and when the numerous needles of apatite are included, there is evident a tendency to elongation in almost all the constituents of the rock. The large well-formed crystals of olivine, still fairly fresh, are, however, an exception to the rule just mentioned. These quite fresh rocks are probably of Keweenawan age like most of the diabase dikes on the north shore of Lake Superior, while the other eruptives described appear to be older, though not so old as the Huronian schists which they penetrate.

It is believed that with the possible exception of the gabbros, which may be older than the syenites, and the diabases which are distinctly younger, all the rocks which have been referred to belong to the same magma and represent phases of differentiation. The dikes of heronite or analcite tinguaite, though found several miles to the east of the nearest syenite, are to be looked on, no doubt, as split off from the large mass described.

The older nepheline or elaeolite rocks and their associates can no longer be considered rare. In the province of Ontario they are known to occur very widely spread in Dungannon and adjoining townships, where they were first noticed by Dr. Adams, and where they have been followed up for many miles by Professor Miller because of their connection with the corundum-bearing band of the Laurentian. The series of eruptives described in this paper form another large mass of nepheline syenites and related rocks, though of a very different type; and the malignites described by Dr. Lawson from Poohbah Lake, west of Lake Superior, make a third, each with ite own peculiarities differing markedly from the others. The nepheline rocks of Montreal make another Canadian locality, though on a small scale, and with their alnöite dikes, as described by Dr. Adams, present still another type; the whole illustrating strikingly the great variability of this group of plutonic and dike rocks as contrasted with most others.

To refer to the areas described in the United States by Pirsson, Washington, Osann and others, would lead too far; and a mere list of the localities in Europe, India, South America, etc., would require considerable space.

In concluding this notice of the Port Coldwell and Peninsula syenitic rocks, it should be mentioned that a number of them are handsome ornamental stones, as proved by polished specimens prepared by the Bureau of Mines for the Buffalo Exposition, where they attracted considerable attention. The dark gray augite syenite with its gleams of blue from the feldspars is a particularly fine stone, resembling the famous Norwegian syenite though on the whole finer in grain. As it can be obtained close to the Canadian Pacific railway and beside an excellent harbor on Lake Superior, in quarries affording blocks of almost any required dimensions, it should prove of importance in the future.

Toronto University, Toronto, Ontario, Canada.

ART. XIX.—*The Double Ammonium Phosphates in Analysis;* by MARTHA AUSTIN.

[Contributions from the Kent Chemical Laboratory of Yale University—CIX.]

THE function of ammonium salts in the formation of double ammonium phosphates for the purposes of analysis has been the subject of a good deal of study. Manganese, which tends to fall as the tribasic phosphate, $Mn_3P_2O_8$,* appears in the presence of a sufficiency of ammonium salt in the form of the ammonium manganese phosphate $(NH_4)MnPO_4$, which gives the pyrophosphate, $Mn_2P_2O_7$, on ignition. Magnesium,† on the other hand, tends to pass under the influence of ammonium salt toward the condition of the diammonium magnesium phosphate which yields the metaphosphate on ignition. Further, in the cases of zinc and cadmium‡ it has been my experience that the presence of a considerable amount of ammonium salt is essential to the precipitation of the ideal double ammonium phosphates of both these elements, although in the case of cadmium, too large an amount of the ammonium salt prevents complete precipitation and apparently occasions the formation of a phosphate too rich in ammonia. The solvent effect of the reagents in the case of mercury phosphate‡ is very great, yielding a new salt the composition of which has not been investigated in recent years. Beryllium§ is only partly converted to that ammonium beryllium phosphate which yields the pyrophosphate on ignition, even in the presence of large amounts of ammonia salt. Neither an ammonium salt nor ammonia in solution converts the phosphates of barium, strontium, and calcium‡ to the double ammonium phosphates. Of these three elements barium alone falls in the form of the hydrogen barium orthophosphate. In certain recent articles upon the precipitation of the double ammonium phosphates some of the facts mentioned above have been called in question.

In the determination of zinc and manganese Dakin‖ has proposed to substitute ammonium phosphate as the precipitant in place of microcosmic salt (hydrogen ammonium sodium phosphate) in presence of a considerable amount of ammonium chloride, and to wash with a one per cent solution of the precipitant followed by alcohol. Dakin's analytical results, taken without scrutiny, would seem to show that the precipitate pro-

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* Gooch and Austin, this Journal, vi, 233.

† Gooch and Austin, this Journal, vii, 187. Neubauer, Zeitschr. anorg. Chem., ii, 45–50; iv, 251–266; x, 60–65; Zeitschr. angew. Chem., 1896, 435–440; Jour. Am. Chem. Soc., xvi, 289.

‡ Austin, this Journal, viii, 206.

§ Roessler, Zeitschr. anal. Chem., xvii, 148.

‖ Chem. News, lxxxii, 101; lxxxiii, 37.

duced by ammonium phosphate (in only moderate excess) and washed with a one per cent solution of the precipitant and alcohol has the ideal constitution of the double phosphate and leaves upon ignition the pyrophosphate.

From the standpoint of theory it is difficult to see why the ammonium phosphate should be more effective in producing the normal ammonium double salt than is hydrogen ammonium sodium phosphate in amount sufficient to supply the ammonium equivalent, or than a mixture of the equivalent amount of any soluble phosphate in association with enough ammonium salt to supply the same amount of the ammonium radical or ion. Whether the conversion of the tribasic phosphate of the type $\overset{II}{R}_3P_2O_8$ to the double ammonium phosphate of the type $(NH_4)\overset{II}{R}PO_4$ be viewed either as dependent upon the interaction according to mass of reagents assembled, or from the point of view of the ion theory,* the action of a solution of ammonium phosphate should not differ much from that of equivalent amounts of other ammonium salt and soluble phosphate. My own experience with the double ammonium zinc phosphate confirms this view.† In the following table are reproduced from my former paper the data of certain experiments bearing upon this point.

$Zn_2P_2O_7$ corresponding to $ZnSO_4$. Taken. grm.	Found. grm.	Error in terms of $Zn_2P_2O_7$. grm.	Error in terms of Zinc. grm.	Zinc left in the filtrate. grm.	$(NH_4)_3PO_4$. grm.	NH_4Cl. grm.	Time of standing. hours.
			A				
(1) 0·6355	0·6206	0·0149–	0·0060–	trace	3·13	....	1½
(2) 0·6355	0·6254	0·0101–	0 0040–	trace	3·13	....	16
(3) 0·6355	0·6300	0·0055–	0·0022–	trace	3·13	....	16
			B				
					$HNaNH_4PO_4.4H_2O$ grm.		
(4) 0·6355	0·6271	0·0084–	0·0034–	trace	4·47	0·5	1
(5) 0·6355	0·6256	0·0099–	0·0040–	none	4·47	0·5	20
			C				
(9) 0·6355	0·6335	0·0020–	0·0008–	none	4·47	10	16
(10) 0·6355	0·6381	0·0026+	0·0010+	none	4·47	20	½
(11) 0·6355	0·6379	0·0024+	0·0009+	none	4·47	20	2
(12) 0·6355	0·6386	0·0031+	0·0012+	none	4·47	20	½
(13) 0·6355	0·6393	0·0038+	0·0014+	none	4·47	20	½
(14) 0·6367	0·6355	0·0012+	0·0005+	none	4·47	30	16

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* Gooch and Austin, this Journal, vi, 233; Boettger, Ber. Chem. Gesell., xxxiii, 1019.

† This Journal, viii, 210.

The results of the experiments of Section B, in which the precipitation was made by microcosmic salt in presence of a small amount of ammonium chloride, show an average constitution of the precipitate similar to that of the precipitate obtained in A by an equivalent amount of ammonium phosphate, but the results of both series, A and B, vary considerably from the ideal much more closely approximated in the experiments of C, in which precipitation was made in the presence of a large excess of ammonium chloride. With these results those of Dakin are not in accord. Upon examination, however, Dakin's procedure appears to be open to criticism.

In the first place, it appears that the asbestos employed by Dakin was of the hydrous (serpentine) variety, which disintegrates when heated and is readily acted on by many reagents. Though previously treated with hydrochloric acid, it was, by Dakin's account, perceptibly soluble in a solution of ammonium phosphate. After drying at 100°–105° the crucible and felt lost some decimilligrams on ignition. It was on this account that Dakin weighed precipitate and filter, after drying at 100°–105°, when the double phosphate was to be estimated as such, or after ignition when the zinc pyrophosphate was weighed, and then, dissolving the precipitate in nitric acid, reweighed the crucible and asbestos, and by difference from the former weight obtained the apparent weight of the precipitate. The inevitable loss through disintegration or solubility of the filter in the nitric acid used to dissolve the precipitate in Dakin's procedure, must raise the corresponding apparent weight of the precipitate itself. Any series of results based upon the use of such material must of necessity be imperfect to the extent to which the ignited filter disintegrates or dissolves under the action of the nitric acid used to dissolve the precipitate.

Anhydrous (amphibole) asbestos, the material of which I made use, is insoluble, under the conditions of analytical work, in ordinary reagents including even the strong acids, as has been abundantly shown.* It is likewise completely insoluble in ammonium phosphate under the conditions of the work described, as I have found by experiment. Herein lies one cause of difference between Dakin's results and mine.

A second source of error in Dakin's procedure is found in the fact that precipitates of the double ammonium phosphates are washed in a one per cent solution of the reagent, ammonium phosphate followed by "redistilled alcohol." Dakin calls attention to the fact that absolute alcohol must not be

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* Gooch, Am. Chem. Jour. i, 317. Mar, this Journal, xii, 288; xliii, 521. Browning, this Journal, xliv, 399. Phinney, this Journal, xlv, 468.

used, but makes no mention of the exact strength of the alcohol employed in his work.

In order to test the insolubility of ammonium phosphate in alcoholic washing I have made various experiments, the details of some of which are given in the following account. Portions of a solution of manganous chloride, standardized as the sulphate according to the method* described in a former paper, were carefully measured from a burette, ammonium chloride and microcosmic salt were added in the proportions formerly recommended, and precipitation of the ammonium manganese phosphate was completed exactly as directed. After cooling, the precipitates were collected on asbestos under pressure in a perforated platinum crucible. In the experiments the results of which are given under A of the table, the precipitate was in each case washed with distilled water made faintly ammoniacal, while in those recorded under B, C, and D of the table the precipitate was washed with two hundred cubic centimeters of a one per cent ammonium phosphate solution, and rinsed with forty cubic centimeters of alcohol of different strengths,—sixty, eighty and eighty-eight per cent,—applied in successive portions.

$Mn_2P_2O_7$ corresponding to $MnCl_2$ taken.	Washed with ammoniacal water. A	Washed with 1% $H(NH_4)_2PO_4$ rinsed with 60% alcohol. B	Washed with 1% $H(NH_4)_2PO_4$ rinsed with 80% alcohol. C	Washed with 1% $H(NH_4)_4PO_4$ rinsed with 88% alcohol. D
grm.	grm.	grm.	grm.	grm.
0·3020	0·3042	0·3050	0·3058	0·3066
	0·3020	0·3041	0·3074	0·3086

From these experiments it appears that the procedure involving the washing of a precipitate of ammonium manganese phosphate by a one per cent solution of ammonium phosphate, draining with the pump, and then completing the washing with alcohol, results in a contamination of the precipitate proportionate to the strength of the alcohol used. Even the thin felt of asbestos alone when washed with ammonium phosphate followed by alcohol retains amounts of

Weight of asbestos felt.	Weight of asbestos felt after washing ten times with a 1% solution of ammonium phosphate and rinsing with distilled water.	Weight of asbestos felt after washing with a 1% solution of ammonium phosphate and rinsing with alcohol of the strength given.		
		60%	80%	88%
grm.	grm.	grm.	grm.	grm.
0·0681	0·0681	0·0682	0·0684	0·0686

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* This Journal, v, 209.

that salt proportionate to the strength of the alcohol employed. This is shown in the accompanying statement.

So it appears that in washing with ammonium phosphate and alcohol, according to Dakin's procedure, the precipitate of the double ammonium phosphate must be loaded with foreign material to a degree dependent upon the conditions. This error is in the same direction as that introduced by the solubility of the serpentine in nitric acid. With these two sources of error active, the most remarkable thing about Dakin's results is that they happen to agree so closely with mine, the solubility of the serpentine asbestos and the insolubility of the ammonium phosphate in alcohol together counterbalancing the deficiency due to imperfect constitution of the double ammonium phosphate.

As to the experience of Miller and Page* upon the ammonium cadmium phosphate, in consequence of which they concluded not only that my method for the estimation of cadmium is unsatisfactory, but that "asbestos filters should be avoided on account of the solvent action of either ammonium phosphate or nitric acid," it is sufficient to direct attention to the fact that their analytical examination of this process is wholly worthless by reason of their use of serpentine asbestos.

With suitable anhydrous asbestos at disposal, the estimation of magnesium, manganese, cadmium and zinc precipitated as the double ammonium phosphates, according to the directions and with the precautions laid down in the former papers from this laboratory to which reference has been made, is perfectly practicable. Concerning the manganese and zinc phosphates, in particular, it may be reiterated that with a sufficiency of ammonium salt, preferably the chloride, and with an excess of the precipitant present, the precipitation is complete and the phosphate formed of nearly ideal constitution. In the precipitation of the ammonium cadmium phosphate the proportions of the reagents must be regulated with care. The use of ammonium phosphate followed by rinsing in alcohol is not only wholly unnecessary but always altogether undesirable.

* School of Mines Quarterly, xxii, 391.

Art. XX.—*On the Electrical Resistance of Glass, Quartz, Mica, Ebonite and Gutta-percha;* by Ogden N. Rood, Professor of Physics in Columbia University.

In the August number of this Journal for 1901,* I published an account of an electrometer intended for measuring very high electrical resistances, and at the same time described a set of units of resistance that had been made with its help, the highest of which reached to 14,000,000 of megohms. Since then, with a similar set of high resistances, measurements of the external and internal resistances of certain insulating substances have been undertaken, which may not be without interest, in spite of the fact that they are to be regarded as first approximations. The reason of this limitation is to be found, not in any especial uncertainty in the resistance of the units employed, but in another direction, viz: metallic connection with substance under experiment is necessary, but mere mechanical contact is not sufficient to abolish contact-resistance, which is apt to be quite large, and various expedients were adopted to remove this troublesome difficulty. The best of these appeared to be the application of an amalgam of tin and mercury, of the consistence of soft butter, to the parts in question, but others were also employed; as, for example, in the case of gutta-percha, it seemed fair to cement the tinfoil to it with a liquid solution consisting mainly of gutta-percha, while in the case of ebonite, a metallic powder was attached to its surface by a very weak solution of shellac, and this again overlaid by tinfoil. Another source of error lies in the *time* of exposure to the electrical current, as the resistance of the substance through which it flows is apt to increase with the time. The initial resistance, or more properly the average resistance during the first stroke of the electrometer, was in each case noted, and an effort was made to adjust matters so that this should be about one minute, but very often it differed considerably from this amount of time, a drawback which could only be remedied by a large amount of extra labor and expenditure of time. It is owing then to these two factors that the measurements given below are to be regarded as first approximations. On the other hand, no difficulty was encountered in causing the current to pass through glass, quartz, mica, gutta-percha and ebonite, or to flow over their surfaces.

Mode of experimenting.—Mr. H. C. Parker determined for me the resistance of five small units in the ordinary way, and

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* This Journal, vol. xii, p. 91.

these were used to build up a large set of high resistances similar to those described in my article already alluded to. All this was done twice, and during these operations, the resistances of the insulating substances under experiment were determined, as far as possible, immediately. In the case of surface conduction, tinfoil was cemented on the ends of the strip and fringed with a line of metallic powder. For internal conduction, metallic surfaces were fastened to opposite sides of the plate, which was provided with a guard-rim of tinfoil, cemented with a solution of gum arabic and glycerine all around its edges, and grounded to prevent surface electricity from reaching its opposite side; a precaution which in the case of quartz and ebonite is not necessary, quartz giving the same result with and without the guard-rim, and the surface conduction of ebonite in dry weather is again still smaller than that of quartz.

In order to compare together the results obtained, those for surface conduction are reduced to the *calculated* resistance that would be offered by *one* surface of one square centimeter between the terminals. For internal resistance, the *calculated* resistance of coatings one square centimeter in area, with a thickness of one millimeter of substance between them, is given. A set of one hundred dry cells was employed in each case; its electromotive force was 150 volts. The striking distance of the electrometer was one millimeter, except in the case of very high resistances, where it was reduced to one-half or one-quarter of a millimeter.

Internal resistance of quartz.—The thickness of the plate was 1·71^{mm}, the metallic coatings, each, one square centimeter in area. Calculating the resistance for a thickness of 1^{mm}, I obtained, on

Feb. 19th	860,000	Ω	Hyg.	18°
" 22d	910,000	"	"	27°

The coatings were composed of an amalgam of tin and mercury.

Internal resistance of glass.—Very numerous measurements were made on plates of ordinary glass, and on others colored by oxide of cobalt, and even one plate of glass 6·2^{mm} in thickness was employed. The current traversed all of these with a certain facility, but the resistance of the cement used to attach the coatings increased from week to week, and consequently it is not worth while to give any figures at present. The internal and external resistances of two excellent Leyden jars of recent German make were also measured; in both cases the external resistance was very considerably greater than the internal; hence, in use, the main leakage would be through the substance of the glass. It would, therefore, seem undesirable to obtain capacity by thinness of wall.

Internal resistance of gutta-percha.—Two sheets of gutta-percha were employed, their thickness being 2·79$^{\text{mm}}$. Tinfoil was cemented on them with a solution of gutta-percha, and the results were fairly constant as seen below, where the actual figures obtained are given :

No. 1	6,030,000	Ω	Feb. 19th	Hyg. 18°
“ 2	6,270,000	“	“ “	“ “
“ 1	5,240,000	“	“ 24th	“ 27°
“ 2	6,640,000	“	“ “	“ “
	6,050,000	“		

Calculating this for a surface of one square centimeter and a thickness of one millimeter, we obtain, 18,500,000 Ω.

Internal resistance of ebonite.—Three plates of this material were used, one having a thickness of 2·29$^{\text{mm}}$; the other two were only ·5$^{\text{mm}}$ thick. The coatings were made of a metallic powder backed by tinfoil, all of which probably did not insure the best possible contact.

Reducing the results to the standard of one square centimeter of surface and a thickness of one millimeter, we have

No. 1	76,400,000	Ω	Hyg. 32°
“ 2	45,200,000	“	“ “
“ 3	45,000,000	“	“ “
	55,000,000	“	

Internal resistance of mica (muscovite, beautiful large sheets).—The thickness of No. 1 was ·122$^{\text{mm}}$; Nos. 2 and 3 had a thickness of ·32$^{\text{mm}}$. The coatings were made in the same way as with ebonite. Reducing to an area of one square centimeter and a thickness of 1$^{\text{mm}}$, I obtained for

No. 1	100,000,000	Ω	Hyg. 32°
“ 2	190,000,000	“	“ “
“ 3	110,000,000	“	“ “
	133,000,000	“	

From this it would seem that the internal resistance of mica is somewhat greater than that of ebonite, though, as will be shown later on, its surface resistance is much smaller.

Surface resistance of plate glass (window glass, commercial).—This proved to be unexpectedly regular, in spite of some variations in the hygrometric condition of the air. Two plates were employed, each having a length of 23·7$^{\text{cm}}$ between the terminals. The actual figures obtained on three different occasions are as follows :

No. 1	3,400,000	Ω	Feb. 19th	Hyg.	18°
“ 2	3,600,000	“	“ 22d	“	27°
“ 1	3,700,000	“	March 3d	“	32°
“ 2	3,600,000	“	“	“	32°
	3,570,000	“			

Calculating this for *one* surface of one square centimeter between terminals gives 1,590,000 Ω.

Surface resistance of cobalt glass.—From previous experiments it was known that the surface resistance of cobalt glass is considerably greater than that of the ordinary varieties of window glass, and the results given below confirm this idea. Four strips were used, with an average length between terminals of 4^{cm}. The experiments were all made on the same day, the hygrometer indicating 34 per cent of moisture. The actual figures obtained are:

No. 1	24,400,000	Ω	Hyg.	34°
“ 2	21,700,000	“	“	“
“ 3	24,400,000	“	“	“
“ 4	21,700,000	“	“	“
	23,000,000	“		

Calculating this for *one* surface of one square centimeter between terminals gives 22,000,000 Ω.

Surface resistance of mica.—Four slips of mica were used; the distance between terminals was 2·5^{cm}; the actual figures were:

No. 1	29,900,000	Ω	Hyg.	35°
“ 2	25,600,000	“	“	“
“ 3	39,400,000	“	“	“
“ 4	31,600,000	“	“	“
	31,600,000	“		

Calculating for *one* surface of one square centimeter, we obtain 50,760,000 Ω.

Surface resistance of gutta-percha.—Two slips of the material were used, the distance between terminals being 1^{cm}. The actual figures were:

No. 1	17,500,000	Ω	Feb. 20th	Hyg.	17°
“ 2	18,900,000	“	“ “	“	“
“ 1	13,000,000	“	“ 28th	“	35°
“ 2	7,700,000	“	“ “	“	“
“ 1	18,800,000	“	March 3d	“	32°
“ 2	19,500,000	“	“ “	“	“
	16,000,000	“			

Calculating the mean for *one* surface of one centimeter between terminals, we have 432,000,000 Ω.

Surface resistance of quartz (*crystal*).—The distance from terminal to terminal was 1·5^{cm}; the actual figures were:

76,000,000	Ω	Feb.	20th	Hyg.	17°
75,000,000	"	"	27th	"	34°

Calculating the mean for one surface of one square centimeter, we have 521,000,000 Ω.

Surface resistance of ebonite.—Two strips were used; the breadth of gaps was in one case 5·5^{mm}, in the other 6·2^{mm}.

Calculating the resistances actually obtained, for one surface of one square centimeter we have

No. 1	1,107,000,000	Ω	Hyg.	34°
" 2	2,940,000,000	"	"	"
	2,000,000,000	"		

These results are sufficiently discordant; those with quartz are scant, but damp weather prevented additional observations.

In closing this article, I give two determinations of the resistances employed in the investigation, for the purpose of showing the degree of accuracy readily obtainable in the process of building up high units by my method. The two operations were separated by an interval of about a week; the units were one year old.

53,760	53,830 Ω
71,860	72,370 "
81,400	80,500 "
244,000	241,000 "
220,000	205,000 "
297,000	292,000 "
389,000	384,000 "
1,161,000	1,163,000 "
585,000	554,000 "
1,565,000	1,504,000 "
1,401,000	1,380,000 "
2,246,000	2,193,000 "
2,891,000	3,140,000 "
2,203,000	2,193,000 "
3,707,000	3,432,000 "
2,990,000	3,130,000 "
3,070,000	3,130,000 "
1,958,000	1,803,000 "
7,808,000	8,194,000 "
7,902,000	8,460,000 "
8,720,000	8,540,000 "
5,584,000	5,560,000 "
8,120,000	8,194,000 "
6,780,000	6,906,000 "

New York, June 1st, 1902.

SCIENTIFIC INTELLIGENCE.

Miscellaneous Scientific Intelligence.

1. *American Association.*—The fifty-first annual meeting of the American Association for the Advancement of Science was held at Pittsburg from June 28 to July 3. The President of the meeting was Professor Asaph Hall, U. S. N. The attendance was rather large, 431 members registering; the number of papers read was also very considerable, amounting to some 320, including the addresses delivered and also papers before the affiliated societies. The local committee provided some fifty excursions for the entertainment and instruction of the members and the many manufacturing establishments of the region offered a rich field for study and observation. The address by the retiring President, Professor Charles S. Minot, was upon the subject "The Problem of Consciousness in its Biological Aspects;" this is printed in the number of Science for July 4 and the following issues of the same journal give the other addresses and general proceedings in great fullness.

The officers elected for the following year are as follows:

President: Ira Remsen, Johns Hopkins University.

Vice Presidents: Section A, G. B. Halsted, Austin, Texas; B, E. F. Nichols, Dartmouth College; C, C. Baskerville, Chapel Hill, N. C.; D, C. A. Waldo, Purdue University; E, W. M. Davis, Harvard University; F, C. W. Hargitt, Syracuse, N. Y.; G, F. V. Colville, Washington; H, G. M. Dorsey, Chicago; I, H. T. Newcomb, Philadelphia.

Permanent Secretary, L. O. Howard, Washington; *General Secretary*, H. B. Ward, University of Nebraska; *Treasurer*, R. S. Woodward, New York.

The next meeting of the Association will be held in Washington, D. C., Dec. 29, 1902 to Jan. 3, 1903, during the recently established convocation week.

Obituary.

Dr. Carlo Riva, Docent in petrography and Assistant in the mineralogical laboratory of the University of Pavia, was killed by an avalanche June 3d, during the ascent of the Monte Grigna, southeast of Lake Como. Dr. Riva was one of the most promising of the younger petrographers and mineralogists of Italy and had already published several papers describing rocks from the Monte Adamello and other regions in the Alps, from Italy and Sardinia; he was also correspondent for the Zeitschrift für Krystallographie, and gave promise of a long and productive career. His American friends, who were familiar with his charming personality, will learn with deep regret of his untimely end.

JOHN E. WOLFF.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XX.—*The Relationships of some American and Old World Birches*; by M. L. Fernald. (With Plates V–VI.)

[Contributions from the Gray Herbarium of Harvard University, New Series, No. xxiii.]

A recent attempt satisfactorily to identify some birches from the alpine summits of New England has made it necessary to study in detail certain species of the Old World. In this detailed study so many well-known European and Asian forms have been found identical with trees and shrubs of America which have ordinarily passed as endemic, that the following notes are offered as a partial solution of the difficulties which have long surrounded the species of *Betula*. The writer has been specially fortunate in having constant access to a large suite of specimens in the Gray Herbarium which were examined and labelled by Regel in the preparation of his monograph on the Betulaceæ in DeCandolle's Prodromus.* The material in the United States National Herbarium and in the Herbarium of the Geological Survey Department of Canada has been generously loaned by Messrs. F. V. Coville and J. M. Macoun, the collections of the Arnold Arboretum have been placed at his disposal, and valuable specimens and notes on northwestern forms have been freely furnished by Professors L. F. Henderson and C. V. Piper. Thus it has been possible to examine a very complete representation of the genus.

The birches are trees of boreal range. Unknown in the southern hemisphere and the tropics, they abound throughout the northern and mountainous sections of North America, Europe and Asia, reaching a more extreme northern range on both continents than any other trees.† By Regel and other

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* Regel in DC. Prodr., xvi, part 2 (1864), 161–189.

† See F. A. Michaux, Hist. des Arb., ii, 129, and Sylva, ii, 47; Sargent, Silva, ix, 46; Rehder in Bailey, Cyc. Am. Hort., i, 158.

early students of the group various European and American species were considered essentially identical; but among recent authors there has been an increasing tendency to regard nearly all American forms as endemic, and to maintain as organically distinct trees growing, for instance, on the American and the Asian sides of Behring Sea.

That there is not only a strong similarity, but a marked proportion of identity, in the herbaceous floras of the circumboreal regions has long been recognized; and, although the tendency to ignore this almost axiomatic truth has been conspicuous in the work of certain American as well as European botanists, the increasing evidence of its validity has forced itself upon the attention of others. This similarity in the boreal floras of the eastern and western hemispheres was very emphatically pointed out by Sir Joseph Hooker in his discussion of the Distribution of Arctic Plants.* Although our knowledge of the distribution and relationships of plants has very greatly increased since Hooker's tabulation was made, his outlines still furnish an approximately accurate basis for generalizations. If we consider the boreal distribution of some well-known northern genera whose species were then clearly interpreted, we shall find that of the 61 Arctic species of *Carex* recognized by Francis Boott, 58 extend southward into temperate Europe, 51 into temperate America, and 43 into temperate Asia; of the 16 Arctic *Junci* recognized by Hooker all 16 extend into temperate Europe, 15 into temperate America, and 14 into temperate Asia; of Hooker's 24 Arctic species of *Saxifraga*, 19 extend into temperate America, 17 into temperate Europe, and 14 into temperate Asia. This estimate is altered from that of Hooker only in so far as recent data has been immediately accessible to the writer; but it does not, of course, take into account such well-known species as *Carex riparia*, *C. Pseudo-Cyperus*, *Juncus tenuis*, etc., which occur in temperate regions of both hemispheres, though not within the Arctic Circle, but which, if counted, would increase the number of identical species in the eastern and western hemispheres.

Toward the warmer regions of each continent the number of identical plants rapidly diminishes, and the proportion of endemic species becomes very great. But in view of the marked similarity of the herbaceous vegetation of northern Europe, Asia and North America, it seems only logical to expect a notable proportion of identities between the trees and shrubs of boreal range, especially when, as in *Betula* and *Salix*, several species extend nearly or quite to the northern limits of

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* J. D. Hooker, Trans. Linn. Soc., xxiii, pt. 2, 251–358; see also Gray, Mem. Am. Acad., n. s., vi, 377–449, and extract "Flora of Japan," in Sci. Pap. of A. Gray, selected by C. S. Sargent, ii, 124–141.

vegetation and are rapidly spread by means of their thin-winged or hairy fruit. In fact, this relation of the Alaskan willows to those of the Old World is brought out by Mr. F. V. Coville in his scholarly monograph on the Willows of Alaska,* in which he recognizes 23 species, 2 of them circumpolar in distribution, and 9 others occurring in Siberia. That is, of the 23 willows recognized by Mr. Coville in Alaska, only 12, or scarcely more than one-half, are endemic North American species. A similar detailed study of northeastern *Salices* will, it seems to the writer, likewise show a closer relationship between certain other American and Old World forms than has been generally recognized.

The examination of the birches by the writer has led to the uniting of some well-known American and Old World trees and shrubs. The conclusions reached in his studies, and certain details of the studies themselves, may best be presented by discussing separately the species which have been specially examined.

§ **Albæ.** Trees or shrubs: the wing two or three times as wide as the achene; rarely only a little broader.

BETULA ALBA.

The original *Betula alba* of Linnæus† seems to have embraced both the common white birches of northern and central Europe. In 1788, however, Roth distinguished the two trees: "Betula *alba.* B. foliis ovato-acuminatis inciso-serratis scabris, ramis erectis strictis"; and "Betula *pendula.* B. foliis ovato-acuminatis inciso-serratis glabris, ramis flaccidis pendulis."‡ This separation of the two trees by Roth has been very generally ignored by recent European authors, nevertheless, and the species with pubescent ("scabrous") leaves and upright branches, the true *Betula alba* as interpreted by Roth, is universally known abroad as *B. pubescens*, Ehrh.,§ while the smooth-leaved species with pendulous branches, the *Betula pendula*, Roth., is ordinarily known by its later name, *B. verrucosa*, Ehrh.

By some authors, as Prantl‖ and Guerke,¶ these two white birches are treated as distinct species, while by others the entire group is regarded as a polymorphous species with many subspecies and varieties. Rehder, in Bailey's Cyclopedia of American Horticulture, disposes of the forms in this way,

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[*] Proc. Wash. Acad. Sci., iii, 297-362 (1901).

[†] Sp., ii, 982 (1753).

[‡] Roth, Fl. Germ., i, 404, 405 (1788).

[§] Beitr., v, 160, vi, 98 (1790-91).

[‖] Prantl in Engler & Prantl, Nat. Pflanzenf., iii, pt. 1, 45.

[¶] Pl. Eur., ii, 47, 48.

recognizing *Betula alba*, with the two subspecies, *B. pendula*, Roth (*B. verrucosa*, Ehrh.), and *B. pubescens*, Ehrh., each with numerous marked variations. Mr. Rehder, however, keeps separate from the Old World *B. alba* the American *B. papyrifera* and *B. occidentalis.*

The most conservative treatment of the group was, in some particulars, that of Regel in DeCandolle's Prodromus, though many of his varieties have proved of little value. There Regel recognized two species of white birches (his section *Albæ*), *Betula alba*, L., and *B. microphylla*, Bunge. *B. alba*, however, he divided into nine subspecies:

> *verrucosa*, with numerous varieties, from Europe, Asia and America;
> *populifolia*, a well-known strictly American tree;
> *mandshurica*, a local Asian tree;
> *latifolia*, with varieties, from central and northern Asia to Japan and Kamtschatka;
> *occidentalis*, with varieties, from North America;
> *papyrifera*, with varieties, from North America and Siberia;
> *pubescens*, with varieties, from Europe, Asia and North America;
> *tortuosa*, from northern Europe and Siberia;
> *excelsa*, a doubtful form referred to by earlier authors.

Thus it is clear that Regel, the most devoted student of the birches, found it impossible to distinguish as clear species the diverse trees and shrubs which pass as white or canoe birches.

The recently accumulated material shows that Regel's course was perhaps the most philosophic of any which has been proposed. Yet the primary characters of the trees, first clearly distinguished by Roth, are generally so constant that it seems better to the writer to recognize as species, i. e., as centers of variation, the two forms designated by him. These were the true *Betula alba*, with mostly stiff and ascending branches, the young branchlets puberulent or pubescent and the ovate often doubly serrate leaves more or less pubescent beneath, at least when young; and *B. pendula*, with more flexuous branches, the branchlets glabrous or verrucose with resiniferous atoms, and the deltoid or rhombic-ovate often simply serrate leaves glabrous, and more or less glutinous at least when young. These two trees in their characteristic forms are now very well understood abroad, though some of their reduced forms present perplexing problems. But since the days of Regel the American trees have been very generally regarded as endemic species, and it is to the discussion of this question that special attention is here directed.

Betula alba (as interpreted by Roth).

As already stated, *Betula alba*, L. (as interpreted by Roth) has passed in Europe as *B. pubescens*, and under this latter name it is ordinarily distinguished from *B. pendula*, Roth (*B. verrucosa*, Ehrh.). The species is generally recognized as occurring through northern and central Europe and across Asia, and by Regel and his followers it was regarded as likewise American, though by recent authors it has been excluded from our flora. The typical form of *B. alba* is the large White Birch of northern Europe, with ascending branchlets, puberulent or hairy twigs, and ovate or rhombic-ovate leaves more or less pubescent beneath, especially when young.

The representative of this tree in America is our common Paper or Canoe Birch, *Betula papyrifera*, Marsh.* (*B. papyracea*, Ait.†), which was discussed in detail by Michaux in his Sylva.‡ There Michaux wrote at such length as "will not be deemed superfluous by persons who justly appreciate the importance of precise ideas on subjects like the present," of the Canoe Birch (*B. papyracea*), the European White Birch (*B. alba*, including, at least in the illustration, *B. pendula*, Roth), and the American White or Old Field Birch (*B. populifolia*).

Michaux's plate of *Betula papyracea* is of a northern form very closely approaching var. *cordifolia*, Regel; and in commenting upon this tree he said "the bark is of a brilliant white, like that of the White Birch of Sweden, and, like that too, it is almost indestructible. . . . . . This bark, like that of the European species, is devoted to many uses," which are very fully enumerated. In his discussion of the European *B. alba* he said, "The trunk and limbs of the large trees are covered with a thick bark, whose epidermis is white and perfectly similar to that of the White Birch [*B. populifolia*] and the Canoe Birch [*B. papyracea*]. The small branches likewise resemble those of the species just mentioned [*B. papyracea*], being slender, flexible, and of a brown color spotted with white." He then discussed the uses of the European White Birch, concluding his remarks with: "Such are the principal uses of the European Birch, all the valuable properties of which are completely united in the Canoe Birch of North America." In his discussion of *B. populifolia*, Michaux further said: "The trunk of this species is clad in a bark of as pure white as that of the Canoe Birch and of the European Birch; but its epidermis, when separated from the cellular tissue, is incapable of being divided, like that of the two preceding species, into thin sheets; which constitutes an essential

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* Arbust. Am., 19 (1785).

† Hort. Kew, iii, 337 (1789).

‡ Michaux, Sylva, ii, 50–57.

difference." And in his summary of characteristics, he said: "The White Birch of Europe and the Canoe Birch resemble each other in their wood, their bark, and their ample proportions, which are perhaps superior in the American species. They differ in the form of their leaves, and they grow on very different soils: the Canoe Birch is exclusively attached to rich lands constantly cool, and capable of yielding an abundant harvest of corn or of clover, and it propagates itself naturally only in that part of North America which corresponds in climate to the 54th and 55th degrees of latitude in Europe."

These distinctions pointed out by Michaux are not, however, of such fundamental importance as to prove the American Canoe Birch (*Betula papyrifera*) organically distinct from the White Birch (*B. alba*, L., *B. pubescens*, Ehrh.) of Europe. Michaux made no distinction in his Sylva between the true *Betula alba* and the smooth-leaved and smaller *B. pendula*, Roth. His plate was of the latter plant, which has more deltoid leaves than the true *B. papyrifera*, but is quite like another American tree soon to be discussed. The foliage of the true *B. alba* is, nevertheless, as will be seen on comparison of American and European material, so similar as to present no apparent distinctive feature. The Canoe Birch in its best development, which Michaux places at a height of 70 feet, is found in deep soil on hillsides; but, had that keen observer been permitted to remain longer in our northern regions and to have explored the upper slopes of our mountains, he would have found the same tree there growing from the crevices of bare ledges—quite as barren a soil as that occupied by the European tree, which, by his own statement, may be 70 or 80 feet high. The more southern occurrence of the American tree is at least negative evidence of its identity with the tree of Scandinavia, northern Germany and Russia, for, as is now well known, the isotherms which cross New England pass far to the north in Europe, and the vegetation of northern New England and adjacent Canada has more than once been compared with that of Scandinavia. In fact, Michaux himself, in discussing the range of the Canoe Birch, said: "This part of North America, though situated 10 degrees further south, very nearly resembles Sweden and the eastern part of Prussia, not only in the face of the soil, but in the severity of the climate." Thus the comparative notes of Michaux leave little by which to distinguish the American from the European tree; and it is further worthy of note that in Boswell Syme's enumeration of the uses of the bark of the European tree he says: "In Russia it is applied to the same purposes for which that of the Canoe Birch is used in North America, boats being formed of it that are nearly as light and portable as those made by the Red Indians of Canada."[*] There is, then, no evidence from the descriptions and comparisons of Michaux and other well-informed European authors that the American *Betula papyrifera* is separable from the true *B. alba* of northern Europe.

The American tree presents numerous but apparently inconstant variations in the size and toothing of its leaves, and the size of its strobiles and achenes. These variations, however, are very closely matched by specimens in American herbaria of the European *Betula alba* (*B. pubescens*, Ehrh.). If, for example, we compare branches collected by Robert Chalmers at Campbellton, New Brunswick, in 1887, or Rydberg's No. 1,005, from the Black Hills of South Dakota (distributed as *B. occidentalis*) with a Bohemian specimen from Tausch and Russian material from Regel; Macoun's Cypress Hills (Assiniboia) material (No. 5,919) with Christiania (Norway) material from Blytt; a sheet in the Gray Herbarium, collected on Lake Winnipeg by Bourgeau, with Hampe's No. 1,321 from the Hartz Mts., in central Germany; or Clement's No. 2,919 from Nebraska and Medford (Massachusetts) material of Wm. Boott's with the 1807 sheet of *B. pubescens* sent by Regel to the Gray Herbarium; we cannot help being impressed by the identity of the pubescence, leaf-outline, strobiles, etc. Other comparisons of American and European specimens emphasize this identity; so that, in view of these facts and the essential similarity of bark, branches and stature, as pointed out by Michaux and others, there seems no question that *Betula papyrifera* is the true *B. alba* of Linnæus.

Betula alba, forma *occidentalis*.

In the discussion of *Betula papyrifera* in his Silva, Professor Sargent refers[†] to the tree of the northwest coast, a form which "differs from the eastern [*papyrifera*] in its greater height and rather darker colored bark, in its more pubescent branchlets, which sometimes do not become glabrous until their second season, although vigorous shoots of young plants in the east are often clothed with thick pubescence, and in its rather larger leaves, which, on the lower surface, are also more pubescent." Later, however, the same author has identified[‡] this large tree with *B. occidentalis*, Hooker,[§] not the small tree or half-shrub taken for *B. occidentalis* by Nuttall and other American authors, including Sargent, Silva, ix, 65, t. 453; and he concludes that the bark "is very different from that of the eastern tree, and it is probably best to consider it a species."

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[*] Syme, English Botany, viii, 184.

[†] Sargent, Silva, ix, 59.

[‡] Sargent, Bot. Gaz., xxxi, 238 (1901).

[§] Fl. Bor.-Am., ii, 155 (1839).

The original material of *Betula occidentalis* came from the Strait of Juan de Fuca; and if we examine specimens from that region we shall find them matching in every character of pubescence, leaves and strobiles large forms of eastern *B. alba* (*B. papyrifera*), as already intimated by Professor Sargent.* Branches collected by Professor L. F. Henderson in 1888 on the Gulf of Georgia, essentially a continuation of the Strait of Juan de Fuca, are clearly *B. occidentalis*, as shown by a tracing at the Arnold Arboretum of the original Scouler specimen. These specimens from the Gulf of Georgia have some of the branchlets strongly hirsute with sordid hairs mixed with abundant resiniferous atoms, while other (perhaps older) branchlets appear quite glabrous. In the original description of *B. occidentalis*, Hooker emphasized the abundance of resin, though nothing was said of hairs upon the branchlets. This character, however, is extremely variable, as shown by a large suite of specimens from Washington and British Columbia; and, admitting this inconstancy in the amount of resin and pubescence, the Gulf of Georgia branches seem to the writer quite inseparable from many sheets representing *B. alba* (*B. papyrifera*) from different sections of America. In such characters as are shown in herbarium material they are identified with the following among other specimens: Almota Creek, Whitman Co., Washington (*Piper*, No. 3,570), very resiniferous but not hairy, thus matching the original description; Cascade Mts. and Sumass Prairie, lat. 49°, British Columbia (*Lyall*), the latter the type of *B. alba*, subsp. *occidentalis*, *β*, *commutata*, Regel, the branchlets resiniferous but not hairy, thus agreeing with Hooker's original description; Pend d'Oreille River, Washington (*Lyall*), branchlets quite as hairy as in the Gulf of Georgia tree; Hill City, South Dakota (*V. Bailey*, sheet No. 230,000, U. S. Nat. Herb.), branchlets hairy; Black Hills, South Dakota (*Rydberg*, No. 1,005), branchlets hairy; Queenstown Heights, Ontario (*Macoun*, Herb. Geol. Surv. Can., No. 23,636), branchlets resiniferous, hirsute at tips; Goat Island, Niagara Falls, New York (*Coville*, sheet No. 294,829, U. S. Nat. Herb.), branchlets puberulent; Bald Eagle Ridge, Center Co., Pennsylvania (*Porter*), branchlets as in Gulf of Georgia specimens; North Conway, New Hampshire (*Wm. Boott*), branchlets as in last; Mountain Rock, Ellsworth, Maine (*Fernald*), branchlets resiniferous, slightly hairy; Manuels, Newfoundland (*Robinson* and *Schrenk*, No. 139), branchlets as in last. Other specimens from the coastal region of Washington and British Columbia are quite like some eastern branches. Thus Lake and Hull's plant from Tukanon River, Washington, and Macoun's No. 23,639 from Vancouver, are inseparable from

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*Silva, l. c., Bot. Gaz., l. c.

a Niagara specimen collected by Asa Gray; and Piper's No. 1,128 from Whatcom Co., Washington, cannot be distinguished from Lowrie's material from Bald Eagle Mt., Blair Co., Pennsylvania (sheet No. 149,835, U. S. Nat. Herb.), and the old specimen of Wm. Oakes's from Topsfield, Massachusetts, referred by Regel to *B. occidentalis*, var. *commutata;* and in their leaves these trees very closely approach a Canoe Birch growing at Oak Island, Revere, Massachusetts, and well-known to the local botanists from its lustrous brown bark. From herbarium specimens, then, there is no character by which to separate the northwestern *Betula occidentalis* from the eastern *B. alba* (*papyrifera*).

The important character upon which Professor Sargent lays stress in his recent note* is the color of the bark, which in the northwestern tree is usually brown. This character alone seems hardly sufficient to separate specifically the two trees, especially in view of such brown-barked trees in the East as that on Oak Island; a tree growing at the foot of Mountain Rock, Ellsworth, Maine (represented in the Gray Herbarium), with gray-brown bark strongly tinged with plum-color; and Robinson and Schrenk's No. 139, from Newfoundland, in which the old bark, though becoming pale, retains much of the brown which is often seen in young trees. Furthermore, it is worthy of note that the Pacific Coast tree is not thoroughly constant in its bark. The Henderson plant of 1888, from the Gulf of Georgia (essentially the type locality), was sent to the late Sereno Watson, who called it *B. occidentalis.* Subsequently, however, Professor Henderson, writing under date of December 9, 1897, of the difficulties in studying this group, said: "Just where *B. papyrifera* leaves off and *B. occidentalis* begins, I am, and always have been, at a loss to say." He then comments upon a tree which "is undoubtedly *B. papyrifera* in every respect," adding, "and I have no doubt that my number 1,712, from the shores of Lummi Island, Gulf of Georgia, sent Mr. Watson in '88, and referred by him to *B. occidentalis*, is the same thing." Thus it would seem that *Betula alba* (*papyrifera*) is not constant in its pale bark in the East, and that *B. occidentalis* of the Northwest may not always be distinguished by its dark bark.

The tendency of another dark-barked northwestern tree to become quite as pale as the eastern Canoe Birch will be noted in the discussion of a species soon to be considered; but in this connection it is worth while to note a tendency to darkening of color which has been observed in certain other northwestern plants. It is well known that many species of *Carex* growing in shade or in southern areas have pale or hyaline scales, while

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* Bot. Gaz., l. c.

the same plants in exposed or alpine situations have the scales brown, chestnut, or even nearly black.* On the Pacific slope of North America, especially from the Cascade and Coast Ranges to the coast of Oregon, Washington, British Columbia and Alaska, this tendency is likewise very conspicuous. It is well shown in such plants as *Carex praticola*, Rydb., in the Vancouver Island form described as *C. pratensis*, var. *furva*, Bailey; *C. pennsylvanica*, in the variety *vespertina*, Bailey; *C. aurea*, in the Vancouver plant, and in Suksdorf's No. 35 from Falcon Valley, and F. Binn's material from Port Ludlow, Washington; *C. limosa*, in the variety *stygia*, Bailey; *C. filiformis*, var. *latifolia*, in the Vancouver plant, and Hall's No. 607 from Oregon, Suksdorf's No. 51 from Klikitat Co., Washington, and Geyer's No. 72 from Oregon; and *C. rostrata*, in the Vancouver plant, and Piper's No. 994 from Seattle, and Suksdorf's Nos. 55 and 56 from the Cascade Mts. of Washington. The same tendency has likewise been noted in *Eleocharis* and *Juncus*. Without attempting here a discussion of the conditions which tend to produce upon our northwest coast the darkening of scales or other chartaceous portions of plants, it may be suggested that the brown color ordinarily seen in the Canoe Birch of Vancouver and the coastal region of Washington and British Columbia is perhaps due to the same physiological cause.

Emphasis has likewise been laid† upon the great height of this northwestern tree as compared with the eastern *Betula alba* (*papyrifera*). Yet it is interesting to note that David Lyall (whose specimens from the Lower Frazer River are a close match for Hooker's original description and for the tracing of the Scouler specimen) specially commented upon the tree as "growing to the height of 60 or 70 feet,"‡ while Piper's Whitman County trees are much lower. Since the brown-barked *Betula occidentalis* differs, then, only in this somewhat inconstant color of the bark from the ordinarily pale-barked *B. alba*, and since it is often no taller than the eastern tree, it seems to the writer hardly worthy special recognition, and that the tree was well treated by Professor Sargent in the Silva as a local tendency of the white-barked tree.

Betula alba, var. *glutinosa*.

Besides the ordinary Canoe Birch and its brown-barked form of the Pacific slope, there are many tendencies of *Betula alba* in America which deserve special comment. A single tree

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* See, for example, Boott, Ill. ii, 98, etc.; Holm, this Journal, 4th series, ii, 218; Fernald, Proc. Am. Acad., xxxvii, 500, 504.

† Sargent, Silva, l. c.; Bot. Gaz., l. c.

‡ Lyall, Jour. Linn. Soc., vii, 134.

left standing, after the widespread devastation of forest fire, by the Wassataquoik River, near Mt. Katahdin, in Maine, is conspicuous on account of its pendulous "weeping" branches, small leaves and essentially straight peduncles. Though in habit this tree is strikingly like *B. pendula*, its leaves place it nearer *B. alba*. In fact, the material matches perfectly a specimen sent to the Gray Herbarium by Regel, from Finland, of *B. alba*, var. *glutinosa*, Trautv.,* the form *pendula*† figured by Reichenbach (Ic. Fl. Germ., xii, t. 625) as *B. pendula*, though not the species of Roth. This Wassataquoik Valley tree may be known as *Betula alba*, var. *glutinosa*, Trautv. This form (*B. glutinosa*, Wallr.‡) is treated by various European authors as a natural hybrid between *B. alba* (*pubescens*) and *B. pendula*,§ but the apparent absence from Maine of *B. pendula* renders this origin of the tree improbable.

Betula alba, var. **cordifolia.**

Another tree more common in the mountainous portions of New England than *Betula alba*, var. *glutinosa*, differs from the ordinary Canoe Birch only in its cordate-ovate leaves. In this character it is very constant, however, and seems to deserve the varietal recognition given it by Regel as *B. alba*, subsp. *papyrifera*, *β*, *cordifolia*,‖ (*B. cordifolia*, Regel, Mon. 28, t. 12, figs. 29–36). The species, *B. cordifolia*, was based upon one of de la Pylaie's specimens from Newfoundland, and in his later treatment of the tree Regel cited two sheets in the Gray Herbarium, one from Mt. Katahdin, Maine, the other from Lake Superior. The tree is common on the upper wooded slopes of Katahdin and other mountains of northern New England, becoming a dwarf shrub at their summits, where it has passed as *B. papyracea*, var. *minor*, Tuck. Tuckerman's original material and description, however, was of another form soon to be noted. The tree or shrub of the mountainous districts of New England, with cordate leaves, pubescent on the veins beneath, may be known as *Betula alba*, var. **cordifolia** (Regel). Its range is a broad one, from northern LABRADOR (*C. A. Kenaston*, sheet No. 25,240, U. S. Nat. Herb.) and NEWFOUNDLAND to NEW BRUNSWICK, MAINE, the White Mountains, NEW HAMPSHIRE, LAKE SUPERIOR, IOWA (*B. Fink*, No. 109), ALBERTA, BRITISH COLUMBIA, IDAHO, and WASHINGTON.

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* Trautv. ex Regel, Mon. Bet. (1861), 20.

† Regel, l. c., 23.

‡ Sched. Crit., 497 (1822).

§ See Koehne, Deutsch Dendr., 109; Guerke, l. c., 48.

‖ Regel in DC., l. c., 166.

Betula alba, var. **minor.**

The dwarf alpine shrub which was described by Tuckerman as *Betula papyracea*, var. *minor*,* is represented in the Gray Herbarium by material from Tuckerman himself. It is not, perhaps, the commonest dwarf Canoe Birch of the White Mountains, but is a form with the small elliptic- or truncate-ovate leaves strongly glutinous and quite without pubescence. From the comparatively narrow wings of the samaras in Tuckerman's specimens, Regel took the plant to be a form of *B. davurica*, Pallas, of eastern Asia, and upon the Tuckerman sheet he based his *B. davurica*, *β*, *americana*.† The shrub is, however, more properly a phase of *B. alba*, and it occurs likewise on the North Summit of Mt. Katahdin, where it sometimes has the leaves smaller firmer and more glutinous than on Mt. Washington; in Gaspé and in Labrador; and in the mountains of Saskatchewan, Assiniboia and Alberta, where it intergrades with *B. microphylla*. Though ordinarily distinguished from *B. alba*, var. *cordifolia*, by its elliptic- or truncate-ovate glabrous leaves, smaller erect strobiles, and smaller samaras, this second dwarf Canoe Birch shows tendencies to integrade with that form. In its most characteristic development this shrub of the New England mountains matches *B. tortuosa*, Ledebour,‡ described from the Altai Mts. of central Asia, where it had likewise been mistaken by Ledebour for *B. davurica* of Pallas. The range of *Betula tortuosa* has since been extended through northern Russia to Silesia, Finland, Lapland and Greenland, where it is sometimes treated as a species, but by Koehne and by Guerke as a form of *B. alba* (*B. pubescens*, var. *tortuosa* (Ledeb.) Koehne).§

If we compare specimens collected by the late Edwin Faxon at "Willis's Seat" on Mt. Washington, New Hampshire, and Altai material of *Betula tortuosa* sent to the Gray Herbarium from the Imperial Herbarium at St. Petersburg, we shall find the former differing only in its glabrous branchlets. This want of pubescence is, however, quite as conspicuous in a Lapland specimen from Regel of his *B. alba*, subsp. *tortuosa a genuina*. If, again, we compare the original sheet of Tuckerman's *B. papyracea*, var. *minor* from the White Mountains with the plate of *B. tortuosa* in Flora Danica (xvii, t. 2918) we shall find them too close for ready separation. Specimens from Mt. Katahdin are, furthermore, quite inseparable from Rosenvinge's No. 160 from Greenland, distributed from the Botanical Museum of Copenhagen as *B. odorata*, var. *tortuosa* and represented by sheet No. 2,044 in the Herbarium of the Geological Survey of Canada; and various Mt. Washington speci-

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* Tuck., this Journal, xlv, 31 (1843).

† Regel in DC., l. c., 175 (1864).

‡ Fl. Ross. iii. 652 (1849).

§ Deutsche Dendr. 109 (1893).

mens are practically identical with Rosenvinge's Nos. 174 and 210 from Greenland. This shrub or dwarf tree offers considerable variation in the outline and toothing of its leaves, but no more than does the same form abroad; and since the young branchlets and leaves are sometimes pubescent as in *B. alba* its treatment as a dwarf variety seems the wiser course, and the shrub may be known as *Betula alba*, var. **minor** (Tuckerman).

Betula alba, var. **carpatica.**

A shrub growing on Anticosti Island at the mouth of the St. Lawrence (*Macoun* in Herb. Geol. Surv. Can., No. 23,823) differs somewhat markedly from other American forms. It is nearest *Betula alba*, var. *minor*, but differs in its broadly rhombic leaves, mostly cuneate at base and permanently pubescent beneath, especially on the nerves. This shrub is undoubtedly the *B. borealis*, Spach* (*B. pumila*, γ *borealis*, Regel, Mon. Bet. 55, t. 13, figs. 38, 39), described from Newfoundland, and it is identified with Regel's description of *B. pubescens*, ζ *carpatica*† (*B. carpatica*, Waldst. and Kit. in Willd. Sp. iv, 464). The specimens, except in their more abundant pubescence (in this matching Regel's "folia subtus in venarum axillis saepe barbata"), are well matched by a Lapland sheet distributed by Regel as *B. pubescens*, var. *carpatica;* and they are equally well matched by a sheet distributed by Fries as *B. glutinosa*. This plant, *B. glutinosa* of Fries, not Wallroth, is treated by Guerke as identical with *B. carpatica*. The same form is well represented in Flora Danica (xvi, t. 2851) as *B. odorata*, var. *rhombifolia*, Lange, with *B. odorata*, var. *carpatica*, Lange (*B. carpatica*, Waldst. and Kit.) cited as a synonym. Guerke, however, does not identify *B. rhombifolia*, Tausch, with *B. carpatica*, and considering this doubt it is least confusing to call the plant *Betula alba* var. **carpatica** (Waldst. and Kit.). The same form occurs in the Herbarium of the Canadian Geological Survey from Banff, Alberta (*Sanson*, Nos. 22,298 and 22,444), though in its somewhat resiniferous branchlets the first cited specimen tends toward *B. microphylla*, Bunge. An old specimen collected by Dr. Richardson on the Franklin Expedition (sheet No. 23,628, Herb. Geol. Surv. Can.) is apparently the same.

BETULA PENDULA.

Betula pendula, var. *japonica.*

Aside from *Betula papyrifera* and *B. occidentalis* the only birch of the section *Albae* generally recognized in America until within three years has been *B. populifolia*, a purely

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* Spach, Ann. Sci. Nat., ser. 2, xv, 196 (1841). † Regel in DC., l. c. 168.

American species quickly distinguished by its comparatively low stature and southern range, its chalky white or gray-flecked close and scarcely defoliating bark, its glossy extremely caudate-attenuate deltoid leaves, its compact grayish brown fruiting strobiles averaging 3^{cm} long and 6^{mm} thick, and the samara rarely $3{\cdot}5^{mm}$ broad. Very recently, however, three trees have been described from northwestern America as unique American species: *Betula kenaica*, W. H. Evans,[*] from Alaska; *B. alaskana*, Sargent,[†] from Saskatchewan and Alaska; and *B. fontinalis*, Sargent,[†] the Rocky Mountain half-shrub which has there passed as *B. occidentalis.*

The writer has not seen the original material of *B. kenaica*, but a large suite of specimens collected by Messrs. Coville and Kearney in the type region, on the Harriman Alaska Expedition, has been placed in his hands by Mr. Coville. This series of 15 sheets in the United States National Herbarium is supplemented by very important notes by Mr. Coville on the color of the bark, etc.

The first specimens cited by Professor Sargent for his *Betula alaskana* are one of Bourgeau's collected on the Saskatchewan during the Palliser Expedition, and Macoun's material from Prince Albert, Saskatchewan, collected in July, 1896 (not 1876 as originally published). The other material came from Alaska and the tree is said to be "the 'canoe birch' of all travellers in Alaska, and it is the common birch tree of the Yukon Valley." The Bourgeau plant, the first specimen cited by Professor Sargent and consequently (for want of any specially indicated specimen) to be regarded as the type, is in the Gray Herbarium. This plant was labelled by Regel and was included by him in the Prodromus as *B. alba*, subsp. *verrucosa* δ *resinifera*, a form otherwise known to him from Amur, near Udskoi (latitude 55°) on the Okhotsk Sea, and from the neighboring province, Transbaikalia. *B. verrucosa*, var. *resinifera* was distinguished by Regel from the typical *B. verrucosa* by the densely resiniferous branchlets, a character very conspicuous in the Bourgeau specimen, but less marked in Macoun's Saskatchewan material. And although in *B. kenaica* the twigs were originally described as "not resin-dotted," later collections show the character to be inconstant and that the twigs are sometimes quite as glandular or resiniferous as in the Bourgeau specimen of *A. alaskana;* and furthermore, *B. alaskana* has the twigs only "more or *less* verrucose with conspicuous resinous glands," so that little stress should be laid upon this character.

A comparison of the original descriptions of *Betula kenaica* and *B. alaskana* shows no point by which they can be sep-

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[*] Bot. Gaz. xxvii, 481 (1899).

[†] Bot. Gaz. xxxi, 236, 239 (1901).

arated. Both are trees commonly with red-brown or brown-gray bark, both have the twigs smooth or resiniferous, the leaves dark green above, paler beneath and ultimately quite glabrous. The fruiting catkins are described in practically the same terms. *B. kenaica* is common in the region of Kenai Peninsula and Kadiac Island; while *B. alaskana* is characterized as "the 'canoe birch' of all travellers in Alaska," and the range given includes "the Alaskan coast on the shores of Lynn Canal . . . ; and westward." Since Lynn Canal lies on the coast in the same latitude as Kenai Peninsula and scarcely 500 miles to the eastward, the general range covered by Professor Sargent's "westward" may well include the type region of *Betula kenaica.*

A comparison of specimens of *Betula kenaica* and *B. alaskana* likewise fails to reveal any distinctions. For instance, Coville and Kearney's No. 2,423 of *B. kenaica* (sheet No. 373,620 in the U. S. Nat Herb.) is quite inseparable from Macoun's Prince Albert material (No. 12,952*a*, Herb. Geol. Surv. Can.), one of the original specimens cited for *B. alaskana;* and neither of these specimens can be separated in habit, twigs, leaves or pubescence from No. 20,327 of the Canadian Geological Survey Herbarium, material collected by R. G. McConnell near Dawson City on the Yukon, where *B. alaskana* is said to abound. Furthermore, although the Bourgeau specimen of *B. verrucosa*, var. *resinifera*, the first cited specimen of *B. alaskana*, is young, its leaf-outline and very resiniferous twigs seem quite identical with those of Coville and Kearney's No. 2,412 of *B. kenaica* (sheet No. 373,618, U. S. Nat. Herb.). There is, then, no question that *Betula alaskana* described in 1901 is identical with *B. kenaica*, published in 1899.

Both Mr. Evans and Professor Sargent had their species compared at St. Petersburg, before publication, with Siberian material; and it is certainly very unfortunate that these comparisons were not more satisfactorily made, since very many sheets in the Gray Herbarium, as well as the United States National Herbarium, show what appear to be identical branches collected in Asia over a wide range of country,—from Kamtschatka to northwestern Siberia (Yenisei River), south to Japan, Mandschuria, Mongolia and Sungaria. This Asian tree was treated by Regel in the Prodromus as *Betula alba*, subsp. *mandshurica* and *latifolia*, while the more strongly resiniferous were included in his subsp. *verrucosa*, δ *resinifera.* The form treated by Regel as subspecies *latifolia* had, however, been described by Siebold* in 1830 as *Betula japonica.*

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* Verh. Batav. Gen., xii (1830), 25.

In Asia as in northwestern America the abundance of resin on the branchlets seems to vary without any accompanying change in leaf-outline or other character perceptible in the specimens; and by comparison with well authenticated Asian specimens of *Betula verrucosa*, Ehrh. (*B. pendula*, Roth), *B. mandshurica*, Regel, and *B. latifolia* (*B. japonica*) with its vars. *Tauschii* and *kamtschatica*, essentially all the available material of the American *B. kenaica* (including *B. alaskana*) can be exactly matched. Thus such specimens as Coville and Kearney's Nos. 1,408, 1,422, and 2,425 of *B. kenaica* (Nos. 373,608, 373,609, 373,622, U. S. Nat. Herb.) and an old sheet in the National Herbarium from Fort Simpson (Mackenzie District) are good matches for Japanese material collected by Maximowicz and distributed as *B. alba*, subsp. *latifolia α Tauschii*, Regel (represented in the Gray Herb. and by sheet No. 25,341 in the U. S. Nat. Herb.). These specimens also match too closely the original description and figure of var. *Tauschii*, Regel.* Further material of var. *Tauschii* collected by Maximowicz in Mandschuria and distributed from the Imperial Herbarium at St. Petersburg (represented in Gray Herb. and by sheet No. 25,345, U. S. Nat. Herb.) has the leaves more coarsely and irregularly toothed than the specimens previously cited, but in this it is not distinguishable from Coville and Kearney's No. 2,412 of *B. kenaica* (sheets Nos. 373,618, 373,619, U. S. Nat. Herb.) nor from the Bourgean specimen, type of *B. alaskana;* nor does this foliage differ from that of specimens collected by Korjhinsky at Blagovyeschensk, Amur (represented in Gray Herb. and by sheet No. 273,721 in U. S. Nat. Herb.). Furthermore, these specimens cannot be separated by any apparent character from Kamtschatkan material sent to the Gray Herbarium by Regel as his *B. latifolia*, var. *kamtschatica*, and they are quite like his original figure of that variety;† while Macoun's Saskatchewan specimen (No. 12,952*a*) and McConnell's Dawson specimen (No. 20,327) of *B. alaskana*, and Coville and Kearney's Nos. 1,442, 1,444, 1,445, and 1,626 of *B. kenaica* (sheets Nos. 373,610, 373,611, 373,612, 373,616, U. S. Nat. Herb.) are quite as inseparable from Regel's original description and figure of *B. alba*, subsp. *mandshurica*.‡ It is thus very evident that *Betula kenaica* and *B. alaskana* cannot be treated as local American trees, but that they are quite identical with the well-known *B. pendula* or with the Asian tree which was described by Siebold in 1830 as *B. japonica*, and figured in its various forms by Regel in 1865.

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* Bull. Soc. Imp. Nat. Mosc., 1865, 399, t. 7, figs. 11–14 (repr. Bemerkungen über die Gattungen Betula und Alnus (1866) 12, t. 7, figs. 11–14).

† Bull. Soc. Imp. Nat. Mosc., l. c., figs. 16–20.

‡ Bull. Soc. Imp. Nat. Mosc., l. c., fig. 15.

This Asian tree, which presents indiscriminate variation in the size and toothing of its leaves and the abundance of resin on its branches, was treated by Miquel* as a variety of the Eurasian *Betula alba;* while by Rehder it is more properly considered a variety of the subspecies *B. pendula* (*B. verrucosa*). This disposition of the tree seems most advisable, since typical *B. pendula* crosses northern Asia and is distinguished from the trees which Siebold called *B. japonica* and Regel called *B. latifolia* only by an inconstant tendency of the leaves to be more cuneate at base. The form of the tree with broad leaves rounded or truncate at base, common in northern Asia, and including much of *B. kenaica* and *B. alaskana*, should be known, then, as *Betula pendula*, Roth, var. *japonica* (Siebold), Rehder in Bailey Cyc. Am. Hort. i, 159.

Reference has been made to the tendency of *Betula alba* to develop brown bark when it occurs upon the northwest coast of America. Similar reddish or brown bark likewise ordinarily distinguishes the northwestern tree which has been called *B. kenaica* (*B. alaskana*) from the true *B. pendula*. But this is not a sufficiently constant character to separate it specifically from the Asian specimens which so closely match it in every detail shown in the herbarium. The writer has been unable to find any clear statement that the bark of *B. pendula*, var. *japonica*, is either white or brown. Bourgeau, however, who had previously remarked upon the abundance of *Betula papyrifera* on Ile Royale, Lake Superior,† and who was consequently familiar with the ordinary white-barked tree, referred the Saskatchewan tree without question to that species;‡ and Macoun referred his Prince Albert tree without comment to *B. papyrifera*. The fact that these acute collectors of the first mentioned specimens of *B. alaskana* saw in their Saskatchewan trees only the white-barked *B. papyrifera* is sufficient evidence that the brown bark of *B. alaskana* is not a character to be confidently relied upon. Furthermore, Mr. Coville writes of *B. kenaica* under date of March 12, 1901: "In certain individual trees, however, and perhaps on exposure to certain climatic conditions the layers of the bark separate and the bark turns white as in *papyrifera*. This factor has made it difficult for the collectors who have observed the tree to tell whether in upper Cook's Inlet there is a white-barked birch distinguishable from *kenaica*." Sheets Nos. 373,611, 373,619, and 373,620 in the United States National Herbarium show strips of lichen-covered bark of *B. kenaica* no darker

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* Miquel, Ann. Bot. Mus. Lugd. Bat. ii, 136.

† Bourgeau in letter to Sir Wm. Hooker, Palliser, Rep. Brit. N. A. Expl. Exped. 247.

‡ Bourgeau, l. c. 249; see also Hooker, ibid., 260; Gray, ibid., 263; Sullivan, ibid., 85, etc.

than is occasionally seen in *B. alba* (*B. papyrifera*) in the Northeast and already mentioned in the discussion of *B. occidentalis.* The color of the bark, then, furnishes no satisfactory reason to separate *Betula kenaica* from the Asian *B. pendula*, var. *japonica.*

Betula pendula (typical).

The broad-leaved var. *japonica* is not the only form of *Betula pendula* which crosses from Europe and Asia into North America. As already noted, the typical European *B. pendula* with leaves cuneate at base extends across northern Asia. Some of the specimens which have been referred to *B. alaskana* are quite inseparable in their leaves, branches, and strobiles from European specimens; and, furthermore, this characteristic European form extends southward and eastward in America to western Illinois, the Great Lakes, and the St. Lawrence Valley. Sheet No. 351,017 of the United States National Herbarium, collected as *B. populifolia* in woods at Warren, Illinois, by L. M. Umbach, is not distinguishable from sheet No. 25,340 from Sungaria in central Asia, nor from material in the Gray Herbarium collected in Sweden (*Blomberg*, No. 1,691). Sheet No. 261,119 of the U. S. National Herbarium, collected by Professor James Fowler in Ontario as *B. populifolia*, has the strobiles and leaves of *B. pendula* and it cannot be separated from material in the Gray Herbarium from Christiania, Norway (*Blytt*), and from St. Petersburg, Russia (*Regel*). A sheet in the Herbarium of the Geological Survey of Canada (No. 12,950), collected in the Province of Quebec as *B. populifolia* by W. Scott, is quite identical with sheet No. 149,801 of the U. S. Nat. Herb. from Savoy. Various other leaf-specimens from Quebec, Manitoba, and other regions of temperate North America are probably *B. pendula*, but without fruit it is at present unwise so to refer them. The American specimens cited were gathered as the endemic *Betula populifolia*, at least one of them in "woods"; and since undoubted *B. pendula* is found from the Saskatchewan Plains northward, there seems little question that the European tree, crossing Asia, is truly indigenous likewise in the northeastern sections of America, just as are *Coptis trifolia*, *Drosera rotundifolia*, *Viburnum Opulus*, *Lysimachia thyrsiflora*, and many other well known species* which occur in northern Europe, central and northern Asia, Japan, northwestern America, and northeastern America.

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* Among them *Caltha palustris*, *Viola Selkirkii*, *Parnassia palustris*, *Potentilla palustris*, *Circaea alpina*, *Pyrola minor*, *Moneses grandiflora*, *Menyanthes trifoliata*, *Rumex persicarioides*, *Allium Schoenoprasum*, *Juncus effusus*, *Eriophorum gracile*, *Carex filiformis*, *Hierochloe borealis*, etc., etc. See Gray, Mem. Am. Acad., n. s., vi, 377–499; and Extract "Flora of Japan" in Sci. Pap. of A. Gray, selected by C. S. Sargent, ii, 124–141.

BETULA MICROPHYLLA.

Professor Sargent has recently referred* to the fact that the writer identifies the common brown-barked tree or half-shrub of the Rocky Mountains with Bunge's *Betula microphylla* described from the Altai of central Asia. Professor Sargent, however, was unwilling to identify the American tree with Bunge's species, and he accordingly proposed for it the new name *B. fontinalis.* But a further comparison of *B. fontinalis* and an authentic branch from the Altai of Bunge's species sent from the Imperial Herbarium of St. Petersburg to the Gray Herbarium, some of the original Tyan Shan material of Regel's *B. alba*, subsp. *soongorica*† in the Gray Herbarium and in the United States National Herbarium, the figures of Regel's *B. fruticosa*, var. *cuneifolia*,‡ and lastly the original detailed full-page description by Bunge of his *B. microphylla*,§ has more firmly convinced the writer that all three of these trees described from the Altai and the Tyan Shan ranges are one species, *B. microphylla*, Bunge; and that this species differs from *B. rhombifolia*, Nutt. (*B. occidentalis*, Nutt. and of many other authors, not Hook. *B. fontinalis*, Sargent) only in growing among the mountains of central Asia rather than among those of northwestern America.

A comparison of Bunge's original description of *Betula microphylla* with Nuttall's description of his *B. occidentalis*,‖ the tree subsequently called by Sargent *B. fontinalis*, shows no definite character of leaves, strobiles, samaras, nor twigs upon which the two may be separated; and Bunge's words, "epidermide trunci flavescente neque alba, primo intuito distinctissima,"¶ are certainly not inapplicable to the small tree of northwestern America described in the Botany of California "with close dark-colored bark (at length light brown)."** Furthermore, if we compare with the branch of *B. microphylla* sent from St. Petersburg to the Gray Herbarium the original specimen of Nuttall's *B. rhombifolia*†† (preserved in the Gray Herbarium and referred by Sargent to *B. fontinalis*), and such specimens as Macoun's from the North Saskatchewan and Dawson's from the Columbia River (Herb. Geol. Surv. Can., Nos. 23,620, and 23,624) or F. W. Anderson's material from McCarthey Mts., Montana (U. S. Nat. Herb. No. 25,261), we shall be perplexed to make out points of distinction. If we also compare with some of the original material of Regel's *B. alba*, subsp. *soongorica*, β *microphylla* from 5,000 ft. in

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* Bot. Gaz. xxxi, 239.

† Bull. Soc. Imp. Nat. Mosc. (1868) vi—repr. Enun. Pl. Semenow. (1869) 99.

‡ Regel, Mon. Bet. (1861) 35, t. 7, figs. 16–23.

§ St. Pétersb. Mém. Savans Étrang. ii (1835) 606—reprint, Fl. Alt. Suppl. 84.

‖ Nutt., Sylva, i, 22, t. 7 (1842).

¶ Bunge, l. c.

** Watson, Bot. Cal. ii, 79.

†† Nutt., l. c. 24, t. 8.

the Tyan-Shan Mountains as represented in the Gray Herbarium and by sheet No. 25,339 in the U. S. National Herbarium, such specimens as V. Bailey's No. 5 from South Dakota, Coville and Leiberg's No. 81 from Nevada, and R. S. William's No. 404 from Montana (sheets Nos. 229,983, 275,933, and 290,087, U. S. Nat. Herb.); or Macoun's Devil's Lake plant, Dawson's South Kootenai Pass Plant, and Macoun's Crow Nest Pass Plant (Nos. 2,050, 23,623, and 24,368, Herb. Geol. Surv. Can.); or Lake and Hull's No. 790 from Washington, Rydberg and Bessey's No. 3,928 from Montana, Rydberg's No. 1,006 from the Black Hills, and A. Nelson's No. 1,647 from Wyoming, we shall be further perplexed in separating the American species from the Asian. Similar comparisons of American specimens with the figures of *B. fruticosa*, var. *cuneifolia* (which by Regel was identified with *B. microphylla*), lead to the same result. In view of this evidence and the essentially identical descriptions of Nuttall and Bunge, the writer is still unable to see in *Betula fontinalis*, Sargent (*B. occidentalis*, Nutt., not Hook. *B. rhombifolia*, Nutt., not Tausch) anything but *B. microphylla*, Bunge, of the mountains of central Asia.

§ **Nanae.** Shrubs: wings of the samaras narrower than, or very rarely as broad as the achenes.

The Dwarf Birches like the Canoe Birches present such tendencies to intergradation that it is difficult to draw clear specific lines between them. Yet in America three fairly marked species or centers of variation can be distinguished. These are *Betula pumila*, L., with the young shoots normally pubescent with long soft hairs, and quite glandless, but in an extreme form with glands or resiniferous atoms mixed with the long pubescence; *B. glandulosa*, Michx., with the young shoots glandular or resiniferous, at most puberulent with close short hairs; and *B. nana*, L., a tiny shrub with the young shoots puberulent or finely pubescent, but not glandular. In its typical form confined to arctic and alpine regions of Greenland, Europe and Asia, *B. nana* is represented in America by

BETULA NANA, var. MICHAUXII.

A very dwarf birch with cinereous-puberulent glandless branches and tiny suborbicular or flabelliform leaves has been collected at various points in Newfoundland, Labrador, and the Hudson Bay region, and has been referred to *Betula nana*, L., or its var. *flabellifolia*, Hook. An examination of this material shows that the strobiles are made up of simple oblong scales, instead of the deeply three-lobed scales characteristic of *B. nana* and most other species of the genus.

This dwarf shrub of Newfoundland and Labrador is without question *Betula Michauxii*, Spach,[*] based upon the *B. nana* of Michaux, not L., and made by Spach the type of his section *Apterocaryon*. Subsequently the plant was raised to generic rank by Opiz,[†] and called *Apterocaryon Michauxii;* while, on the other hand, Regel in his first Monograph treated[‡] the plant as a variety of *B. nana*, though he later recognized[§] it as distinct. Habitally the plant is quite inseparable from the European *B. nana;* and since sheet No. 334,540 of the United States National Herbarium, from Nugsuak Peninsula in Greenland, shows strobiles with simple and variously divided scales, it seems that Regel's earlier treatment of the plant was wiser and that the Newfoundland and Labrador representative of *Betula nana* is var. *Michauxii* (Spach) Regel.

BETULA PUMILA.

In its normal form *Betula pumila, L.*[‖] has the leaves and branchlets quite glandless and in their youngest stages densely pubescent with silky hairs. The shrub, however, passes imperceptibly into a state (var. *glabrescens*, Regel) in which the branchlets and leaves are quite glabrous. This tendency is common, but apparently not of such constancy as to merit special recognition. It is interesting to find, however, that the specimens which represent this tendency are inseparable from *B. alpestris*, Fries,[¶] of Greenland, Iceland, Scandinavia and north Germany, an identity which was at least suspected by Regel.[**] Such specimens in the Herbarium of the Geological Survey of Canada as Macoun's No. 23,840 from Anticosti and Waghorne's No. 23,821^b from Labrador are quite inseparable from sheet No. 149,806 in the U. S. Nat. Herb. of *B. alpestris* from the Dovre Mts., Norway (*Ahlberg*) and a sheet in the Gray Herbarium from Lapland (*Andersson*), except in the length of the petiole. This character, however, is very inconstant and it seems to the writer an insufficient point on which to keep apart two plants which are otherwise inseparable. Nor are the extreme American plants otherwise different from the plate representing *B. fruticosa*, var. *humilis*, Reichenbach (Ic. Fl. Germ. xii, fig. 1280) and referred by Guerke to *B. alpestris*, and the plate of *B. alpestris* in Flora Danica (Suppl. t. 37). The name *B. pumila*, however, long antedates *B. alpestris*, Fries, and it should now be applied to the shrub of northern Europe as well as America. The true *Betula pumila* occurs in swamps from LABRADOR and NEWFOUNDLAND west-

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[*] Ann. Sc. Nat., ser. 2, xv, 195.

[†] Lotos, v (1855), 258.

[‡] Regel, Mon. Bet. (1861) 45.

[§] Regel in DC. Prodr. xvi, part 2 (1864), 171.

[‖] Mant. 124 (1767).

[¶] Summ. Veg. Scand. i, 212 (1846).

[**] Regel in DC., l. c. 173.

ward, and locally south to Morris Co., NEW JERSEY, Champaign Co., OHIO, Lake Co., INDIANA and McHenry Co., ILLINOIS, in Greenland, northern Europe and Siberia. The leaves vary much in outline and in the degree of permanence of the pubescence; and the samaras in the breadth of the wings and achenes. Narrowly obovate and orbicular leaves are often found upon the same shrub, so that species or varieties based upon these characters (as *B. Grayi*, Regel, Bull. Soc. Imp. Nat. Mosc. xxxviii, 406, t. 6, figs. 9–13) have little value.

Betula pumila, var. *glandulifera.*

In the Great Lake region, however, and from there northward and westward, where *Betula pumila* meets *B. glandulosa*, it presents a perplexing form. In its long pubescence (when well developed) the shrub seems to be *B. pumila*, but mixed with the pubescence and sometimes upon the leaves are the characteristic glandular atoms of *B. glandulosa.* Ordinarily, though, the shrub is readily distinguished from the latter species by the longer pubescence of the young shoots. This intermediate and transitional form, *Betula pumila*, var. *glandulifera*, Regel in DC. l. c., occurs from western ONTARIO and MICHIGAN to MINNESOTA, SASKATCHEWAN and BRITISH COLUMBIA, south to IDAHO and OREGON.

BETULA GLANDULOSA.

*Betula glandulosa** presents two variations which in their extreme developments appear very distinct, but which again so mingle their characters as to be quite inseparable. Typical *B. glandulosa* is an upright shrub sometimes several feet high, but in exposed situations it becomes dwarfed and widespreading. In the typical form of the species the leaves are obovate, but occasionally on these shrubs orbicular or reniform leaves are found. This shrub with obovate leaves is most common in the interior of North America, from the YUKON and MACKENZIE RIVERS to HUDSON STRAITS, south in the mountains to northern CALIFORNIA, UTAH, COLORADO, and SOUTH DAKOTA; across the plains to MANITOBA and LAKE SUPERIOR; and through LABRADOR and locally to the higher mountains of northern NEW ENGLAND. It is also in GREENLAND, KAMTSCHATKA and the ALTAI MOUNTAINS.

On the eastern mountains (Albert, Katahdin and Washington), in Labrador, and in the Altai the shrub passes imperceptibly to a form with orbicular or reniform leaves, var. *rotundifolia*, Regel† (*Betula rotundifolia*, Spach‡); but on

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* Michx., Fl. Bor.-Am. ii, 180 (1803).

† Regel in DC., l. c. 172 (1864).

‡ Spach, l. c. 194 (1841).

the coast of Alaska, the islands of Behring Sea, and adjacent Kamtschatka this depressed form with small orbicular or reniform leaves retains its characteristics in a marked degree, and were the plant known only from that district it would stand as an undoubted species.

Mr. Coville has called the attention of the writer to a shrub four to six feet high which is associated with the depressed *Betula glandulosa*, var. *rotundifolia*, and the Cook's Inlet tree which is identified with *B. pendula*, var. *japonica*. This intermediate shrub is well represented in the National Herbarium, and it is possible, as Mr. Coville suggests, that it is of hybrid origin, since similar hybrids of trees and dwarf shrubs have before been noted.* The material presents a strong superficial resemblance to Greenland specimens of *B. alba*, var. *minor*, although the strongly resiniferous branchlets hardly place it with that shrub.

In conclusion, it should be emphasized that the specific lines in *Betula*, as in *Alnus*, *Quercus* and *Salix*, are often too vague. It is quite possible to trace by a series of specimens a direct connection between the dwarf *Betula nana* or *B. glandulosa* and the tall *B. alba*. Thus *B. nana* in its larger development is separated with difficulty from the Scandinavian *B. alpestris*. This shrub, in turn, is quite like glabrate states of the American *B. pumila*, which, through its var. *glandulifera*, passes to *B. glandulosa*, the larger developments of which pass in the Cascade Mts. to *B. microphylla*, and in the Saskatchewan region to *B. alba*, var. *minor*. The latter shrub is often inseparable on the New England mountains from *B. alba*, var. *cordifolia*, which on the lower slopes becomes a large tree and passes gradually to the broad-leaved form figured by Michaux as *B. papyracea*. A very similar series is readily made to include *B. pendula* and *B. humilis*. But since it is obviously impracticable to regard all these forms as one species, it seems wiser to recognize the more marked centers of variation as species which are admitted to pass by exceptional tendencies to other forms ordinarily distinguished by marked characteristics.

The American representatives of § *Costatae*, *Betula nigra*, *B. lenta*, and *B. lutea*, are represented by related species in Asia, but none of these trees are of very boreal range, and they appear well distinguished as endemic species.

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* *B. pubescens* [*alba*] × *humilis*, Warnst. Verh. Bot. Ver. Brandenb. xi, 129 (1870).

B. nana × *verrucosa* [*pendula*], Sael. Medd. Soc. Faun. et. Fl. Fenn. xiii, 256 (1886).

B. nana × *pubescens* [*alba*], Koehne, Deutsche Dendr. 112 (1893).

B. pumila × *lenta*, Jack, Gard. and For. viii, 243, fig. 36 (1895).

The American forms of §§ *Albae* and *Nanae* now recognized by the writer and discussed in the preceding notes may be briefly enumerated as follows:

B. ALBA, L. Sp. ii, 982 (1753); Roth, Fl. Germ. i, 404. *B. papyrifera*, Marshall, Arbust. Am. 19 (1785). *B. papyracea*, Ait. Hort. Kew. iii, 337 (1789). *B. pubescens*, Ehrh. Beitr. v, 160, vi, 98 (1790–91). *B. odorata*, Bechst. Diana, i, 74 (1797).—NEWFOUNDLAND to ALASKA, south to PENNSYLVANIA, INDIANA, NEBRASKA, WYOMING, IDAHO and WASHINGTON; passing on the Pacific coast to the dark-barked forma *occidentalis* (*B. occidentalis*, Hook. Fl. Bor.-Am. ii, 155 (1839)); ICELAND, northern EUROPE and ASIA, south in the mountains to northern SPAIN, ITALY, etc. (Pl. V, figs. 1–6.)

B. ALBA, var. GLUTINOSA, Trautv. ex Regel, Mon. Bet. 20 (1861). *B. glutinosa*, Wallr. Sched. Crit. 497 (1822). *B. pendula*, Reichenb. Ic. Fl. Germ. xii, t. 625, not Roth.—Valley of Wassataquoik River, MAINE; SWEDEN, FINLAND, GERMANY, SWITZERLAND, AUSTRIA.

B. ALBA, var. CORDIFOLIA. *B. cordifolia*, Regel, Mon. Bet. 28, t. 12, figs. 29–36 (1861). *B. alba*, subsp. *papyrifera*, *β*, *cordifolia*, Regel in DC. Prodr., xvi, pt. i, 166 (1864). *B. papyrifera*, var. *minor*, Wats. and Coult. in Gray, Man. ed. 6, 472 (1889), in part, not *B. papyracea* var. *minor*, Tuck.—LABRADOR and NEWFOUNDLAND to NEW BRUNSWICK, MAINE, NEW HAMPSHIRE, LAKE SUPERIOR, IOWA, ALBERTA, BRITISH COLUMBIA, IDAHO, and WASHINGTON.

B. ALBA, var. MINOR. *B. davurica*, Ledeb., Fl. Alt. iv, 245 (1833), not Pallas. *B. papyracea*, var. *minor*, Tuckerman, this Journal, xlv, 31 (1843). *B. tortuosa*, Ledeb., Fl. Ross. iii, 652 (1849). *B. odorata*, var. *alpigena*, Blytt, Norg. Fl. 402 (1861). *B. alba*, subsp. *tortuosa*, Regel, in DC., l. c. 168 (1864). *B. davurica*, *β*, *americana*, Regel, l. c. 175 (1864). *B. odorata*, var. *tortuosa*, Lange, Fl. Dan. xvii, 10, t. 2918 (1877). *B. papyrifera*, var. *minor*, Wats. and Coult. l. c., in part. *B. pubescens*, var. *tortuosa*, Koehne, Deutsche Dendr. 109 (1893).—LABRADOR to the mountains of MAINE, NEW HAMPSHIRE and VERMONT; mountains of SASKATCHEWAN, ASSINIBOIA, and ALBERTA; GREENLAND, ICELAND, LAPLAND, FINLAND, northern GERMANY, ALTAI MTS.; dwarf forms from ALASKA resemble this variety, but have the strongly resiniferous branchlets of *B. glandulosa* and *B. pendula*. (Pl. V, figs. 7–12.)

BETULA ALBA, var. CARPATICA. *B. carpatica*, Wald. and Kit. in Willd. Sp. iv, 464 (1805). *B. borealis*, Spach, Ann. Sci. Nat., ser. 2, xv, 196 (1841). *B. glutinosa*, Fries, Summ. Veg. Scand., 212 (1846), not Wallr. *B. pumila*, *γ*, *borealis*, Regel, Mon. Bet. 55, t. 13, figs. 38, 39 (1861). *B. alba*, subsp.

pubescens, ζ *carpatica*, Regel in DC., l. c. 168 (1864). *B. odorata*, var. *carpatica*, Lange, Haandb., ed. 3, 708 (1864). *B. odorata*, var. *rhombifolia*, Lange, Fl. Dan., xvi, t. 2851 (1871).—Anticosti, Quebec; Alberta; and northward; Scandinavia to Germany, Austria and Russia. (Pl. V. figs. 13–14.)

B. pendula, Roth, Fl. Germ. i, 405 (1788). *B. verrucosa*, Ehrh., Beitr. vi, 98 (1791). *B. alba*, var. *verrucosa*, Wallr., Sched. Crit., 495 (1822). *B. alba*, var. *vulgaris*, Spach, l. c. 186 (1841). *B. odorata*, Reichenb., Ic. Fl. Germ., xii, fig. 1288 (1850), not Bechst. *B. gummifera*, Bertol., Fl. It., x, 229 (1854). *B. alba*, subsp. *verrucosa*, *a*, *vulgaris* and δ, *resinifera* (in part), Regel in DC., l. c. 163, 164 (1864). *B. kenaica*. W. H. Evans, Bot. Gaz., xxvii, 481 (1899), in part. *B. alaskana*, Sargent, Bot. Gaz., xxxi, 236 (1901), mostly.—Quebec to Illinois, Alberta, Mackenzie and Alaska; Europe and Asia, widely distributed. (Pl. V, figs. 15–18; Pl. VI, figs. 19–22.)

B. pendula, var. japonica, Rehder in Bailey, Cyc. Am. Hort., i, 159 (1900). *B. japonica*, Siebold, Verh. Batav. Gen. xii, 25 (1830). *B. latifolia*, Tausch, Fl. Ratisb., 751 (1838). *B. alba*, subsp. *verrucosa*, δ *resinifera*, Regel in DC., l. c. 164, in part; subsp. *mandshurica* and *latifolia*, Regel, l. c. 165 (1864). *B. kenaica*, W. H. Evans, l. c. (1899), mostly. *B. alaskana*, Sargent, l. c. (1901), in part.—Sungaria to Japan, north to the Yenisei River, Siberia, and Kamtschatka; east to Peel River and Fort Simpson, Mackenzie, and along the Alaska coast; and apparently on the coast of Washington Co., Maine (trees sterile). (Pl. VI, figs. 23, 24.)

B. populifolia, Marshall, Arbust. Am., 19 (1785). *B. alba*, var. *populifolia*, Spach, Ann. Sci. Nat., ser. 2, xv, 187 (1841). *B. alba*, subsp. *populifolia*, Regel, in DC., l. c. 164 (1864).—Prince Edward Island to central Maine, southwestern Quebec, and western New York, south mostly on the coastal plain to Delaware.

B. microphylla, Bunge, St. Pétersb. Mém. Savans Étrang., ii (1835), 606—reprint, Fl. Alt. Suppl. 84. *B. occidentalis*, Nutt., Sylva, i, 22, t. 7 (1842), not Hook. *B. rhombifolia*, Nutt., l. c. 24, t. 8, not Tausch. *B. fruticosa*, var. *cuneifolia*, Regel, Mon. Bet. (1861) 35, t. 7, figs. 16–23. *B. alba*. subsp. *soongorica*, Regel, Bull. Soc. Imp. Nat. Mosc., vi, (1868)—reprint, Enum. Pl. Semenow (1869) 99. *B. fontinalis*, Sargent, Bot. Gaz. xxxi, 23 (1901).—In the mountains from Alaska to northern California, Saskatchewan, South Dakota, and New Mexico; Altai and Tyan Shan Mts., central Asia. (Pl. VI, figs. 25–32.)

B. nana, L., var. Michauxii, Regel, Mon. Bet. (1861), 45. *B. Michauxii*, Spach, l. c. 195 (1841). *Apterocaryon Michauxii*, Opiz, Lotos, v (1855), 258.—Hudson Bay, Labrador and Newfoundland. (Pl. VI, figs. 47, 48.)

B. PUMILA, L., Mant. 124 (1767). *B. alpestris*, Fries, Summ. Veg. Scand., i, 212 (1846). *B. fruticosa*, var. *humilis*, Reichenb. Ic. Fl. Germ., xii, fig. 1280 (1850). *B. nana* var. *alpestris*, Regel, Mon. Bet. 45 (1861). *B. Grayi*, Regel, Bull. Soc. Imp. Nat. Mosc., xxxviii, 406, t. 6, figs. 9–13 (1865).—LABRADOR and NEWFOUNDLAND to ONTARIO, south to Morris Co., NEW JERSEY, Champaign Co., OHIO, Lake Co., INDIANA, and McHenry Co., ILLINOIS; GREENLAND, SCANDINAVIA, northern GERMANY, FINLAND, LAPLAND, RUSSIA, SIBERIA. (Pl. VI, figs. 33–38.)

B. PUMILA, var. GLANDULIFERA, Regel in DC., l. c. 173 (1864).—ONTARIO and MICHIGAN to MINNESOTA, SASKATCHEWAN and BRITISH COLUMBIA, south in the mountains to IDAHO and OREGON.

B. GLANDULOSA, Michx., Fl. Bor.-Am., ii, 180 (1803). *B. nana* of various American authors, not L. *B. Littelliana*, Tuckerman, this Journal, xlv, 30 (1843).—GREENLAND and HUDSON STRAITS to KAMTSCHATKA, and the Altai Mts. of SIBERIA; south in eastern America to the higher mountains of MAINE and NEW HAMPSHIRE; in the interior to LAKE SUPERIOR and MANITOBA; and in the western mountains to SOUTH DAKOTA, COLORADO, UTAH, and northern CALIFORNIA. (Pl. VI, figs. 39, 40.)

B. GLANDULOSA, var. ROTUNDIFOLIA, Regel in DC., l. c. 172 (1864). *B. rotundifolia*, Spach, l. c. 194 (1841). *B. nana*, var. *sibirica*, Ledeb., Fl. Ross., iii, 654 (1849).—GREENLAND and northern LABRADOR to KAMTSCHATKA, and the Altai Mts. of SIBERIA, south to the higher mountains of MAINE and NEW HAMPSHIRE, and along the coast of ALASKA. Perhaps hybridizing with *B. pendula*. (Pl. VI, figs. 41–44.)

EXPLANATION OF PLATES.*

PLATE V, figs. 1–6, BETULA ALBA.

FIGURE 1.—Leaf of young flowering branch of *B. pubescens*, Ehrh., from the Vosges Mts., near Rambervilles, France (*Joad*).
FIGURE 2.—Leaf of fruiting branch of *B. papyrifera*, Marsh., from Lake Winnipeg, Manitoba (*Bourgeau*).
FIGURE 3.—Leaf of fruiting branch of *B. occidentalis*, Hook., from Pend d'Oreille River, British Columbia (*Lyall*).
FIGURE 4.—Leaf of young branch of *B. pubescens*, Ehrh., from Bohemia (Tausch).
FIGURE 5.—Leaf of fruiting branch of *B. papyrifera*, Marsh., from Southport, Maine (*Fernald*).
FIGURE 6.—Leaf of fruiting branch from Austria—after Ettingshausen and Pokorny, Phys. Pl. Aust. iii, t. 201.

PLATE V, figs. 7 to 12, B. ALBA, var. MINOR.

FIGURE 7.—Leaf of fruiting branch of *B. tortuosa*, Ledeb., from the Altai Mts., Siberia (ex. herb. St. Petersb.).
FIGURE 8.—Leaf of fruiting branch of *B. odorata*, var. *tortuosa*, Lange, from the Dovre Mts., Norway—after Lange, Fl. Dan. xvii, t. 2918.
FIGURES 9, 10.—Leaves of original fruiting branches of *B. papyracea*, var. *minor*, Tuck., from Mt. Washington, New Hampshire.
FIGURE 11.—Leaf of dwarf form of *B. papyracea*, var. *minor*, Tuck., from Mt. Washington, New Hampshire (*Faxon*).
FIGURE 12.—Leaf of fruiting branch of *B. odorata*, var. *minor*, Rosenvinge in herb., from Greenland (*Hartz*).

PLATE V, figs. 13, 14, B. ALBA var. CARPATICA.

FIGURE 13.—Leaf of fruiting branch of *B. borealis*, Spach, from Anticosti, Quebec (*Macoun*).
FIGURE 14.—Leaf of *B. alba*, subsp. *pubescens*, ζ *carpatica*, Regel, from Lapland (*Regel*).

PLATE V, figs. 15 to 18, PLATE VI, figs. 19 to 22, B. PENDULA.

FIGURES 15, 17.—Leaves of young flowering branch of *B. alba*, subsp. *verrucosa*, δ *resinifera*, Regel (type of *B. alaskana*, Sargent) from Saskatchewan (*Bourgeau*).
FIGURES 16, 18.—Leaves of fruiting branch of *B. verrucosa*, Ehrh., from Christiania, Norway (*Blytt*).
FIGURE 19.—Leaf of fruiting branch of *B. pendula*, from Warren, Illinois (*L. M. Umbach*, sheet No. 351,017 U. S. Nat. Herb.).
FIGURE 20.—Leaf of fruiting branch from Gotland, Sweden (*Blomberg*).
FIGURE 21.—Leaf of *B. alba*, subsp. *mandshurica*, Regel, from Mandschuria—after the original illustration (Regel, Bull. Soc. Imp. Nat. Mosc., 1865, t. 7, fig. 15).
FIGURE 22.—Leaf of fruiting branch of *B. verrucosa*, δ *resinifera*, Regel, from Nushagak River, Yukon District, Alaska (*McKay*).

PLATE VI, figs. 23, 24, B. PENDULA, var. JAPONICA.

FIGURE 23.—Leaf of *B. alba*, subsp. *latifolia*, *a Tauschii*, Regel, from Eastern Asia—after Regel, Bull. Soc. Imp. Nat. Mosc., 1865, t. 7, fig. 11.
FIGURE 24.—Leaf of *B. kenaica*, W. H. Evans, from Cook Inlet, Alaska (*Coville and Kearney*, No. 2412).

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* The plates illustrating this paper have been carefully prepared by Mr. F. Schuyler Mathews. Unless otherwise stated, the figures are life-sized.

Plate VI, figs. 25 to 32, B. MICROPHYLLA.

FIGURE 25.—Leaf of young shoot of *B. microphylla* from the Altai Mts., Siberia (ex. herb. St. Petersberg).

FIGURE 26.—Leaf of *B. fruticosa*, var. *cuneifolia*, Regel (syn. *B. microphylla*, Bunge) from the Altai Mts., Siberia—after Regel, Mon. Bet. (1861) t. 7, fig. 18.

FIGURE 27.—Leaf of fruiting branch of *B. occidentalis*, Nutt. (*B. fontinalis*, Sargent) from Idaho Springs, Colorado (*Engelmann*).

FIGURE 28.—Small leaf from fruiting branch of *B. occidentalis*, Nutt. (*B. fontinalis*, Sargent) from Coulee City, Washington (*Lake and Hull*, No. 790).

FIGURE 29.—Leaf of young shoot of *B. occidentalis*, Nutt. (*B. fontinalis*, Sargent) from the Black Hills, South Dakota (*Rydberg*, No. 1006).

FIGURE 30.—Leaf of fruiting branch of original material of *B. alba*, subsp. *soongorica*, *β microphylla*, Regel, from the Tyan Shan Mts., Central Asia (Semenow).

FIGURES 31, 32.—Leaves of fruiting branch of *B. occidentalis*, Nutt. (*B. fontinalis*, Sargent) from Laramie Peak, Wyoming (*A. Nelson*, No. 1647).

Plate VI, figs. 33 to 38, B. PUMILA.

FIGURE 33.—Leaf of sterile shoot of *B. pumila* from Anticosti, Quebec (*Macoun*).

FIGURE 34.—Leaf of sterile shoot of *B. alpestris*, Fries, from Lapland (*Laestadius*).

FIGURE 35.—Tip of branch from Bonne Espérance, Quebec (*Allen*, No. 70).

FIGURE 36.—Leaves of glabrate form from Bay of Islands, Newfoundland (*Waghorne*).

FIGURE 37.—Leaves of *B. alpestris*, Fries, from Norway—after Lange, Fl. Dan., Suppl. t. 37.

FIGURE 38.—Leaves of young branch of *B. alpestris*, Fries, from Lapland (*Andersson*, No. 186).

Plate VI, figs. 39, 40, B. GLANDULOSA.

FIGURE 39.—Leaf of branch from Mt. Washington, New Hampshire (*J. A. Allen*).

FIGURE 40.—Leaves of branch from Hopedale, Labrador (*Sornborger*, No. 80).

Plate VI, figs. 41 to 44, B. GLANDULOSA, var. ROTUNDIFOLIA.

FIGURE 41.—Leaf from Mt. Washington, New Hampshire.

FIGURES 42, 43.—Leaves from Nunivak Island, Behring Sea (*J. M. Macoun*).

FIGURE 44.—Leaf from the Altai Mts., Siberia (ex. herb. St. Petersb.).

Plate VI, figs. 45, 46, B. NANA.

FIGURE 45.—Fruiting branch from Grenjadastad, Iceland (*Elizabeth Taylor*).

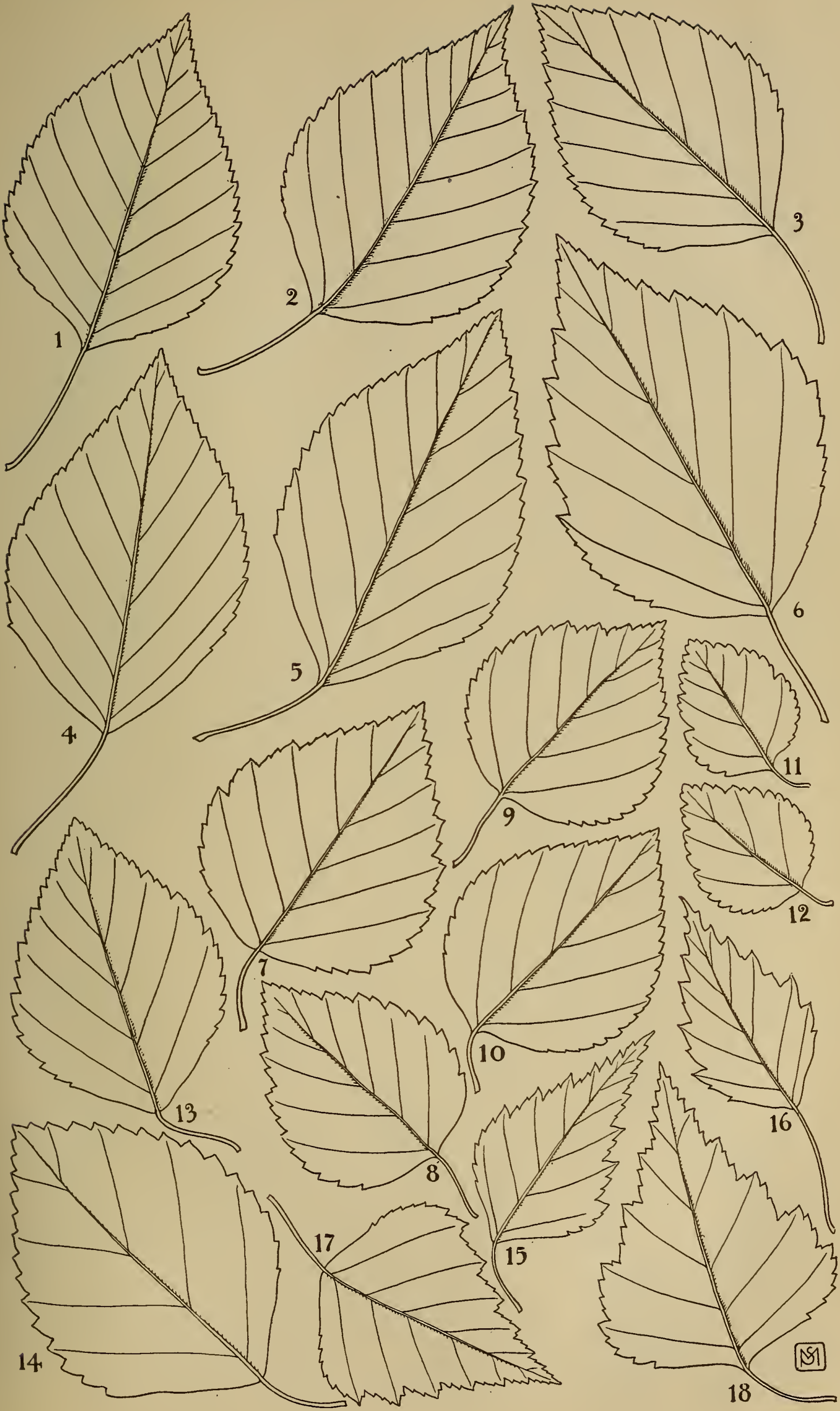
FIGURE 46.—Scale from same, enlarged three times.

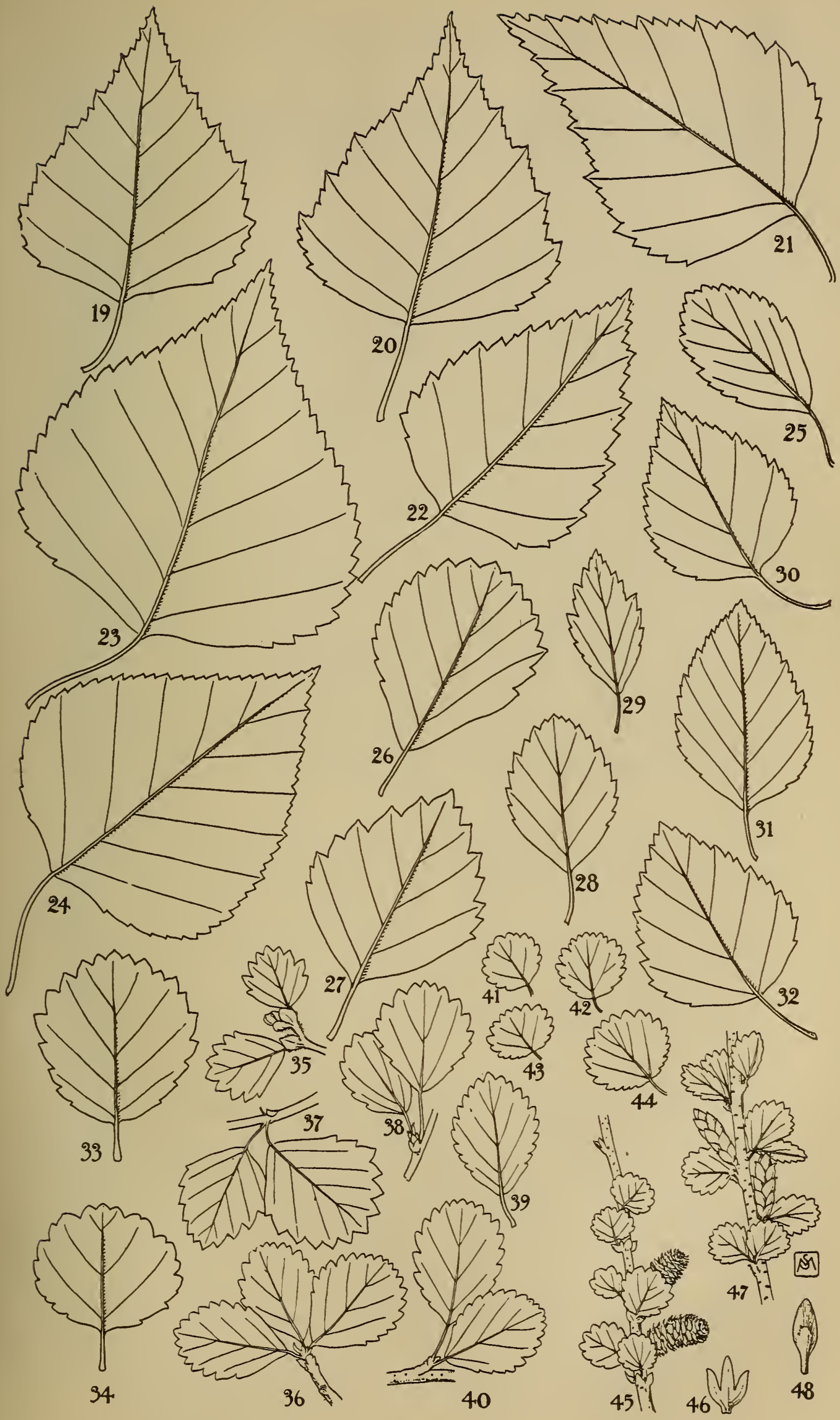
Plate VI, figs. 47, 48, B. NANA, var. MICHAUXII.

FIGURE 47.—Fruiting branch from Grand Lake, Newfoundland (*Waghorne*).

FIGURE 48.—Scale from same, enlarged three times.

Plate V.

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Art. XXII.—*On the Fertile Fronds of Crossotheca and Myriotheca, and on the Spores of other Carboniferous Ferns, from Mazon Creek, Illinois;* by E. H. Sellards. (With Plate VII.)

Information in regard to the spore-bearing organs of Carboniferous ferns has accumulated slowly and with difficulty. The parts of the plants are usually disconnected, and more or less fragmentary. Dimorphic genera are not uncommon, and specimens connecting the fertile and sterile segments or fronds are rare. It is usually difficult to correlate genera described from microscopic structure with others based on plant impressions. And yet, a satisfactory knowledge of a considerable number of genera and species has resulted from the work of the various investigators who have taken up this subject since the time of Brongniart. These investigations indicate that ferns with the annulus absent or but slightly developed, and having other Marattiaceous characters, predominated in the Carboniferous, and included a much greater range of form and structure than is seen in the living representatives of the family. Besides the numerous exannulate ferns, others are known with a well-developed annulus, and are, therefore, presumably Leptosporangiate. The reference of these fossils to their respective families of living ferns is attended with more or less doubt. The Hymenophyllaceæ, Gleicheniaceæ, Schizæaceæ, and Osmundaceæ have been recognized with some degree of certainty.

Prof. Renault, of the Museum of Natural History of Paris, has recently described *Parkerioidea* Renault, a genus from the Coal Measures of Grand' Croix, near St. Étienne. The character of the annulus, the form of the spores, and the ornamentation of the exospore have led him to refer this form to the Parkeriaceæ. Certain of the spores show sculpturing, while others are smooth and have three radiating lines at the apex. The former are interpreted as microspores, the latter as megaspores.*

The same writer had previously detected what he believed to be indications of heterospory in *Pecopteris*, one of the Marattiaceous ferns,† as well as in an extinct family of ferns, the Botryopterideæ.‡ The evidence of heterospory in the Botryopterideæ has not been fully accepted.§ The papers on *Pecopteris* and *Parkerioidea* are mentioned more fully later in the present article, where, in connection with the descrip-

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* Comptes Rendus de l'Academie des Sciences, March 10, 1891.

† Ibid., October 21, 1891.

‡ Bull. Soc. Hist. Nat., Autun., iv, 1891.

§ See Scott, Studies in Fossil Botany, p. 289; Zeiller, Éléments de Paléobotanique, p. 74.

tion of the spores of some Carboniferous ferns, it is pointed out that, as far as the radiating lines ("lines of dehiscence") at the apex are concerned, they cannot be considered characteristic of megaspores.

The fructification of several genera of Carboniferous ferns is well shown in an exceptionally large and complete collection from Mazon Creek, Illinois, in the Yale Museum. The sporangia are often preserved, and in many cases the spores are found in place, and can be removed and studied. In the present paper the Mazon Creek representatives of two interesting genera, *Crossotheca* and *Myriotheca*, will be described, together with the spores of some other species.

In the earlier American literature many of the fertile ferns were grouped together without sufficient regard to their true generic separation. *Sorocladus*, as established by Lesquereux,* was so broadly defined as to include more than one natural genus. *S. stellatus* was the first of the five species described under the genus. Four of the species referred in the "Coal Flora" to *Sorocladus* had been previously placed by Lesquereux in the Tertiary *Staphylopteris* Presl. It was probably Schimper's objection to considering these forms under Presl's genus that led Lesquereux to create a separate genus for them.†

One of the five original species of *Sorocladus*, *S. ophioglossoides*, has been referred by David White to *Crossotheca*, and *S. sagittatus* was recognized as falling naturally within the same genus.‡

Crossotheca.

Zeiller, Ann. Sci. Nat. (Bot.), ser. 6, vol. xvi, 1883.

Crossotheca is a genus of more than ordinary interest, because of its dimorphic fronds, its large marginal sporangia, and large spores. Several species are known in Europe, all of Coal Measure and Permian age. Besides the two species just mentioned from this country, a third is added in the present paper.

Crossotheca sagittata.

Plate VII, figures 1–3*c*, 8.

Staphylopteris sagittatus Lesq., Geol. Surv. Ill., vol. iv, p. 407, pl. xiv, figs. 4–6, 1870.

Pecopteris abbreviata Brongn. ? Lesq., Geol. Surv. Ill., vol. iv, p. 403, 1870; Second Geol. Surv. Penn., Description of the Coal Flora, vol. i, p. 248, pl. xlvi, figs. 4–6*a*, 1880.

Sorocladus sagittatus Lesq., Coal Flora, vol. i, p. 329, 1880; Atlas, pl. xlviii, figs. 10–10*b*, 1879; vol. iii, p. 761, pl. C, figs. 4–5, 1884.

Pecopteris Fontainei, Lesley's Dict. of the Fossils of Penn., p. 606, 1889 text figure. See, also, Lesquereux, unpublished manuscript.

* Second Geol. Surv. Penn., Description of the Coal Flora, vol. i, p. 327, 1880.

† Paléont. végét., vol. iii, p. 512.

‡ Mon. U. S. Geol. Surv., No. 37, Flora of the Lower Coal Measures of Missouri, pp. 60–64, 1899.

Crossotheca sagittata preserves the details of fructification much better than the other American species, and illustrates well the characters of the genus. The large fertile pinnules are expanded at the base in the form of an arrow, thus allowing greater area for the attachment of the sporangia. The small pinnules are slightly or not at all enlarged at the base. The upper surface of the pinnule is flat with a distinct median line, and with the lateral veins obscured. The sporangia are unusually large, measuring $2\frac{1}{2}$ to 4^{mm} in length and $\frac{1}{2}$ to $\frac{3}{4}^{mm}$ wide. They are placed as seen in figures 1, 2, and 3, in a single row around the entire border of the pinnule, free nearly or quite to the base, and are often seen filled with spores.

Figure 2 gives a side view of the pinnule as partly freed from the matrix, and showing the full length of the sporangia.

From a study of the type of the genus, Prof. Zeiller thought it probable that the sporangia were united in little clusters at the ends of the nerves. The specimens figured and others in the Yale collection indicate that in the case of *C. sagittata*, at least, the sporangia are attached side by side in a single row, without any tendency toward grouping. The same specimens confirm the statements of Zeiller that these are individual sporangia, since, in the specimens at hand, they are often filled with spores, in contradistinction to Stur's interpretation of the fringed pinnules as dehisced sporocarps.*

Some of the best preserved sporangia show a slit on the outer side, as seen in figure 3*a*, which probably indicates the place of dehiscence.

The sterile part of the frond is very different from the fertile, so much so that if not found in direct connection their relation would hardly be suspected. The pinnules are small, rounded, close, oblique, connate, and decurrent at the base, the smaller entire, the larger becoming lobate. The ultimate pinnæ are broadly linear-lanceolate, alternate, oblique, and close, often touching. The rachis is large and round. The midrib of the pinnule is broad, shallow, and decurrent. The lateral veins curve regularly to the border, and fork once, twice, or three times, according to the size of the pinnule. The surface is rough, appearing minutely scaly. Some of the veins are heavier than others, giving the venation an irregular appearance.

The extreme apex of the frond is often sterile, the fertile pinnules and pinnæ appearing at some distance below. This is not always the case, however, since in the frond figured by Lesquereux ("Coal Flora," volume iii, pl. C, figure 4) the entire apical part is fertile. It is not possible to state, on any evi-

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* Abhandl. d. k. k. Geol. Reichsanstalt, Wien, 1885–87, Flora der Schatzlaren Schichten, Part I, pp. 273–275.

dence at hand, whether the entire frond below the apex was fertile, or only a few of its segments. There is no indication of sterile segments below the fertile ones, although some of the incomplete fronds reach a length of 15 or 16^{cm}. It is probable that some of the fronds were entirely sterile, and that others were mostly sporangia-bearing, the apical part only being, in most cases, sterile.

The spores of this species are large, from ·056 to ·060^{mm}, round, and marked at the apex by three distinct radiating lines. The exospore is thick, resistant, brownish, and marked by minute warty thickenings.

The sterile fronds were at first doubtfully referred by Lesquereux in the "Coal Flora" to *Pecopteris abbreviata* Brongn.* In volume iii of the same work, however, a small part of the sterile apex is figured in connection with the fertile frond, and David White states that Lesquereux's unpublished manuscript contains descriptions and figures of the two parts in connection.† In the Yale collection the fertile and sterile parts are shown in direct connection in no less than nine instances. (See figure 8.)

Crossotheca trisecta sp. n.

Plate VII, figures 4–4c, 9.

A second and apparently new species is present in the material from Mazon Creek. The sterile part of the frond is much like that of *C. sagittata*, but the fertile pinnules are entirely different. The latter are usually trisectate. The central lobe is elongate-ovate, or nearly round, and borne at the end of a slender stalk. The lateral lobes are smaller, round, and borne on short lateral stalks. A second pair is sometimes borne by the larger pinnules. Lateral lobes may be lacking in one or two pinnules near the apex of the pinna. The sporangia are probably smaller than those of *C. sagittata*, and are not distinctly preserved on either of the two fertile fronds in the present collection. The sporangia-bearing lobes have a form much like that of the type of the genus *C. Crépini*, but the type species lacks the trilobate appearance of the pinnules, and has more finely divided sterile fronds having a different type of venation.‡ *C. ophioglossoides* from Clinton, Missouri, has narrower and longer fertile pinnules.

The lines on the upper surface of the pinnule, present on other species of the genus, are much more distinct than on *C.*

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* Second Geol. Surv. of Penn., Description of the Coal Flora, vol. i, p. 248; Atlas, pl. 46, figs. 4–6, 1880.

† Mr. White informs the writer that the name *Pecopteris Fontainei*, sp. nov., is given to the sterile fronds of this species in Lesquereux's manuscript.

‡ See the figures of *C. Crépini* given by Zeiller, Ann. Sci. Nat. (Bot.), ser. 6, vol. xvi, 1883, and by Stur under the name of *Sorotheca Crépini*, Flora der Schatzlaren Schichten, pl. xxxv, figs. 3, 4.

sagittata, and sometimes branch. The figured specimen is 15^{cm} long; the first 5 or 6^{cm} are sterile, the remaining pinnæ being partly or entirely fertile. When detached and in fragments the sterile part of the frond is distinguished with difficulty from that of *C. sagittata*. The pinnules are perhaps more finely lobate.

The spores are smaller than those of *C. sagittata*, measuring from ·030 to $·036^{mm}$. They are somewhat triangular, with a smooth, thin exospore.

The name *Crossotheca trisecta* is suggested for the species.

Myriotheca.

Zeiller, Ann. Sci. Nat. (Bot.), ser. 6, vol. xvi, 1883.

Myriotheca has numerons independent, sessile, round or egg-shaped sporangia, covering the entire lower surface of the pinnule. The genus is represented at Mazon Creek by a single species, which apparently is the fern described by Lesquereux from Morris, Ill., as *Sphenopteris scaberrima*,* although the rachis is smooth or striate, not punctate as given for that species. The round sporangia are very numerous, close, or almost contiguous, half immersed in the leaf substance, and cover the entire lower surface without any kind of regularity of arrangement or grouping. The spores are of medium size, measuring from ·036 to $·040^{mm}$, triangular, with the sides sometimes slightly concave. The genus is a rare one both in Europe and in America. No other species has been reported from this country. The genus was founded by Zeiller on a single fragment from the Coal Measures of France. The European specimen representing the type species, *M. Desaillyi*, has smaller pinnules with a tendency to become lobate. The sporangia of the American species are nearly round, and larger than those of the European species, measuring ·40 to $·50^{mm}$.

Because of the absence of any indication of an annulus, Prof. Zeiller included both *Crossotheca* and *Myriotheca* with the Marattiaceæ. The large size of the spores and comparatively small output to the sporangium are, however, characters not met with in the living representatives of that group. The position of the sporangia, marginal in *Crossotheca*, and covering the whole lower surface of *Myriotheca*, is unusual for Marattiaceous ferns.

Spores of other Ferns from the same Locality.

At least four other species of ferns in the Yale collection have the spores preserved. All retain their natural brown color, and something of their food contents, and, as far as appearances are concerned, might be spores from living plants.

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* Geol. Surv. of Illinois, vol. iv, p. 408, pl. xv, figs. 1 and 2, 1870.

Some of the larger spores have granular bodies within or clinging to them, which show a dark spot at the center and something of the structure of concentric starch grains.

The spores from a large number of fronds of two species have been examined in order to find whether or not there were indications of more than one kind of spores. The species studied were *Pecopteris* (*Ptychocarpus*) *unita* Brongn., and the form referred doubtfully by Lesquereux to *P. villosa* Brongn.,* which probably belongs to the *Asterotheca* division of *Pecopteris.* Both species are extremely abundant at Mazon Creek, and the sporangia-bearing fronds numerous. The spores of *P. villosa* are small, measuring only ·013 to ·016^{mm}, smooth and spherical. The exospore is very thin. The spores of the European examples of *P. unita* have already been made known by Renault.† The spores of the specimens at hand are ·016 to ·018^{mm} long, and ·010 to ·011 wide, being elongate or bean-shaped when seen from the side. The exospore is thick and smooth. The three radiating lines at the apex can be seen on some spores. As in other Marattiaceous ferns, the spore output to the sporangium in both species was evidently very great. The spores from many specimens of both species and from various parts of the same specimen present no differences in structure, size, or sculpturing, that could be interpreted as indicating two kinds of spores. It is, therefore, practically certain that both were homosporous, and this is exactly what might be expected in typically Marattiaceous ferns. The fact is of interest in connection with Renault's paper referred to above, in which unusual conditions are observed in one of the European species of *Pecopteris.* The fern described by Renault, which is of the *Asterotheca* division or sub-genus of *Pecopteris*, has one set of spores which are smooth and marked at the apex by three radiating lines. These are considered megaspores. In the same sorus, and possibly in the same sporangium, are other spores of about the same size, thought to be microspores, which lack the lines at the apex and show structures interpreted as the mother cells of antherozoids.

The second paper by the same author describes somewhat similar appearances in *Parkerioidea.* The megaspores are smooth and show the triradiate lines at the apex. The microspores, found in the same sporangium, lack the lines, and are sculptured with a polygonal network.

The three radiating lines are seen on the spores of all the ferns examined by the writer, when viewed from the apex, and

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* According to Mr. Robert Kidston, Fossil Flora of the Radstock Series, Trans. Roy. Soc. Edinburgh, vol. xxxiii, Part II, 1886-7, p. 37, *P. villosa* has a doubtful existence, having been established in all probability on a villous specimen of *P. oreopteridia* or a closely related species.

† Bassin Houiller et Permien d'Autun et d'Epinoe, Pt. II, p. 10.

on both micro- and megaspores of *Selaginella*, and the Carboniferous Lycopods, as well as on such heterosporous living ferns as *Marsilea*. The tetrahedral division of the spore mother cell, of which the three radiating lines are indicative, is well known to be extremely constant, not only for the Pteridophytes, but for all those plants commonly grouped under the Archegoniateæ, and for the microspores of most of the flowering plants.*

The lines, therefore, cannot be considered characteristic of, or in any way distinguishing megaspores. Their absence in some cases may be due to imperfect preservation, or they may be obscured by the view of the spore presented. In the case of *Parkerioidea*, there is some doubt as to whether it is not possible that the spores when seen from the apex present the lines and a smooth face, and when seen from the base are sculptured, the lines being obscured by the thickness of the spore.

The recent studies of Prof. Bower† have directed attention to the importance of the size of the spores and the number to the sporangium. Bower's investigations show that among living ferns an increase in the size of the spores, correlated with a decrease in the output to the sporangium, accompanies, in a general way, the advance in development and specialization from the Marattiaceæ through the various families of the Leptosporangiate ferns. The little that is definitely known of the spores of fossil ferns supports Bower's conclusions. It is a question, however, how far the size and number of the spores may be relied upon to separate Marattiaceous from non-Marattiaceous ferns.

The spores of *Pecopteris villosa* are smaller than those of such living Marattiaceæ as *Angiopteris evecta*, *Kaulfussia*, *Marattia Douglassii*, or *Danæa moritziana*. *Crossotheca* and *Myriotheca* have much larger spores, comparable in size to many of the Leptosporangiate ferns. It is hardly possible, with fossil ferns, to count the number of spores to the sporangium, but it is evident that in the case of *Pecopteris unita* and *P. villosa*, the output to the sporangium was very great, while that of *Crossotheca* and *Myriotheca* was comparatively small.

Geological Department, Yale University Museum.

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* See Campbell, University Text-book of Botany, 1902, pp. 199 and 323.

† Studies in the Morphology of Spore-Producing Members, Parts III and IV, Phil. Trans. Roy. Soc., vol. clxxxix, 1897, pp. 35–81; vol. cxcii, 1899, pp. 29–138.

EXPLANATION OF PLATE VII.

FIGURE 1.—*Crossotheca sagittata;* part of a fertile frond. The lower and the upper pinnules on the right hand side show the expanded base. The second pinnule from the base on the same side gives the full length of the sporangia. × 1½.
FIGURE 2.—Same species; a pinnule with the matrix removed to show the full length of the sporangia. × 2.
FIGURE 3.—Same species; a medium sized pinnule seen from the base and side. × 2.
FIGURE 3*a*.—A single sporangium. × 4.
FIGURE 3*b*.—Spores of the same species. × 240.
FIGURE 3*c*.—Cross section of a fertile pinnule with sporangia. × 2.
FIGURE 4.—*Crossotheca trisecta* sp. n.; fertile and sterile parts of frond. × ½.
FIGURES 4*a*, 4*b*.—Fertile pinnules of *C. trisecta.*
FIGURE 4*c*.—Spore of *C. trisecta.* × 240.
FIGURE 5.—*Myriotheca scaberrima;* fertile pinnules. × 2.
FIGURES 5*a*–5*c*.—Spores of the same species. × 240.
FIGURES 5*d*, 5*e*.—Starch grains from the spores of the same species. × 240.
FIGURES 6*a*–6*d*.—Spores of *Pecopteris villosa.* × 240.
FIGURE 7.—*Pecopteris unita;* fertile pinna. × 2.
FIGURES 7*a*–7*d*.—Spores of the same species. × 240.
FIGURE 8.—*Crossotheca sagittata;* fertile and sterile parts in connection. [× 1½.
FIGURE 9.—*Crossotheca trisecta;* sterile pinnule. × 2.

4c

5d

6a

6b

6c

6d

7a

7b

7c

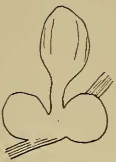
7d

4a

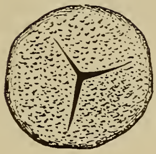
5c

5e

4b



3b



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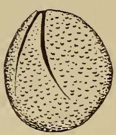
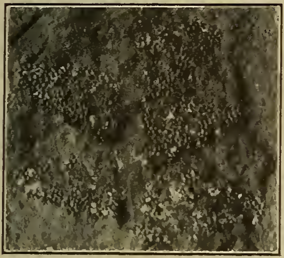


5b

5a

5



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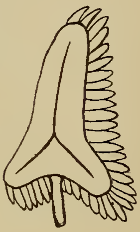
3a

3c

3



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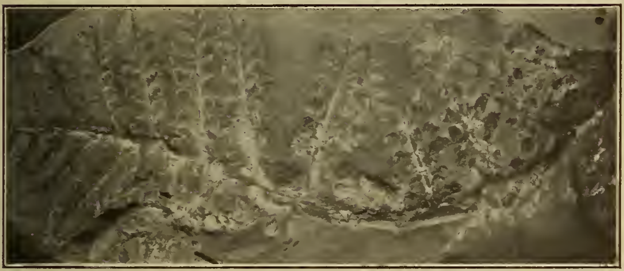

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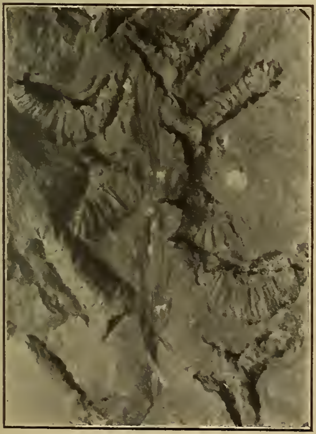

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Carboniferous Ferns.

Art. XXIII.—*On the Validity of Idiophyllum rotundifolium Lesquereux, a Fossil Plant from the Coal Measures at Mazon Creek, Illinois*; by E. H. Sellards.

The genus *Idiophyllum* was proposed by Lesquereux for a species of Carboniferous plants represented by a single specimen from Mazon Creek, Illinois.*

The species *I. rotundifolium* appeared to present characters so peculiar that the genus was placed by Lesquereux in his classification with the "Ferns of Uncertain Relation," and was compared with *Dictyophyllum*, and with dicotyledonous leaves.

1

Figure 1.—Obverse of the type of *Idiophyllum rotundifolium* Lesqx.

In working over a large collection of plants from the same locality, in the Yale Museum, the writer has found the obverse side of Lesquereux's type. The obverse (figure 1) is well preserved, and completely demonstrates the true nature of the plant. The fossil represents the distorted apical part of a young and not fully expanded fern frond. The tip is pushed to one side, crowding the lateral pinnæ and partly obscuring the outline of the pinnules. The pinnules, however, are much more distinct than is represented in Lesquereux's figure of the counterpart. They are 6 to 10^{mm} in length, 3 to $3\frac{1}{2}^{mm}$ in width, alternate, obtuse, and somewhat cordate at the basal attachment. The rachis is longitudinally striate; the lateral pinnæ are close, oblique, and alternate. In all these characters *Idiophyllum rotundifolium* agrees with *Neuropteris rarinervis* Bunb., a

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* Second Geol. Surv. Penn., Description of the Coal Flora, vol. i, p. 159; Atlas, pl. xxiii, fig. 11, 1880.

species common at the locality. The outline and cordate base of the pinnules, and especially the faint indication of lobation of the upper border, just above the base (figure 2), are characters of *N. rarinervis.* Although the lateral nervation is mostly obscured, there can be little doubt regarding the specific identity. The lateral venation shown in figure 2 is taken from several pinnules. The lateral pinnæ are somewhat more crowded than is usual for *N. rarinervis*, a condition explained by the immaturity of the frond. The plant is a difficult object to photograph, but the figure here given will perhaps help to clear up some of the peculiarities attributed to the fossil. The appearance of nerves "sometimes crossing each other in contrary directions and forming by intervention regular quadrate or rhomboidal meshes" is caused by the crowding and overlapping of the pinnules.

2

FIGURE 2.—A single pinnule; showing the characters of *Neuropteris rarinervis* Bunb.; taken from the right side of the specimen. × 2.

Altogether, it seems evident that the species *Idiophyllum rotundifolium* is a synonym of *Neuropteris rarinervis*, and that the genus *Idiophyllum* has no status in systematic fossil botany.

Through the courtesy of Mr. David White, the writer has recently had an opportunity of examining the type of *Idiophyllum rotundifolium*, now in the Lacoe Collection of the United States National Museum. The plant is not entirely freed from the matrix, the tips of the lateral pinnæ on the right side and at the top being still partly covered. Mr. White had also recognized that the fossil represents an immature frond, and agrees with the writer that it is *Neuropteris rarinervis.*

Yale University Museum, Geological Department.

ART. XXIV.—*The Precipitation of Ammonium Vanadate by Ammonium Chloride;* by F. A. GOOCH and R. D. GILBERT.

[Contributions from the Kent Chemical Laboratory of Yale University—CX.]

BERZELIUS was the first to point out and utilize in analysis the fact, that when a vanadate in concentrated solution is treated with a saturated solution of ammonium chloride, white insoluble ammonium metavanadate is deposited.* The method of treatment was modified by v. Hauer† in that solid ammonium chloride was added to the solution of the vanadate, as concentrated as possible, until it failed to dissolve, the mixture allowed to stand and then treated with a large amount of strong alcohol, the precipitate filtered off, washed with alcohol, dried, ignited in a covered platinum crucible until all ammonium chloride was volatilized, and the residue ignited carefully with ammonium nitrate. Roscoe‡ was unable to obtain exact quantitative results by this method on account of the solubility of the ammonium metavanadate in the alcoholic mixture and the danger of mechanical loss during the ignition. Holverscheit also, in testing v. Hauer's method,§ noted loss of vanadium, due to solubility of the ammonium vanadate in the alcoholic liquid, finding in every case vanadium in the filtrate by means of ammonium sulphide or by hydrogen dioxide. In the average of six determinations Holverscheit found a loss of 0·0015 grm. calculated as V_2O_5. Another modification of the method was proposed by Ditte,‖ who, finding that precipitation by an excess of ammonium chloride was complete in a solution made colorless by boiling with free ammonia, attributed the deficiency in the amount of V_2O_5 found after precipitation under the prescribed conditions, to volatilization of the vanadium during ignition under the influence of ammonium chloride, and endeavored to avoid liability to such error by making it certain that no ammonium chloride should remain with the metavanadate at the time of ignition. To this end, the solution made colorless by boiling with ammonia was cooled to 30°–40°, nearly saturated with ammonium chloride and finally treated with four or five times its volume of alcohol; the precipitate thus thrown down was filtered off, washed with absolute alcohol until free from ammonium chloride, dried and ignited, the carbonized residue having been washed with nitric acid before the final ignition. Holverscheit's criticism of Ditte's process consisted in showing that losses which may occur in the ignition, and

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* Ann. Phys. xcviii, 54, 1831.

† Jour. Prakt. Chem., lxix, 388.

‡ Ann. Chem. Suppl., viii, 101.

§ Inaug. Diss., Berlin, 1890, p. 11, et seq.

‖ Compt. Rend., civ, 982.

which were found to be trifling when care was used, are mechanical and not due to volatilization; and, secondly, that in his experience the average error of seven trials resulted in a loss of 0·0029 grm. whether upon 0·1398 grm. or 0·2796 grm. of V_2O_5. Holverscheit rejects both the method of v. Hauer and that of Ditte as inexact on account of the solubility of the ammonium metavanadate.

In 1883,* previous to the proposal of Ditte, Wolcott Gibbs applied in the determination of vanadic acid in the vanadio-molybdates (and sometimes in vanadio tungstates), another and much simpler modification of the method of Berzelius. Gibbs' method consists in boiling the double vanadate with ammonia (to convert the complex salt into a mixture of vanadate and molybdate), adding a saturated solution of ammonium chloride in large excess, concentrating the liquid kept alkaline with ammonia to a small volume, standing twenty-four hours, collecting the precipitated ammonium vanadate upon an asbestos filter in a perforated crucible, washing with a cold saturated solution of ammonium chloride, and, either igniting the precipitate and weighing the residue of V_2O_5 upon the asbestos, or dissolving the precipitate with boiling water, reducing to the condition of V_2O_4 and titrating by permanganate. This method is called in question by Rosenheim,† who gives analytical results of certain experiments which, according to Rosenheim's description, are not at all upon the lines laid down by Gibbs. In the first place nothing is said by Rosenheim as to concentrating the mixture to a relatively small volume after adding a saturated solution of ammonium chloride in very large excess; and in the second place Gibbs did not make the final washing with dilute alcohol, as Rosenheim says he did, but finished the washing with a cold saturated solution of pure ammonium chloride. Rosenheim's variation of the experimental procedure in these important particulars, vitiates his conclusions with regard to the precipitation of vanadic acid from solution by ammonium chloride, that "small amounts nevertheless remain, as Roscoe rightly affirms, in solution." Rosenheim's opinions of the method are echoed by Milch,‡ Liebert§ and Euler.‖

We have thought it desirable, therefore, to investigate anew the question as to whether the precipitation of ammonium metavanadate by ammonium chloride is complete enough to place that mode of separating vanadic acid from solutions of its salts within the list of good analytical methods.

The ammonium vanadate used in our experiments was ana-

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* Proc. Am. Acad., x, 242, 249; Am. Chem. Jour., v, 371, 378.

† Inaug. Diss., Berlin, 1888.

‡ Inaug. Diss., Berlin, 1887.

§ Inaug. Diss., Halle, 1891.

‖ Inaug. Diss., Berlin, 1895.

lyzed by the iodometric method of Holverscheit,* and found to contain 76·14 per cent of V_2O_5.

The ammonium chloride employed was shown to be pure and free from iron by heating a solution of it to boiling, adding bromine water and a slight excess of ammonia, and filtering. No residue whatever remained upon the filter.

In each experiment a weighed portion of ammonium vanadate was put in a small beaker and heated with about 25^{cc} of water and a few drops of ammonia upon the steam bath until solution was complete. To the solution were added 25^{cc} of a cold saturated solution of ammonium chloride and a few drops of ammonia. The mixture remained upon the steam bath, with addition from time to time of a little ammonia to keep the metavanadate of normal composition and colorless, until the volume had been reduced to about 25^{cc}, and was then cooled. On cooling, a small amount of ammonium chloride crystallized out, but only a little if the proportion had been properly adjusted. If too large an amount of ammonium chloride crystallized out, it was nearly redissolved by the cautious addition of ammonium hydroxide. The mixture was allowed to stand twenty-four hours to insure complete crystallization of the ammonium metavanadate, and was then filtered on a weighed asbestos filter and perforated crucible, the precipitate being transferred and washed with a cold saturated solution of ammonium chloride. Crucible and precipitate were heated, at first very gently to drive off the ammonium chloride without occasioning mechanical loss of the vanadium, and finally to redness and fusion of the pentoxide remaining. At the outset some difficulty was occasionally found in removing from the walls of the beaker the adherent crystals of ammonium vanadate, but this difficulty was overcome, in the experiments recorded, by the device of forming upon the walls of the beaker before using it a film of paraffin of extreme thinness by rinsing the beaker with a dilute solution of paraffin in naphtha (0·5 gram. of paraffin in 300^{cc} of naphtha) and allowing the naphtha to evaporate. Crystals of the vanadate adhering to the walls of the beaker thus previously prepared, are easily removed by means of the ordinary rubber or "policeman." Table I contains the record of six consecutive experiments made after some preliminary study of the method. The washings and filtrate were in several instances acidified with hydrochloric acid and tested with hydrogen dioxide without giving indication of the presence of vanadium.

These results are sufficient to show that the method of Gibbs is capable of yielding an analytical separation of value, but as Gibbs pointed out it is ordinarily preferable to estimate the

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* Inaug. Diss., Berlin, 1890, p. 49.

Table I.

NH_4VO_3 taken. grams.	V_2O_5 present. grams.	V_2O_5 found. grams.	Error. grams.
0·5	0·3807	0·3814	0·0007 +
0·5	"	0·3818	0·0011 +
0·5	"	0·3813	0·0006 +
0·5	"	0·3808	0·0001 +
0·5	"	0·3808	0·0001 +
0·5	"	0·3799	0·0008 —

vanadium by volumetric means rather than to go through the tedious and exacting process of ignition to recover the vanadium pentoxide. Gibbs used the method of reduction by hydrogen sulphide, and titration of the tetroxide by permanganate, but for the purpose of testing the method we have thought it best to use the same method for determining the metavanadate separated which was used to determine the composition of the vanadate taken, viz., Holverscheit's iodometric method. In the beginning some trouble was experienced in the proper handling of the separated vanadate for this purpose. To dissolve the precipitate in hot water introduced too much hot water into the distilling flask; filtering on paper and then putting paper and vanadate into the flask together introduced an error, due probably to the action of the freed bromine upon the paper. The difficulty was finally overcome satisfactorily by collecting and washing the separated ammonium metavanadate upon asbestos felt deposited upon a perforated platinum cone of considerable size,* rolling up the felt enclosing the crystals of vanadate, then putting asbestos and vanadium into the distillation flask, without addition of any water, ready for the addition of potassium bromide and hydrochloric acid according to Holverscheit. The use of so much asbestos made it difficult, however, to boil the mixture of acid, bromide, vanadium and asbestos, so recourse was taken to heating this mixture in the hot air chamber of a high temperature paraffin bath. The mass of asbestos made it necessary to use more hydrochloric acid to overcome the viscosity of the mixture, and the use of so much acid introduced the element of danger that the volatilization of the acid to the receiver containing potassium iodide might, in presence of air, set free iodine outside the reaction of the process; so the flask was connected with a carbon dioxide generator, and the operation was carried on in an atmosphere of carbon dioxide. With the exception of the paraffin bath substituted for the burner as a source of heat, the arrangement of the apparatus is shown in the accompanying figure. Following with 1·5 grams of potassium bromide, the introduction of asbestos and vanadate, the distillation flask B

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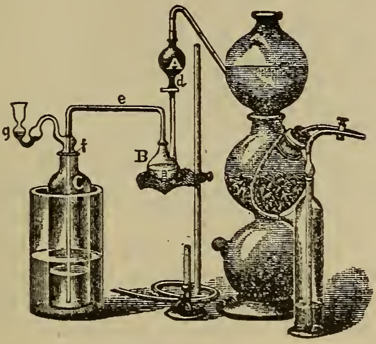
* Am. Chem. Jour., vol. i, p. 320.

was connected, as shown in the figure, with the receiver charged with a solution of 2·5 grms. of potassium iodide in boiled water, and the apparatus was filled with carbon dioxide. The stopcock of A was closed, the bulb of A was charged with 50$^{cm^3}$ of strong hydrochloric acid, the connection with the carbon dioxide generator was again made, with care to displace all residual air from the bulb. The acid was introduced into B by opening the stopcock and, in a gentle current of carbon dioxide, the heating was continued an hour after the development of color in the receiver showed that bromine was coming over from the flask. The iodine set free in the receiver was titrated with sodium thiosulphate standardized against iodine of value known by comparison with $\frac{n}{10}$ arsenious acid. The standard of the ammonium vanadate taken, as determined by the Holverscheit method in its simple form, was found to be unchanged when portions of the salt were treated according to the modification necessitated by the presence of so much asbestos in the trial tests, viz., in presence of more acid and in an atmosphere of carbon dioxide.



In this manner the determinations of the following table were made:

TABLE II.

NH_4VO_3 taken. grams.	Standard $Na_2S_2O_3$ used. cm^3	V_2O_5 found. grams.	Error. grams.
0·1000	8·35	0·0760	0·0001 –
0·1000	8·39	0·0764	0·0003 +
0·1000	8·38	0·0763	0·0002 +
0·1000	8·37	0·0962	0·0001 +
0·1000	8·32	0·0757	0·0004 –
0·1000	8·25	0·0751	0·0010 –
0·1000	8·36	0·0761	0·0000
0·1000	8·33	0·0758	0·0003 –

These results, representing determinations of the vanadium pentoxide in the ammonium metavanadate after separation by the same method used in determining the amount of pentoxide in the vanadate taken, abundantly confirm the conclusions reached by a consideration of the results of Table I.

So it appears that the criticism of Rosenheim, obviously made under a misapprehension of the details of the Gibbs method, to which Milch, Liebert and Euler give their acquiescence, is unfounded. The process of Gibbs gives a practically complete precipitation of ammonium vanadate, when to the solution of the soluble vanadate such an excess of ammonium chloride, with a little ammonia, is added, that the solution, after concentration and cooling, deposits ammonium chloride, and the mixture is allowed to stand twenty-four hours. Should too much ammonium chloride for convenient handling crystallize out on cooling, this is to be redissolved by the careful addition of ammonia; but care should be taken that after standing, a little solid ammonium chloride and free ammonia should still remain in the mixture. The precipitated ammonium vanadate is to be washed with a cold saturated solution of pure ammonium chloride, and the vanadium in the vanadate determined by any appropriate means. Volumetric processes are to be preferred to the slow ignition. We do not recommend as a suitable procedure for ordinary use the complicated modification of the Holverscheit method, which was employed in this investigation in order that the same method of determination of vanadium might be used before and after the separation process. Reduction as suggested by Gibbs, and titration by permanganate or the iodimetric estimation of Browning,* should be of service in ordinary cases.

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* Zeitschr. Anorg. Chem., vii, 158.

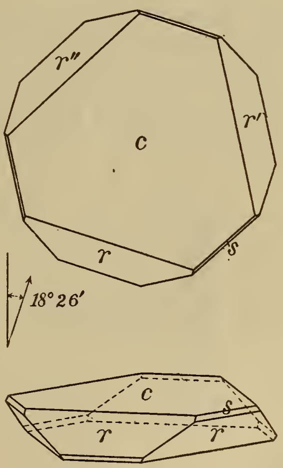
Art. XXV.—*Some Additions to the Alunite-Jarosite Group of Minerals*; by W. F. Hillebrand and S. L. Penfield.

Concerning two new varieties of jarosite which will be described in the present communication, one is from Nevada, and was collected by Mr. H. W. Turner of the United States Geological Survey and sent to the survey laboratory at Washington for identification; the other is from New Mexico, and was sent by Mr. J. H. Porter of Denver, Colorado, to the Mineralogical Laboratory of the Sheffield Scientific School. Except for slight differences in color the two minerals look exactly alike, each consisting of minute, isolated, tabular crystals, which, as may be seen with the microscope, consist of combinations of a rhombohedron with largely developed basal planes. By chance it happened that the present writers discovered that they were both engaged in the investigation of compounds belonging evidently to the same group, and it was decided to bring the results together into one paper.

Natrojarosite.

The material collected by Mr. Turner was obtained on the east side of Soda Springs Valley, Nevada, on the road from Sodaville to the Vulcan Copper Mine. It consists of a glistening powder, made up of perfect crystals having the habit shown in figure 1, although generally only one rhombohedron, *r*, is present instead of two, as shown in the figure. The largest crystals observed were 0·15^{mm} wide and 0·025^{mm} thick, and the general average would not be over half that size. In spite of being so minute, however, it was possible to measure the angles of the crystals with the reflection goniometer, the chief difficulty arising not so much from their small size as from the vicinal character of the basal planes. After repeated trials a crystal was found having a fairly good basal plane, and from this crystal the following angles were obtained:

1



		Measured.			Measured.	Calculated.
$c \wedge r$,	$0001 \wedge 10\bar{1}1$	=51° 53′*	$c \wedge s$,	$0001 \wedge 02\bar{2}1$	=68° 42′	68° 35′
$c \wedge r'$,	$0001 \wedge \bar{1}101$	=51 53	$c \wedge s'$,	$0001 \wedge \bar{2}021$	=68 48	" "
$c \wedge r''$,	$0001 \wedge 0\bar{1}11$	=52 26	$r \wedge r'$,	$10\bar{1}1 \wedge \bar{1}101$	=86 5	85 54

The crystals belong to the rhombohedral division of the hexagonal system, and the angle $c \wedge r$, 51° 53′, which is probably very nearly correct, has been assumed as fundamental, and from it the following axial ratio has been calculated :

$$c = 1{\cdot}104.$$

That the axial ratio as given is very near the truth is shown by the fact that the measurements of $c \wedge s$ and $r \wedge r$ do not vary many minutes from the calculated values; while on a number of other crystals, measurement of the angle $c \wedge r$, though varying considerably, was found to be not far from 52°. The angles of $c \wedge r$ and $r \wedge r'$ of the ordinary potassium jarosite are 55° 16′ and 90° 45′, respectively.

Under the microscope the crystals exhibit normal optical properties. Using a high power lens and convergent light, the thicker crystals show the dark cross and the beginnings of the first ring of the interference figure. The birefringence is negative. The color of single crystals, when seen under the microscope in transmitted light, is golden-yellow. Many of the crystals show numerous brown inclusions. The color shown by a mass of the crystals is yellowish-brown, and the material glistens, owing to reflections from the basal planes of the minute crystals.

The material used for the chemical analysis was the purest that could be obtained, although crystals containing the brownish inclusions just mentioned could not be avoided, and there were occasional brown ferruginous particles mixed with the crystals. The specific gravity of the material was found to be 3·18 at 30·5° C. The results of the analysis by Hillebrand are as follows :

		Ratio.	
Fe_2O_3	50·98	0·319	3·29
Na_2O*	6·03	0·094	1·01
K_2O	0·35	0·004	
SO_3	30·96	0·387	4·00
H_2O below 105°	0·12		
H_2O above 105°	11·03	0·613	6·33
As_2O_5	0·20		
SiO_2	0·23		
CaO	0·04		
	99·94		

The ratio of $Fe_2O_3 : Na_2O : SO_3 : H_2O$ is evidently 3 : 1 : 4 : 6 as in ordinary jarosite, where the alkali is potash instead of

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* Of the soda ·22 per cent is not extracted by hot water after full ignition of the mineral and hence may belong to a feldspar or some other foreign mineral. Only 5·81 per cent is assumed to belong to the jarosite and used in deriving the molecular value.

soda. The slight excess of Fe_2O_3 and H_2O, as indicated by the ratio, is evidently due to some ferric hydroxide; probably the dark ferruginous impurities seen under the microscope are in part responsible for this, and there are also traces of some arsenate and silicate present. Regarding the excess of Fe_2O_3 and H_2O as due to impurities, it is found that 94 per cent of the material analyzed may be regarded as pure natrojarosite, as indicated below:

	After deducting impurities.			Theory for $Na_2Fe_6[OH]_{12}[SO_4]_4$.
Fe_2O_3	46·43	or	49·39	49·49
Na_2O	5·81	"	6·18	6·39
K_2O	0·35	"	0·37	----
SO_3	30·96	"	32·94	32·99
H_2O	10·45	"	11·12	11·13
	94·00		100·00	100·00

That six per cent of impurities should be present in a crystalline powder such as analyzed is not surprising, when it is taken into consideration that it would require something like 2,500,000 crystals to make one gram of material, the estimation being based on the assumption that the crystals are $0·10^{mm}$ in axial diameter and $0·02^{mm}$ thick, which is certainly above their average size.

Among the specimens from Cook's Peak, New Mexico, sent to the Sheffield Laboratory by Mr. Porter, were some masses of a rather firmly cemented aggregate of minute crystals of a mineral of the jarosite group. The specimens are of a brownish-yellow color, and have in places the glistening appearance of a mica-schist. They also look as though they had been subjected to pressure and had been somewhat sheared. The material is rather easily crushed, and the powder when examined with the microscope exhibits the properties of the natrojarosite just described. The crystals are associated with a little limonite and quartz, and pure material for analysis could not be obtained. Only a partial analysis, therefore, was undertaken with the following results:

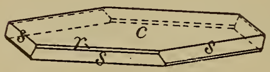
Fe_2O_3	55·60
Na_2O	4·49
K_2O	0·77
PbO	0·96

SO_3 and H_2O were present but not determined. The results are sufficient to indicate that the material is essentially natrojarosite.

Plumbojarosite.

This material is from Cook's Peak, New Mexico. It occurs as a glistening, crystalline powder and as loosely cohering masses which may easily be crushed by pressure between the fingers. The crystals are very symmetrical, and are exactly like those of natrojarosite, figure 1, although generally only one rhombohedron r is present. On the average the crystals are a trifle smaller and noticeably thinner than those of natrojarosite. A number of crystals were measured on the reflecting goniometer, the chief difficulty arising rather from the vicinal character of the faces than from their small size. One unusually large crystal, 0·28^{mm} broad and 0·015^{mm} thick, was finally found, having the development shown in figure 2, which is unusual, for generally r $(10\bar{1}1)$ and not s $(02\bar{2}1)$ is the prevailing rhombohedron. Fortunately the crystal was so taken up on a minute point of wax that the measurement of $s \wedge s$ in three rhombohedral zones was possible. The results of five measurements of $s \wedge s$ over the upper and lower pole edges varied between 109° 5′ and 109° 30′, the average being 109° 16′; while six measurements over the middle edges varied between 70° 10′ and 71° 00′, the average being 70° 36′. The average of the two supplementary values gives $s \wedge s$, $2\bar{2}01 \wedge 02\bar{2}1 = 109° 20'$, which has been assumed as fundamental, and from it the following axial ratio has been calculated:

2



$$c = 1·216.$$

On the crystal from which the foregoing measurements were obtained the basal plane was vicinal and hence no reliable measurements of $c \wedge s$ could be had from it. On a number of other crystals, however, the angle of $c \wedge r$ was measured with varying results, the variation resulting from the uncertainty of the reflections from the basal planes. Four measurements of $c \wedge r$, which were recorded in the note-book as derived from the best reflections, varied between 54° 15′ and 54° 44′, the average being 54° 30′, while $c \wedge r$, $0001 \wedge 10\bar{1}1$, by calculation from the fundamental measurement, is 54° 32′. Hence it may be assumed that the axial ratio as established is reasonably exact. The calculated value of $r \wedge r$, $10\bar{1}1 \wedge \bar{1}101$, is 89° 42′.

In polarized light the crystals exhibit normal optical properties and negative birefringence. Being on the average thinner than crystals of natrojarosite, it is seldom that, with the highest powers and convergent light, even the beginning of the first ring of the uniaxial interference figure is visible. Individual crystals show under the microscope in transmitted light a golden-yellow color. A mass of crystals has the appearance of a glistening dark-brown powder, the color being decidedly darker than that of natrojarosite.

The analysis of the mineral was made on the very best material, having a specific gravity of 3·665 at 30° C. The results are surprising, and were wholly unlooked for, since it is found that this jarosite contains lead in the place of alkalies. The results by Hillebrand are as follows :

	I.	II.	III.	IV.	Mean.	Ratio.	
Fe_2O_3	42·36	42·38			42·37	0·265	3·15
Al_2O_3?[*]	·12	·08	·11		·10	0·001	
PbO	19·69	19·99	19·89	19·79	19·84	0·089	1·05
K_2O	·17				·17		
Na_2O	·21[†]				·21[†]		
SO_3	27·05	27·07			27·06	0·338	4·00
H_2O below 105°	·02				·02		
H_2O above 105°	9·59	9·49			9·54	0·530	6·27
SiO_2	·56	·51	·47		·51		
CuO	·27	·27			·27		
CaO	·05				·05		
MgO	·01				·01		
					100·15		

The ratio of $Fe_2O_3 : PbO : SO_3 : H_2O$ is very close to 3 : 1 : 4 : 6, indicating that the mineral is a variety of jarosite, and the slight excess of Fe_2O_3, H_2O, and PbO + alkalies, may be accounted for by assuming that slight impurities are present, partly ferric hydroxide, in part some lead salt, and perhaps a soluble silicate, as shown by the complete solubility of the silica in acids. Assuming that the ratio is exactly 3 : 1 : 4 : 6, it is found that 4·36 per cent of impurities are present, and the remaining 95·64 per cent may then be regarded as plumbojarosite, as follows :

		Theory for $PbFe_6[OH]_{12}[SO_4]_4$.	
Fe_2O_3	40·59	or	42·44
PbO	18·86	"	19·72
SO_3	27·06	"	28·29
H_2O	9·13	"	9·55
	95·64		100·00

Since it took probably 2,500,000 crystals of natrojarosite to make one gram of material, it certainly must have taken fully 4,000,000 to make a gram of plumbojarosite, for the crystals of the latter mineral, though somewhat heavier, are decidedly thinner than those of the former; hence the presence of 4·5

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[*] The presence of alumina was not definitely proved. The figures here given are the differences between the several weights of the ammonia precipitates and those of the ferric iron in them, as determined by permanganate after reduction by hydrogen sulphide.

[†] Probably somewhat high.

per cent of impurities in such a crystalline product is not to be wondered at.

Jarosite and Alunite.

As seen from the analyses of these minerals which have been published, the alkali metal they contain is almost always potassium, though sodium is at times present. The formulas assigned to the two minerals are therefore $K_2O+3Fe_2O_3+4SO_3+6H_2O$ and $K_2O+3Al_2O_3+4SO_3+6H_2O$, which may be variously expressed, as will be indicated later.

A mineral corresponding to natrojarosite of this article, though containing a little potash, has been described by W. P. Headden* from the Buxton mine, Lawrence Co., S. D. The crystals are described as scales, consisting of a combination of base and rhombohedron. The material analyzed was evidently somewhat impure, as quartz and some As_2O_5 are reported. As the As_2O_5 evidently does not belong to jarosite, the assumption may be made that some scorodite, $FeAsO_4·2H_2O$, is present, and the results of Headden's analysis may then be interpreted as follows:

	Original analysis.	Scorodite and quartz.	Natrojarosite.			Ratio.
Fe_2O_3	46·27	1·60	44·67	or	50·10	3·13
Na_2O	4·35		4·35	"	4·86	1·04
K_2O	1·47		1·47	"	1·65	
CaO	0·39		0·39	"	0·44	
SO_3	28·46		28·46	"	31·93	4·00
H_2O	10·55	0·72	9·83	"	11·02	6·13
As_2O_5	2·36	2·36	----		----	
Quartz	6·10	6·10	----		----	
	99·95	10·78	89·17		100·00	

Thus, assuming the presence of 4·68 per cent of scorodite and 6·10 of quartz, and deducting them, the remainder agrees very closely with natrojarosite, giving a good ratio, very near 3 : 1 : 4 : 6.

Alunite containing considerable soda has been described by W. Cross† from Rosita Hills, Colorado, and by E. B. Hurlburt‡ from Red Mountain, Colorado, and analyses of both minerals show about equal percentages of K_2O and Na_2O, or a molecular ratio of $K_2O:Na_2O = 4:7$. The occurrence, therefore, of sodium in the jarosite-alunite group is in accordance with previous observations, but the case is quite different with lead. As far as the present writers are aware, this is the first instance on record where lead has been observed isomorphous with the alkali metals. It is interesting to note that the alunite from Red Mountain, Colorado, occurs as a crystalline powder,

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* This Journal (3), xlvi, p. 24, 1893.

† Ibid. (3), xli, p. 472, 1891.

‡ Ibid. (3), xlviii, p. 130, 1894.

the crystals being exactly like those of natrojarosite and plumbojarosite, except that they are a trifle smaller and white, or colorless when seen under the microscope.

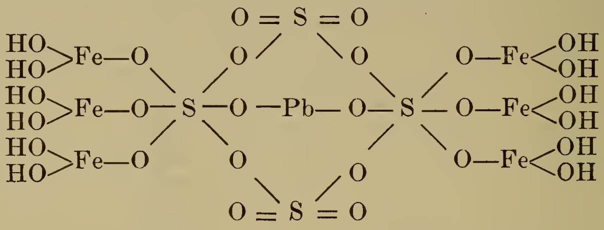
From a chemical standpoint the most interesting feature of the new minerals is the light they throw upon the isomorphism of potassium, sodium and lead. Ordinarily, even potassium and sodium are not isomorphous, as shown by the fact that their simple salts seldom crystallize in the same form. Although KCl and NaCl both crystallize in cubes, it is not certain that both salts belong to the same group of the isometric system. It has been shown, for example, by etching, that KCl crystallizes like NH_4Cl in the plagihedral group of the isometric system, while the etchings produced on halite seem to indicate that it crystallizes in the normal group. Again at Stassfurt, Germany, sylvite and halite both occur crystallized side by side upon the same hand specimen, instead of mixing as isomorphous molecules. Even in such complex molecular compounds as the feldspars, the potassium and sodium salts crystallize as orthoclase and albite, rather than as isomorphous mixtures. Lastly potassium has a strong tendency to form alums which is not shared by sodium. In contrast to these differences in chemical nature, we have in the jarosite-alunite group of minerals not only the alkali-metals, potassium and sodium, but, what seems still more remarkable, *lead*, playing the same rôle in the compounds, and yielding crystals which are surprisingly alike in all their physical properties. The writers can at present offer no other reason for the isomorphism in the group of minerals under consideration than that the alkalies and lead play so small a rôle, and the remaining constituents so prominent a part in the complex chemical molecules, that the latter control or dominate the crystallization by virtue of what may be called their *mass effect.*

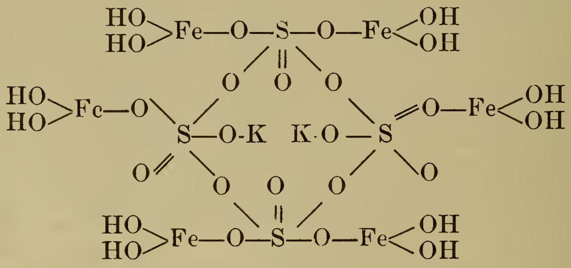
The alunite from Red Mountain, described by Hurlburt, was analyzed in the Sheffield Mineralogical Laboratory under the direction of one of the present writers, and it was found that water was first expelled from the compound at a rather high temperature, thus indicating that the mineral contains hydroxyl and no water of crystallization: accordingly it was shown that the seemingly complex formula of the mineral, expressed by the ratio $Al_2O_3 : K_2O : SO_3 : H_2O = 3 : 1 : 4 : 6$, may be much simplified to $K[Al(OH)_2]_3[SO_4]_2$. In the light of the present investigation it now seems best to abandon the above simple formula and adopt one containing double the number of atoms, in order to make clear the isomorphism between K_2, Na_2 and Pb. The formulas of the minerals of the group would then be expressed as follows:

Alunite,	$K_2[Al(OH)_2]_6[SO_4]_4$	or	$K_2Al_6[OH]_{12}[SO_4]_4$
Natroalunite,	$Na_2[Al(OH)_2]_6[SO_4]_4$	or	$Na_2Al_6[OH]_{12}[SO_4]_4$
Jarosite,	$K_2[Fe(OH)_2]_6[SO_4]_4$	or	$K_2Fe_6[OH]_{12}[SO_4]_4$
Natrojarosite,	$Na_2[Fe(OH)_2]_6[SO_4]_4$	or	$Na_2Fe_6[OH]_{12}[SO_4]_4$
Plumbojarosite,	$Pb[Fe(OH)_2]_6[SO_4]_4$	or	$PbFe_6[OH]_{12}[SO_4]_4$

In the case of the lead compound one atom of lead, and in the others two atoms of either potassium or sodium, are combined in complex molecules containing fifty other atoms; hence that the complex of fifty atoms, to the right of the K_2, Na_2 and Pb in the foregoing formulas, should control or dominate crystallization by virtue of *mass effect*, and condition an isomorphism between such unlike elements as sodium, potassium and lead, is not so surprising as would at first appear.

Having adopted the double formulas, as given above, there are numerous ways of writing developed formulas, of which the following are perhaps the simplest and most satisfactory:





It is interesting to note that although K_2, Na_2 and Pb play so small a rôle in the alunite-jarosite molecules, the substitution of Na_2 for K_2 is attended by quite a marked variation in the angles of the crystals, greater in fact than is generally observed in isomorphous replacements. That alunite and jarosite containing potash would be nearly alike in their angles is expected, since crystals of corundum and hematite are surprisingly alike as shown by the following comparison:

	Axial length.	$r \wedge r'$	$c \wedge r$
Corundum, Al_2O_3 ----	1·3630	93° 56′	57° 34′
Hematite, Fe_2O_3-----	1·3656	94 00	57 37

The relations of the minerals of the alunite-jarosite group are as follows:

	Axial length.	$r \wedge r'$	$c \wedge r$	Birefringence.
Alunite	1·252	90° 50′	55° 19⅔′	positive
Jarosite	1·245	90 45	55 16	negative
Natrojarosite	1·104	85 54	51 53	negative
Plumbojarosite	1·216	89 42	54 32	negative

From the foregoing table it is seen that the substitution of sodium for potassium in jarosite has brought about greater variation in the angles of the crystals than the substitution of the bivalent metal lead for potassium.

The three minerals, natrojarosite, plumbojarosite and the Na-K-alunite from Red Mountain, are very interesting when studied together as microscopic mounts, the crystals being practically alike in size and development, and illustrating very beautifully on the one hand the isomorphism of aluminum and iron, on the other the isomorphism of potassium, sodium and lead. The three substances must have formed under like conditions, and it is believed that they are solfataric products, formed under the combined action of heat and pressure. Being difficultly soluble, they have formed, like many precipitates, as fine crystalline powders.

The three products just mentioned, when heated in closed tubes behave alike; they suffer no change on gentle heating, but when the temperature is sufficiently high to decompose the chemical molecules, the crystals break up into fine powder or dust, which is carried along by the escaping vapors and deposited for a considerable distance along the sides of the tubes. In addition to water, SO_2 and SO_3 are copiously given off during decomposition. In the case of natrojarosite, and the same would doubtless hold true for the Na-K-alunite, it is found that after ignition, one-fourth of the sulphate radical has been retained by the alkali metal, and may be extracted by water. In the case of plumbojarosite, however, all of the sulphate radical is expelled by ignition, doubtless because the ferric-oxide present serves to decompose any lead sulphate which might have a tendency to form. Anglesite, $PbSO_4$, when heated alone in a closed tube suffers no decomposition, but when finely triturated with limonite and heated, acid water is given off. Finely powdered natrojarosite and plumbojarosite are slowly but completely soluble in boiling hydrochloric acid. Plumbojarosite when fused with sodium carbonate on charcoal yields globules of lead and a coating of lead oxide.

It has seemed to the writers best to designate the new compounds described in this article as natrojarosite and plumbojarosite, the names signifying their relation to a well known species. Other members of this group will doubtless be found, and the name natroalunite might be employed to designate the two varieties of alunite from Colorado mentioned on page 216, where the proportion of the soda to the potash molecule is 7:4. It is highly probable that a series of alunite-jarosite compounds could be made artificially.

It is with pleasure that the writers acknowledge their indebtedness to Messrs. Turner and Porter for calling attention to the interesting compounds described in this article.

Laboratories of the U. S. Geological Survey, Washington, and of the
Sheffield Scientific School, Yale University, New Haven,
Feb., 1902.

ART. XXVI.—*The Niagara Limestones of Hamilton County, Indiana;* by EDWARD M. KINDLE.

HAMILTON County is located slightly north of the geographical center of Indiana. The drift in this part of the State is so deep that the Paleozoic rocks are rarely exposed at the surface. Only a few outcrops occur in the county. The most extensive exposure is the one at Connor's mill on White river, five miles above Noblesville. Two small quarries southwest of Fishersville afford an equally good opportunity to study the Paleozoic rocks of the county. Several days were spent by the writer in collecting from the beds exposed at these two localities.

Connor's mill.—The outcrop at Connor's mill consists of a hard, light buff dolomite, which is exposed for two or three hundred yards below the dam. The beds show a dip of 20° to 40° to the southwest. Above the dam one-third of a mile the limestone outcrops again, dipping 30° to the northwest.

The following is a list of fossils collected from beds exposed below the dam:*

Favosites favosus	r.
Streptelasma cf. calicula	r.
Amplexus shumardi	r.
Eucalyptocrinus cf. crassus	r.
Conchidium multicostatum	a.
Conchidium sp.	r.
Atrypa reticularis	c.
Stropheodonta profunda	c.
Leptaena rhomboidalis	c.
Meristella sp.	r.
Spirifer nobilis	r.
Trematospira camura	r.
Spirifer niagarensis	c.
Spirifer cf. crispa	r.
Dalmanella elegantula	r.
Plectambonites cf. sericea	r.
Conocardium sp.	r.
Platyostoma cf. niagarense	c.
Spherexochus romingeri	a.
Calamene niagarensis	c.
Illaenus insignis	c.
Phacops cf. trisulcatus	c.
Encrinurus sp.	c.

Fishersburg quarries.—Southwest of Fishersburg one-half mile a very pure white sandstone has been quarried for glass

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* The species listed will be described and figured in a future paper.

Figure 1.—Niagara limestone at Connor's mill.

Figure 2.—Fishersburg quarry, showing unconformity between Niagara limestone and underlying sandstone.

making. It is a fine-grained, massive, loosely-cemented rock, crumbling easily. A buff dolomite, having the same lithological characteristics as the outcrops at Connor's mill, rests upon the sandstone. The line of contact between the two formations is clearly shown in the quarry and is seen to be a very irregular one, resembling unconformity. The sandstone is believed however to be a local lense. Such lenses are known at other localities in the State where both the upper and lower contact with the Niagara limestone is clear. The limestone on either side of the projecting mass of sandstone extends below the surface of the pool which fills the quarry. The limestone beds show a dip of about 35° to the north.

A careful search failed to discover any fossils in the sandstone.

The fauna of the limestone as well as its physical characters indicate that it belongs to the same formation as the beds at Connor's mill.

A comparatively short time was spent in collecting from the Fishersburg quarries, and for this reason the following list of fossils from that locality includes fewer species than the preceding list:

Streptelasma cf. calicula	r.
Favosites niagarensis	c.
Spirifer cf. radiatus	r.
Conchidium multicostatum	a.
Reticularia cf. bicostata	r.
Orthothetes subplanus	r.
Stropheodonta sp.	c.
Meristella sp.	c.
Nucleospira pisiformis	r.
Leptaena rhomboidalis	r.
Spirifer nobilis	r.
Illaenus insignis	r.
Spherexochus romingeri	r.
Phacops cf. trisulcatus	r.
Encrinurus sp.	r.

Correlation.—Richard Owen described the outcrop at Connor's mill in his report published in 1863,* but offered no opinion as to the age of the beds. The earliest reference to the age of these beds occurs in a report on the geology of Hamilton county† by Dr. R. T. Brown, who considered them to be of Devonian age. No paleontological evidence was offered in support of this opinion, the author of the report stating that "the outcrops of rock in Hamilton county are

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* Rep, Ind. Geol. Surv. for 1859-62, p. 102.

† 14th Ann. Rep. Ind. Geol. Surv., 1884, p. 27.

quite barren of fossils." In 1901* the limestones at Connor's mill and near Fishersburg were referred by the writer to the Niagara, but the paleontological evidence for this determination was not given. The faunal lists here given clearly show the Niagara age of these beds. The Lockport (Niagara) limestone is their probable equivalent in the Niagara group.

The Hamilton county outcrops are the most southern exposures in the State which show highly tilted Niagara strata. The orogenic disturbances, which caused a general tilting of the Niagara rocks in northern Indiana previous to the beginning of Devonian sedimentation, did not affect the southern portion of the State, where they lie nearly horizontal, and are conformable with the Devonian rocks. North of the Ohio river eighty miles the Niagara rocks are slightly unconformable with the Devonian,† but nearly horizontal. The Devonian rocks have not been observed in contact with the Niagara in Hamilton county, but it is very probable that they are unconformable as they have been shown to be further north in the Wabash valley.‡

U. S. Geol. Survey,
New Haven, Conn., June, 1902.

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* 25th Ann. Rep. Dept. Geol. and Nat. Res., Ind., p. 559.

† Kindle, 25th Ann. Rept. Dept. Geol. Nat. Hist., Ind., plate 16.

‡ Ibid., p. 562.

ART. XXVII.—*On the Velocity and the Structure of the Nucleus;* by C. BARUS.

1. *Nucleation produced by shaking and its velocity.*—Table I contains the results for the absorption velocity, k, of nuclei shaken out of dilute solutions. The data were obtained by measuring the condensational coronas in a spherical vessel (diameter, $2R = 30^{\text{cm}}$) in the lapse of time. If the loss of nuclei be regarded as taking place at the walls of the vessel and to constitute a drain on the whole nucleation (n particles per cub. cm.) which moves radially outward at the rate k, then the equation[*] $n = n_0 \epsilon^{-3kt/R}$ may be assumed. The time elapsed, t, is usually given in minutes. To deduce from k the velocity of the nucleus, κ, I have for the present regarded it as sufficient to multiply by 6 or preferably by $15/\pi$, so that $\kappa = 5{\cdot}1\,k$. The concentration, c, is given in per cents or grams of dry salt in $100^{\text{cub cm}}$ of solution. It is essential that a definite bulk (usually $500^{\text{cub cm}}$) be used throughout, if the data are to be at once comparable.

TABLE I.—Nuclei shaken out of solutions by 10 jerks. Bulk of solution usually 500^{cm^3}. Nucleation, $n = n_0\,\varepsilon^{-3kt/R}$. $R = 15^{\text{cm}}$.

Solvent.	Solute.	Concentration, c. %	Nucleation, n.	Absorption velocity, k. cm/min.	Nuclear velocity, κ. cm/min.
Water	Water	0	32	1·5	7·6
			85	6·7	34·
			26	9·4	48·
Water	HCl	·5	160	·06	·30
		·005	140	·02	·10
		·00005	80	2·3	12·
Water	H_2SO_4	·6	215	·03	·15
		·003	130	·07	·36
Water	NaCl	2	175	·01	·05
Water	$CaCl_2$	2	240	·04	·20
		1	240	--	--
	(double bulk)	1	460	·04[†]	·20
Water	$FeCl_3$	2	230	--	--
		·5	180	--	--
Water	$Fe3NO_3$	1·2	175	·03	·15
		·12	160	·03	·15
Water	$Al3NO_3$	1·2	200	·07	·36
		·12	80	·03	·15
Water	$Ca2NO_3$	1·4	260	·04	·20
		·014	90	·02	·10
		·0014	60	·10	·51

[*] This Journal (4), xiii, pp. 91, 94, 1902.

[†] Note the doubled n and single k.

Table I (continued).

Solvent.	Solute.	Concentration, c. %	Nucleation, n.	Absorption velocity, k. cm/min.	Nuclear velocity, κ. cm/min.
Water	$Ca2NO_3$	·00014	60	1·4	7·1
Water	Alum (dry)	1·5	200	·05	·25
		·015	90	·11	·56
Water	Na_2SO_4	·9	450	·07	·36
		·009	110	·12	·61
		·00009	50	2·1	11·
Water	$H_4N\,NO_3$	2	190	·03	·15
		·02	129	·11	·56
Water	K_2SO_4	2	280	·06	·31
		·02	140	·07	·36
Water	Na_3PO_4	·9	195	·06	·31
Water	Sucrose	2	160	·13	·66
		·02	51	·19	·97
Water	Glucose	1·6	150	·14	·71
		·016	50	1·0	5·1
Water	Glycerin	2·6	95	1·1	5·6
		·026	50	2·3	12·
Water	Urea	2	110	·19	·97
Water	Alcohol	0	55	4·8	24·
		1·6	43	1·8	9·
Water	Tartaric acid	2	130	·02	·10
		·02	100	·02	·10
		·0002	95	·20	1·0
Benzol	Naphthalene	2	90*	·04	·20
		·02	90	·03	·15
		none	80	·02	·10
Benzol	Paraffine	1	130	·02	·10
		0	80	·04	·20
Benzine	none	--	72	·16	·82

2. *Remarks on the data.*—The main deductions from these tables have been briefly given elsewhere† and need not therefore be detailed here. Great caution is necessary because of the inevitable irregularities of the results. The dependence of the nucleation, n, on the concentration c, agrees fairly well with the equation, $n = n_0 + A/(\log(B/c))$, where A and B are constants. Hence in making comparisons, it will be convenient to refer all data to the logarithmic concentration, log c, from the peculiar character of the results. In a general way the number of nuclei evolved, *caet. par.*, depends on the mass of solute dissolved per cub. cm., and for 1 per cent solutions is within rather narrow limits independent of the saline

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* These data are computed as if the solvent were water. They are thus partly relative. The data needed to find n for benzol are not consistently forthcoming.

† Science, xv, pp. 912–914, 1902.

or acid solute taken. For neutral organic solutes, the number, n, is little more than half as large. This seems then to be in the nature of a class distinction. Pressure decrements of less than 2^{cm} suffice to precipitate the nuclei; but for the small supersaturations, the greater number re-evaporate to the nuclear stage and many exhaustions are needed to throw them out. For the high degrees of supersaturation all nuclei are precipitated at once. The number of nuclei generated depends on the bulk of solution shaken and on the intensity of the agitation. Hence they seem to arise in the solution itself and not by friction with the walls of the vessel. The attempt to find a limiting number has not yet been successful. Incidental conditions which have not all been traced to their source seem to have considerable influence on n.

3. *Persistence of nuclei.*—A comparison of the data for n and those of k for the same concentration shows that for the same solution n decreases with log c while k increases with log c, the arena of greatest variation being the very dilute solutions which merge into water. Usually the growth of k continues even after the decrease of n has appreciably subsided. Corresponding to the greater n which characterizes the saline solutes as compared with the neutral organic solutes, the velocities of the nuclei of the latter are greater than those of the former, under otherwise like conditions. Nuclei with neutral organic solutes in water are less persistent. Extreme persistence may be obtained with the volatile hydrocarbon solvents with an appropriate solute, like benzol-paraffine, and often the solute seems to be spontaneously nuclei-producing, like benzol-naphthalene. In general persistence for a given nucleus is a question of the mass dissolved per cub. cm. of the solution; but cases like water-tartaric acid occur in which a low order of nucleation, n, is associated with exceptional persistence, or low values of k.

4. *Structure of the nucleus.*—From experiments like the present I recently came to the conclusion that all condensation nuclei are concentrated solutions; that the increment of vapor pressure due to increasing convexity is eventually, but slightly before molecular diameters are reached, compensated by a decrement of vapor pressure due either to concentration[*] or to electric charge.[†] The latter case is interesting inasmuch as the nuclei are just about large enough that a single electron spread out over the surface would suffice to equilibrate[‡] the increment of vapor pressure due to surface tension. The concentration hypothesis is more straightforward and requires

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[*] Science, xv, pp. 912–914, 1902.

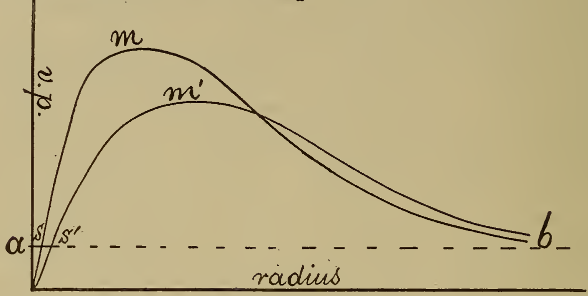
[†] This Journal (4), xiii, pp. 400–402, 1902; ibid., p. 473.

[‡] This Journal (4), xiii, p. 473, 1902.

less imagination, and it will therefore be chiefly referred to in the following discussion. The nucleus is to be regarded small enough that it is not *symmetrically* bombarded by the molecules of vapor. Hence its velocity is conceived to be increasingly larger as it is smaller, i. e., as the conditions favorable to non-symmetrical bombardment increase. If too large it will be stationary, apart from gravity; if small enough, it must eventually acquire the molecular velocities themselves.

5. The relations of equilibrium here involved are peculiar and need a more detailed elucidation. If vapor pressure increases with increasing convexity, for capillary reasons, but eventually decreases again as a result of the concentration reached on evaporation, to a value nearly zero or at least below the normal vapor pressure at a flat surface, it follows that as the size of the drop continually decreases the vapor pressure at its surface must pass through a maximum. The accompanying diagram* is an attempt to represent the case graphically for two given solutions, by making the vapor pressures the ordinates, and the radii of the given droplet of solution the abscissas. The line *ab* indicates the normal vapor pressures. All particles whose sizes taken from the curve *bm′s′* correspond to the abscissas between *s′* and *b* therefore evaporate in the lapse of time, those lying near the maximum, *m′*, fastest, those lying near *s′* or *b* with proportionate slowness, while the latter are also lost by subsidence and may be dismissed from consideration. On the other hand, a particle whose radius is smaller than the abscissa corresponding to *s′* will grow so that *as′* is the stable radius of the nucleus obtained by shaking the given dilute solution.

1



If the solution is weaker, the droplet shaken out of it will have to evaporate further to reach the critical density of the stable nuclear state, and the increment of vapor pressure due to surface tension will also be larger or the maximum, *m*, will be higher. The curve *bms* now represents the conditions and is to be similarly interpreted.

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* The two curves should have been drawn preferably without intersecting.

If the solvent is pure or contains only a trace of solute, the nucleus will vanish completely, or else the particle left may be too small to serve as a condensation nucleus for a given pressure decrement of exhaustion. The size after the lapse of time depends on the fixed quantity of salt originally entrapped.

If the vapor is not quite saturated, the chances for evaporation will be enhanced. The line *ab* will be correspondingly lowered, but equilibrium may result for a smaller size of nucleus, until eventually the solid saline residue of the nucleus alone is left. In so far as these concentration nuclei occur in the atmosphere, one is justified in concluding that their size (apart from the effects of temperature and barometric pressure on surface tension and vapor density*) will increase under mean atmospheric conditions as they are suspended at higher distances above the earth's surface, until the levels of perpetual saturation are invaded.

6. There is one outstanding question relating to the time losses which must now be considered. These coefficients, dn/dt, are much smaller for concentrated than for weak solutions. This observation was referred to the diffusion of the nucleus and its absorption at the walls of the vessel with different velocities, k. The diagram shows, however, that near the points s there must be retarded evaporation for all particles, because of the small differences of vapor pressure remaining. Hence the persistence of nuclei shaken out of solutions might be ascribed to this effect. True, no reason is evident why stronger solutions should differ from weak solutions in their relative time losses, $d \log n/dt$. Referring to Table 1 again, solutions of $CaCl_2$, H_2SO_4, which can not dry in a saturated atmosphere, are seen to show nothing exceptional in their behavior. It may be computed that the stable nucleus is, in this case, not even very concentrated. Special experiments are nevertheless needed to clear up the matter, and they must be so devised as to give direct evidence of the occurrence of diffusion or motion of nuclei, and the value of its amount. If this is large enough to be compatible with the data for k in this chapter, then the hypothesis of retarded evaporation may be dismissed.

It is with this end in view that the experiments of the next table are contrived and the results show that the motion of the phosphorus nucleus, as actually observed, is considerably faster than the average case computed for the nuclei in the present chapter, and consequently the interpretation here accepted is corroborated.

7. *Motion of nuclei directly observed.*—Table II shows the velocity of the nuclei as found directly in a tower-like receiver 1 meter high, into the bottom of which the nuclei have been introduced. The height of the fog bank, κ', seen on exhaustion

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* Note that temperature and elevation produce opposed effects.

after the lapse of a definite number of minutes, give the velocity sought at once, after correcting for the instantaneous elevation of the plane of demarcation due to the withdrawal of non-nucleated air from the top of the apparatus. The table gives the ratios p'/p of pressures after and before exhaustion, respectively. The experiments are very trying, chiefly because of the difficulty of finding the initial position (time $t = 0$) of the plane of demarcation between clean and nucleated air. For this reason I will also give the height of the fog bank seen on exhaustion after 50 minutes. The table shows that incidental conditions (whether the inflowing filtered air be quite dry or not, etc.), often very subtle, largely influence the results, but a detailed explanation, for which there is no room here, must be given elsewhere.

TABLE II.—Apparent and corrected rates of motion (κ^1 and κ) of phosphorus nuclei in different saturated vapors.

Pressure-ratio.	Vapor.	Apparatus, etc.	$\kappa^1 \times 10^2$. cm/min.	$\kappa \times 10^2$. cm/min.	Height of fog bank after 50^m. cm.
·83	Benzol	Tower	75	61	42
·78	Toluol	Globe	80	62	40
·90	"	Tower	43	39	21
·83	Acetone	Tower	58	48	32
"	"	Initial rate	75	62	38
"	Amyl	Tower, initial ;	100	83	51
"	Alcohol	apparent	75	62	46
"	Ethyl	Tower	106	88	62
"	Alcohol	Dried air	72	60	51
"	Methyl	Tower	24	20	29
"	Alcohol	Dried air	64	53	42
"	Water	Estimated[*]	10,000	8300	—

8. *General comparison of nuclear velocities.*—It will now be opportune to make a comparison of all the nuclear velocities made in widely different experiments throughout my work. I will begin with the results of my first memoir[†] on the subject, in which the velocities of phosphorus nuclei in ordinary atmospheric air were studied both by mechanical methods (steam jet and absorption tubes), and by the electrical condenser methods. The mean value of $k = 18$ cm./min. may be taken. Hence in air, $\kappa = 90$ cm./min., nearly. The number of particles was of the order of $n = 10^4$ per cub. cm. of air.

In more recent experiments and by a method[‡] of comparing

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[*] Rise or fall of the strands or fog filaments.

[†] Experiments with Ionized Air; Smithsonian Contributions, pp. 1–93, 1901.

[‡] This Journal (4), xiii, p. 92, 1902.

coronas of different orders, for phosphorus and other nuclei, present in saturated water vapor to the average extent of 10^4 per cub. cm., the value $k = {\cdot}1$ cm./min. was ascertained. This is equivalent to $\kappa = {\cdot}5$ cm./min., in air saturated with water vapor.

This datum may now be compared with the diffusion velocities of Table II of this chapter, in which fresh phosphorus and other nuclei were used, densely distributed and tested in a variety of vapors, alcoholic, hydrocarbon, etc. The usual values of diffusion velocity lie between $\kappa = {\cdot}5$ cm./min. and ·9 cm./min., being thus of the order of the preceding case. Water vapor itself did not admit of measurement. The value estimated from the filamentary advance immediately after the nuclei enter, 80 cm./min., agrees more closely with the case for atmospheric air at the beginning of the paragraph. As stated elsewhere, there is much in the behavior of water which is left unexplained. When the nuclei are first introduced into the mixture of air and saturated water vapor, the air effect does not seem to be negligible.

Finally the experiments on the evanescence of the nuclei produced by shaking solutions lead to a series of values of k as follows. A few hundred nuclei per cub. cm. were usually present after shaking the solutions, and less than 50 (usually) after shaking pure water.

For the saline solutions of 1–3 per cent, of ·01 per cent and of ·0001 per cent, respectively, $\kappa = {\cdot}25$, ·40, and 10. For pure water $\kappa = 25$ or even 50.

For aqueous solutions of solid neutral organic solutes of 1–3 per cent, and ·01 per cent, $\kappa = {\cdot}8$, and 3, respectively. The acid organic solutes like tartaric acid seem to behave quite differently. The solutions of this body of 2 per cent, ·02 per cent and ·0002 per cent, showed diffusion velocities of $\kappa = {\cdot}1$, ·1, and 1·0, respectively, thus evidencing uniformly greater persistence of nucleation than even the saline bodies.

For neutral liquid organic solutes in aqueous solution of 1–3 per cent and ·01 per cent $\kappa = 6$ and 12. Nuclei from these bodies are thus very fleeting.

Finally for hydrocarbon solution of solid hydrocarbons of 1–3 per cent, $\kappa = {\cdot}10$ or ·20, not differing much in persistence, etc., from the salt solutions.

The total range found for the diffusion velocity of nuclei produced by shaking solutions of less than 3 per cent is thus from $\kappa = {\cdot}1$ to 50 cm./min., increasing with the degree of dilution of the solution, the largest value cited (pure water) closely approaching the datum for phosphorus nuclei in atmospheric air, $\kappa = 90$ cm./min.

These variations of the velocity of the nuclei produced by shaking and its relation to the order of values found in the direct experiments with phosphorus nuclei given in Table II, is accounted for by the thermodynamic hypothesis for their occurrence, which makes them particles of concentrated solution. The size of the nucleus for a given solvent depends essentially on the extremely small mass of solute which it happens to contain. It is larger when shaken from the more concentrated dilute solutions than from the weaker solutions, because the critical density is reached in the former case with less evaporation and the capillary increment of vapor pressure to be compensated is at the same time smaller.

Thus it is quite reasonable to suppose that the nucleus obtained from phosphorus or other emanations will be smaller and therefore more mobile than the nucleus shaken out of the more concentrated dilute solutions, but not so small in general as the nuclei shaken out of pure water or any other pure solvent, in which the amount of solute is an actually vanishing quantity. To carry out this comparison one should eliminate the peculiar features of water and use the same neutral solvent in both cases: but if the above results for benzol in Tables I and II are brought together, the same inferences follow.

9. *Conclusion.*—Among the tenable hypotheses, each of which has some peculiarity in its favor, the above paragraphs are believed to sustain the inference that condensation nuclei in a nearly saturated medium are concentrated solutions. In proportion as the medium is less saturated, they may pass into the dry solute if such a one is present. The conditions of equilibrium which are supposed to intervene are given in § 5. Evidences in favor of this point of view are varied. In the first place the velocity and therefore the size of the nucleus, no matter of what origin, varies with the medium in which it is suspended or is generated. Two mechanical suggestions may be offered in explanation: either the nucleus condenses more or less vapor spontaneously as assumed above, or the nuclei themselves cohere into greater or smaller clusters, depending on the medium. I pointed out that the latter case calls to mind the suspension of clays, etc., in water or other liquids. The endeavor to refer the differences to specific inductive capacity or to the ionizing properties of the liquids breaks down with such solvents as acetone.

Of all the nuclei tested, those produced by shaking seemed to be simplest as to their origin and therefore best adapted to throw light on the subject. At first sight such a nucleus should be the dry residue left after evaporation; but the efficiency of gaseous solutes like HCl, etc., shows that a solid solute is not necessary. In view of the astonishingly small quantity of solute which suffices to produce persistence, however, it is a question whether the total absence of solid solute in experiments with acid solutions can be guaranteed. The next evidence is perhaps better; if it were a mere question of fixed residue, then the neutral organic solutes like the sugars, urea, glycerine, etc., should be quite as effective in producing persistent nuclei as the saline solutes. Table I shows that this is not the case. Finally since the pressure decrement of much less than 2^{cm} of mercury produces precipitation, the vapor pressure excess at the surface of the nucleus is small, and quite within the limits of reduction produced by solution. The evidence from hygroscopic bodies in which dry residues are out of the question, has already been given. § 6.

Turning now to the electrical point of view, one notices at the outset a marked similarity in the trend of the above results to the researches of Lenard* on the electricity produced by waterfalls and jets. He showed that pure water when properly comminuted by spraying was made electrically positive while the surrounding air became electrically negative, that these charges originated in the liquid in contact with air and could be indefinitely increased with the intensity with which the spray was projected against a solid obstacle. This is in harmony with the conditions for producing the above nuclei. Again, the electric manifestations stated for pure water were totally changed in character by the addition of mere traces of solute to the water. Thus in case of dilute salt solutions the liquid on comminution became negatively charged, and the air positively charged. As little as ·005 per cent of salt was sufficient to nearly wipe out the water effect. This then is quite similar to the conditions of persistence of nuclei instanced in the above tables.

Lenard's explanation is in terms of the "Doppelschicht," which for pure water is conceived to be negative outward, and for aqueous solutions and other bodies usually positive outward, and due purely to voltaic contact. If this view is correct, i. e., if air in contact with pure water is invariably negative by contact action no matter whether the surface is plane or markedly convex, and if air in contact with salt solutions is invariably positive, the solution being negative, then it is the negatively charged nucleus (solution) which persists and the positively charged nucleus (pure water) which is fleeting or virtually non-existent. It follows, therefore, that condensation with subsidence is equivalent to a removal of negative electricity provided the air charge is not simultaneously removed. Cf. § 5.

Brown University, Providence, R. I.

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* Lenard, Wied. Ann., xlvi, pp. 584–636, 1892.

ART. XXVIII.—*Note on Corundum and a Graphitic Essonite from Barkhamsted, Connecticut;* by B. K. EMERSON.

SOME years ago I received from Mr. W. E. Manchester of Pleasant Valley in Barkhamsted who is well acquainted with the mineralogy of the region, a large block of a heavy bluish black rock which proves to be corundum, and several specimens of a very peculiar large garnet which are penetrated by quite thick sheets of graphite.

The accompanying rock, which seems to be the country rock and which occupies a large area, is a coarse mica schist, which in a northwest direction for two miles abounds in smaller garnets 2–5^{mm} across, of red color, accompanied by dark reddish brown staurolite crystals an inch across, and also cyanite in blackish crisscrossed blades an inch wide and two inches long. Near where the cyanite occurs there comes in above it a fibrolitic gneiss which I have, farther north, associated with the Algonkian. This latter rock contains layers, an inch thick; of a compact or finely fibrous fibrolite (faserkiesel) containing many large grains of magnetite. The mineral proves under the microscope to be made up of almost pure matted fibrolite needles.

Garnet.—The remarkable garnets occur in well-formed dodecahedrons above two inches in diameter and extend over a broad area forming a very coarse continuous drusy surface, some crystals rising so as to show almost all their faces, others fused into large groups which rise several inches above the surface of attachment. They do not, however, present the aspect of crystals which have grown freely into a cavity, since the faces are not polished and continuous but rather dull and often deeply excavated with deep and irregular cavities from which some mineral has been removed by solution. In the least weathered crystals there are still large grains of included calcite visible, and we may assume that the mineral which has been removed from the depressions was calcite, that the whole broad surface of great crystals has grown from a base of mica schist up into a bed of crystalline limestone, which has been removed by solution from the surface of the crystals.

The character of the crystals agrees with this derivation. They are pale honey-yellow to almost colorless, agreeing in tint and general appearance closely with the crystals from Gatineau, Canada, except that they are simple dodecahedrons, are much larger and lack the polished faces, though this may be due to a subsequent weathering. They are doubtless a quite pure essonite. Because of this weathering they have now a dull gray and unattractive appearance, and this is increased by the fact that about half the surface of each crystal face is occupied by a dull black mineral in irregular blotches, arranged in a somewhat pegmatitic way. This sometimes increases in amount so as to occupy almost the whole surface of each face of the large crystals, and these faces are then irregular, and in the great mass of aggregated crystals where this is carried to the extreme it is continued up to a rather sharp plane beyond which the crystals are quite free from the black mineral, and this plane passes through the middle of the largest crystals.

In a section cut through a crystal where the surface was almost all black, the dark color disappeared rather suddenly about half an inch from the surface, but the dark mineral penetrated in narrow wedge-like plates far into the comparatively pure garnet.

The mineral is a pure soft graphite, especially in the wedge-like projections last mentioned, or a very fine granular mixture of graphite and garnet over the gray areas.

When a fractured surface on a slide is examined with a lens it has nowhere a homogeneous or crystalline appearance, but looks more like a fine-grained white aplite, and this character is maintained under the microscope which shows a brightly polarizing mosaic in which one can, with difficulty, detect here and there a nonpolarizing grain of garnet.

Large grains or phenocrysts of twinned calcite are very abundant, and the rest of the field is mostly made up of large feathery aggregates of coarse columnar wollastonite, full of minute blebs of quartz and quite large anhedra of diopside.

It is remarkable that such large well-formed crystals have so small a fraction of garnet in their composition. It is only at the surface that a thin layer of nearly pure garnet can be found.

Corundum.—The corundum block is from a very pure bed about two and a half inches thick, with the glistening luster of the Ceylon massive emery. It is a dark blue over most of its surface with small irregular patches of pistachio-green.

The specific gravity of the rock is 3·64. It scratches topaz.

Under the microscope the rock is made up of stout colorless grains two to four times as long as wide, with straight, distinct, almost cubical fracture lines.

These grains have a very low polarizing color, gray to white of the first order. They have a much higher index of refraction than the cyanite which is scattered in them, in porphyritic plates.

The cyanite is in rather square blades with good cleavage and basal parting and around its borders has broken up into an alteration product.

The whole field is filled with coaly matter in trains, aggregates and groups of round balls which often occupy the center of the corundum grains. This carbonaceous matter has plainly been introduced in an oily or tarry condition and has been inspissated in place, and the abundant graphitic matter in the garnet gives indication of the same origin.

Amherst College, Amherst, Mass.

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[FOURTH SERIES.]

Art. XXIX.—*An Experimental Investigation into the Existence of Free Ions in Aqueous Solutions of Electrolytes;* by Julius Olsen.*

Van't Hoff in 1887† showed that the gas laws of Boyle, Gay-Lussac, and Avogadro, hold also for dilute solutions. From considerations of osmotic pressure, theoretically and experimentally, he was able to apply Avogadro's law to solutions, and gave it as follows:

"The pressure which a gas exerts at a given temperature, if a definite number of molecules is contained in a definite volume, is equal to the osmotic pressure produced by most substances under the same conditions, if they are dissolved in any given liquid."

These laws may be combined in the well known expression

$$PV = RT$$

which holds for most substances, where P is the osmotic pressure and V, T, and R, as in the gas law, are volume, absolute temperature, and $= \frac{PV}{T}$ for a perfect gas, respectively, and includes Avogadro's law if we consider kilogram-molecules of the substances, as Horstmann has shown.

Van't Hoff found that the above expression held for most substances, but there were many important exceptions. These exceptions were the acids, bases, and salts; in these the osmotic pressures were greater than the law required. In other words, he found that the solutions with abnormal osmotic pressures were the electrolytes. He accordingly introduced into the expression the coefficient i and wrote it

$$PV = iRT$$

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* An abstract of a thesis presented to the Graduate Faculty of Yale University for the degree of Doctor of Philosophy.

† Zeitschr. Phys. Chem., i, 481, 1887.

This coefficient would be *one* for "ideal" solutions and greater than *one* for the acids, bases and salts.

Arrhenius* showed, also in 1887, how these exceptions might be explained; and thus the law hold for *all* substances. The osmotic pressure, other things being equal, depends upon the number of particles present in a given volume of the solution, in the same way as the pressure of a gas depends upon the number of its particles. If then the osmotic pressure is too great, there must be more particles present than were put in. These substances must therefore be dissociated, i. e., the molecules split up into two or more parts. Arrhenius reasoned in this manner.

This same assumption had been made use of to explain the abnormal pressures of some gases; but on account of the chemical objections had not before been applied to solutions. Arrhenius accordingly brought forth again the electrolytic theory of Clausius, and established it, seemingly, by showing how to calculate the amount of dissociation.

Clausius had believed that "some of the molecules of an electrolyte are dissociated into their ions, which move about independent of each other." During electrolysis these momentarily free ions would be guided to their respective poles. According to this theory there is no direct decomposition of the electrolyte by the current, as was held by Grotthüss in his theory. It has been shown since the time of Grotthüss that electricity moves with the same ease in electrolytes as in metals, so there is no place for such work as decomposition.

From the activity coefficient (a), which he considers the ratio of the actual molecular conductivity to the maximum conductivity, i. e., the conductivity at infinite dilution, Arrhenius proceeds to show how to determine the coefficient i of the formula, and thus test the theory. By a comparison of the lowering of the freezing point of a liter of water, in which a gram molecule of the substance is dissolved, and i as calculated from the conductivity method, he found the agreement to within the limits of experimental error.

The theory has since been tested by a great many men, by the method of the lowering of the freezing point, the rise of the boiling point, osmotic pressure, conductivity, etc. There are seemingly some exceptions as shown by Kahlenberg† and others, but the preponderance of evidence is certainly in its favor so far. Some of these exceptions may be due to the somewhat limited knowledge we have of the true composition of some substances. And the law has its limitations, in the same way as the gas laws, and holds only for dilute solutions. The theory, at least, explains a great many phenomena that cannot be explained, at present, by any other means.

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* Ibid., i, 631, 1887.

† Am. Jour. Phys. Chem., June, 1901.

No direct experimental proof was attempted until Ostwald and Nernst,* in 1889, performed the following experiment. It will be given substantially in their own language.

A glass tube about 30 or 40^{cm} in length, provided with a stopcock, was drawn out to a fine capillary at one end. The tube was then partly filled with mercury and hung upright, with the capillary in a solution of dilute sulphuric acid. By suction at the upper end the mercury was drawn up and the sulphuric acid after it. When at a convenient height, about the middle of the capillary, the stopcock was closed and the liquid thus held in place. A platinum wire fused into the tube connected with the mercury.

A large glass flask was now filled with dilute sulphuric acid and insulated by placing it on a disk of hard rubber. The outer surface of the flask was coated with tinfoil and its neck varnished with shellac. The contents of the flask were connected with the sulphuric acid into which the capillary tube dipped, by means of a wet string. The positive pole of a small electric machine was brought in contact with the tinfoil, and the mercury of the capillary electrometer connected with the earth.

As soon as the electric machine was set in motion the mercury of the electrometer rushed up and at the same time bubbles of gas separated, which broke the thread of mercury in a number of places.

This is the explanation given.—By charging the outer covering of the flask with positive electricity, the negative electricity on the inner side would be attracted and held, while the positive would be repelled. The latter would go by the wet string to the capillary electrometer and then by the platinum wire to the earth. There is no closed current; the entire movement of electricity is produced by induction. This proves, they say, that free ions were present and that they moved.

They performed several other experiments, but all are on the same principle, and the same conclusions are drawn.

There seems to be good reason for the belief that the conclusion arrived at does not necessarily follow, but that we need further proof.

The potential of an electric machine is very high and the flask they used in connection with the capillary electrometer is really a condenser. As no substance insulates absolutely there must be in such an arrangement some current, and in such a restricted path there is a possibility of a considerable difference of potential. They do not say that the potential difference, between the two ends of the capillary electrometer, was measured. If this exceeded about 1·22 volts there was electrolysis and consequently a formation of gas bubbles.

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* Zeitschr. Phys. Chem., iii, 271, 1889.

J. H. Pratt* shows that no current passes through a capillary electrometer below 1·22 volts. If no current can pass through a Lippmann electrometer before about the electrolytic limit of decomposition is reached, then this instrument is not a good one for this experiment.

In order further to test the capillary electrometer when connected for some time to voltages below 1·22, I made an instrument as follows:

A glass tube about 15^{cm} in length was drawn to a capillary at about 5^{cm} from one end. Into this shorter portion a platinum wire was fused. The tube was then filled with mercury and dilute sulphuric acid and inverted into a beaker containing dilute sulphuric acid and mercury. A cork was put on the upper end, and by releasing this a little the boundary between the mercury and sulphuric acid could be brought into the capillary. A space was left above the mercury so that it could recede when connected up to a Daniell. A platinum wire connected with the mercury in the beaker.

In this form the instrument, so far as its effective action is concerned, is exactly the same as that used by Ostwald and Nernst.

It was connected up to a Daniell of about 1·05 volts for hydrogen polarization and watched every few minutes for five hours, but no bubbles of gas were observed. It was afterwards connected up at the same voltage for eight hours with the same result.

Incidentally it may be stated that it was found that, if the tube was sealed at the upper end and entirely filled with mercury so there was no chance for it to recede, bubbles were formed in a few minutes, first at 1·05 and later with a new tube and new mercury at about ·88 volts.

In 1888 Ostwald† cites the following as a proof of the existence of free ions in solutions, but does not perform the experiment.

Let two vessels, A and B, be filled, for example, with a solution of potassium chloride, insulated and connected by a siphon filled with the same liquid. Now let a negatively charged body, K, be brought near to A; it will act inductively upon the system. A will become positive and B negative. If now the siphon be removed and then the body K, A will remain positive and B negative. To discharge A we can connect it with the earth, and the potassium ions, which are positive, will give up their charge and become atoms. These would act upon the water, forming potassium hydroxide, and hydrogen, which would escape from the solution as a gas.

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* This Journal, 1888

† Zeitschr. Phys. Chem., ii, 1888.

Ostwald says that the amount of gas liberated would be too small to be seen, and so, as before stated, he does not attempt the experiment, but a year later, together with Nernst, gives the experiment previously mentioned.

It was believed that an electrostatic charge would attract and repel the unlike and like charged ions respectively. And as it is the ions which in giving up their charge produce a current, then if these ions could be guided by an electrostatic charge we should get a current with electrodes indifferent to the solution, and be able to detect it with a sufficiently delicate galvanometer.

These were the beliefs upon which the following investigation was founded.

The experiments were performed on a brick pier capped with a granite slab and entirely independent of any vibration of the building. A delicate Rowland galvanometer together with a telescope and scale was used. The scale was about $156 \cdot 0^{cm}$ from the mirror of the galvanometer. The deflections were read to $0 \cdot 1^{mm}$.

A U-tube was first used, into which were placed platinum wire electrodes. The wires were wound into a spiral in order to increase the surface exposed. Before putting them in, the electrodes were heated to a white heat in a blowpipe flame. Distilled water and a trace of sulphuric acid was used. It was found that the cell always gave a deflection; however, it was intended to take the deflection first, before an electrostatic charge had acted upon the solution, and then taking out the electrodes, let a charge from an electrophorus act upon the solution for some time and then put in the electrodes and take the deflections again.

It was found that an electrode taken out of dilute sulphuric acid and exposed to the air while the other remained in the solution was, when replaced, strongly negative. As this effect was so decided, and the exposure of the two electrodes could not be made of exactly the same duration, nothing could be gained from this method.

A cell was now made from a low round beaker about $53 \cdot 0^{cm}$ in diameter. Platinum foils $2 \times 2 \cdot 5^{cm}$ were welded to platinum wires which were run up through corks in a piece of wood that served as a cover for the cell. The foils were bent so as to fit around the curvature of the beaker and be about $2 \cdot 0^{mm}$ distant from its edge. The cover of the cell was held in place by small nails driven into it from the under side, and it could be turned around so as to bring the electrodes into any desired position around the edge of the cell.

The cell was placed on a wooden stand in such a way that the disk of an electrophorus could be brought as close as I pleased to either electrode. 10, 5, 1 and $\frac{1}{5}$ per cent solutions of sulphuric acid were tested in this cell. The deflections just after the electrodes were put in the solution were very large and the cell could not be worked to any advantage until after a couple of days. The deflections with the more dilute solutions were not so large, and thus it did not take so long for them to get into working condition.

The electrophorus disk did not hold the charge over 8 or 10 minutes and had to be recharged. Every time a charged body was brought near to the cell, although the galvanometer circuit was open there was a considerable deflection due to ordinary electrostatic induction, and this would show itself also on closing the circuit to take a deflection. It was necessary then to avoid this as much as possible, and this could be done if the charge could be retained for a considerable time. The knobs of two Leyden jars were then placed close to the opposite electrodes and charged, the one positive and the other negative, by a friction machine. The jars of course hold the charge much better, but the effect did not seem to be very decided, which is perhaps due to the small surface exposed by the knobs.

In order to have a charge that would waste but slowly and at the same time have a considerable surface exposed, I connected the knobs of two Leyden jars to the disk of an electrophorus. The disk was about $21{\cdot}0^{cm}$ in diameter and was generally brought to within about 2·0 or $3{\cdot}0^{cm}$ of the cell and the knobs of the jars charged with the friction machine. The intensity of the electrostatic charge was judged, partly, by the induction produced while charging, and as this arrangement gave by far the greatest induction, it was believed to have the greatest effect on directing the ions, as was found later to be true. The friction machine gave a spark of from $\frac{3}{4}$ to 1 inch in length. The induction while charging is considerable, and although it seems to be about the same in whatever position the electrodes or disk are placed, so long as the charge is of the same sign, and although the recharging, with the jars, need be done only every 20 or 30 minutes, yet it was thought best to charge the jars only when the electrodes and jars are always in the same relative position.

The following positions were used and will be designated as follows:—Positions (1), (2), (3) and (4), figure 1.

The T-shaped figure represents the disk, which can be charged by the jars and the electric machine. The cell is represented as seen from above. The arcs of circles represent the platinum electrodes.

The jars in connection with the disk were charged only when in positions (1) or (4), and discharged before the electrodes were turned into positions (2) or (3).

The galvanometer circuit is kept open except at the moment of taking a deflection. The direction of the galvanometer needle was determined beforehand.

The time between each deflection in the different series was generally 2 or 5 minutes. I will describe a 20-minute series, deflections being taken every 2 minutes, starting from position (1).

Before the jars were charged, the deflections were taken in position (1) every 2 minutes for 20 or 30 minutes or until the deflections became about uniform; then the cover of cell together with the electrodes were turned through 90° into position (2), say. The turning was done very slowly and carefully so as not to disturb the liquid more than necessary, and care was also taken to avoid shaking or turning the cell. The deflections were then taken in position (2) every 2 minutes for 20 minutes, and then the electrodes were turned 180° through the first position into position (3), and the deflections taken in that position every 2 minutes for 20 minues. These readings would indicate the condition of the liquid at positions (2) and (3) before being acted upon by an electrostatic charge, and comparing these readings with the readings after the solutions has been acted upon by a charge would show the effect of the charge.

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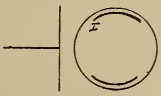
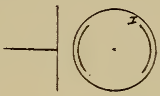
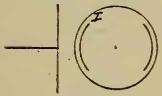
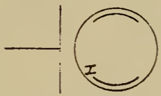

Position 1.


Position 2.


Position 3.


Position 4.

After the condition of the liquid was determined as above stated, the electrodes were turned into position (1) and the jars in connection with the disk charged positive or negative by the friction machine. The charge was allowed to act for the same interval of time as was used before, namely, 20 minutes, and the deflections taken in this position also, in order to keep the cell always in the same condition, that is, deflections were taken every two minutes throughout the entire experiment. If the cell is allowed to rest even a few seconds over the regular interval, a change in the amount of the deflection is noticed. The cell runs down quickly and recovers quickly.

If the deflections in any direction are large at the beginning of the observations, the direction cannot be reversed by this charge, and this method and the effect is only a differential one, but if the cell is in a more stable condition the directions can be reversed, and this was done scores of times.

The induction produced when the jars are discharged is of course in the opposite direction from what it is when charging, but it is not large and does not appear in the third reading of 2-minute intervals. Diffusion acts against the heaping up of positively or negatively charged ions in any part of the liquid, and this often appears in the last observations of a 20-minute series.

A solution of potassium hydroxide and a solution of potassium sulphate were also tested by this method, using platinum electrodes as before, with the same results as with dilute sulphuric acid.

2

Top view Side view

Incidentally it may be mentioned that the induction produced, in the galvanometer circuit, by bringing up a charged body to the cell was of about the same order of magnitude whether there was any liquid in the cell or not.

One acid, one salt, and one base were used in these experiments. The only reason for choosing these particular ones was, that it was necessary to employ some substance which on being decomposed and set free would not affect the platinum electrodes, and it was desirable also to have substances whose ions were known to have a considerable velocity.

Distilled water was always used.

It was now thought that it would be interesting to study the effect of an electromotive force, less than the decomposition value, upon an electrolyte. Accordingly the following experiments were performed:

No electrostatic charge was here employed.

A solution of different percentages of sulphuric acid was put into a cell having four platinum electrodes. The cover of the cell was so made that the inner or middle electrodes could be rotated independently of the outer.

The two inner electrodes *a* and *a'* were connected to the galvanometer circuit, and the two outer electrodes A and A′ were to be connected to a Daniell. *a* and A were about 8·0 $^{\mathrm{mm}}$ apart, and *a* and *a'* about 50·0 $^{\mathrm{mm}}$ apart. The circuit to the galvanometer was closed only while taking a deflection, and this was never done while the circuit of the Daniell was closed.

The connections were generally made as follows (fig. 2):

If *a* of the galvanometer circuit was found to be negative and *a′* positive when beginning the observations, then A was connected to the positive pole and A′ to the negative pole of a Daniell. After the Daniell had been connected thus for a few minutes, it was disconnected and the sign of *a* and *a′* tested by closing the galvanometer circuit. *a* might still be negative and *a′* positive, but by connecting up the Daniell the same way and repeating this, *a* could always be made of the same sign as A. Then keeping the circuit of the Daniell open and leaving everything else as before except turning the electrodes *a* and *a′* through an arc of 180°, so that they exchanged places, and after a few minutes closing the galvanometer circuit, it was found that the direction of the deflection was reversed. Turning back to the first position would reverse it again. This could be repeated several times without connecting up the Daniell again.

This would show that the liquid in the neighborhood of a positive pole connected to a Daniell is charged with positive ions, or around the negative pole is charged with negative ions, or both.

The electrodes connected to the Daniell became polarized and remained so for some time. The same results were obtained, however, if after disconnecting the Daniell, the electrodes were discharged by short circuiting them. In this case the Daniell had to be connected for a longer period to obtain the same result, but this was all.

By connecting the Daniell to the *inner* electrodes and the galvanometer to the *outer* electrodes, the results were the same but it took a longer time.

This would show that the ions diffuse in all directions, but that they are more numerous between the electrodes.

Richarz and Lonnis* have shown, by means of the reaction with titanic acid, the presence of hydrogen peroxide at the cathode in dilute sulphuric acid at electromotive forces too small to produce an evolution of gas. But no hydrogen peroxide was discovered at voltages below one Daniell.

The same results as those above mentioned with one Daniell were obtained in my experiments by using $\frac{1}{4}$, $\frac{1}{2}$ or $\frac{3}{4}$ the voltage of a Daniell, but it took a correspondingly longer time. When the electrolytic limit of decomposition was reached, the deflections became very large and the solution responded more quickly to the influence of an electrostatic charge, but the

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*Zeitschr. Phys. Chem., xx, 1896.

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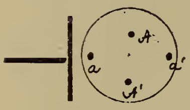

direction of the deflections were the same as before. In the experiments of the effect of an electrostatic charge on a solution which has been subjected, first, to an electromotive force less than the electrolytic limit of decomposition, and then on the solution after the decomposition limit has been exceeded, a cell of the form shown in fig. 3 was used.

a and *a'* are the electrodes connected to the galvanometer circuit; A and A' are the electrodes which may be connected to the Daniell, and T is the disk which may be charged electrostatically.

As has been stated, a larger and more prompt effect was noticed when an electromotive force, although below the decomposition value, was connected up to a cell and then an electrostatic charge brought up than when no current had previously been allowed to act upon it. Also that a pair of electrodes became of the same sign as the nearest electrode connected to a Daniell, this also although below the decomposition value of the solution.

This may be explained as follows:

Either the ions already free are heaped up around the electrodes as they become charged by the current, or the current, although below the decomposition value for the evolution of gases, yet decomposes the electrolyte. Accordingly the following experiment was performed.

According to H. C. Jones,[*] strong acids and bases are completely dissociated at dilutions of about one one-thousandth normal solutions. If there is complete dissociation, then there are of course no more molecules to be decomposed by the current unless the water decomposes. I took, in order to be sure of complete dissociation, a one-fourteen-hundredth normal solution of sulphuric acid, and using the cell shown in figure 2, subjected the outer electrodes A and A' to a potential difference of about 0·8 volt.

After taking several deflections by closing the *aa'* or galvanometer circuit, in order to get the cell into a somewhat steady condition, and noting the direction of the deflections, the AA' circuit was connected up to a potential difference of about 0·8 volt from a Daniell, in such a direction as to increase the deflections in the galvanometer circuit. It did increase the deflections and on reversing the direction of the current from the Daniell, the deflections in the galvanometer circuit decreased and finally reversed.

Here no decomposition of the sulphuric acid could take place as it was completely dissociated before, and the voltage

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[*] Theory of Electrolytic Dissociation, p. 190.

was too low to decompose the water; hence it would seem that there are free ions present and that they are heaped up around the electrodes when they are charged by a Daniell.

Some time after the preceding experiments the following were performed.

It is known that when two metal electrodes, as for example copper, are placed in a solution of their salt and the circuit closed, that the smallest potential difference between them will give rise to a current and the metal will be dissolved from the anode and deposited on the cathode.

If then we take two copper electrodes, weigh them carefully and they on being placed in a solution of copper sulphate do not give too decided a deflection, we may be able to change the direction of the deflection by an electrostatic charge and then on short circuiting them and keeping up the charge we should get a diminution in weight of the anode and a gain in weight of the cathode.

Copper wires were bent into a flat zigzag form, in order to give a larger surface exposed and at the same time so that they might be placed near to the edge of the cell and consequently as near as possible to the electrostatic charge.

The electrodes were marked, cleaned in nitric acid, washed, dried and carefully weighed. The electrodes on being placed in the solution gave a decided deflection, but I was able to reverse this direction with two ordinary sized Leyden jars connected to a disk of an electrophorus and charged by a friction machine. The circuit was then closed through the galvanometer, and the electrostatic charge renewed occasionally by giving the electric machine a few turns. If the circuit was closed without any external resistance as by a short thick wire, the cell ran down quickly and sometimes gave a deflection in the opposite direction, so the circuit was made through the galvanometer. The circuit was kept closed for about three-quarters of an hour, breaking it only while recharging jars. The electrodes were then taken out, washed with distilled water, dried, and again weighed. It was found that the cathode had gained about $1{\cdot}2^{\mathrm{mgm}}$ and the anode lost about $0{\cdot}4^{\mathrm{mgm}}$.

It had been found throughout these experiments that the negative charge was not as effective as the positive, which is perhaps due principally to its wasting faster than the positive. However, having four Leyden jars connected to the disk so as to hold the charge longer, I found the negative charge the more effective, and the direction of the deflection would often be reversed at the first observation taken after charging. The first observation was not generally taken until about 10 minutes after charging so as to allow the induction to disappear. Having reversed the direction with a negative charge, the jars were discharged. Now leaving everything as before but charging the jars positive, the direction of the deflection was again reversed.

The experiments were repeated with pure zinc amalgamated electrodes in zinc sulphate with the same results. The zinc cell did not, generally, give as large a deflection as the copper and so could more easily be reversed.

The greater effectiveness of the negative charge when it is sufficiently large may be due to the fact that the positive ions move faster than the negative, and the attracted ions would be guided more effectively than the repelled.

Toward the close of this work the humid weather interfered with the experiments somewhat, but results were obtained which indicated that it would be possible to entirely waste away the anode, by letting the electrostatic charge act on the closed circuit for a sufficiently long time.

It was intended also to test a non-electrolyte by this method, using a sugar solution, but the distilled water I was able to obtain always gave a deflection in the galvanometer, showing that it contained some dissociated electrolyte, and therefore this test could not be made.

These experiments have shown :—

1. That, when a cell containing an electrolyte is connected to a Daniell, although the electromotive force is below the decomposition value of the electrolyte, the solution in the neighborhood of the anode becomes positive, or in the neighborhood of the cathode becomes negative, or both.

2. That, after an electrolyte has been electrolyzed by a current, it is affected by an electrostatic charge in such a way that the liquid nearest the charge becomes of the opposite sign, or the liquid farthest from the charge becomes of the same sign as the charge, or both.

That is, an electrolyte after having been electrolyzed acts as if it contained particles charged with electricity which are free to move and may be directed by an electrostatic charge.

3. That an electrolyte subjected to an electromotive force less than the decomposition value of the solution behaves in a similar manner.

4. Finally, that an electrolyte which has never been acted upon by a current also behaves in a similar manner when acted upon by an electrostatic charge.

That is, it behaves as if it contained particles charged with electricity, which are free to move, and these particles have not been produced by a current.

This corresponds to the definition of free ions.

In conclusion I wish to thank Professor Wright, who suggested the subject and a large number of the experiments, and whose advice and assistance has always been cheerfully given.

Sloane Physical Laboratory, New Haven, June, 1902.

ART. XXX.—*On the Solution of Problems in Crystallography by Means of Graphical Methods, based upon Spherical and Plane Trigonometry;* by S. L. PENFIELD.

INTRODUCTION.—It is believed that all who have occasion to teach mathematical crystallography must have had experiences similar to those of the present writer. There are occasional students who find the subject very easy. These are naturally persons who are proficient in mathematics, and have good imaginative powers and a quick eye for grasping geometric forms. A little guidance from the instructor and some experience in handling crystals and apparatus are all that such persons require in order to obtain a very satisfactory grasp of the subject. The majority of students, however, find the subject somewhat difficult, one of the chief reasons for this being that they are troubled by the mathematics, although the latter embraces, for the most part, only simple principles of geometry and spherical and plain trigonometry. Probably the majority of those who undertake the study of crystallography are especially interested in the subject because of its practical bearings on chemistry, mineralogy and petrography. They are not especially mathematical in their tastes, and the calculations needed for the solution of the numerous problems which arise seem difficult and distasteful, not so much because of want of suitable training, but because, in all probability, mathematical principles have not been used very much in their other studies, perhaps, for a number of years; hence it is that innumerable difficulties and discouraging mistakes are often encountered when numerical calculations are made by means of formulas and logarithms. Probably all crystallographers have found numerical calculations burdensome, and the only real way to absolutely avoid mistakes is either to do all work in duplicate, or to apply some other method of checking results. The main object of the present communication is to set forth and explain certain graphical methods, based chiefly upon the stereographic projection, which have been found very useful in the writer's laboratory, and it is believed that they are especially applicable not only for the presentation of crystallography to beginners, but also for the solution of many complicated problems which may arise.

All who have worked much at crystallography have doubtless made use of graphical methods to a greater or less extent, and many descriptions of such methods may be found, but for the purposes of the present communication it does not seem necessary to review the work already done by others, as the methods to be presented, though based on simple principles, are worked out, for the most part, along lines differing from those generally recommended. The principles involved in solving problems in spherical trigonometry by graphical methods have been already fully explained by the present writer in a communication entitled, "*The Stereographic Projection and its Possibilities from a Graphical Standpoint*,"* to which frequent reference will be made. The advantages of the methods there described are that the mathematical principles involved may be comprehended easily, and only a simple and inexpensive outfit is needed for carrying on the work. With a little study, the methods may be mastered by any one, whether well equipped in mathematics or not, and for the solution of most problems the results are sufficiently exact. Whenever numerical calculations must be made, the processes of solving the problems graphically furnish the key to the methods of making needed calculations.

From an educational standpoint it is always a gain to do things understandingly, rather than mechanically, and the advantages of the graphical methods about to be described are that approximate solutions of all kinds of problems in crystallography may be made quickly without the use of tables or formulas of any kind, while at the same time an accurate and useful projection, or map, has been constructed.

In the actual study of crystals, after having made all necessary measurements and determined the system of crystallization, three processes must generally be followed: (1) The determination of the symbols of the several forms observed. (2) The determination of the axial ratio from certain selected *fundamental measurements*. (3) The calculations of a number of interfacial angles from the fundamental measurements. For the first of these processes graphical methods are quite sufficient, especially when it is borne in mind that, owing to the numerous imperfections of crystals, the best measurements which may be had are at times only approximately near the truth. The two remaining processes must be carried out by means of numerical calculations, unless the methods suggested by Fedorow† are employed, but the graphical methods, if likewise followed out, will furnish a ready means of checking numerical work. It may also be pointed out that as examples multiply of minerals and other chemical compounds whose crystallographic properties have been carefully studied, it becomes less often necessary to make calculations; for the work on any compound, when once well

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* This Journal (4) xi, pp. 1–24 and 115–144, 1901.

† Zeitschr. für Kryst., xxxii, 464, 1890.

done and recorded in the literature, need not be repeated. Hence a student of crystallography, working as would naturally be the case, on well-known compounds, may be able to solve the majority of the problems presented for study by means of graphical methods, and thus be spared much of the time-consuming labor of making numerical calculations.

Outfit.—For executing the graphical methods described in this paper the following articles are needed: (1) Paper upon which a graduated circle and certain stereographic scales have been printed. (2) Stereographic protractors for plotting and measuring. (3) Beam-compass. (4) Curved ruler. (5) Two triangles and a set of drawing instruments, including a needle-point and hard pencils.

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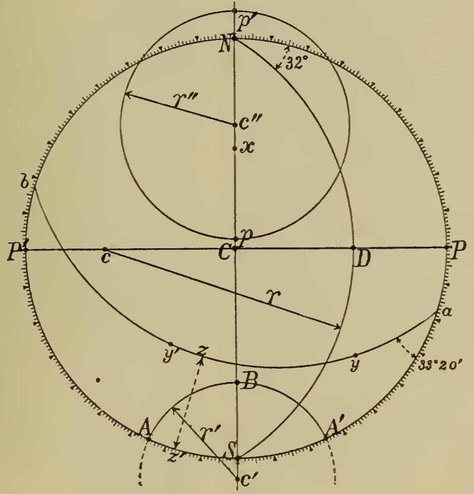
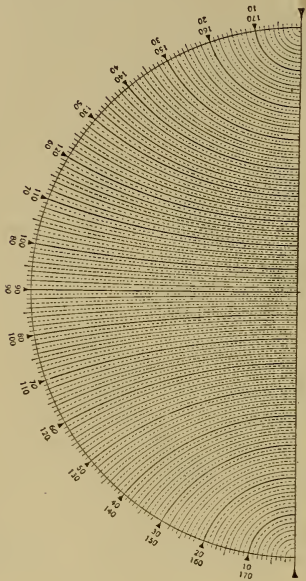


The uses of most of the above-mentioned appliances have already been described, and only a few suggestions concerning them are now needed. The paper mentioned has a circle of 14^{cm} diameter, graduated to degrees, printed on it, the circle shown in figure 1 being a reduced copy. Four scales, of which frequent use will be made, are also printed on the paper. No. 1 gives the lengths of radii for describing arcs of great circles; for example, if it is known that the point *D*, figure 1, is 32° from *P*, the radius *r* for describing the great circle *NDS* may be taken directly from the scale. Scale No. 2 gives the lengths of radii for describing arcs of small circles about points which are located on the divided circle; for example, it being known that the point *B*, figure 1, is 25° from *S*, and through B a small circle ABA' is to be drawn, every point of which is 25° from S, the radius r' is given by the scale. On a sphere, the center for describing such a circle would be at S; in the stereographic projection, however, the center c' lies beyond S, on the diameter NS. Scale No. 3 is a stereographic scale, giving the distance in degrees from the center C to any desired point; for example, in figure 1, to the point x, which is 51° from C. About x a small circle has been drawn, every point of which is 46° from x. By means of scale No. 3 the needed points were located; x, 51°; p, $5° = 51° - 46°$; and p', $97° = 51° + 46°$, all measured from C; and the radius r'' for describing the circle is half the distance from p to p', the center c'' falling somewhat beyond x. Scale No. 4 gives decimal parts of the radius of the divided circle, and is used for measuring the lengths of axes, assuming the radius of the circle as unity.

2



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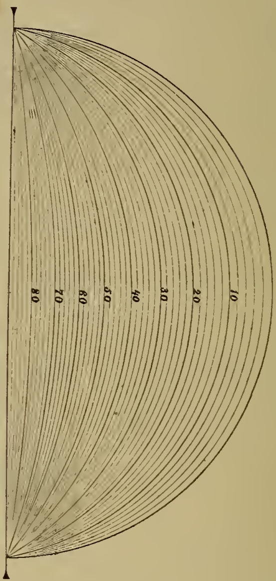

The stereographic protractors needed are three in number. One of these (referred to as protractor No. I and shown in figure 4 of the former article) is printed on cardboard, and has along its base line a graduation which will be referred to in this paper as the *stereographic scale.* The scale is the same as a portion of that designated as No. 3 on the drawing paper; hence this protractor is not essential, but its convenience will recommend it. The second protractor, figure 2, is a measuring scale, consisting of a series of stereographically projected small circles drawn about the 0° and 180° points. It was described in the former paper as protractor No. II, having a circular form, but one-half of the circle, which is superfluous, has since been cut away from the original plate. It will be referred to in this paper as the *small circle protractor.* The third protractor, figure 3, consists of a series of stereographically projected great circles, and will be referred to as the *great circle protractor.* Purposely no numbers are printed on this protractor, and those using it will do well to lay it printed side down and number the graduation with India ink, as shown in figure 3. If a number then happens to interfere with the uses of the protractor, it may be easily washed away. The uses of the protractors may be explained by reference to figure 1. If y and y' are two points on a stereographic projection, the great circle passing through them may be found by centering the great circle protractor, figure 3, over the projection and turning it until an arc is found which passes through, or proportionately near, y and y'. The position of the protractor then determines the points a and b on the periphery, and its graduation gives the angle at a, 33° 20′, or the distance z to z'. Knowing the distance z to z', the radius for constructing the great circle may be taken directly from scale No. 1 of the drawing paper. By now applying the small circle protractor, figure 2, with its 0° and 180° points at a and b, the distances a to y and a to y' may be determined from the graduation, and the difference gives the distance y to y'. Thus a great variety of measurements may be made with facility and rather astonishing accuracy.

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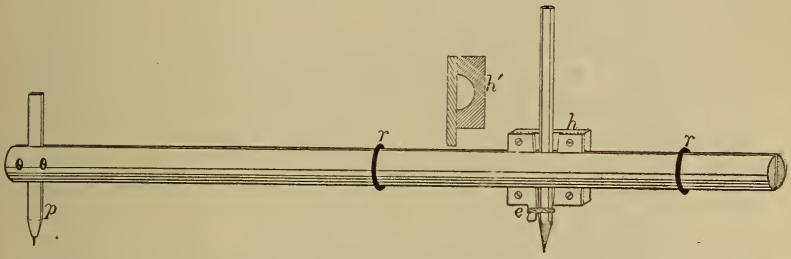

A beam-compass is an essential for accurate work, as ordinary dividers are not stiff enough to be relied upon for drawing circles having long radii. A compass constructed on the principles shown in figure 4 may be recommended, the idea having been suggested by Professor Charles B. Richards of the

Engineering Department of the Sheffield Scientific School. The beam is constructed from a round stick of hard wood, ⅞ inch diameter, sawed lengthwise. The needle-point *p* is prepared by gluing the surfaces of two pieces of hard wood, placing a needle between them and pressing in a vise. After hardening of the glue, the piece is trimmed down to convenient size, and is held firmly in place between the half-rounds by means of two screws. Two rings *r* and *r* (obtained from a harness shop) serve to grip the pencil firmly between the two sticks. The block *h* is not essential, serving simply to hold the pencil (fastened by an elastic at *e*) when its position is shifted. A fine adjustment is had by moving the upper end of the pencil, which gives a much slower motion to the point. In order to adjust the pencil quickly with reference to scales 1 and 2 of the drawing paper, it is convenient to have these scales pasted on the beam. The writer has found compasses of this description most convenient, and rather prefers them to the beam-compasses listed by dealers in drawing instruments at a rather high price.

A curved ruler is indispensable for drawing some very flat circular arcs. The form first suggested by Wulff* and modified by the present writer† is recommended. The ordinary drawing instruments need no especial comment. Two triangles of transparent celluloid (45° and 60°), measuring about 12 inches along the hypothenuse, are recommended. Their edges serve as rulers, and when held one against the other, the edge of the farther triangle being set at any desired angle, the direction may be transferred to any point by sliding the farther triangle along the edge of the near one, held firmly against the drawing paper.

As the scale upon which the plotting is done is rather small, a lens is recommended, and it is especially convenient to have one mounted on a stand. The kind suggested by the writer, and shown in figure 33 of his earlier paper, though expensive, has proved most useful.

Having described the necessary outfit, attention may next be directed to consideration of the principles upon which the methods of plotting are based.

The Spherical Projection.—The stereographic is often called the *spherical projection*, but it is believed that it would be best to restrict the use of the latter term, in so far as it concerns crystallography, to the projection of the faces of a crystal upon a sphere. This latter conception is a very simple one: A crystal is supposed to be located at the center of a sphere,

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* Zeitschr. für Kryst., xxi, p. 253, 1892.

† The Stereographic Projection and its Possibilities, loc. cit., p. 138.

figure 5, its vertical axis orientated so that it corresponds with the axis joining the north and south poles; then from the center of the sphere lines, *normals* are supposed to extend out, at right angles to the several crystal faces, until they touch the surface of the sphere, where they locate points, known as the *poles* of the faces. Figure 5 was plotted with much care in clinographic projection, and was made partly with the idea of putting on record a good figure illustrating the simple principles of the spherical projection. A combination of cube *a*, octahedron *o*, and dodecahedron *d* is shown, with normals extending to the surface of an imaginary sphere. The projected

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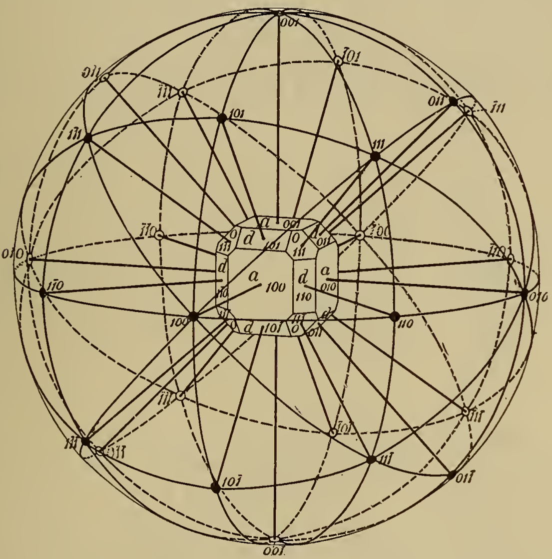
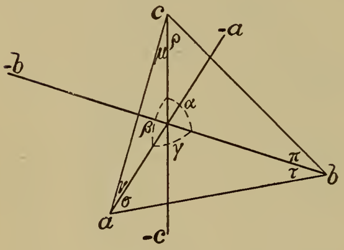


great circles, uniting the poles of the faces, are shown in the figure as ellipses. The figure well illustrates the important principle, that the normals to a series of faces which are in a zone all lie in one plane, and touch the sphere on an arc of a great circle. The length of arc between the poles of any two faces, as measured on a great circle, is the same as the angle between the normals, hence the same as between the faces as measured with the reflection goniometer. Wire models constructed on the principles shown in figure 5 are very helpful to beginners.

For studying crystals, it is convenient to make use of the stereographic projection. Generally the poles of one hemisphere only (the upper) are represented, the projection being made on the horizontal plane, or plane of the equator. The point of vision is then at the south pole, $00\bar{1}$, of figure 5. A model, similar to one made by the writer and illustrated in an article on Map Projection,* is a help in conveying to beginners correct ideas of the principles upon which the stereographic projection is based.

The fundamental proposition of mathematical crystallography.—That property which must first be ascertained for every crystallized substance is its system of crystallization, and then follow the determinations of the inclinations and lengths of the axes. Figure 6 represents a general proposition (the axes shown are those of rhodonite, triclinice) in which the quantities sought are the axial inclinations α, β and γ, and the lengths of the axes a and c, it being assumed that b is equal to unity. The angles α, π and ρ of figure 6 are those of a plane triangle with the axes b and c for its sides, and it is evident that after having determined a (the b axis being unity) it is only necessary to find either π or ρ in order to solve the triangle and obtain the length of the c axis. Likewise, γ having been determined, it is only necessary to find either τ or σ in order to obtain the length of the a axis. With β and the length of one axis, either a or c, determined, the length of the other axis may be found if either μ or ν is known. For the complete solution of a problem in the triclinic system, therefore, the axial inclinations α, β and γ must be determined, and in addition only two other angles are needed (τ and π, for example) in order to find the lengths of a and c. As will be shown, all of the desired parts α, π and ρ ; γ, σ and τ ; and β, μ and ν are to be found on a stereographic projection, where angles are preserved so that they may be measured.

6



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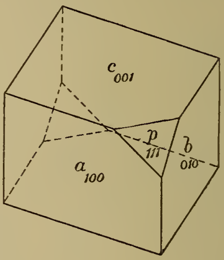

Figure 7 represents a hypothetical case, a combination of the three pinacoids a, 100 ; b, 010 ; and c, 001 of rhodonite, in combination with the pyramid p, 111. Five measurements made on such a crystal suffice for the solution of the problem, and for rhodonite they may be as follows :

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* This Journal, xiii, p. 247, 1902.

$a \wedge b$, $100 \wedge 010 = 94^\circ\ 26'$ $a \wedge p$, $100 \wedge 111 = 56^\circ\ 19'$
$a \wedge c$, $100 \wedge 001 = 72\ \ 36\frac{1}{2}$ $c \wedge p$, $001 \wedge 111 = 29\ \ 49$
$b \wedge c$, $010 \wedge 001 = 78\ \ 42\frac{1}{2}$

The lengths and inclinations of the axes derived from the foregoing measurements are as follows:

$$a : b : c = 1{\cdot}07285 : 1 : 0{\cdot}62127;$$
$$\alpha = 103^\circ\ 18';\quad \beta = 108^\circ\ 44';\quad \gamma = 81^\circ\ 39'$$

From the measurements given above the poles a, b, c and p of rhodonite have been accurately located in the stereographic projection, figure 8, and through the poles the principal zones, corresponding to those of figure 5, have been drawn. The relation between figures 6 and 8 is a most important one. The angles α, π and ρ, made by the meeting of the great circles at the pole a, figure 8, are identical with α, π and ρ of figure 6, and a like correspondence holds true at the poles b and c of figure 8, as indicated by similarity in the lettering. In order to make clear that the angles α, π and ρ of the stereographic projection, figure 8, are identical with α, π and ρ of the rhodonite axes, which, it must be remembered, are shown in clinographic projection in figure 6 and therefore somewhat distorted, let it be assumed that a model corresponding to figure 5, but constructed so as to represent the triclinic system, is at hand. Since the front pinacoid a of figure 7 is parallel to the b and c axes, its normal is at right angles to the plane of these axes; hence if we imagine ourselves as looking at the b and c axes of a triclinic crystal in the direction of the normal to the

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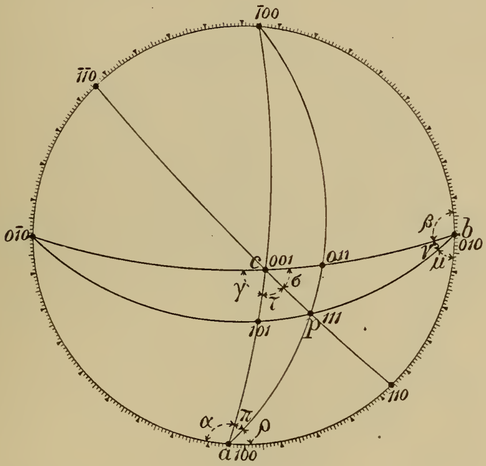

face *a*, 100 (the axes being properly orientated within a sphere, and the latter standing sufficiently far away to give the effect of orthographic projection), the relations shown in figure 9 would be seen. The outer circle represents the bounding surface of the imaginary sphere. The *b* and *c* axes are seen within the sphere with their true inclination and lengths; $a = 103° 18'$, and $b : c = 1.00 : 0{\cdot}621$. Normals to all crystal faces parallel to the *c* axis (compare figure 5) are located in a plane at right angles to the *c* axis, which plane would be foreshortened in orthographic projection to the line *CC′*. Likewise normals to all faces parallel to the *b* axis lie in the plane represented by the line *BB′*. Since the planes represented in figure 9 by *CC′* and *BB′* are at right angles, respectively, to

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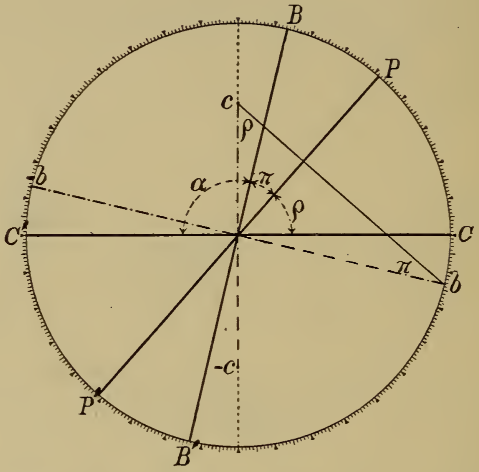

the *c* and *b* axes, they must make with one another an angle equal to that of the axes, that is *α*. All forms intersecting the *b* and *c* axes at their unit lengths, therefore, having the direction of their intersections represented by the line *b c*, figure 9, would have their normals in a plane at right angles to the direction *b c*. This plane seen in orthographic projection is represented by the line *PP′*, and, therefore, owing to the construction, the planes *BB′* and *PP′* make with one another an angle equal to *π*. In like manner the planes *CC′* and *PP′* make with one another an angle equal to *ρ*. Hence it is that the angles made by the planes in which the normals are located, represented by *CC′*, *BB′* and *PP′* in figure 9, are to be found in the stereographic projection, figure 8, at *a*, a line from *a* to the center of the sphere being the common intersection edge of the three planes. In like manner it may be demonstrated that at the poles *b* and *c*, figure 8, where normals to the pinacoid 010 and the base 001 meet the sphere, the plane angles β, μ and ν and γ, σ and τ of figure 6 are to be found. How these facts are to be made use of, will subsequently be shown by examples.

Another principle which may be made use of for the solution of many problems is that based upon the conditions established by three faces in a zone, known by some as the cotangent and tangent relation.* For the purpose of illustrating this principle, reference is made to figure 10, which represents a regular arrangement of dots conditioning angles like those found in the prismatic zone of crystals of rhodonite. The dots may be regarded as representing crystal particles or molecules, and the forms shown by the heavy outline of the figure are the planes *a* (100), *b* (010), *m* (110), *M* (1$\bar{1}$0) and *f* ($\bar{1}$30), as seen in orthographic projection. It may be assumed that the crystal is made up of layer upon layer of particles like the one shown, figure 10 being an orthographic projection of such a system of particles, as seen in the direction of the vertical axis of the crystal. Since rhodonite is triclinic, a single layer of particles, represented by the dots, does not lie in a plane parallel to the paper, but in a plane tilled down to the front and right by an amount indicated by the axial inclinations

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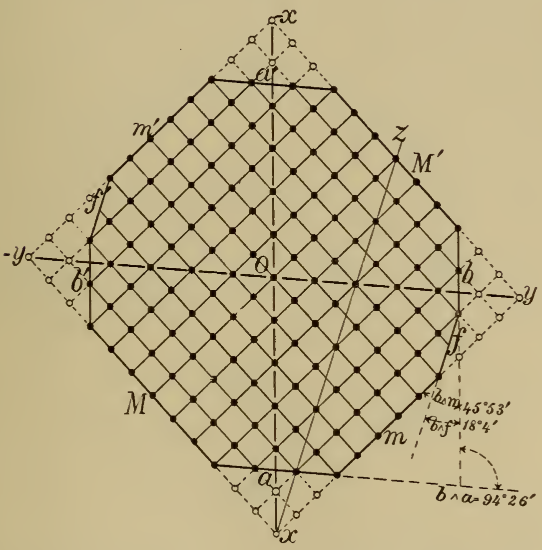

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*Dana's Text Book of Mineralogy, edition of 1898, p. 31.

$\beta = 108° 44'$, and $\alpha = 103° 18'$. The lines x, $-x$ and y, $-y$, therefore, are not the true crystallographic a and b axes, but the somewhat foreshortened orthographic projections of the axes. Notwithstanding foreshortening, however, for all purposes of calculation in the zone under consideration, the lines $x, -x$ and $y, -y$ are *lines of reference*, regarding which the law of definite mathematical ratio of crystal faces holds true, the same as for real crystallographic axes. The angle between $x, -x$ and $y, -y$ is determined by the measurement of b (010) on a (100), and the angles of a third form, m (110), establishes the relative lengths of the lines of reference Ox and Oy. Any fourth face in the zone, therefore, when referred to Ox and Oy must have an inclination in conformity with the fundamental law of definite mathematical ratio. For example, in figure 10 the face f is parallel to the line $x\,z$ which intersects the line of reference Oy at one-third its length; the symbol of f is therefore 130, and the angle $b \wedge f$ is wholly dependent upon the two angles $b \wedge a$ and $b \wedge m$. Hence it is, that knowing the symbols and angles of three faces in a zone, the angle of a fourth face may be found if its symbol is given, or its symbol may be determined if its angle is given.

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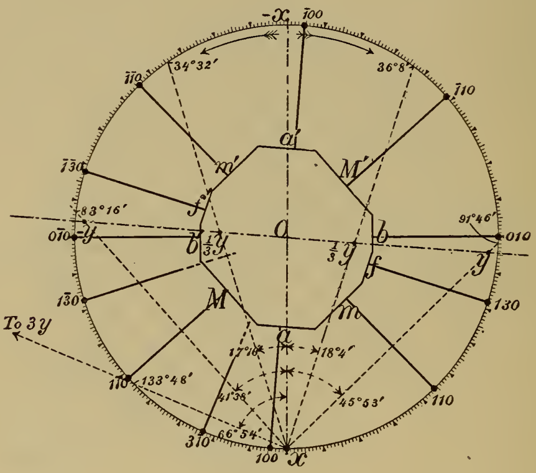


Figure 10 furnishes a key to the solution of problems like the one just given. Let it be assumed that on a rhodonite crystal two angles have been measured, as follows: $b \wedge a = 94° 26'$ and $b \wedge m = 45° 53'$, and that the poles 010, 100 and 110 are plotted on a divided circle, figure 11. Lines of reference $x, -x$ and $y, -y$ are then drawn through the center, parallel, respectively, to the b and a faces, therefore intersecting the divided circle at 90° from the poles 010 and 100. A line parallel to the face m (at right angles to the normal to m) is next drawn. To do this easily use may be made of the principle of geometry that the angle between two lines meeting at the circumference of a circle is measured by half the arc intercepted on the periphery; hence the line may be drawn from x to 91° 46′ (twice $b \wedge m$, 45° 53′) on the graduation of the divided circle, measured from $-x$. This line determines a point y on the second line of reference, and establishes the ratio of Ox to Oy, the numerical value of which, however, need not be determined. Designating the distances Ox and Oy as x and y, respectively, the law of definite mathematical ratio demands that all faces in the zone under consideration must intercept the two lines of reference at definite multiples or fractions of x and y. In figure 11 the angle of $b \wedge f$ is 18° 4′, and by drawing a line from x to 36° 8′ (double the angle) on the periphery it is found that it intersects at $\frac{1}{3}y$; the symbol of the face is therefore 130. Likewise by drawing lines from x to $-\frac{1}{3}y$, $-y$, and $-3y$, the angles of the forms $1\bar{3}0$, $1\bar{1}0$ and $3\bar{1}0$ (measured from $0\bar{1}0$) are found, the values being most easily obtained by halving the arcs intercepted on the periphery, as indicated in the figure. The case just cited, although a simple one, is general, for it is wholly a matter of choice in the orientation of a rhodonite crystal that the forms designated as b, f, m, a, etc. are taken as parallel to the vertical axis.

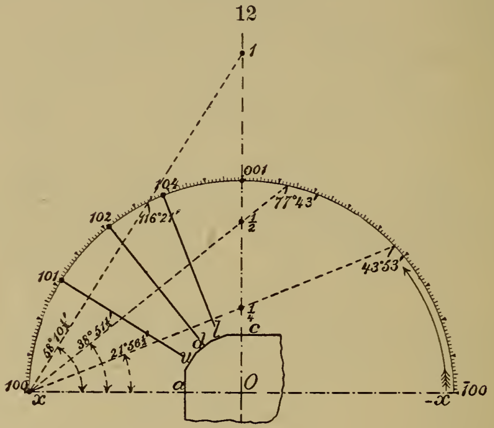
Cases may arise where reliable measurements may be had from three known forms, for example, b, f and m, figure 11, and it is desired to find the angle of a fourth form a, 100, which may either be absent, or be of such poor quality as to yield no satisfactory measurement. To solve such a problem construct the line $x, -x$ parallel to b, and from x draw lines parallel to f and m. The direction of a is then found by constructing a line through the center which will be intersected by the lines previously drawn in the ratio $\frac{1}{3} : 1$. With the aid of a straight edge and a pair of dividers such a line is easily found.

Again, it will often happen that the zone under consideration is of such a nature that the ratio of the intercepts on the line of reference Oy can not be told by simple inspection, in which case the following procedure may be resorted to. Any four faces taken in succession may be designated as A, B, C and D, and their indices, respectively, as hkl; mno; pqr, and xyz. Taking the first line of reference (corresponding to $x, -x$, figure 11) as parallel to the face A, the ratio of the intercepts on a line parallel to the fourth face D may be found from a system of left to right, right to left, cross-multiplication and subtraction, carried out according to the following scheme :*

$$\begin{array}{llll} A,\ hkl & \quad 1-2 & \quad 1-3 & \quad 2-3 \\ \underline{B,\ mno} & = \dfrac{hn-km}{my-nx}; & \dfrac{ho-lm}{mz-ox}; & \dfrac{ko-ln}{nz-oy} \\ B,\ mno & & & \\ D,\ xyz & & & \end{array}$$

$$\begin{array}{llll} D,\ xyz & & & \\ \underline{C,\ pqr} & = \dfrac{xq-yp}{pk-qh}; & \dfrac{xr-zp}{pl-rh}; & \dfrac{yr-zq}{ql-rk} \\ C,\ pqr & & & \\ A,\ hkl & & & \end{array}$$

The result of multiplying one of the upper expressions by that directly beneath gives the desired intercept. The result in some cases is indeterminate, as, for example, schemes 1−3 and 2−3 applied to prismatic zones, where the third index of the forms is zero, or scheme 1−2 applied to a zone between some prism and base, where the first and second indices of the forms maintain the same ratio. When a numerical solution is desired the following equation is generally made use of:



$$\frac{\text{Cot } AC - \cot AD}{\text{Cot } AB - \cot AD} = \text{rational intercept.}$$

Provided AD equals 90°, its cotangent equals zero, and the problem is then much simplified. It may then be easier to

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* Note.—The scheme of cross-multiplication and subtraction here suggested is essentially like that given in Dana's Text Book of Mineralogy, page 31, Groth's Physikalische Krystallographie, page 584, and other works, but by adopting, as has been done, a somewhat more symmetrical arrangement and procedure, the operation is more easily remembered and carried out.

consider the relation in terms of tangents rather than cotangents. The tangent principle, though simple, is so exceedingly important that it is thought best to introduce an example indicating a graphical method of solution. The illustration, figure 12, is chosen from barite, the forms shown being those of the macrodome zone, with $c=001$, and $a=100$. It is assumed that the angles have been measured as follows: $c \wedge l = 21° \ 56\frac{1}{2}'$; $c \wedge d = 38° \ 51\frac{1}{2}'$, and $c \wedge u = 58° \ 10\frac{1}{2}'$. The poles are easily located on the graduated circle, and the slopes of the several faces plotted by drawing lines from x to points on the periphery equal to twice the value of the angles, measured from $-x$. It is then evident that if u is taken as the unit dome 101, the intercepts of d and l on the vertical axis are respectively $\frac{1}{2}$ and $\frac{1}{4}$, and their symbols therefore 102 and 104. If the length of the a axis of barite were known ($a=0{\cdot}815$), the slopes of u, d and l would naturally be plotted from the unit length of a, when the slope of u would determine the length of the vertical axis ($c=1{\cdot}314$). For plotting and measuring the lengths of axes, the radius of the divided circle may be taken as *unity*, and measurements of axial lengths made by means of scale No. 4 of the sheets on which the divided circles are printed.

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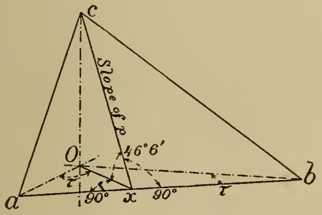

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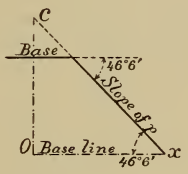

Another procedure applicable to all cases where the axial inclinations are 90° is illustrated by figures 13, 14 and 15. In figure 13 three axes meeting at 90° at O, and their intersections with a pyramid abc, are shown in clinographic projection. The line Ox, at right angles both to the vertical axis and the edge ab, is an important factor to consider, and may be designated as the *base-line* of the triangle cOx. Another important factor to be considered is the slope of the pyramid, or its inclination, along the line xc, with the base-line Ox. From figure 14, which represents a section along the plane cOx of figure 13, it may be seen that the slope of a pyramid, or the angle made by the line cx with the *base line* Ox, is the same as the interfacial angle of base on pyramid, 46° 6′ in the figure. Knowing the *base-line* Ox and the slope of any pyramid, therefore, the problem may be plotted to scale and the length of the vertical axis *Oc* determined. The foregoing simple trigonometric relations may now be applied to figure 15, where the divided circle is employed for the double purpose of a stereographic projection and for solving problems in plane trigonometry. Let it be supposed that the poles of the three pinacoids 100, 010 and 001, and of a pyramid *p* have been accurately located in stereographic projection. Through 001 and *p* a line is drawn which is the projection of a great circle (a meridian) determining the point *m* on the divided circle. Since the axial inclinations are 90°, the value of τ (compare figures 6 and 8) is measured by the arc $100 \wedge m$, which in figure 15 is 39° 11′. Considering the radius of the divided circle as *unity* and as equal to the *b* axis, the tangent of τ ($100 \wedge m$) gives the intercept on the *a* axis; accordingly this may be found by drawing a chord from 010 to a point on the divided circle equal to twice $100 \wedge m$, measured from $0\bar{1}0$. Applying scale No. 4 of the printed sheets along the direction of the *a* axis, the length of the axis is found to be 0·815. The chord *ba*, figure 15, determines also the point *x* on the radius passing through *p*, and the distance from *x* to the center is the *base-line* corresponding to *Ox* of figures 13 and 14. The numerical value of the length of the *base-line*, which is equal to the sine of τ, need not be determined, but the distance may be transposed to *x*′ on the horizontal line by means of dividers. Applying the stereographic scale to the radius passing through *p*, the angle of $001 \wedge p$ (the slope of the pyramid) may be measured, equal to 46° 6′ in figure 15, and a line drawn at this

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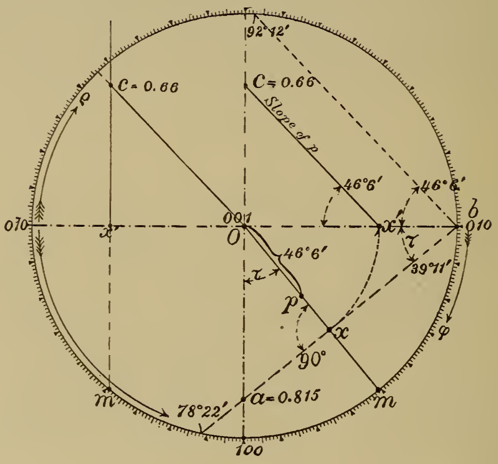

angle from x' intersects the vertical line at a point c, which, when measured with scale No. 4 of the printed sheets, gives the length of the vertical axis, $c=0{\cdot}66$. The whole procedure of determining the lengths of the a and the c axes is exceedingly simple both in its principles and in its execution, and with slight modifications may be applied even to the monoclinic system where the b axis is at right angles to the a and c axes.

Instead of laying off the *base-line* Ox' to the right of the center by means of dividers, as shown in figure 15, it may be plotted to the left, by making use of the principle that Ox equals the sine of τ. Accordingly locate m to the left on the divided circle, and draw a vertical chord; then plot the slope of p from the center, making use of the graduation of the divided circle, and measure the length of the vertical axis on the chord $x'c$. On one divided circle, therefore, a stereographic projection may be made in three quadrants, reserving the upper left hand quadrant for plotting the length of the vertical axis. It may be noted that almost at a glance at such a chart the two important angles of the two-circle goniometer, φ and ρ, may be told from the graduation; for example, the radius through p, figure 15, determines m, and, therefore, the angle φ, measured from 010, which is nearly 51° in figure 15; and the slope of p, plotted from the center and intersecting the vertical chord at 0·66, meets the divided circle at a little over 46°, which is the angle ρ, measured from $0\bar{1}0$. For plotting measurements made with the two-circle goniometer and interpreting the results, the method is most admirably adapted.

Having explained at considerable length the principles involved in solving problems graphically, some examples of the application of the methods to specific problems in the several crystal systems will next be given. The examples cited are problems which have been encountered in the writer's laboratory, and in all cases it will be assumed that the fundamental measurements were made to the nearest minute, hence the results of plotting will indicate the accuracy of the graphical methods. Generally, the scheme indicated in figure 15 will be followed, that is, the stereographic projection will be made on the lower half of the divided circles, reserving the upper half, or the upper left hand quadrant, for plotting the intercepts on the vertical axis. The horizontal radius, from the center to the right, will indicate the b axis and the lower radius the a axis. *Base-lines* corresponding to Ox of figures 13, 14 and 15 will be transposed to the horizontal diameter, as in figure 15, and indicated by correspondence in lettering. The graphical solutions were all executed carefully with fine pencil lines and subsequently traced with India-ink in order to adapt the work to photo-engraving. The illustrations, therefore, are all from the original sheets on which the plotting was done.

ISOMETRIC SYSTEM.

In this system the axes are of equal lengths, and it is necessary to determine from measured angles the symbols of the forms, or, having the symbols given, to find the interfacial angles. The first problem that will be presented is one which might, for example, be given to a beginner for the purpose of introducing the subject of mathematical crystallography and showing the relations between crystal forms and their angles. It may be supposed that the student is supplied either with models or crystals from which measurements are derived.

Starting with a simple combination, the poles of the cube are first located at 100, 010 and 001, figure 16, and those of the dodecahedron at distances of 45°, midway between them, the positions of 101 and 011 being determined by the stereographic scale. By means of the small circle protractor it may now be found that the distances between the poles of the dodecahedron are 60°. The octahedron truncates the solid angles of a cube, and is in the zones between cube and dodecahedron (compare figure 5); its poles may therefore be located by drawing the necessary great circles. The pole 111 being thus located, it may be found by the stereographic scale that the distance from 001 to 111 is $54\frac{3}{4}°$, theory 54° 44′, and from 111 to 110 is $35\frac{1}{4}°$, while like results will be obtained by measuring from 100 or 010 with the small circle protractor. Thus a conception is quickly gained, not only of the relations of the important forms, cube, octahedron and dodecahedron, but also of the values of their interfacial angles.

For simplicity of plotting, the tetrahexahedron is the next best form to consider, and a fluorite crystal with bevelled edges may be chosen as an example for study. The angle of one of the bevelling face to cube is 18° 26′, and the poles appear on the stereographic projection in the zones between cube and dodecahedron. To determine the symbol of one of the poles, for example, 310, figure 16, it is only necessary to note the distance from 100 (18° 26′) and draw a line from 010 making the same angle with the diameter, which line intersects the front axis (radius) at $\frac{1}{3}$; the ratio on the first and second axes is therefore $\frac{1}{3}\,a : a$, and the indices of the pole are 310. The interfacial angle of the tetrahexahedron, the distance from 310 to 301, measured with the small circle protractor, was found to be 25° 50′, theory 25° 50′.

The trisoctahedron bevels the edges of an octahedron; its poles, therefore, are always to be found on the zones between octahedron and dodecahedron. Taking a crystal of galena, an octahedron with bevelled edges, as an example, the angle of the trisoctahedron, measured over an octahedral edge, is 38° 56′. One-half of the foregoing angle, 19° 28′, is therefore that of trisoctahedron on dodecahedron, and the pole between 110 and 111 is easily located by means of the stereographic scale. To determine the symbol of the form, which, being in the zone between 110 and 111, must have a 1 : 1 relation on the first and second axes, draw the line from 010 to 100 and thus determine the base-line *Oy*. The slope of the face, its angle on 001, is 70° 32′ (complement of 19° 28′), hence from *y*′ (the base-line transposed to the horizontal diameter) construct a line at 70° 32′, which, if continued, will meet the vertical axis (radius) at 2*a*. The form intersects the axes, therefore, at *a* : *a* : 2*a*, the indices being 221. To fix the pole 212 between 111 and 101, place the small circle protractor over the projection, its zero at 010, and space off the distance 19° 28′ from 101 with dividers; then transpose to the paper. Another and better way is to lay off the distance 19° 28′ from 001 on the horizontal diameter, and construct a small circle with radius

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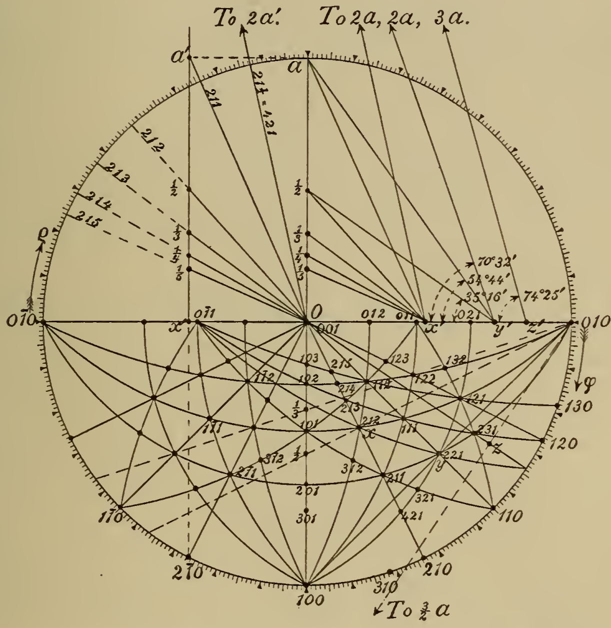

70° 32′, taken from scale No. 2 of the printed sheets. To find the interfacial angle from 221 : 212, make use of the great circle protractor for finding the great circle between the poles, construct the great circle and measure with the small circle protractor as indicated on page 253. From 221 to 212 was found to be 27° 35′, and from 221 to 122, 27° 15′, the calculated distance being 27° 16′.

The poles of the trapezohedron are found on the great circles between octahedron and cube. With garnet as an example, measurement may be made over an axis, and the angle is 70° 32′, one-half of which is the angle of cube on trapezohedron. The pole between 001 and 111 may then be located by means of the stereographic scale, at 35° 16′ from 001, and the slope plotted from the base-line *Oy′* goes to $\frac{1}{2}$ on the vertical axis; the indices are therefore 112. By applying the great circle protractor it is found that 112 is in the zone of the dodecahedrons 101 and 011, and this relation may be made use of for locating other poles of the trapezohedron, 211 and 121. Other interfacial angles may then be measured; for example, $112 \wedge 1\bar{1}2$ and $211 \wedge 2\bar{1}1$ were found to be, respectively, 48° 30′ and 48° 10′, theory 48° 11′, and $211 \wedge 121$ and $121 \wedge 112$, 33° 45′ and 33° 15′, theory 33° 34′.

The hexoctahedron most frequently met with on garnet bevels the edges of the dodecahedron, the angle between the bevelling faces being 21° 47′, or 10° 54′ from the trapezohedrons. To locate the pole between 101 and 112, place the small circle protractor over the projection with its zero at $1\bar{1}0$, then with dividers space off 10° 54′ from 112 and transfer to the paper. A radius drawn through the point thus found intersects the divided circle at a little over $26\frac{1}{2}$° from 100. A line from 010, drawn at right angles to this radius, intersects the first axis (radius) at $\frac{1}{2}$, and establishes the relation $\frac{1}{2}a : a$ on the first and second axes and also the base-line *Ox*. The distance from the hexoctahedron to 001, measured with the stereographic scale, was found to be just short of 37°, and this slope plotted from *x′* intersects the vertical radius at $\frac{1}{3}$. The form is therefore $\frac{1}{2}a : a : \frac{1}{3}a$, the indices being 213. The poles of the hexoctahedron under consideration are especially easy to locate by means of zones, as indicated in figure 16, and to show the accuracy with which the plotting was done some distances measured on the projection are given, as follows: $111 \wedge 231 = 22°\ 5'$, theory 22° 12′; $010 \wedge 231 = 36°\ 45'$, theory 36° 42′; $312 \wedge 3\bar{1}2 = 31°\ 10'$, theory 31° 00′; and $001 \wedge 231 =$ 74° 25′, theory 74° 30′. The method of finding the symbol of the pole 231 ($\frac{3}{2}a : a : 3a$) by means of the base-line *Oz* and slope 74° 25′ is indicated in figure 16, but needs no discussion. Attention is called to the six poles in the zone between 001 and 210, determined by the intersections of zones. Their distances from 001 being measured with the stereographic scale, the slopes may be plotted either from x' to the right or, better, from the center, and their intersections with the vertical radius, or the perpendicular erected at x' to the left, then determined. The distances from 001 to the several poles, measured with the stereographic scale, were found to be as follows:

Form	215	214	213	212	211	421
Measured,	24° 5′	29° 5′	36° 55′	48° 10′	66° 00′	77° 15′
Calculated,	24 5	29 12	36 42	48 11	65 54	77 23

Two methods for determining the symbol of a hexoctahedron, observed in combination with the cube on crystals of fluorite from Weardale, Durham, England, are indicated by figure 17. No zones were encountered in measuring the crystal, hence two measurements were necessary for determining the form, those made being between two hexoctahedron faces adjoining a cube, 21° 13′, and from cube to hexoctahedron, 24° 19′. Starting from the center of a stereographic projection, the poles of eight faces of the hexoctahedron must lie on a small circle drawn about 001 with a radius of 24° 19′, which may be taken from the stereographic scale. Moreover, the poles of the hexoctahedron must lie symmetrically on either side of a radius passing through 111, distant 10° 36′ (half of 21° 13′) from the pole of a possible truncating face, or 79° 24′ (the complement of 10° 36′) from 11̄0 and 1̄10; accordingly the point p was located at 10° 36′ from the center on the radius to 11̄0, and, taking the radius 79° 24′ from scale No. 2 of the

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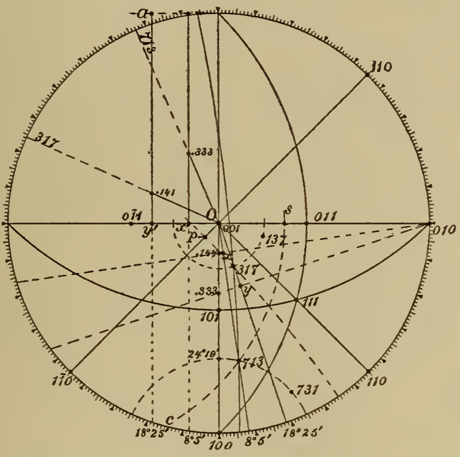

sheets, a small circle through *p* was constructed which intersected the small circle previously drawn at the point marked 317. Through the point thus found a radius was drawn, which intersected the divided circle at 18° 25′, and from 010 a line at right angles to the radius was drawn, thus determining the intercept $\frac{1}{3}$ on the first axis, as also the base-line *Oy*. The angle of cube on hexoctahedron is 24° 19′, hence a line drawn from the center at this angle was found to meet the perpendicular from y' at 0·141, determined by scale No. 4 of the printed sheets, or practically $\frac{1}{7}$th of the radius, the true value being 0·143 ; hence the axial relation of the face under consideration is $\frac{1}{3}a : a : \frac{1}{7}a$, the indices being 317.

It is always an advantage to plot near the periphery of a stereographic projection, where the spaces between degrees are larger than near the center; therefore a solution, similar to the one just given, but made about 100, is also shown in figure 17. The small circle with radius 24° 19′, taken from scale No. 2, was first drawn about 100. All points on the zone 100 to 011 are 90° from $0\bar{1}1$, hence the desired pole may be located by means of a small circle constructed about $0\bar{1}1$ at a distance of 79° 24′. To do this, two points were located on the horizontal diameter at 79° 24′ from $0\bar{1}1$, to the right and left, making use of scale No. 3 of the printed sheets. One of these points is at *s*, figure 17, the other too far to the left to be shown, and through them the small circle *sc* was constructed, which intersects the small circle previously drawn at the desired point, marked 713. To find the symbol, the radius through the pole 713, and the chord from 010 at right angles to it, were drawn; thus the intercept on the first axis was found to be 0·144 or $\frac{1}{7}$. By means of the stereographic scale the distance from 001 to the pole 713 was found to be 67°, and this angle plotted from the center intersects the perpendicular from x' at 0·333 or $\frac{1}{3}$. The axial relation is therefore $\frac{1}{7}a : a : \frac{1}{3}a$, the indices being 713. The distance from 713 to 317, measured with the small circle protractor, was found to be 43° 15′, theory 43° 13′.

TETRAGONAL SYSTEM.

In this system the problem presents itself of finding from one fundamental measurement the length of the vertical axis, and from interfacial angles the symbols of occurring forms. The example chosen for illustration is a crystal of octahedrite from Brazil, given to the writer by Professor Groth of Munich. The crystal, shown in figure 18 in orthographic* and clino-

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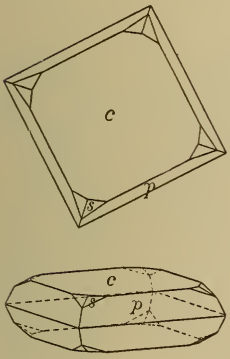
* The orthographic projection is represented as revolved 18° 26′ about the vertical axis, the reason for which will be explained in an article now in preparation.

graphic projection, was studied and figured by Mr. P. B. Condit.

The combination is a simple one, base *c* (001), pyramid *p* (111) and ditetragonal pyramid *s*. As fundamental measurement the angle of $p \wedge p$ over the base, 136° 36′, was chosen, from which $c \wedge p = 68° 18'$ is obtained. The poles of the pyramid *p* are easily located, figure 19, by means of the stereographic scale. Erecting a perpendicular at x' to represent the vertical axis, and plotting the angle 68° 18′ from the center, the length of the vertical axis was found by means of scale No. 4 to be 1·774, the calculated length being 1·777. By means of the small circle protractor the distances between the poles of the pyramid, $111 \wedge 1\bar{1}1$ and $111 \wedge \bar{1}11$ were found to be 82° 20′ and 82° 15′, the calculated value being 82° 9′.

18



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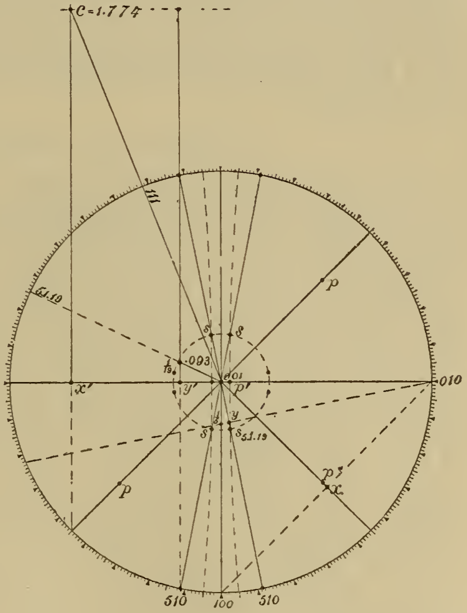

For the determination of the symbol of the ditetragonal pyramid, the angles between two adjacent *s* faces and from *c* to *s* were measured, as follows: $s \wedge s = 9° 40'$, $c \wedge s = 25° 30'$. About the center a small circle with radius 25° 30′, taken from the stereographic scale, was first described, upon which the poles of the pyramid must be located. Since $s \wedge s$ is 9° 40′, four of the poles (those lettered *s* in figure 19) must be symmetrically located at 4° 50′ on either side of the vertical diameter: accordingly p' was located at 4° 50′ from 001 on the horizontal diameter, and by means of the curved ruler a small circle was drawn through p' and points on the divided circle 4° 50′ from 100 and $\bar{1}00$. The intersections of the small circles shown in figure 19 locate the poles of four of the s faces. Through the poles thus found diameters were drawn, which were found to intersect the divided circle at about 11° 10′ from 100, and a chord from 010 at right angles to one of these diameters intersects the front axis (radius) at just a trifle short of 0·2, or $\frac{1}{5}$. The distance 100 to 510 by calculation is 11° 18′. Erecting a perpendicular at y' and plotting the angle $c \wedge s$, 25° 30′, from the center, the intersection on the perpendicular, measured with scale No. 4, was found to be 0·093 or $\frac{1}{19}$th of the vertical axis found, 1·774÷19=·0933. The relation of the s faces on the axes is therefore $\frac{1}{5}a : a : \frac{1}{19}c$, giving 5·1·19 as the indices.

Hexagonal System.

The example chosen for illustrating this system is a crystal of calcite from Egremont, England, shown in figure 20. The angle $r \wedge r$, 74° 55′, was selected as the fundamental measurement, and the poles of r were located as follows: Since $r \wedge r = 74° 55'$, $a \wedge r$, figure 21, must equal the complement of one-half $r \wedge r$, or 52° 32½′; accordingly, on the radii Oa_1 and $O-a_3$ the points s were located at 52° 32′, respectively, from a_1 and $-a_3$, and, using scale No. 2 of the printed sheets, small circles sc were drawn through the points s, which intersect at r. The distance Or, measured with the stereographic scale, was found to be 44° 40′, calculated 44° 37′. The inclination thus found, plotted from O, meets the perpendicular from x' at 0·854, calculated 0·854. Having located the poles r, the great circles uniting them were constructed. The two scalenohedrons v and ς are in the principal zones of the rhombohedron, between r and a, and were located on the stereographic projection by the measurements $a \wedge v = 23° 31'$ and $a \wedge \varsigma = 10° 34'$, the small circles $c' s'$ and $c'' s''$, respectively, 23° 31′ and 10° 34′ from $-a_3$, figure 21, serving the purpose. The radius through v and the chord from a_2 at right angles to it establish the relation on the horizontal axes, $\frac{1}{2}a : a - \frac{1}{3}a$, and also the length of the base-line Oy. The slope of the face, the distance Ov, measured with the stereographic protractor, was found to be 69° 00′, calculated 69° 2′, and this angle plotted from the center intersects the perpendicular from y' at just a trifle short of 0·854, or unity, the discrepancy being due to slight errors in plotting; for example, the radius through v should have intersected the divided circle at 19° 6′ from m, whereas, as plotted, it fell just short of 19°, an error perhaps of 8′. The symbol of the scalenohedron, as indicated by the method, is $\frac{1}{2}a : a : -\frac{1}{3}a : c$, or $21\bar{3}1$. The radius through ς, and the chord at right angles to it from a_2, establish the relation on the horizontal axes, $\frac{3}{4}a : a - \frac{3}{7}a$, and also the length of the base-line Oz. The slope of the face, measured with the stereographic scale, was 80° 35′, calculated 80° 32′, and this angle plotted from the center intersected the vertical form z' at a distance $2{\cdot}993c$, practically $3c$. The symbol of the scalenohedron is therefore $\frac{3}{4}a : a : -\frac{3}{7}a : 3c$, or $43\bar{7}1$. The rhombohedron M was determined by the measurement $r \wedge M = 31° \ 10'$, giving $0001 \wedge M = 75° \ 47'$. This angle, plotted from the center, would intersect at $4c$, measured from x', or, instead of extending the drawing to such an extent, the slope may be plotted from c, as indicated in figure 21, and its intersection with the base-line, equal $\frac{1}{4}x'O$, determined. The symbol of M is therefore $40\bar{4}1$.

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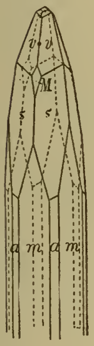

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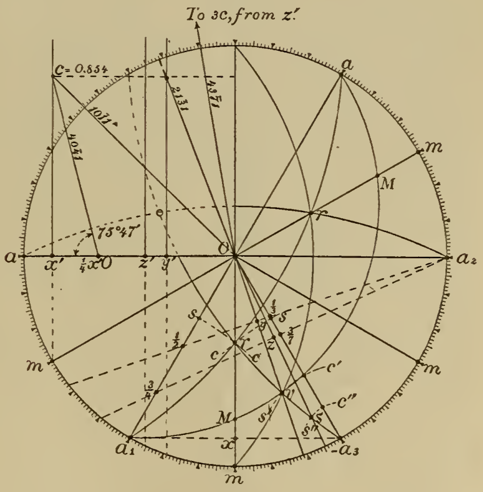

It seems worth while to call attention to a procedure employed in solving a complex problem encountered in the study of calcite crystals from Union Springs, N. Y.* The form to be considered is that of a scalenohedron v_1, in the same zone as v and ς, figure 21, but just a trifle steeper than v. The angle v on v_1 measured 3° 55′; hence since $a \wedge v = 23° \ 31'$, $a \wedge v_1 = 19° \ 36'$. Employing the same method of plotting as indicated in figure 21, the radius through the pole of v_1 was found to intersect the divided circle at 21° from m (theory 21° 3′), and a chord drawn from a_2, at right angles to it, gave

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* This Journal (4) x, p. 237, 1900.

the following intersections with the horizontal axes, as determined by scale No. 4 of the printed sheets, $0·573a : a : -0·365a$. The foregoing figures, which indicate a parameter relation, are not easily interpreted, but their reciprocal values ($1·746 : 1 : -2·740$), which are equivalent to the indices, make it clear what the relation is, namely, $1\frac{3}{4} : 1 : -2\frac{3}{4}$. The distance 0001 to v_1, measured with the stereographic scale, was found to be 72° 35′ (theory 72° 30′), and the intercept on the vertical axis, plotted in the same manner as, for example, *v* in figure 21, was found to be almost exactly $\frac{4}{3}c$, the reciprocal (index) being $\frac{3}{4}$. The indices expressed as fractions are therefore $1\frac{3}{4}·1·-2\frac{3}{4}·\frac{3}{4}$, or, cleared of fractions, $7·4·\overline{11}·3$.

ORTHORHOMBIC SYSTEM.

The example chosen for illustrating this system is a crystal of anglesite from Eureka, Utah, selected from a suite of beautiful specimens sent to the present writer by Mr. Maynard Bixby of Salt Lake City. In figure 22 the crystal is shown both in orthographic and clinographic projection, the figure having been drawn by Mr. W. E. Ford of the Sheffield Laboratory. The method employed in plotting is indicated by figure 23. The positions of the poles of the prism *m*, 110, and brachydome *o*, 011, were first located from the fundamental measurements, $m \wedge m$, $110 \wedge 1\bar{1}0 = 76° \ 16'$ and $o \wedge o$, $011 \wedge 0\bar{1}1 = 104° \ 24'$. These measurements are especially favorable for determining the lengths of the *a* and *c* axes, which are the tangents, respectively, of τ and π, figures 6 and 8, or the tangents of one-half the given angles; hence it is only necessary to draw two chords from *b*, intersecting the graduated circle at 76° 16′ and 104° 24′, measured from $0\bar{1}0$, figure 23. Thus the lengths of *a* and *c*, measured on the respective radii by scale No. 4, were found to be 0·786 and 1·289, calculated 0·786 and 1·289. The slope of the brachydome, $c \wedge o = 52° \ 12'$ ($\frac{1}{2}$ of $o \wedge o$), may also be plotted in the upper left-hand quadrant, and the length of the *c* axis measured on a perpendicular erected at $0\bar{1}0$, as indicated. The macrodomes *d* and *l* will be considered next. These were located on the vertical diameter by means of the angles $c \wedge d = 39° \ 23'$ and $c \wedge l = 22° \ 19'$, and lines plotted at these angles in the upper left-hand quadrant intersect the perpendicular from *a′* (*c a′* equals the length of the *a* axis) at distances equal respectively to $\frac{1}{2}$ and $\frac{1}{4}$ the length of the *c* axis, thus determining the symbols $d = 102$ and $l = 104$. The position of the pyramid *p* is determined by the intersections of the zones *a* : *o* and *c* : *m*. Thus plotted, the slope of *p*, measured with the stereographic scale, was found to be 64° 30′, calculated 64° 24′, and a line drawn at this angle from the center meets the perpendicular from x′ at a distance equal to the length of the c axis; hence the symbol of p is 111. The pyramid y, in the zone $o : p$, was determined by the angle $o \wedge y = 26° 42'$, from which $a \wedge y = 63° 18'$; hence a small circle *sc*, drawn at 63° 18′ from a, figure 23, fixes the position of y. A radius through y was found to intersect the divided circle at 57° 30′ from a, 100, which corresponds with the pole of the prism n, and a chord from b, at right angles to this line, intersects the front radius at a distance equal to $2a$. The intercepts on the first and second axes of n, y, and a third face in the zone, μ, are therefore $2a : b$, the indices of n being 120. The slope

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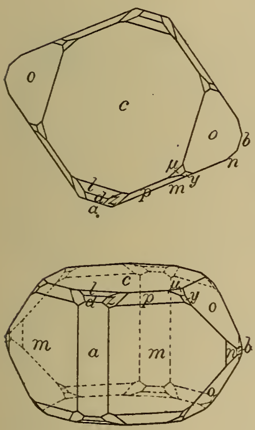

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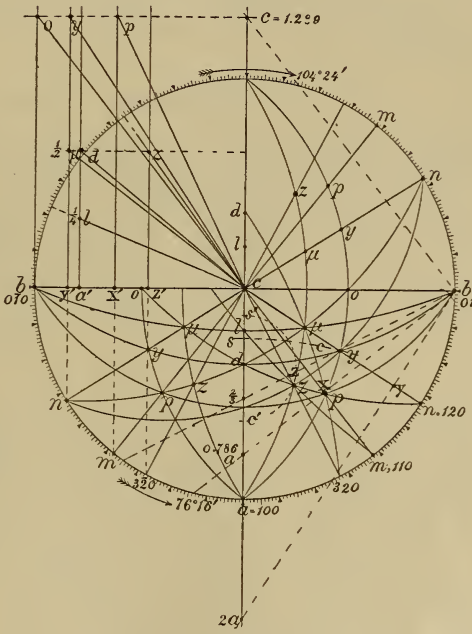

of y, measured with the stereographic scale, was found to be 56° 45′, calculated 56° 48′, and a line at this angle intersects the perpendicular from y′ at a distance equal to the length of the c axis; hence the parameter relation of y is $2a : b : c$, the indices being 122. The pyramid μ was located by the measurement $c \wedge \mu = 37° 23'$, and a line at this angle meets the perpendicular from y′ at a distance equal to $\frac{1}{2}c$; hence the parameter relation of μ is $2a : b : \frac{1}{2}c$, the indices being 124. The pyramid z, in the zone $d : p$, was located by the measurement $d \wedge z = 24° 49'$. This was done by first determining the zone n, p, d, μ and o by means of the great circle protractor, and then constructing a small circle s' c' about d at a distance of 24° 49′. A chord from b at right angles to the radius through z was found to intersect the front radius at $\frac{2}{3}a$. The slope of z, measured with the stereographic scale, was 54° 15′, calculated 54° 16′, and a line at this angle intersects the perpendicular from z′ at a distance equal to $\frac{1}{2}c$. The parameter relation of z is therefore $\frac{2}{3}a : b : \frac{1}{2}c$, giving as the indices 324. In addition to the lines needed for the graphical solution of the foregoing problem, numerous zones are shown in figure 23 which were easily determined by means of the great circle protractor. The figure indicates that, starting with the poles of m (110) and o (011), it would have been a simple matter to have determined the location of the poles and the symbols of all the forms by no other means than zonal relations.

MONOCLINIC SYSTEM.

The graphical methods employed in this system may be illustrated by pyroxene, a crystal of which is represented in orthographic and clinographic projection in figure 24. The figure, which represents a common habit of pyroxene from northern New York and Canada, was drawn by Mr. H. H. Robinson. As fundamental measurements the following were chosen: $m \wedge m$, $110 \wedge 1\bar{1}0 = 92° \ 50'$; $a \wedge c = 100 \wedge 001 = 74° \ 15'$; and $d \wedge s$, $\bar{1}01 \wedge \bar{1}11 = 29° \ 35'$. In stereographic projection, figure 25, the location of the poles of the prism m and of the base c, the latter by means of the stereographic scale, need no special comment. The construction of the great circles through m and c is then an easy matter, and the angles which they make at c with the vertical diameter are equivalent to τ of figures 6 and 8. The measurement of τ, 47° 30′, was made on the great circle GC at 90° from c.* Since γ, figure 6, is 90° in the monoclinic system, the tangent of τ must equal the length of the a axis; hence τ was laid off from b, and a determined as 1·093, calculated 1·092. Since $d \wedge s = 29° \ 35'$, $b \wedge s$ must be the complementary angle, 60° 25′; hence the pole of s was located by the intersection of a small circle (60° 25′ from b) with the great circle through c and m. Great circles through a and s and b and s were then drawn, thus determining the poles of p and d. The angle π, compare figures 6 and 8, was measured on the great circle (diameter) at 90° from a, and found to be 30° 35′; hence, referring to figure 6, since a is 90°, the tangent of π must equal the length of the c axis, which, when plotted from b, was found to be 0·592, calculated 0·589. The arcs mp and mc, measured with the small circle

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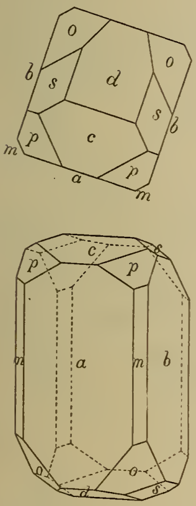
* This Journal (4), xi, p. 18, 1901.

protractor, were found to be 45° 10′ and 79° 20′, calculated 45° 20′ and 79° 10′. By means of the stereographic scale $c \wedge d$ was determined as 31° 10′, calculated 31° 20′. The poles of the pyramid *o* were located by means of the measurement $m \wedge o = 35° \ 30'$, a small circle from *m*, $\bar{1}10$, being used. The great circle *ao* made an angle, π', of 49° 45′ at *a*, which, when plotted from *b*, was found to intersect the vertical radius at 1·180, practically 2*c*, the calculated value being 1·178; hence the axial relation of *o* is $-a : b : 2c$, the indices being $\bar{2}21$. The poles of *o* could also have been located by constructing a great circle through *m* and *s*, 110 and $\bar{1}11$, thus determining $\bar{2}01$, and then a second great circle through *b* and $\bar{2}01$.

24



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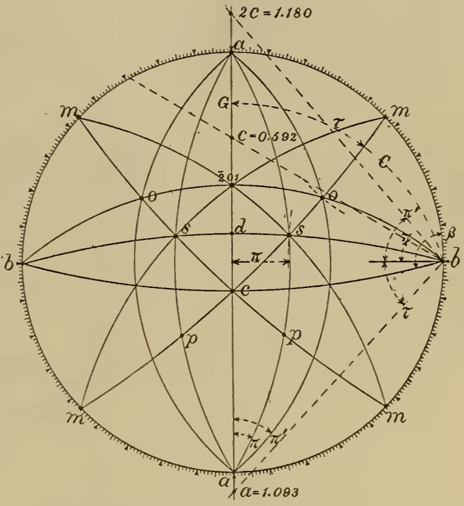

For the purpose of showing the adaptability of the stereographic projection to measurements made with the two-circle goniometer, and also for illustrating another method of treating the monoclinic system, a problem encountered in the study of azurite crystals from Broken Hills, New South Wales, will be presented. The crystals, which are exceptionally beautiful, were measured and figured by Mr. Ralph G. VanName. They are lengthened in the direction of the ortho axis, like the ordinary development of epidote, and the habit is well illustrated by figure 26, drawn in clinographic projection with the *b* axis to the front. The crystal was orientated on the goniometer with the orthodome zone horizontal and the pinacoid *a*, 100, vertical, thus making an imaginary clino-pinacoid the polar face, although the form was not present on the crystal.

In the stereographic projection, figure 27, the angles φ, determined by the readings of the vertical circle, were laid off on the divided circle, starting from *a*, 100, and the angles ρ, given by the readings of the horizontal circle, were plotted on their respective diameters by means of the stereographic scale. The angles for making the projection shown in figure 27 are as follows:

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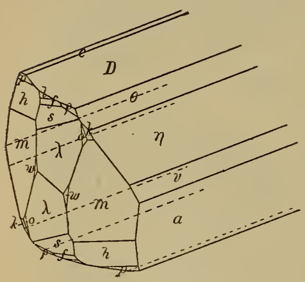

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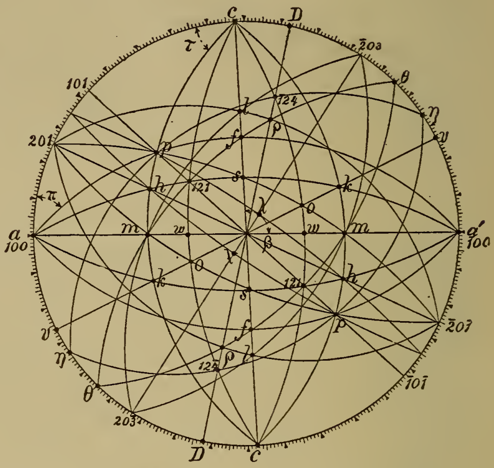
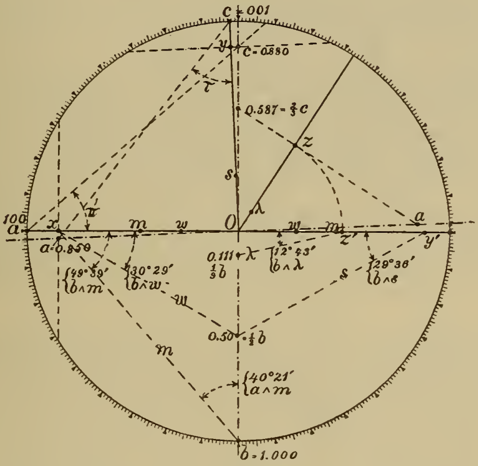


	φ	ρ		φ	ρ
a, 100,	00° 00′	90° 00′	*D*, $\bar{1}04$,	102° 15′	90° 00′
m, 110,	"	49 39	*ϱ*, $\bar{1}34$,	"	57 10
w, 120,	"	30 29	*λ*, $\bar{2}\cdot18\cdot3$,	122 59	12 43
h, 221,	25 18	53 02	*θ*, $\bar{1}01$,	134 51	90 00
p, 111,	42 50	59 06	*η*, $\bar{3}02$,	146 32	"
c, 001,	87 36	90 00	*v*, $\bar{2}01$,	153 47	"
l, 023,	"	59 37	*k*, $\bar{2}21$,	"	52 08
f, 011,	"	48 40	*o*, $\bar{2}41$,	"	32 44
s, 021,	"	29 36			

Having located the poles of the several faces, the zones shown in figure 27 were easily found by means of the great circle protractor. Starting, then, with the assumption that the symbols of two poles are known, for example, *m*, 110, and *p*, $\bar{1}11$, it is possible to determine the symbols of the remaining forms by no other means than that afforded by zonal relations. As it is the object of this paper, however, to indicate the methods of graphical solution, the problem may be dealt with in a manner analogous to that employed in the orthorhombic system, since the *b* axis is at right angles to the plane of the *a* and *c* axes. In order not to complicate figure 27 to too great an extent, the solutions depending upon plane trigonometry were worked out on a second divided circle, shown in figure 28. Having located the poles *a*, 100, and *c*, 001, the vertical and clino axes are represented by diameters at 90° from them, as indicated by broken-dashed lines; the lower half of the vertical diameter, however, may be employed for plotting the relations of the *b* axis, the length of which is unity. Referring to figure 27, the angles π and τ (compare figures 6 and 8) were measured, respectively, by the stereographic scale as 41° 20′ and 40° 20′, and these inclinations plotted from *a* and *c*, figure 28, determine the lengths of the *c* and *a* axes, which were

28



found to be as follows: $c=0·880$ and $a=0·850$, calculated, $c=0·880$ and $a=0·850$. In order to determine the relations of the prisms *m* and *w*, through unity on the *a* axis, a line was drawn at right angles to the radius through *m* and *w*, thus fixing a base-line *Ox;* then from *x* the inclinations of *m* and *w* (the ρ angles), 49° 39′ and 30° 29′, are plotted, and, as shown in figure 28, they intercept the lower radius at unity and one-half, respectively. Since the lower radius is taken to represent the *b* axis, the axial relation of *m* is $a : b : \infty c$, and of *w*, $a : \frac{1}{2}b : \infty c$, the indices being 110 and 120. Naturally the reverse of this method may be employed to advantage for determining the length of the *a* axis in this system, when the inclination β and the prismatic angle are given. For determining the symbol of a clinodome, for example *s;* through unity on the *c* axis draw a line at right angles to the radius through *s*, thus determining the base-line *Oy*, and from *y′* (the distance *Oy* transferred to the horizontal diameter) lay off the ρ angle of *s*, 29° 36′, which intercepts the lower radius (*b* axis) at one-half; hence the axial ratio of *s* is $\infty a : \frac{1}{2}b : c$, the indices being 021. For a pyramidal face, for example λ, through unity on the *a* axis, a line at right angles to the radius through λ was drawn, which in figure 28 was found to intercept the vertical axis at 0·587, or exactly $\frac{2}{3}c$. Thus the intercept on the vertical axis and the base-line *Oz* are determined. From *z′*, on the horizontal diameter, a second line was drawn at an inclination of 12° 43′, the ρ value of λ, which intersects the lower radius at 0·111, or $\frac{1}{9}b$. The axial ratio of λ is therefore $-a : \frac{1}{9}b : \frac{2}{3}c$, the indices being $\bar{2}\cdot18\cdot3$. Thus it makes no difference how complex the symbol may be, it is only necessary to keep in mind a few simple principles and the result is quickly obtained.

Finally, having made a projection such as shown in figure 27, the small circle protractor may be applied to it and the distances between any desired poles determined. Some results actually obtained in this way are as follows:

	Meas.	Cal.		Meas.	Cal.		Meas.	Cal.
$c \wedge m$,	88° 10′	88° 10′	$c \wedge k$,	71° 25′	71° 25′	$a \wedge p$,	50° 50′	51° 00′
$c \wedge p$,	52 30	52 28	$c \wedge o$,	77 24	77 25	$a' \wedge k$,	45 05	44 55
$c \wedge h$,	68 10	68 12	$m \wedge p$,	35 45	35 42	$a' \wedge o$,	61 05	60 59

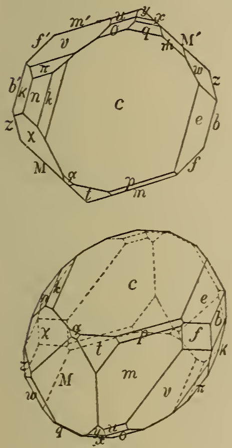
TRICLINIC SYSTEM.

For illustrating the application of graphical methods to this system a somewhat complex crystal of anorthite has been chosen, shown in orthographic and clinographic projection in figure 29. The crystal was studied and figured by Mr. J. C. Blake. The following were selected as fundamental measurements for making the stereographic projection, figure 30, and solving the problem:

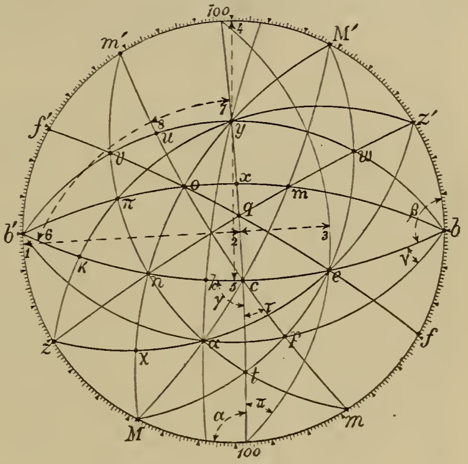
$b \wedge m$, $010 \wedge 110 = 58°\ 04'$
$m \wedge M$, $110 \wedge 1\bar{1}0 = 59\ \ 29$
$b \wedge c$, $010 \wedge 001 = 85\ \ 50$
$m \wedge c$, $110 \wedge 001 = 65°\ 53'$
$b \wedge e$, $010 \wedge 021 = 43\ \ 12$

Having located *b*, *m* and *M* on the divided circle, the position of 100 was first determined by the relation of four faces in a zone, explained on page 260, *b*, *m* and *M* being, respectively, the first, second and fourth faces, and 100 the unknown third face. This problem, as solved by itself on a separate sheet, is shown in figure 31. The lines of reference *Ox* and *Oy* are at right angles respectively to *bb′* and *MM′*. A line drawn from *x*, at right angles to the radius through *m*, intersects *Oy* at a point marked ½. By solving the equation given on page 262 the ratio of the cotangents is found to be ½ : 1, hence a line from *x* to the point 1 on the line *Oy* determines the direction of the pinacoid 100. A line from the center at right angles to xy fixes the pole of 100, which was found to be 87° 5′ from b, calculated 87° 6′. Having located the pole 100, the direction Oy', parallel to xy, may now be taken as the second line of reference. Lines from x to $\frac{1}{3}Oy'$, both to the right and left of the center, intercept the divided circle at 58° 50′ and 62° from $-x$, and angles equal to one-half of these values

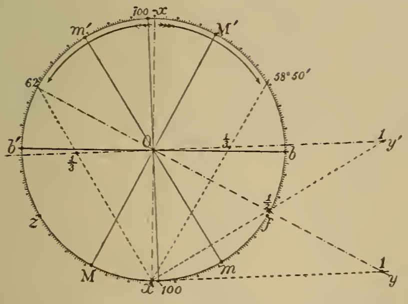
29



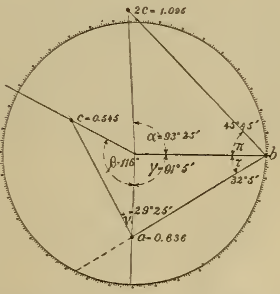
30



31



32



(page 260) give the inclinations $b \wedge f$ and $b' \wedge z$, namely, 29° 25′ and 31°, calculated 29° 29′ and 30° 58′. The indices of f and z are therefore 130 and $1\bar{3}0$. The pole c, figure 30, was next located from the measurements $b \wedge c$ and $m \wedge c$, small circles about the poles b and m serving for this purpose. The small circles are not shown in the figure, but that about b, having a long radius, was constructed by means of the curved ruler,* that about m by means of a radius taken from scale No. 2 of the sheets. Having located c, the great circles b,c,b'; m,c,m'; and $100,c,\bar{1}00$ were drawn, thus determining the angles α, β,

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* The Stereographic Projection and its Possibilities, loc. cit., p. 12.

γ and τ; compare figures 6 and 8. The angle α was measured by means of the stereographic scale on the diameter 1 to 2, figure 30, and found to be 93° 25′, calculated 93° 14′. Similarly β was measured on the diameter 4 to 5, and found to be 116°, calculated 115° 56′. To measure γ and τ, a great circle at 90° from c was first constructed.* The supplement of γ, from 6 to 7, was then determined as 88° 55′ by means of the small circle protractor, giving as the value of γ, 91° 5′, calculated 91° 12′. In like manner the arc from 7 to 8 was measured, giving 32° 5′ as the value of τ. On still a third sheet, shown in figure 32, the angles α, β and γ were plotted, and also τ, the latter determining the length of the brachy axis, $a = 0{\cdot}636$, calculated 0·635. It is still necessary to make use of the fifth fundamental measurement, from b to e, in order to determine the length of the vertical axis. By means of a small circle about b, figure 30, the position of e, on the great circle b,c, was located, and a great circle through 100, e and $\bar{1}00$ determines π. The value of π, measured on the diameter from 2 to 3, was found to be 45° 45′, and when plotted as shown in figure 32, the length of $2c$ was found to be 1·095; hence $c = 0{\cdot}5475$, calculated 0·550. The value obtained directly from π in this case is $2c$, because the symbol of e is 021.

Having located, as in figure 30, the poles b, m, 100, M, c and e, and also f and z from figure 31, the remaining forms of the crystal were easily identified by means of zonal relations and the measurement of a few angles. The construction of the zones shown in figure 30 would have proved a laborious task had it not been for the great circle protractor. This was used not only for determining the zones, but, far more important, its graduation furnished the means of getting the radii of the circular arcs from scale No. 1 of the sheets.

		Meas.	Cal.	Error.
$c \wedge t$,	$001 \wedge 201$,	41° 30′	41° 28′	+ 2
$c \wedge q$,	$001 \wedge$	34 45	34 46	− 1
$c \wedge x$,	$001 \wedge \bar{1}01$,	51 40	51 26	+14
$c \wedge y$,	$001 \wedge \bar{2}01$,	81 30	81 14	+16
$c \wedge p$,	$001 \wedge 111$,	33 10	33 17	− 7
$c \wedge \alpha$,	$001 \wedge 1\bar{1}1$,	34 35	34 10	+25
$c \wedge m$,	$001 \wedge \bar{1}11$,	54 10	54 17	− 7
$c \wedge o$,	$001 \wedge \bar{1}\bar{1}1$,	58 00	57 52	+ 8
$c \wedge u$,	$001 \wedge \bar{2}\bar{2}1$,	85 00	84 50	+10
$c \wedge \kappa$,	$001 \wedge 0\bar{6}1$,	75 20	75 10	+10
$c \wedge n$,	$001 \wedge 0\bar{2}1$,	47 00	46 46	+14
$c \wedge k$,	$001 \wedge$	18 55	18 38	+17
$b' \wedge \chi$,	$0\bar{1}0 \wedge$	52 20	52 11	+ 9
$b' \wedge \pi$,	$0\bar{1}0 \wedge$	34 10	34 20	−10
$b' \wedge v$,	$0\bar{1}0 \wedge$	38 05	38 16	−11
$b' \wedge w$,	$010 \wedge$	38 55	38 42	+13

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* The Stereographic Projection and its Possibilities, loc. cit., p. 18.

A list of measurements made with the small circle protractor is given in the table on the foregoing page. The average of the errors is 11′, with errors of more than a quarter of a degree in only three instances. In figure 30, the angle between the great circles b,c and b,p determines ν (compare figures 6 and 8), which was found to measure 29° 25′. The angle ν, plotted from unity on the a axis, as shown in figure 32, gives another method for determining the length of the c axis; in this case c was measured as 0·545, calculated 0·550.

Conclusion.

In the foregoing pages the attempt has been made to indicate not only the methods of plotting problems in the several systems, but, also, to give an idea of the accuracy of the results thus obtained. In judging the accuracy of the results it must be kept in mind that the scale employed was quite small, the engraved circle being only 14^{cm} ($5\frac{1}{2}$ in.) diameter. Each problem presented was worked out from fundamental measurements, as would have been the case if done by numerical calculation, and the results indicate that for all practical purposes graphical methods are in every way satisfactory. The lengths of axes have frequently been obtained correctly to the third place of decimals, and never varied more than one in the second place, and measurements of arcs and angles by the stereographic protractors have been reasonably close to the calculated values in all cases. After becoming familiar with the principles involved in dealing with the projection—and they are not difficult to understand—any problem may be worked out without the use of prescribed formulas, or tables of any kind, and this the writer believes is one of the great advantages of the method. Then, too, it is a very simple step to proceed from a graphical to a numerical solution, for the principles involved are identical, and it is only necessary to apply the formulas of spherical and plane trigonometry in order to obtain the desired results by calculation. The writer has never made use of formulas for solving even the most complex problems of crystallography, other than those needed for the general cases which arise in dealing with spherical and plane triangles, and it is his belief that the too general use of prescribed formulas is, if anything, a hindrance to true progress in crystallography. Graphical methods will also be found to have very decided value as giving a ready means of checking the results of numerical calculations. During the past two years, since they have been in use, numerous cases have arisen where mistakes in calculation have been made, at times amounting to less than a degree, but they have been almost instantly detected by applying the protractors to the stereographic projections. Generally it has been found that mistakes were due to errors (carelessness, perhaps, is a better term) in such simple processes as addition and subtraction.

In an earlier communication* a description was given of blackboard appliances which have proved most useful for demonstrations of the stereographic projection on a rather large scale before a class. Thus, in the discussion of any problem which may arise, a projection may be made in a few minutes, from which the zonal relations, symbols and angles of the forms may be determined. As a demonstration of the practicability of the method, a projection of pyroxene, like figure 25, page 277, was constructed from fundamental measurements, and the following determinations made, the time consumed being nineteen minutes:

Given, $m \wedge m''' = 92^\circ\ 50'$; $c \wedge p = 33^\circ\ 49'$ and $a \wedge c = 74^\circ\ 10'$.
Axes determined, $a : b : c = 1{\cdot}11 : 1 : 0{\cdot}585$.
Axes calculated, $a : b : c = 1{\cdot}092 : 1 : 0{\cdot}589$.

Angles.	Meas.	Cal.	Angles.	Meas.	Cal.
$m \wedge c$, $110 \wedge 001$	$=79^\circ$	$79^\circ\ 9'$	$o \wedge o$, $\bar{2}21 \wedge \bar{2}\bar{2}1$	$=84'$	$84^\circ\ 11'$
$c \wedge d$, $001 \wedge \bar{1}01$	$=31$	31 20	$c \wedge o$, $001 \wedge \bar{2}21$	$=65$	65 21
$p \wedge p$, $111 \wedge 1\bar{1}1$	$=48\frac{1}{4}$	48 29	$a \wedge p$, $100 \wedge 111$	$=53\frac{1}{2}$	53 38
$s \wedge s$, $\bar{1}11 \wedge \bar{1}\bar{1}1$	$=59\frac{1}{2}$	59 11	$a \wedge s$, $\bar{1}00 \wedge \bar{1}11$	$=76\frac{1}{2}$	76 34
$c \wedge s$, $001 \wedge \bar{1}11$	$=42\frac{1}{2}$	42 2	$a \wedge o$, $\bar{1}00 \wedge \bar{2}21$	$=62\frac{1}{2}$	61 32

It should be stated that the foregoing problem was executed with blackboard crayon, and with beam-compass and scales graduated to every fifth degree only.

Finally the writer would state that in his own laboratory the graphical methods have proved most serviceable, and it is believed that by means of them a far better insight into mathematical crystallography and the meaning of zonal relations and angles has been gained by the students, than when other methods were employed. There is no wish to discourage numerical calculations; such must be made, and facility in making them must be acquired, but the graphical methods, if properly interpreted, are, if anything, a decided help, for they give meaning to the calculations, which, far too often, are made by prescribed formulas, wholly meaningless to the average student.

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* The Stereographic Projection and its Possibilities, loc. cit., p. 140.

Sheffield Laboratory of Mineralogy and Petrography,
Yale University, New Haven, May 1902.

ART. XXXI.—*The Estimation of Bromic Acid by the Direct Action of Arsenious Acid*; by F. A. GOOCH and J. C. BLAKE.

[Contributions from the Kent Chemical Laboratory of Yale University—CXI.]

IN a former paper from this laboratory* it has been shown that iodic acid may be reduced quantitatively by arsenious acid. In the work of which the present paper is an account the attempt has been made to apply arsenious acid similarly to the quantitive estimation of bromic acid, according to the equation

$$3H_3AsO_3 + HBrO_3 = 3H_3AsO_4 + HBr.$$

In the following series of experiments, made to discover the limits within which regularity of action might be expected, definite amounts of arsenious oxide dissolved in acid potassium carbonate were mixed with measured portions of a solution of potassium bromate, sulphuric acid was introduced in the amounts indicated, and, after standing either at the ordinary temperature, on the steam-bath or at the boiling temperature, potassium acid carbonate was added and the arseniate remaining was titrated with iodine to color, the indication being confirmed by addition of starch. The conditions of acidity, the excess of arsenious oxide, the dilution, the time of action, and the temperature were varied within wide limits. The potassium bromate for this particular series of experiments was thrice recrystallized from water, dried at 110°, and made up in solution containing 2·8 grms. to the liter. Of this solution 25 or 50$^{cm^3}$ were measured out for each experiment.

TABLE I.

Volume not exceeding 200$^{cm^3}$.

$KBrO_3$ taken. grm.	As_2O_3 taken. grm.	H_2SO_4 (1:1) taken. cm^3.	Time of digestion.	As_2O_3 unchanged. grm.	As_2O_3 oxidized. grm.	Error in terms of $KBrO_3$. grm.
Heated at the boiling temperature.						
0·1400	0·4950	10	30 min.	0·2476	0·2474	0·0008—
0·1400	0·4950	10	30 "	0·2480	0·2470	0·0010—
0·1400	0·6188	10	20 "	0·3708	0·2480	0·0006—
0·1400	0·7425	8	25 "	0·4941	0·2484	0·0003—
0·1400	0·7425	8	25 "	0·4943	0·2482	0·0004—
0·1400	0·6188	7	20 "	0·3704	0·2484	0·0003—
0·1400	0·6203	7	20 "	0·3720	0·2483	0·0004—

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* Gooch and Pulman, this Journal, xii, p. 450 (1901).

AM. JOUR. SCI.—FOURTH SERIES, VOL. XIV, NO. 82.—OCTOBER, 1902.
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TABLE I—*Continued.*

Volume not exceeding 200$^{cm^3}$.

$KBrO_3$ taken. grm.	As_2O_3 taken. grm.	H_2SO_4 (1 : 1) taken cm_3.	Time of digestion.	As_2O_3 unchanged. grm.	As_2O_3 oxidized. grm.	Error in terms of $KBrO_3$. grm.
Heated at the boiling temperature.						
0·1400	0·6188	5	15 min.	0·3712	0·2476	0·0008 –
0·1400	0·4950	3·5	15 “	0·2480	0·2470	0·0010—
0·1400	0·4950	3·5	15 “	0·2482	0·2468	0·0011 —
[0·1400	0·4950	2·5	15 “	0·2629	0·2321	0·0097 —]
0·0700	0·2475	5	15 “	0·1240	0·1235	0·0005 —
0·0700	0·2475	5	15 “	0·1239	0·1236	0·0004 —
0·0700	0·2475	5	15 “	0·1258	0·1217	0·0015 —
0·0700	0·2475	5	15 “	0·1244	0·1231	0·0007 —
0·0700	0·2475	5	10 “	0·1239	0·1236	0·0004 —
0·0700	0·2475	5	10 “	0·1237	0·1238	0·0003 —
0·0700	0·1584	5	10 “	0·0345	0·1239	0·0003 —
0·0700	0·1584	5	10 “	0·0357	0·1227	0·0009 —
0·0700	0·1584	5	10 “	0·0356	0·1228	0·0009 —
0·0700	0·1584	5	10 “	0·0353	0·1231	0·0007 —
0·0700	0·1881	5	10 “	0·0649	0·1232	0·0007 –
0·0700	0·1881	5	10 “	0·0640	0·1241	0·0002 —
0·0700	0·1881	5	10 “	0·0649	0·1232	0·0007 —
0·0700	0·1881	5	5 “	0·0652	0·1229	0·0008 —
0·0700	0·1881	5	5 “	0·0652	0·1219	0·0008 —
0·0700	0·2475	2·5	10 “	0·1238	0·1237	0·0004 —
0·0700	0·2475	2	10 “	0·1235	0·1240	0·0002 —
0·0700	0·2475	1·15	10 “	0·1242	0·1233	0·0006 —
0·0700	0·2475	1·15	10 “	0·1240	0·1235	0·0005 —
[0·0700	0·2475	1·15	5 “	0·1300	0·1175	0·0038 —]
Heated on the steam-bath —80°.						
0·1400	0·4950	10	150 min.	0·2476	0·2474	0·0008 —
0·1400	0·4950	10	150 “	0·2476	0·2474	0·0008 —
0·1400	0·4950	4	240 “	0·2473	0·2477	0·0007 —
0·1400	0·4950	4	240 “	0·2475	0·2475	0·0008 —
0·1400	0·4950	4	180 “	0·2472	0·2478	0·0006 —
0·1400	0·4950	4	180 “	0·2470	0·2480	0·0005 —
0·1400	0·4950	3·5	90 “	0·2475	0·2475	0·0008 —
0·1400	0·4950	3·5	90 “	0·2476	0·2474	0·0008—
[0·0700	0·2475	1·15	30 “	0·1622	0·0853	0·0217—]
Digested at the ordinary temperature.						
0·1400	0·4950	4·	46 hrs.	0·2480	0·2470	0·0005 —
0·1400	0·4950	3·5	41 “	0·2475	0·2475	0·0008 —
0·1400	0·4950	3·5	41 “	0·2470	0·2480	0·0005 —
0·1400	0·4950	3·5	17 “	0·2490	0·2460	0·0016—
0·1400	0·4950	3·5	17 “	0·2492	0·2458	0·0017 —

An examination of these results discloses the fact that for conditions varying within a rather wide range the oxidation of the arsenious oxide reaches a fairly definite limit. The bromate effects practically the same proportionate oxidation of arsenious oxide in a volume of 200^{cm^3} or less, whether the sulphuric acid of half-strength present amounts to $3 \cdot 5^{cm^3}$ or 10^{cm^3}, and whether the time of digestion is 15 minutes or 30 minutes at the boiling temperature, one and one-half or four hours on the steam-bath, or two days at the ordinary temperature. Setting aside those experiments in which the addition of acid did not exceed the equivalent of alkali carbonate present by more than 1^{cm^3}, the average absolute variation from theory of the entire list of forty-two experiments amounts to 0·0007— grm. in terms of bromate, individual variations departing from the average by about the same figure. The obvious meaning of this fact seems to be that the slight error is due to impurity in the potassium bromate employed and not to incomplete oxidizing action on the part of the bromate.

In the following series of experiments another preparation of bromate was employed, and its value was fixed by reduction with acidified potassium iodide and titration of the iodine set free according to the method formerly proposed by Kratchmer.* The rate at which the action proceeds, according to the equation

$$6HI + HBrO_3 = HBr + 3H_2O + I_2,$$

has been investigated by Ostwald,† by Noyes,‡ and by Judson and Walker.§ Time of action, proportion of iodide to bromate, excess of acid, and dilution are all, within limits, determining factors in the reaction; but in the analytical process it is usually assumed that the reaction goes soon to completion if free acid and a moderate excess of potassium iodide are present. In the following table are recorded the results of experiments in which measured amounts of standard solutions of potassium bromate (approximately 2·8 grms. to the liter) were treated with potassium iodide and hydrochloric or sulphuric acid for definite times in glass-stoppered bottles, the iodine liberated being determined by titration with sodium thiosulphate standardized against nearly decinormal iodine of value fixed by comparison with decinormal arsenious oxide dissolved in acid potassium carbonate.

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* Zeit. Anal. Chem., xxiv, 546 (1885).
† Zeit. Phys. Chem., ii, 127 (1888).
‡ Zeit. Phys. Chem., xix, 599 (1896).
§ Jour. Chem. Soc., lxxiii, 410 (1898).

TABLE II.

A

	KBrO$_3$ taken. grm.	= Iodine taken. grm.	KI taken. grm.	H$_2$SO$_4$ (1:1) cm^3.	Time of standing. hrs.	Approximate volume. cm^3.	Iodine found. grm.	Error in terms of KBrO$_3$ grm.
(1)	0·1410	0·6423	1	5	none	150	0·6223	0·0044—
(2)	0·1410	0·6423	1	5	none	200	0·5929	0·0108—
(3)	0·1400	0·6378	3	5	½	100	0·6343	0·0008—
(4)	0·1400	0·6378	3	5	½	100	0·6329	0·0011—
(5)	0·1400	0·6378	3	5	½	100	0·6329	0·0011—
(6)	0·1408	0·6416	3	5	22	100	0·6396	0·0004—
(7)	0·1408	0·6416	3	5	22	100	0·6364	0·0011—
(8)	0·1408	0·6416	3	5	22	100	0·6381	0·0008—
(9)	0·1400	0·6378	3	2·5	½	100	0·6340	0·0008—
(10)	0·1400	0·6378	3	2·5	½	100	0·6336	0·0009—
(11)	0·1400	0·6378	3	2·5	½	100	0·6336	0·0009—
(12)	0·1400	0·6378	3	1	½	100	0·6343	0·0008—
(13)	0·1400	0·6378	3	0·5	½	100	0·6331	0·0010—

B

				HCl Sp. gr. 1·18 cm^3.				
(14)	0·1400	0·6378	3	8	½	100	0·6336	0·0009—
(15)	0·1400	0·6378	3	8	½	100	0·6329	0.0011—
(16)	0·1400	0·6378	3	8	½	100	0·6336	0·0009—
(17)	0·1400	0·6378	3	4	½	100	0·6336	0.0009—
(18)	0·1400	0·6378	3	4	½	100	0·6333	0·0010—
(19)	0·1400	0·6378	3	4	½	100	0·6340	0·0008—
(20)	0·1400	0·6378	3	4	1	100	0·6336	0·0009—
(21)	0·1400	0·6378	3	4	1	100	0·6333	0·0010—
(22)	0·1400	0·6378	3	4	1	100	0·6336	0·0009—

In experiments (1) and (2) the excess of potassium iodide was only about 20 per cent over the amount demanded by theory, the time of standing was only the few minutes required for the manipulation of the process, and the dilution was considerable. It is obvious that under these conditions the reaction is very incomplete. On the other hand, a glance at the table makes it evident that the oxidation in all other experiments, whether in A or B, proceeds to practically the same point, showing similar errors. So it appears that the variation in the amount of acid above the minimum, the kind of acid (whether sulphuric or hydrochloric), and the time above the minimum half-hour, within the limits defined, are without apparent effect upon the reaction in the presence of the amount of potassium iodide used, approximately four times the amount required by theory. The balancing error due to the evolution of iodine by the action of atmospheric oxygen upon the acidified solution of the iodide was found by experiment to vary with the strength of the acid and the time of exposure, from 0·0001 grm. to 0·0003 grm. expressed in terms of the bromate, and these values are not greater than the differences observed between parallel determinations of the same sort. Probably, therefore, all the errors as shown in the table should really be increased a trifle to approximate the truth, notably those of the experiments allowed to stand the longest period, twenty-two hours.

The average apparent error of the process as applied to this particular sample of bromate is 0·0009– grm.; and 2·5$^{cm^3}$ of sulphuric acid of half-strength (1:1) or the equivalent amount of hydrochloric acid, 4$^{cm^3}$ of the acid of sp. gr. 1·18, in the presence of about 3 grms. of potassium iodide, complete the action within a half hour, at a dilution of 100$^{cm^3}$, as far as it will go under any of the conditions tried. The phenomenon noted by Ostwald,* that small amounts of hydrochloric acid tend to force the reaction more rapidly than equivalent amounts of sulphuric acid, does not appear in these experiments, no doubt because the action was pushed to the limit by the smallest amount of the weakest acid employed.

The error of deficiency shown again appears to be due to impurity in the sample of bromate rather than to incompleteness of the reaction. If the reaction were incomplete it would be natural to look for the cause in the possibility of the inhibiting influence of the iodine set free,† but it was found in three parallel experiments that the introduction of ·5 grm. of free iodine dissolved in potassium iodide failed to influence the error appreciably. For the present purpose, however, the absolute purity of the bromate is not a matter of moment, if, as seems to be the case, Kratchmer's reaction indicates its value with accuracy, as the basis of experimentation. It seems safe to assume, then, that the average result of experiments (3) to (22) will give a very fair value for the sample of bromate investigated. That is to say, the experiments show an average deficiency in bromate amounting to 0·0009 grm., or to 0·64 per cent.

Portions of this bromate were taken for reduction by arsenious acid. Solutions not exceeding 200$^{cm^3}$ in volume, containing the bromate and a considerable excess of arsenious oxide acidified with sulphuric acid of half-strength, were boiled for periods varying from ten to forty-five minutes, neutralized with potassum acid carbonate, and titrated with iodine. The results are shown in Table III.

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* Loc. cit., p. 131.

† Judson and Walker, loc. cit., p. 411.

TABLE III.

	$KBrO_3$ taken. grm.	As_2O_3 taken. grm.	H_2SO_4 (1:1). cm^3.	Time in minutes.	As_2O_3 unchanged. grm.	As_2O_3 oxidized. grm.	Error in terms of $KBrO_3$. grm.
(1)	0·0701	0·1881	5	10	0·0661	0·1220	0·0014—
(2)	0·0701	0·1881	5	10	0·0650	0·1231	0·0009—
(3)	0·0701	0·2475	5	10	0·1232	0·1243	0·0002—
(4)	0.0701	0·2475	5	10	0·1236	0·1239	0·0004—
(5)	0·0701	0·2475	5	25	0·1234	0·1241	0·0003—
(6)	0·0701	0·2475	5	25	0·1234	0·1241	0.0003—
(7)	0·1402	0·4950	3	15	0·2479	0·2471	0·0012—
(8)	0·1402	0·4950	3	15	0·2476	0·2474	0·0010—
(9)	0·1400	0·6188	7	20	0·3708	0·2480	0·0004—
(10)	0·1400	0·6188	7	20	0·3710	0·2478	0·0005—
(11)	0·1400	0·6188	7	20	0·3706	0·2482	0·0003—
(12)	0·1400	0·6188	7	30	0·3708	0·2480	0·0004—
(13)	0·1400	0·6188	7	45	0·3711	0·2477	0·0006—

Here again, as in the experiments of Table I, the indications of the process of reduction of the bromate by arsenious acid, point to a slight deficiency in the oxidizing power of the bromate. The mean deficiency, 0·0006 grm., differs from the indications of the process of reduction of the same sample by the potassium-iodide method by about 0·0003+ grm.

The question now arises as to what is the impurity in the bromate. In a product recrystallized several times, and in one in which no chloride can be detected, as was the case with the bromate of these experiments, the impurity most natural to look for is potassium chlorate, which, might resist removal in the process of purification by recrystallization. The preparation of bromate upon which these last experiments were made was therefore tested by igniting it and treating the residue with potassium bichromate and sulphuric acid, volatilizing and collecting any chloro-chromic anhydride thus formed, and converting the last into lead chromate.* Traces of chlorine were thus found, which, not appearing in a similar test upon the unignited bromate, must have had their origin in chlorate intercrystallized with the bromate. In a former paper from this laboratory† it has been shown that a chlorate may be determined by adding to it in solution potassium iodide in known amount and an excess of an arseniate and sulphuric acid, boiling the mixture between definite limits of concentration, determining by titration with iodine the amount of arsenious oxide produced, and calculating the amount of chlorate present, from the difference between the amount of arsenious oxide thus produced and that which

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* Gooch and Brooks, this Journal, xl, p. 287 (1890).

† Gooch and Smith, this Journal, xlii, p. 220 (1891).

should be produced if the whole amount of iodide added were allowed to act upon the arseniate alone. There appears to be no reason why a bromate treated by this process should not leave a similar record of its oxidizing power. A mixture of bromate and chlorate should, therefore, in this process, leave a record of the full amount of oxidation of which both together are capable. The following table contains the account of experiments made in this manner upon the sample of bromate the action of which in the iodide method and in the arsenious acid method is recorded in Tables II and III.

TABLE IV.

(H_2SO_4) (1:1) 20^{cm^3}; initial volume 105 to 170^{cm^3}; final volume 35^{cm^3}.

	$KBrO_3$ taken. grm.	H_2KAsO_4 taken. grm.	I value of KI taken. grm.	Iodine corresponding to As_2O_3 produced. grm.	Iodine corresponding to $KBrO_3$. grm.	Error in terms of $KBrO_3$. grm.
(1)	0·0700	2	0·4146	0·0948	0·3198	0·0002+
(2)	0·0700	2	0·4146	0·0954	0·3192	0·0000
(3)	0·0700	2	0·4146	0·0969	0·3177	0·0003—
(4)	0·0700	2	0·4146	0·0975	0·3171	0·0004—
(5)	0·1400	2	0·7832	0·1458	0·6374	0·0001—
(6)	0·1400	2	0·7832	0·1463	0·6369	0·0002—
(7)	0·1400	2	0·7832	0·1462	0·6370	0·0002—

The mean error of these determinations, in which all oxidizing material is calculated as bromate, is not far from 0·0001– grm.

In the case of still another preparation of potassium bromate, made by acting with commercial bromine on potassium hydroxide, crystallizing and recrystallizing several times, determinations by means of arsenious acid and by the arseniate-iodide process resulted as shown in the following statement:

TABLE V.

A.

Arsenious Acid Method.

(Volume not exceeding 100^{cm^3}.)

$KBrO_3$ taken. grm.	As_2O_3 taken. grm.	H_2SO_4 (1 : 1) grm.	Time in minutes.	As_2O_3 unchanged. grm.	As_2O_3 oxidized. grm.	Error in terms of $KBrO_3$ grm.
At the boiling temperature.						
0·0704	0·2475	5	10	0·1241	0·1234	0·0010—
0·0704	0·2475	5	15	0·1239	0·1236	0·0009—
0·0704	0·2475	5	15	0·1236	0·1239	0·0007—

TABLE V—*Continued.*

A.

Arsenious Acid Method.

(Volume not exceeding 100^{cm^3}.)

$KBrO_3$ taken. grm.	As_2O_3 taken. grm,	H_2SO_4 (1:1) grm.	Time in minutes.	As_2O_3 unchanged. grm.	As_2O_3 oxidized. grm.	Error in terms of $KBrO_3$ grm.
			On the steam bath,—80°.			
0·0704	0·2475	5	30	0·1241	0·1229	0·0013 −
0·0704	0·2475	5	30	0·1246	0·1234	0·0010 −
			At atmospheric temperature.			
0·0704	0·2475	5	10	0·2066	0·0409	0·0474 −
0·0704	0·2475	5	10	0·1991	0·0488	0·0426 −
0·0704	0·2475	5	30	0·1533	0·0922	0·0185 −
0·0704	0·2475	5	60	0·1231	0·1244	0·0004 −
0·0704	0·2475	5	120	0·1242	0·1233	0·0011 −
0·0704	0·2475	5	120	0·1238	0·1237	0·0009 −

B.

Arseniate-Iodide Method.

(H_2SO_4) (1:1) 20^{cm^3}; initial volume 110^{cm^3}; final volume 35^{cm^3}.

$KBrO_3$ taken. grm.	H_2KAsO_4 taken. grm.	I value of KI taken. grm.	Iodine corresponding to As_2O_3 produced. grm.	Iodine corresponding to $KBrO_3$. grm.	Error in terms of $KBrO_3$. grm.
0·0704	2	0·3812	0·0607	0·3205	0·0001 −
0·0704	2	0·3812	0·0588	0·3224	0·0003 +
0·0704	2	0·3812	0·0595	0·3217	0·0001 +
0·0704	2	0·3842	0·0590	0·3222	0·0002 +
0·0704	2	0·3812	0·0615	0·3197	0·0003 −
0·0647	2	0·3812	0·0839	0·2973	0·0004 +

The mean error of the arseniate-iodide process applied to this particular sample of bromate is 0·0001 + grm. in terms of bromate; the arsenious acid method shows a mean deficiency of about 0·0009 grm. for the smaller amount of bromate employed, if, as is obviously reasonable, those results are omitted from the averages which were obtained by standing at the ordinary temperature for periods less than one hour.

It appears, therefore, that the deficiency in the indications of the iodide process and the arsenious acid process are satisfactorily accounted for by the presence in the bromate of traces of chlorate; and that the oxidizing power of a bromate may be determined by boiling it in solution with a known excess of arsenious oxide and an excess of sulphuric acid, and determining the amount of arsenious oxide remaining unchanged. A chlorate, as we have found by direct experiment, is scarcely affected by this treatment.

ART. XXXII.—*Solubilities of Some Carbon Compounds and Densities of their Solutions*; by CLARENCE L. SPEYERS.

AT the present time we are more or less inclined to find in solution an action corresponding to vaporization, and as vaporization under ideal conditions is generally considered independent of the contents of the space into which the substance volatilizes, chemical action of course being excluded, so in forming dilute solutions we generally expect the act of solution to be independent of the medium into which the solute passes, that is, independent of the solvent. In some respects our expectations are justified and find their expressions in the van't Hoff laws; but on the other hand, we cannot fail to see that the solvent plays a very important part, for many substances refuse altogether to dissolve in certain solvents, and consequently the simplicity of the gaseous condition cannot be carried over directly to solutes without running the risk of straying away from the path leading to a satisfactory explanation of solution.

It was in the hope of finding that the different molecular aggregations of the solutes would explain their differences in solubility that the following experiments were made. It was in the hope of finding that in a saturated solution the osmotic pressure of the solute in the form of simple molecules would be the same in all solvents because the liquid phases are all balanced by the same solid phase, that is by the same undissolved solute. The large number of measurements of the solubilities of metallic salts were not available on account of ionic decomposition.

The same solutes and solvents were chosen which were used in determining heats of solution* and in determining molecular weights in concentrated solutions.†

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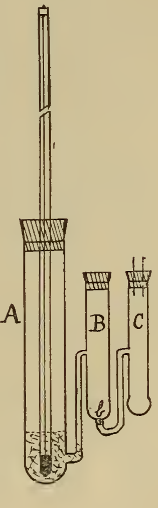

The apparatus shown in figure 1 was used; the tube A was about 17^{cm} long and 2·5^{cm} wide; B was about 12^{cm} long and about 2·0^{cm} wide; C was about of the same size as B. Solution, excess of solute and thermometer were in A. At the bottom of B was a plug of filter paper, *b;* otherwise B was empty, and C was empty. After the tubes were charged, they were sunk in a water bath nearly to the tops of B and C. The solution and solute were kept stirred by air blown through C, the air escaping around the loosely fitting stopper of A. When

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* Journ. Am. Chem. Soc., xviii, 146, 1896. † This Journal, xiii, 213, 1902.

the solvent was other than water, the air was dried by calcium chlorid.

About half an hour was needed to get the temperature of the water bath constant to 0·1° for ten minutes. When that was done, at the end of the ten minutes, the solution with undissolved solute was drawn over into B, and through the filter plug into C. When the solute was a nitrogenous body, the solution was analyzed by the Kjehldahl method; by specific gravity, when the solute was non-nitrogeneous. Evaporation to dryness and weighing the residue was altogether unsuitable, too much decomposition.

The solutions were believed to be in just the right condition, since the large mass of crystals present when the solution was drawn over must have prevented appreciable supersaturation on the one hand, and on the other, as the temperature was always falling at this time, though only very slightly, the solution must have been completely saturated.

The thermometer was carefully calibrated. It was divided into tenths and the temperature is probably correct to this quantity, but hardly correct to a smaller quantity on account of the uncertainty of the temperature of the exposed thread.

The examination and purification of solvents and solutes have already been described.*

The following tables give the results calculated to per cent gram-molecules, that is, to the number of gram-molecules of solute in 100 gram-molecules of solution at the accompanying temperature. The usual chemical formulæ were used in the calculations.

WATER.

Urea.		Urethane.		Chloral hydrate.		Succinimid.		Acetamid.		Resorcinol.	
0·0°	16·77	0·0°	3·61	0·0°	20·66	0·0°	1·58	0·0°	29·64	0·0°	9·78
11·0°	20·82	10·3°	6·09	11·3°	30·23	11·3°	2·74	10·6°	34·35	10·0°	13·27
19·8°	22·69	11·1°	6·62	23·7°	45·86	20·7°	4·23	19·9°	40·72	34·6°	23·67
31·7°	28·24	23·5°	43·70	38·1°	59·41	33·3°	9·91	32·9°	49·62	55·8°	36·74
51·4°	36·67	31·4°	68·91			69·3°	27·14	45·5°	60·14	79·8°	50·91
69·5°	43·15	37·0°	75·58					63·0°	77·10		

METHYL ALCOHOL.

Urea.		Urethane.		Acetanilid.		Naphthalene.		Acenaphthene.	
0·0°	7·34	0·0°	31·18	0·0°	5·38	0·0°	0·87	0·0°	0·39
10·8°	8·71	10·6°	41·70	11·5°	7·02	14·6°	1·68	12·4°	0·38
21·7°	10·81	22·5°	58·58	22·8°	11·12	31·8°	2·97	30·7°	0·73
40·4°	15·96	40·9°	90·00	33·6°	13 96	48·0°	5·83	46·0°	1·55
61·2°	25·77			40·2°	17·05	59·9°	12·34	62·3°	2·46
				47·4°	23·72				
				60·9°	35·24				
				63·3°	33·33				

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* This Journal, l. c.

Ethyl Alcohol.

Urea.		Urethane.		Acetanilid.		Naphthalene.		Resorcinol.		Acenaphthene.	
0·0°	1·95	0·0°	23·91	0·0°	5·01	0·0°	1·80	0·0°	34·37	0·0°	0·57
10·5°	3·04	10·5°	36·86	10·8°	6·84	8·6°	2·13	9·2°	37·69	10·0°	0·84
22·3°	4·07	21·7°	52·21	42·5°	17·93	31·8°	4·82	31·8°	41·84	30·3°	1·70
32·3°	5·61	30·9°	72·35	43·5°	15·40	46·9°	9·70	50·6°	47·07	49·8°	3·86
55·5°	9·18	40·5°	88·32	61·6°	31·36	69·8°	64·23	73·1°	58·03	71·6°	12·94
72·1°	14·40										

Phenanthrene.		Chloral hydrate.		Succininid.		Acetamid.		Benzamid.		p-Toluidin.	
0·0°	0·82	0·0°	34·35	0·0°	0·88	0·0°	18·53	0·0°	3·08	0·0°	20·72
10·9°	0·86	13·5°	41·08	11·1°	1·36	18·6°	32·87	10·4°	4·25	11·7°	33·88
32·1°	1·56	36·0°	83·16	24·2°	2·44	42·5°	56·06	32·6°	8·72	22·1°	50·90
47·0°	2·19	43·4°	92·32	43·7°	5·63	62·0°	78·92	50·4°	14·44		
70·2°	7·52			58·6°	11·49			72·3°	20·86		

Propyl Alcohol.

Urethane.		Naphthalene.		Acenaphthene.	
0·0°	19·48	0·0°	2·09	0·0°	0·88
10·4°	32·27	10·4°	2·70	10·5°	0·97
21·6°	53·31	30·3°	5·34	31·1°	1·88
30·4°	68·75	50·3°	15·34	50·3°	4·37
40·7°	85·74	68·5°	62·9	73·4°	19·9

Chloroform.

Urethane.		Acetanilid.		Naphthalene.		Acenapthene.		Chloral hydrate.	
0·0°	27·56	0·0°	3·24	0·0°	19·58	0·0°	12·72	0·0°	2·67
10·5°	42·66	10·6°	7·32	10·6°	23·14	11·2°	16·54	12·5°	4·23
17·4°	48·78	31·4°	15·64	30·3°	38·53	29·8°	54·62?	27·7°	31·93
31·1°	69·92	45·9°	24·07	52·5°	57·40	52·7°	42·19	44·0°	100·0
39·2°	78·54	61·4°	37·55					44·4°	100·0
								46·3°	100·0

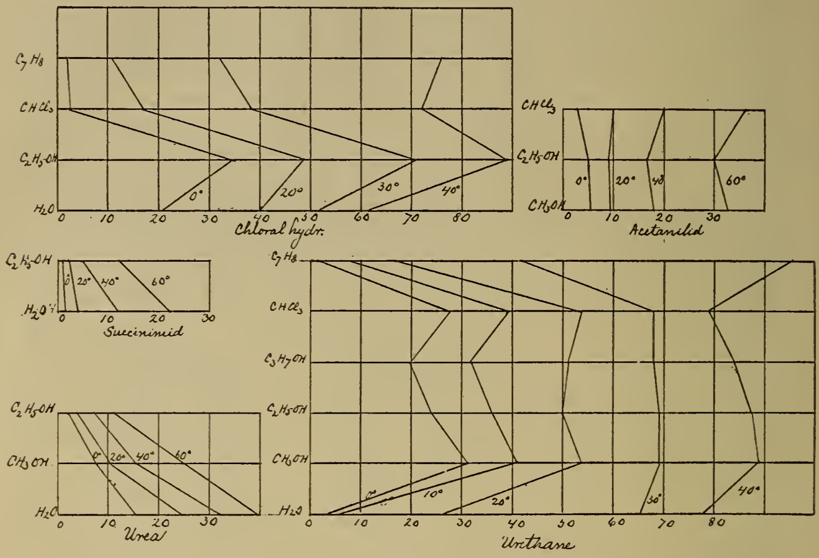
Toluene.

Urethane.		Naphthalene.		Acenaphthene.		Phenanthrene.		Chloral hydrate.	
0·0°	1·77	0·0°	12·82	0·0°	7·88	0·0°	11·88	0·0°	1·78
22·1°	19·63	25·2°	23·26	10·3°	10·76	13·9°	17·40	10·0°	4·24
33·9°	63·60	46·3°	47·37	24·1°	16·53	30·8°	26·90	20·7°	11·42
40·7°	87·86	69·5°	84·43	41·6°	29·29	54·9°	53·25	29·6°	31·18
				61·5°	45·08	78·3°	81·98	42·5°	89·86

It is unnecessary to plot these data, for with the exceptions of urethane in water and chloral hydrate in chloroform, the curves are quite regular. In the cases of urethane and chloral hydrate, the curves change direction very suddenly at about 12°, showing a very sudden decrease in solubility as the temperature decreases from this point.

Plots showing the variation in solubility as we pass from one solvent to another are perhaps of some interest. They are given in figures 2 and 3. The solubilities are expressed in percentage gram-molecules* along the horizontal line in that sol-

2



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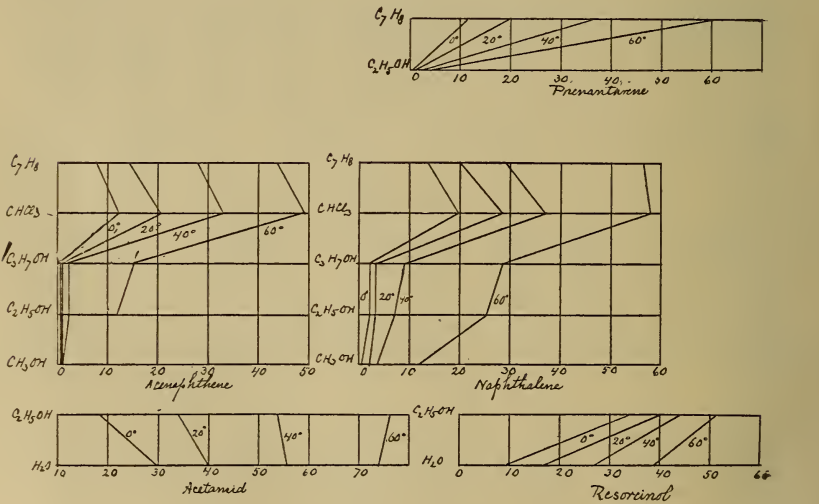

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* According to the ordinary chemical formulæ.

vent whose formula is given at the commencement of the line. We notice that the relative solubility of a solute in several solvents can change very much with the temperature. For instance, acetamid is less soluble in alcohol than in water between 0° and about 50°, but above 50° it is more soluble in alcohol than in water. This is analogous to the relative changes in vapor pressures of some liquids. We notice the small increase in solubility of urethane in water as we pass from 0° to 10° and the rapid increase as we pass beyond that temperature. There seems to be some slight error in the solubility of the aqueous solution at 30°, but there is none at 10°, for the solubility at that temperature was determined twice. We notice also that there is no regularity in change of solubility as the molecular weights of the alcoholic solvents increase, whether we consider the molecular aggregations of the solutes[†] or not.

M. Schroeder[‡] has deduced the equation

$$l\frac{n}{\mathrm{N}+n} = \mathrm{A}(t_0 - t)$$

in which n is the number of gram-molecules of solvent in a saturated solution; A is a constant, the same for each solute whatever the solvent may be. t_0 is the fusion temperature of the solute and t is the temperature of saturation. How this equation is obtained need not be considered. According to it, the curves of solubility of any solute in all solvents should coincide. Schroeder tested the equation with *p*-dibrombenzene in ethyl alcohol, propyl alcohol, isobutyl alcohol, ethyl ether, carbon disulphid, benzene, and brombenzene; with naphthalene in benzene. chlorbenzene, and carbon-tetrachloride; with *m*-dinitrobenzene in benzene, brombenzene, and chloroform. His results justify it, but mine do not; only for solutions of acenaphthene, naphthalene, and phenanthrene are the coincidences at all good.

The specific volumes of the solutions must be known before we can proceed to determine the osmotic pressures of the solutes, and therefore we now pass on to the densities.

These were easily obtained by sinking a pycnometer with a very small mouth into the saturated solution and drawing this in, the very small mouth keeping out particles of solute. Since the solution was kept stirred by air and contained an abundant excess of solute and since the temperature was kept constant for some ten minutes before drawing into the pycnometer, the solutions are to be considered in just the right

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[†] This Journal, l. c.

[‡] Zeitschr. Phys. Chemie, xi, 449, 1893.

condition, neither supersaturated nor undersaturated. The thermometer was the one used for the solubilities and the temperature is certain to 0·1°.

The uncertainty in the density is about 3 units in the third place in extreme cases; in general it is 2 or 3 units in the fourth place, the pycnometer holding between 8·5 and 9·8^{cc} and the weighings being made to milligrams.

The following tables give the temperatures and corresponding densities; namely, weights in grams reduced to vacuum of one cubic centimeter of solution.

Water.

Urea.		Urethane.		Chloral hydrate.		Succinimid.	
0·0°	1·121	0·0°	1·023	0·0°	1·433	0·0°	1·025
19·0°	1·144	11·0°	1·035	15·3°	1·520	15·9°	1·043
32·2°	1·158	24·0°	1·073	31·0°	1·579	36·6°	1·111
46·3°	1·171	38·8°	1·064	46·6°	1·623	50·3°	1·140
64·5°	1·181	39·7°	1·065			65·0°	1·181
84·1°	1·196					84·4°	1·208

Acetamid.		Resorcinol.		Mannitol.	
0·0°	1·055	0·0°	1·101	0·0°	1·044
15·6°	1·046	14·4°	1·125	15·2°	1·050
31·6°	1·037	31·1°	1·149	31·1°	1·076
49·5°	1·022?	45·2°	1·161	47·7°	1·099
68·4°	1·011	63·4°	1·174	68·0°	1·148
		85·4°	1·179	85·9°	1·207

Methyl Alcohol.

Urea.		Urethane.		Acetanilid.	
0·0°	0·8612	0·0°	0·9565	0·0°	0·8602
17·4°	0·8674	15·5°	0·9902	16·7°	0·8698
29·7°	0·8764	28·2°	1·021	29·9°	0·8924
50·5°	0·9086	39·5°	1·044	43·9°	0·9206
66·8°	0·9534			61·7°	0·9596

Naphthalene.		Acenaphthene.		Methyl Alcohol (pure).	
0·0°	0·8194	0·0°	0·8133	0·0°	0·8110
16·6°	0·8088	12·5°	0·8030	18·3°	0·7938
29·0°	0·8048	31·6°	0·7900	29·4°	0·7834
47·0°	0·8086	45·6°	0·7823	46·2°	0·7675
61·7°	0·8436	64·1°	0·7843	59·8°	0·7540
68·0°	0·9022				

Ethyl Alcohol.

Urea.		Urethane.		Chloral hydrate.		Succinimid.		Acetamid.	
0·0°	0·8213	0·0°	0·8914	0·0°	1·110	0·0°	0·8150	0·0°	0·8562
15·7°	0·8113	14·1°	0·9443	16·7°	1·319	17·5°	0·8063	17·8°	0·8696
31·6°	0·8060	30·9°	1·004	33·5°	1·560	33·2°	0·8052	35·0°	0·8974
51·5°	0·8031	43·7°	1·044	40·8°	1·589	57·5°	0·8292	54·4°	0·9416
71·5°	0·8124					79·6°	0·9552	70·3°	0·9815
						80·6°	0·9563		

Resorcinol.		Benzamid.		Acetanilid.		p-Toluidin.		Naphthalene.	
0·0°	1·033	0·0°	0·8331	0·0°	0·8420	0·0°	0·8884	0·0°	0·8175
14·1°	1·036	14·1°	0·8328	17·2°	0·8472	15·6°	0·9168	17·0°	0·8104
36·1°	1·054	36·2°	0·8434	39·0°	0·8721	28·4°	0·9458	31·2°	0·8084
62·5°	1·077	57·2°	0·8754	58·1°	0·9156	40·6°	0·9636	51·0°	0·8230
81·4°	1·107	72·8°	0·9226	76·7°	0·9596			72·4°	0·9563
83·7°	1·112								

Phenanthrene.		Acenaphthene.		Ethyl alcohol (pure).	
0·0°	0·8141	0·0°	0·8108	0·0°	0·8074
15·6°	0·8035	15·0°	0·8013	19·1°	0·7921
35·3°	0·7960	36·3°	0·7910	35·3°	0·7780
52·2°	0·7941	53·4°	0·7890	52·3°	0·7633
76·4°	0·8654	73·0°	0·8186	72·8°	0·7448

Propyl Alcohol.

Urethane.		Naphthalene.		Acenaphthene.		Propyl alcohol (pure).	
0·0°	0·8798	0·0°	0·8285	0·0°	0·8228	0·0°	0·8192
13·3°	0·9156	14·6°	0·8228	12·9°	0·8171	18·0°	0·8067
29·1°	0·9804	30·7°	0·8206	26·6°	0·8110	28·0°	0·7991
42·1°	1·033	41·8°	0·8247	47·4°	0·8063	44·4°	0·7854
		59·7°	0·8634	64·7°	0·8217	65·1°	0·7678
		72·4°	0·9535	83·3°	0·9736	80·6°	0·7538

Chloroform.

Urethane.		Chloral hydrate.		Acetanilid.		p-Toluidin.	
0·0°	1·404	0·0°	1·529	0·0°	1·503	0·0°	1·278
16·4°	1·300	16·3°	1·505	19·1°	1·448	17·3°	1·168
31·2°	1·191	34·4°	1·565	34·2°	1·381	31·4°	1·066
43·4°	1·097	44·6°	1·615	47·3°	1·326	40·8°	0·9906
				62·4°	1·261		
				69·9°	1·227		

Naphthalene.		Acenaphthene.		Chloroform (pure).	
0·0°	1·393	0·0°	1·438	0·0°	1·526
20·2°	1·304	16·5°	1·378	18·2°	1·492
35·2°	1·230	29·1°	1·328	33·4°	1·464
53·2°	1·136	40·3°	1·281	44·6°	1·443
64·5°	1·072	55·8°	1·209	58·6°	1·417

TOLUENE.

Urethane.		Chloral hydrate.		p-Toluidin.		Naphthalene.	
0·0°	0·8872	0·0°	0·8978	0·0°	0·9110	0·0°	0·9124
18·4°	0·8792	18·5°	0·9328	16·6°	0·9228	17·9°	0·9130
34·0°	0·9570	28·4°	1·069	29·4°	0·9430	36·2°	0·9224
45·2°	1·042	40·8°	1·448	40·7°	0·9616	51·6°	0·9374
		42·0°	1·445			73·9°	0·9692

Phenanthrene.		Acenaphthene.		Toluene (pure).	
0·0°	0·9254	0·0°	0·9066	0·0°	0·8840
18·3°	0·9337	13·3°	0·9076	17·6°	0·8678
37·9°	0·9515	32·3°	0·9196	32·1°	0·8544
60·1°	0·9890	57·2°	0·9502	49·8°	0·8381
86·3°	1·038	83·5°	1·006	65·9°	0·8232
				85·0°	0·8048

Of these solutions, so far as they could be examined, only the following contain solutes with normal molecular weights.*

Urea	in	water	at 32° to 41°
"	"	methyl alcohol	" 28°
"	"	ethyl "	" 27°
Acetanilid	"	methyl "	" 31°(?)
"	"	ethyl "	" 21° to 42°
Naphthalene	"	" "	" 28° " 45°
"	"	toluene "	" 29° " 45°
Acenaphthene	"	propyl alcohol	" 45°(?)
"	"	toluene	" 21° to 51°

Selecting 27° as the temperature and taking solubilities at that temperature from solubility curves and densities from density curves, we get the following table:

Solution.	Solubility.	Density.	Osmotic Pressure.
Urea in water	26 grmmols	1·155	10·4 atmos.
" methyl alcohol.....	12 "	0·873	3·0 "
" ethyl "	5 "	0·805	0·9 "
Acetanilid in methyl alcohol	12 "	0·891	2·4 "
" ethyl "	11 "	0·858	1·7 "
Naphthalene in ethyl alcohol	4 "	0·810	0·7 "
" " toluene.....	25 "	0·918	2·3 "
Acenaphthene in propyl alcoh'l	1 "	0·810	0·1 "
" toluene	18 "	0·918	1·7 "

The osmotic pressure is not at all constant for each solute, and we see that the undissolved solute does not balance the dissolved solute to an equal extent in each solvent though the molecular weights of the solutes are simple. So the analogy of solution to vaporization is seen to be far from complete.

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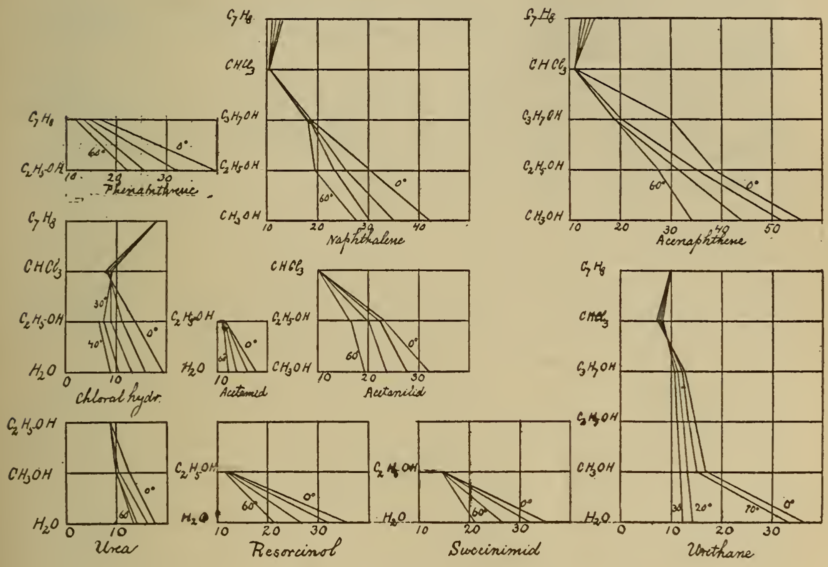
* This Journal, l. c.

In conclusion a few words about the densities and molecular volumes. There is no need of putting the data given above into plots. There is no peculiarity in any of them, not even in the aqueous solution of urethane nor in the chloroform solution of chloral hydrate, but the plots showing variation in molecular volume as a solute passes from one solvent into another are instructive. They are given in figure 4.

4



The formula at the beginning of the horizontal line gives the solvent, and the numbers along the horizontal give the relative volumes of one gram-molecule of solute at the temperature stated on the lines.

For example, the relative volume of one gram-molecule of acenaphthene in chloroform at 10° has been obtained in this way :—

Solubility of acenaphthene from solubility curve$=16{\cdot}0\%$ gram-mols.
Proportion of chloroform$=84{\cdot}0 \cdot 119{\cdot}3/\,(84{\cdot}0 \cdot 119{\cdot}3+16{\cdot}0 \cdot 154)$.
Volume of one gram chloroform at 10° from density curve$=1/1{\cdot}51$cc.
" " chloroform in one gram of solution is $[84{\cdot}0 \cdot 119{\cdot}3/(84{\cdot}0 \cdot 119{\cdot}3+16{\cdot}0 \cdot 154)]\ 1/1{\cdot}51\text{cc}=0{\cdot}5327$cc.
" " one gram of solution at $10°=1/1{\cdot}40$cc.
" " acenaphthene in one gram of solution$=1/1{\cdot}40-0{\cdot}5327=0{\cdot}1811$cc.
" corresponding to one molecule of acenaphthene$=0{\cdot}1811/16=0{\cdot}0113$.

For convenience, the values are all multiplied by 1000 before plotting.

We notice the following:—

The molecular volumes of the solutes are larger in water than in the other solvents and decrease in the order of methyl alcohol, ethyl alcohol, propyl alcohol, toluene and chloroform, the only exception being perhaps choral hydrate in ethyl alcohol compared to its solution in chloroform.

The molecular volumes in chloroform show decided constancy for every temperature and concentration observed, and to a lesser extent in toluene.

In general, the molecular volumes of the solutes decrease as the temperature rises and the concentration increases. The exceptions are urethane and chloral hydrate in chloroform.

Rutgers College, April, 1897–June, 1902.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Radio-active Bismuth.*—Polonium, the radio-active substance occurring with bismuth in pitchblende, was the first of these substances discovered (by Mr. and Mrs. Curie). Subsequent investigations by Giesel led the latter to believe that polonium was nothing more than bismuth made active by induction. MARCKWALD, however, has recently obtained results which indicate that polonium is a distinct element. From a by-product obtained from pitchblende, by the usual methods, bismuth oxychloride was prepared which was strongly radio-active, and which showed no decrease in activity after several months. Upon subjecting a solution of this substance to electrolysis, it was found that the metal which was deposited at first displayed much greater activity than the final product. This result led to the attempt to precipitate polonium, from hydrochloric acid solutions of the oxychloride, by means of a polished stick of metallic bismuth. As a result, the metal became coated immediately with a fine black deposit, which gradually increased, and when it had been removed from the solution and washed, it showed a surprisingly strong effect on the electroscope. At the distance of a decimeter the leaves of the charged electroscope collapsed in a moment, and even a gutta-percha rod which had been well rubbed with fur was immediately discharged upon the approach of the bismuth stick. The important fact was noticed that metallic bismuth is thus able to remove practically all of the active material from a solution. The powder could be scraped from the bismuth rod, and the amount thus obtained from 8^g of bismuth oxychloride was about 5^{mg}. From this result it was calculated that a ton of pitchblende would contain not more than one gram of the substance. The powder was found not to be a pure metal, but to contain some chlorine. Upon heating, a small portion volatilized, probably as chloride, and the residue fused to a white, exceedingly brittle, metallic bead. This was soluble in nitric acid, and the solution, as far as it could be tested, gave reactions for bismuth. The salts are as strongly active as the metal, and the rays are characteristically different from those of radium in being unable to penetrate any intervening substance. Even a piece of filter-paper wrapped around a stick of bismuth coated with the active metal causes it to lose all its effect. The experiments are to be continued with larger quantities of material, and it is hoped that an atomic weight determination may be made.—*Berichte*, xxxv, 365. H. L. W.

2. *A Thermochemical Constant.*—F. W. CLARKE, in a preliminary paper, has made a generalization from a consideration of Thomsen's work on the heats of combustion of certain organic compounds. In the first place, he has re-calculated Thomsen's

results so that they represent the formation of gaseous instead of liquid water. He then finds for the aliphatic hydrocarbons and their non-oxygenated derivatives that $\frac{4K}{12a+6b-c-8n}$ is a constant, where K represents the heat of combustion of the compound, a the number of molecules of CO_2 produced, b the number of molecules of H_2O, c the number of oxygen molecules involved, and n the number of atomic unions or linkings in the compound burned. In fixing the value of n, double and triple linkings are not distinguished from simple ones, so that for all chain molecules n is equivalent to the number of atoms minus one. The coefficients 4, 12, 6, 1 and 8 appear to have been chosen arbitrarily, but the results obtained with them in the cases of fourteen hydrocarbons are remarkably uniform, and the author evidently considers it important that the constant, which averages 13,873 in this case, is very near the neutralization constant of acids and bases, which is 13,700 calories. The same uniform constant was obtained with many other organic compounds by modifying the formula in accordance with the presence of several other elements: thus for halogen compounds were used the formulas $\frac{4K}{12a+6b+h-c-8n}$, $\frac{4K}{12a+6b+2h_1-c-8n}$ and $\frac{4K}{12a+6b+4h_2-c-8n}$, where h, h_1 and h_2 represent the numbers of chlorine, bromine and iodine molecules, supposed by the author to be formed by the complete combustion of the halides. For nitrogen compounds two formulas were used; for cyanides and nitrites, where m represents the number of nitrogen molecules set free, the divisor is $12a+6b+3m-c-8m$, while for amines $3m$ is replaced by $9m$. For sulphur compounds the term $9s$ is introduced, while c_1, the number of oxygen molcecules present in the compound, is subtracted when the latter element is present. In this way conformable results were obtained with nineteen halogen compounds, four cyanides, ten amines, eight sulphur compounds, and eleven alcohols. The ring compounds have not yet been worked out in this way, and there are a few substances in most of the groups which fail to give the usual result. A consideration of the exceptions is deferred until the complete memoir is published. The conclusion is reached that, in any class of compounds, the heat of formation is proportional to the number of atomic linkings within the molecule, and seems to bear no relation to the masses of the atoms which are combined.

It is to be hoped that Professor Clarke has discovered a new and important thermochemical law, but from the arbitrary nature of the formulas used the suspicion arises that the law may be a very obscure one.—*Jour. Amer. Chem. Soc.*, xxiv, 882. H. L. W.

3. *The Heatless Condition of Matter.*—In the June number of this Journal mention was made of BRINKWORTH and MARTIN'S theory that pressure may be able to prevent molecular vibration

and thus cause matter to assume a condition which is devoid of heat. In regard to that notice the editor has received from one of the authors a letter which is too long to be inserted, but which should be acknowledged here. It does not appear that objection is made to our presentation of the main points of the theory, but in relation to our opening remark, "Brinkworth and Martin, with apparent seriousness, have made a curious extension of the kinetic theory," the letter says, "Your abstractor appeared to doubt the seriousness of the paper. I write at once to say that in this matter we are in deadly earnest." The fact is, we intended to convey the idea that the seriousness of the article impressed us. Objection is made to our opinion that "Their deductions are based upon an entirely unproven assumption," and, in this connection, the letter refers to some points which are to be brought out in a future article. It seems to us that no injustice has been done to the authors as far as their preliminary publication is concerned, and that further discussion of their theory should be postponed until their more elaborate paper has appeared. H. L. W.

4. *Elementary Chemistry*, by F. W. CLARKE and L. M. DENNIS. 12mo. Pp. 340. New York, 1902 (American Book Company).—In preparing this little text-book the authors have aimed especially to make it a means of training in the interpretation of evidence. Each generalization is made to follow the evidence upon which it rests. The work is accompanied by a laboratory manual, but a reasonable number of experiments, nearly all of which are of the simplest character, are described throughout the text. The book appears less dry and more interesting than most of the works on the subject on account of the constant attention which is paid to the application of chemistry to human affairs and its utility in modern life. The authors have done no more with the theory of ionization than to give it a very brief mention. Although they consider this theory unsuitable for discussion in a work of this kind, it seems probable that its use in a simple manner would present no more difficulty to the beginner than some of the theories which are introduced. It is satisfactory to notice that the book contains a short treatise (about 60 pages) on organic chemistry, a subject which is too often omitted in books on elementary chemistry. Very few things have been noticed in the work which seem unsatisfactory, but it appears that the somewhat imaginary structural formula for the double sulphate of magnesium and potassium (p. 202) is hardly appropriate in such a book, and objection may be made to the equation $KClO_3 = KCl + O_3$, because O_3 is ozone. A mistake is made in characterizing lithium as the lightest solid known, for solid hydrogen is mentioned in the book. H. L. W.

5. *Liquid Hydrogen and Helium;* from the inaugural address delivered at Belfast by Prof. JAMES DEWAR, President of the British Association.— * * * From this speculative divergency it is clear no definite conclusion could be reached regarding the physical prop-

erties of liquid or solid hydrogen, and the only way to arrive at the truth was to prosecute low-temperature research until success attended the efforts to produce its liquefaction. This result I definitely obtained in 1898. The case of liquid hydrogen is, in fact, an excellent illustration of the truth already referred to, that no theoretical forecast, however apparently justified by analogy, can be finally accepted as true until confirmed by actual experiment. Liquid hydrogen is a colorless, transparent body of extraordinary intrinsic interest. It has a clearly defined surface, is easily seen, drops well, in spite of the fact that its surface tension is only the thirty-fifth part of that of water or about one-fifth that of liquid air, and can be poured easily from vessel to vessel. The liquid does not conduct electricity, and, if anything, is slightly diamagnetic. Compared with an equal volume of liquid air, it requires only one-fifth the quantity of heat for vaporization; on the other hand, its specific heat is ten times that of liquid air or five times that of water. The coefficient of expansion of the fluid is remarkable, being about ten times that of gas; it is by far the lightest liquid known to exist, its density being only one-fourteenth that of water; the lightest liquid previously known was liquid marsh gas, which is six times heavier. The only solid which has so small density as to float upon its surface is a piece of pith wood. It is by far the coldest liquid known. At ordinary atmospheric pressure it boils at *minus* 252·5 degrees or 20·5 degrees absolute. The critical point of the liquid is about 29 degrees absolute and the critical pressure not more than fifteen atmospheres. The vapor of the hydrogen arising from the liquid has nearly the density of air—that is, it is fourteen times that of the gas at the ordinary temperature. Reduction of the pressure by an air-pump brings down the temperature to *minus* 258 degrees, when the liquid becomes a solid resembling frozen foam, and this by further exhaustion is cooled to *minus* 260 degrees, or 13 degrees absolute, which is the lowest steady temperature that has been reached. The solid may also be got in the form of a clear, transparent ice, melting at about 15 degrees absolute, under a pressure of 55^{mm}, possessing the unique density of one-eleventh that of water. Such cold involves the solidification of every gaseous substance but one that is at present definitely known to the chemist, and so liquid hydrogen introduces the investigator to a world of solid bodies. The contrast between this refrigerating substance and liquid air is most remarkable. On the removal of the loose plug of cotton-wool used to cover the mouth of the vacuum vessel in which it is stored, the action is followed by a miniature snow-storm of solid air, formed by the freezing of the atmosphere at the point where it comes into contact with the cold vapor rising from the liquid. This solid air falls into the vessel and accumulates as a white snow at the bottom of the liquid hydrogen. When the outside of an ordinary test-tube is cooled by immersion in the liquid, it is soon observed to fill up with solid air, and if the tube be now lifted out a double effect is visible, for liquid air is produced both in the inside and on the outside of the tube—in the one case by the melting of the solid, and in the other by condensation from the atmosphere. A tuft of cotton-wool soaked in the liquid and then held near the pole of a strong magnet is attracted, and it might be inferred therefrom that liquid hydrogen is a magnetic body. This, however, is not the case: the attraction is due neither to the cotton-wool nor to the hydrogen—which indeed evaporates almost as soon as the tuft is taken out of the liquid—but to the oxygen of the air, which is well known to be a magnetic body, frozen in the wool by the extreme cold.

The strong condensing powers of liquid hydrogen afford a simple means of producing vacua of very high tenuity. When one end of a sealed tube containing ordinary air is placed for a short time in the liquid, the contained air accumulates as a solid at the bottom, while the higher part is almost entirely deprived of particles of gas. So perfect is the vacuum thus formed, that the electric discharge can be made to pass only with the greatest difficulty. Another important application of liquid air, liquid hydrogen, etc., is as analytic agents. Thus, if a gaseous mixture be cooled by means of liquid oxygen, only those constituents will be left in the gaseous state which are less condensable than oxygen. Similarly, if this gaseous residue be in its turn cooled in liquid hydrogen, a still further separation will be effected, everything that is less volatile than hydrogen being condensed to a liquid or solid. By proceeding in this fashion it has been found possible to isolate helium from a mixture in which it is present to the extent of only one part in one thousand. By the evaporation of solid hydrogen under the air-pump we can reach within 13 or 14 degrees of the zero, but there or thereabouts our progress is barred. This gap of 13 degrees might seem at first insignificant in comparison with the hundreds that have already been conquered. But to win one degree low down the scale is quite a different matter from doing so at higher temperatures; in fact, to annihilate these few remaining degrees would be a far greater achievement than any so far accomplished in low-temperature research. For the difficulty is twofold, having to do partly with process and partly with material. The application of the methods used in the liquefaction of gases becomes continually harder and more troublesome as the working temperature is reduced; thus, to pass from liquid air to liquid hydrogen —a difference of 60 degrees—is, from a thermodynamic point of view, as difficult as to bridge the gap of 150 degrees that separates liquid chlorine and liquid air. By the use of a new liquid gas exceeding hydrogen in volatility to the same extent as hydrogen does nitrogen, the investigator might get to within five degrees of the zero; but even a second hypothetical substance, again exceeding the first one in volatility to an equal extent, would not suffice to bring him quite to the point of his ambition. That the zero will ever be reached by man is extremely improbable. A thermometer introduced into regions outside the uttermost confines of the earth's atmosphere might approach the absolute zero, provided that its parts were highly transparent to all kinds of radiation, otherwise it would be affected by the radiation of the sun, and would therefore become heated. But supposing all difficulties to be overcome, and the experimenter to be able to reach within a few degrees of the zero, it is by no means certain that he would find the near approach of the death of matter sometimes pictured. Any forecast of the phenomena that would be seen must be based on the assumption that there is continuity between the processes studied at attainable temperatures and those which take place at still lower ones. Is such an assumption justified? It is true that many changes in the properties of substances have been found to vary steadily with the degree of cold to which they are exposed. But it would be rash to take for granted that the changes which have been traced in explored regions continue to the same extent and in the same direction in those which are as yet unexplored. Of such a breakdown low-temperature research has already yielded a direct proof at least in one case. A series of experiments with pure metals showed that their electrical resistance gradually decreases as they are cooled to lower and lower temperatures, in such ratio that it appeared probable that at the zero of absolute temperature they would have no resistance at all and would become perfect conductors of electricity. This was the inference that seemed justifiable by observations taken at depths of cold which can be obtained by means of liquid air and less powerful refrigerants. But with the advent of the more powerful refrigerant liquid hydrogen it became necessary to revise that conclusion. A discrepancy was first observed when a platinum resistance thermometer was used to ascertain the temperature of that liquid boiling under atmospheric and reduced pressure. All known liquids, when forced to evaporate quickly by being placed in the exhausted receiver of an air-pump, undergo a reduction in temperature, but when hydrogen was treated in this way it appeared to be an exception. The resistance thermometer showed no reduction as was expected, and it became a question whether it was the hydrogen or the thermometer that was behaving abnormally. Ultimately, by the adoption of other thermometrical appliances, the temperature of the hydrogen was proved to be lowered by exhaustion as theory indicated. Hence it was the platinum thermometer which had broken down; in other words, the electrical resistance of the metal employed in its construction was not, at temperatures about *minus* 250° C., decreased by cold in the same proportion as at temperatures about *minus* 200°. This being the case, there is no longer any reason to suppose that at the absolute zero platinum would become a perfect conductor of electricity; and in view of the similarity between the behavior of platinum and that of other pure metals in respect of temperature and conductivity, the presumption is that the same is true of them also. At any rate, the knowledge that in the case of at least one property of matter we have succeeded in attaining a depth of cold sufficient to bring about unexpected change in the law expressing the variation of that property with temperature, is sufficient to show the necessity for extreme caution in extending our inferences regarding the properties of matter near the zero of temperature. Lord Kelvin evidently anticipates the possibility of more remarkable electrical properties being met with in the metals near the zero. A theoretical investigation on the relation of "electrions" and atoms has led him to suggest a hypothetical metal having the following remarkable properties: below 1 degree absolute it is a perfect insulator of electricity, at 2 degrees it shows noticeable conductivity, and at 6 degrees it possesses high conductivity. It may safely be predicted that liquid hydrogen will be the means by which many obscure problems of physics and chemistry will ultimately be solved, so that the liquefaction of the last of the old permanent gases is as pregnant now with future consequences of great scientific moment as was the liquefaction of chlorine in the early years of the last century.

The next step towards the absolute zero is to find another gas more volatile than hydrogen, and that we possess in the gas occurring in cleveite, identified by Ramsay as helium, a gas which is widely distributed, like hydrogen, in the sun, stars and nebulæ. A specimen of this gas was subjected by Olszewski to liquid air temperatures, combined with compression and subsequent expansion, following the Cailletet method, and resulted in his being unable to discover any appearance of liquefaction, even in the form of mist. His experiments led him to infer that the boiling-point of the substance is probably below 9 degrees absolute. After Lord Rayleigh had found a new source of helium in the gases which are derived from the Bath springs, and liquid hydrogen became available as a cooling agent, a specimen of helium cooled in liquid hydrogen showed the formation of fluid, but this turned out to be owing to the presence of an unknown admixture of other gases. As a matter of fact, a year before the date of this experiment I had recorded indications of the presence of unknown gases in the spectrum of helium derived from this source. When subsequently such condensable constituents were removed, the purified helium showed no signs of liquefaction, even when compressed to 80 atmospheres, while the tube containing it was surrounded with solid hydrogen. Further, on suddenly expanding, no instantaneous mist appeared. Thus helium was definitely proved to be a much more volatile substance than hydrogen in either the liquid or solid condition. The inference to be drawn from the adiabatic expansion effected under the circumstances is that helium must have touched a temperature of from 9 to 10 degrees for a short time without showing any signs of liquefaction, and consequently that the critical point must be still lower. This would force us to anticipate that the boiling-point of the liquid will be about 5 degrees absolute, or liquid helium will be four times more volatile than liquid hydrogen, just as liquid hydrogen is four times more volatile than liquid air. Although the liquefaction of the gas is a problem for the future, this does not prevent us from safely anticipating some of the properties of the fluid body. It would be twice as dense as liquid hydrogen, with a critical pressure of only 4 or 5 atmospheres. The liquid would possess a very feeble surface-tension, and its compressibility and expansibility would be about four times that of liquid hydrogen, while the heat required to vaporize the molecule would be about one-fourth that of liquid hydrogen. Heating the liquid 1 degree above its boiling-point would raise the pressure $1\frac{3}{4}$ atmospheres, which is more than four times the increment for liquid hydrogen. The liquid would be only seventeen times denser than its vapor, whereas liquid hydrogen is sixty-five times denser than the gas it gives off. Only some 3 or 4 degrees would separate the critical temperature from the boiling-point and the melting-point, whereas in liquid hydrogen the separation is respectively 10 and 15 degrees. As the liquid refractivities for oxygen, nitrogen and hydrogen are closely proportional to the gaseous values, and as Lord Rayleigh has shown that helium has only one-fourth the refractivity of hydrogen, although it is twice as dense, we must infer that the refractivity of liquid helium would also be about one-fourth that of liquid hydrogen. Now hydrogen has the smallest refractivity of any known liquid, and yet liquid helium will have only about one-fourth of this value—comparable, in fact, with liquid hydrogen just below its critical point. This means that the liquid will be quite exceptional in its optical properties, and very difficult to see. This may be the explanation of why no mist has been seen on its adiabatic expansion from the lowest temperatures. Taking all these remarkable properties of the liquid into consideration, one is afraid to predict that we are at present able to cope with the difficulties involved in its production and collection. Provided the critical point is, however, not below 8 degrees absolute, then from the knowledge of the conditions that are successful in producing a change of state in hydrogen through the use of liquid air, we may safely predict that helium can be liquefied by following similar methods. If, however, the critical point is as low as 6 degrees absolute, then it would be almost hopeless to anticipate success by adopting the process that works so well with hydrogen. The present anticipation is that the gas will succumb after being subjected to this process, only, instead of liquid air under exhaustion being used as the primary cooling agent, liquid hydrogen evaporating under similar circumstances must be employed. In this case, the resulting liquid would require to be collected in a vacuum vessel the outer walls of which are immersed in liquid hydrogen. The practical difficulties and the cost of the operation will be very great; but, on the other hand, the descent to a temperature within 5 degrees of the zero would open out new vistas of scientific inquiry, which would add immensely to our knowledge of the properties of matter. To command in our laboratories a temperature which would be equivalent to that which a comet might reach at an infinite distance from the sun would indeed be a great triumph for science. If the present Royal Institution attack on helium should fail. then we must ultimately succeed by adopting a process based on the mechanical production of cold through the performance of external work. When a turbine can be worked by compressed helium, the whole of the mechanism and circuits being kept surrounded with liquid hydrogen, then we need hardly doubt that the liquefaction will be effected. In all probability gases other than helium will be discovered of greater volatility than hydrogen. It was at the British Association Meeting in 1896 that I made the first suggestion of the probable existence of an unknown element which would be found to fill up the gap between argon and helium, and this anticipation was soon taken up by others and ultimately confirmed. Later, in the Bakerian Lecture for 1901, I was led to infer that another member of the helium group might exist having the atomic weight about 2, and this would give us a gas still more volatile, with which the absolute zero might be still more nearly approached. It is to be hoped that some such element or elements may yet be isolated and identified as coronium or nebulium. If amongst the unknown gases possessing a very low critical point some have a high critical pressure instead of a low one, which ordinary experience would lead us to anticipate, then such difficultly liquefiable gases would produce fluids having different physical properties from any of those with which we are acquainted. Again, gases may exist having smaller atomic weights and densities than hydrogen, yet all such gases must, according to our present views of the gaseous state, be capable of liquefaction before the zero of temperature is reached. The chemists of the future will find ample scope for investigation within the apparently limited range of temperature which separates solid hydrogen from the zero. Indeed, great as is the sentimental interest attached to the liquefaction of these refractory gases, the importance of the achievement lies rather in the fact that it opens out new fields of research and enormously widens the horizon of physical science, enabling the natural philosopher to study the properties and behavior of matter under entirely novel conditions. This department of inquiry is as yet only in its infancy, but speedy and extensive developments may be looked for, since within recent years several special cryogenic laboratories have been established for the prosecution of such researches, and a liquid-air plant is becoming a common adjunct to the equipment of the ordinary laboratory.—*Nature, Sept. 11, 1902.*

6. *Vapor-pressures of Liquid Oxygen and of Liquid Hydrogen.*—In an abstract of a paper by M. W. Travers, G. Senter and A. Jaquerod read before the Royal Society on June 19 (Nature, vol. lxvi, p. 382), the results contained in the following table are given :

Vapor Pressures.

	LIQUID OXYGEN.		LIQUID HYDROGEN.	
Pressure in mm.	Temp. on hydrogen scale.	Temp. on helium scale.	Temp. on hydrogen scale.	Temp. on helium scale.
	°	°	°	°
800	90·60	90·70	20·41	20·60
760	90·10	90·20	20·22	20·41
700	89·33	89·43	19·93	20·12
600	87·91	88·01	19·41	19·61
500	86·29	86·39	18·82	19·03
400	84·39	84·49	18·15	18·35
300	82·09	82·19	17·36	17·57
200	79·07	79·17	16·37	16·57
100	- --	----	14·93	15·13
50	----	----	----	14·11

The authors add, in conclusion :

"Though the pressure coefficients of hydrogen and helium between 0° and 100° C. show no appreciable difference, measurements of low temperatures on the scales of the two thermometers are not identical. It is probable that at the normal temperature both gases may be considered as so nearly perfect that the difference between the gas scale and the absolute scale is insignificant. As the critical point of helium lies much lower than that of hydrogen, measurements of low temperatures on the helium scale should approach more closely to absolute temperatures than measurements on the hydrogen scale. It is pointed out that helium should replace hydrogen as the normal thermometric substance.

The melting point of hydrogen was found to be 14°·10 on the helium scale.

The pure helium used in the thermometric measurements was obtained by passing purified cleveite gas through a coil cooled to 15° in liquid hydrogen boiling *in vacuo.* An unsuccessful attempt was made to liquefy this gas, which could not be condensed at 13° under a pressure of 60 atmospheres.

The vapor pressures of solid neon were measured at temperatures corresponding to 20°·4 ($12·8^{\mathrm{mm}}$) and 15°·65 ($2·4^{\mathrm{mm}}$). It was shown that the vapor pressure did not change as the solid evaporated, proving that neon is a homogeneous substance."

II. GEOLOGY AND MINERALOGY.

1. *Martinique.*—The July issue of the *National Geographic Magazine* is called the "Martinique number," and is devoted to descriptions and discussions of the volcanic eruption of Mt. Pelée which began in May last, together with some references to the contemporaneous eruption of La Soufrière on the island of St. Vincent. The number is of double the usual size and is a valuable contribution to the study of the recent eruptions in the Lesser Antilles, containing as it does the reports of Robert T. Hill, of the United States Geological Survey, and Israel C. Russell, of the University of Michigan, two of the representa-

tives commissioned by the National Geographic Society to investigate the phenomena attending the cataclysms. The number is enriched by the notes by J. S. Diller on the volcanic rocks collected by Hill and Russell; by a chemical discussion by W. F. Hillebrand of analyses of ejecta from the two islands, and by a compilation by James Page of the reports of vessels as to the area over which the dust from the eruptions was distributed. The number is well illustrated with four maps and nineteen photographs. Fourteen of the latter are from excellent negatives taken by Russell.

Hill's report opens with a brief general statement of the geography and geology of the whole chain of the Windward Islands or Lesser Antilles, which are almost entirely volcanic in character, with the exception of Barbados. He holds that the volcanoes of these islands date back to Eocene time, at least; that the greater masses of the present volcanic heights were piled up before the Pliocene, and that "the present craters are merely secondary and expiring phenomena." In discussing the present eruption, after relating the premonitory events of the preceding fortnight, Hill gives in detail the history of the great outburst of May 8 as derived from the accounts of eyewitnesses, and then elaborates his personal observations, which were made between May 21 and 30. He holds that the eruption which destroyed St. Pierre came from a crater low down on the southwest slope of Mt. Pelée, two miles from the northern limit of the city and a mile and a half from the sea, which he calls the "Soufrière" or "Étang Sec" crater. He considers the mud-flows to be primary phenomena of the eruption and to have come from this crater and from several "mud-craters" on the slopes of the mountain, the sites of some of which had long been known as thermal springs.

Hill calculates that only 12·5 square miles, or one-twentieth of the total area of Martinique, have been seriously affected by the eruption. No great geological changes have been brought about, but the configuration of the summit and the outline of the seacoast have been changed somewhat. He says, "There have been no lava flows whatsoever. . . . No true bombs have been ejected or molten rock in any form." His conclusion is that conflagration and death in St. Pierre may ultimately be explained by either of two theories:

(1.) The heat-blast theory. This hypothesis assumes that the lapilli, gases, and steam of the ejected cloud were sufficiently hot to have inflamed the city and destroyed the people by singeing, suffocation, and asphyxiation. It does not account for the forces exerted radially and horizontally, nor for the flame.

(2.) The aërial-explosion theory. The explosion of gases within the erupted cloud after their projection into the air would account for all the phenomena observed.

Russell's report takes the form of a letter to the Society. He does not subscribe to the opinion that the inhabitants of St. Pierre were asphyxiated by noxious gases or killed by a gas explosion.

He holds that the general cause of death and destruction was a blast of steam charged with hot dust, which passed through the city with hurricane force, and that gases, probably in part inflammable, were present, but played only a secondary part in the disaster.

Most of Russell's report is devoted to St. Vincent. He holds that the destruction on this island was due to dust, lapilli and stones which fell on the land while yet hot; but that a hurricane blast of steam charged with burning dust did not sweep down from La Soufrière as it did from Mt. Pelée. The area of devastation on St. Vincent was much greater than on Martinique. Attention is called to the violent secondary or superficial eruptions due to rain or river water coming into contact with the still heated interior of the great deposits of recent ash in the gorges of the Wallibou and Dry Rivers; to the pulsating flow of the Wallibou river due to overloading by volcanic sand; to the canyon-like dendritic drainage forms already produced in the coating of fresh dust and lapilli by the rains; and to the fact that houses standing on the windward (east) slope of the volcano had suffered most on the sides farthest from the crater.

Five miles from the crater Russell found the level fields coated with a layer of new volcanic débris about two feet thick. This would be a minimum measure and the average thickness of the deposit would be several times as great. The greater part of the débris consists of gray scoriaceous andesite and came from the columns of fresh lava that rose in the conduit of La Soufrière. This material was sufficiently cooled to become solid before it was blown into the air, and to a great extent was reduced to dust by the sudden expansion of the steam it contained. In addition to the fragments of fresh lava the fields were strewn with angular masses of older and much more compact lavas torn from the throat of the volcano.

Diller describes the older lavas of Martinique, collected by Hill, as being hypersthene andesite, hornblende-hypersthene andesite, hornblende andesite and dacite (quartz andesite), and the products of the May eruption of Mt. Pelée as belonging to the hypersthene-andesite class. He says that the specimens from St. Vincent are of hypersthene andesites, remarkable for their content of olivine.

Hillebrand concludes that, while the ejecta from the two volcanoes are of the same general type, and while the material from the same vent may vary in composition within limits, according as it is collected near to or far from the vent, and in coherent or finely divided form, yet there are characteristic differences by which it appears easy to distinguish the product of one volcano from that of the other. Diller's report is accompanied by seven analyses of pumice, sand and dust from these eruptions and Hillebrand's discussion by three such analyses. E. O. H.

2. *The Report of the Geological Survey of Louisiana:* G. D. HARRIS, A. C. VEATCH, J. PACHECO.—The papers contained in

this report are of especial economic value to this and neighboring States, including as they do reports on the "Salines of North Louisiana," A. C. Veatch, "Subterranean Waters of Louisiana" and "Oil in Louisiana," by G. D. Harris.

The map of the Mississippi Embayment shows the Jackson Stage for the first time with its most probable northern distribution. The statement with regard to the close of the Cretaceous is of interest at this time because of its importance to the oil industry: "In Louisiana we have reason to believe that the raising and depression of the Cretaceous beds was of a much more violent nature [than farther north], that folds and faults were numerous and on a large scale and a great irregularity of surface feature characterized the newly formed rocks." Professor Harris differs from R. T. Hill and others who believe that there are no "structural complications" in this formation.

Doubt is thrown on the usually accepted theory concerning the origin of the "Mud Lumps" of the Mississippi. No new theory is advanced, but the statement is made that, "that they rise in domes or anticlines and preserve their regular bedding is proven by their structure." "So far as we observed, none were formed as volcano-like cones."

The report on the Salines of North Louisiana, A. C. Veatch, contains a history of the early operations of the various salt wells and licks together with well sections and a discussion of the geology. It is shown that "the principal brine springs are to be regarded as Cretaceous outcrops." The dome structure of these and other north Louisiana Cretaceous outcrops is accepted. The maps of this report and of Reports III and IV are excellent.

The Reports on the Geography and Geology of the Sabine and Ouachita Rivers contain discussions and explanations of the "landslip islands" of the Ouachita River and the shoals of the Sabine River which are of especial interest to physiographers.

One of the most valuable reports, economically, is that on the Subterranean Waters of Louisiana.

It is to be regretted that a volume containing so much valuable matter and so well illustrated by maps and half-tones is not printed on better paper and bound more substantially.

3. *Die Alpen im Eiszeitalter;* von ALBRECHT PENCK und EDUARD BRÜCKNER. Parts 1 and 2. 224 pp., with many charts and figures. Leipzig. (Tauchnitz.)—After fourteen years of investigation Professors Penck and Brückner have begun the publication of their views regarding glaciation in the Alps. The completed work will consist of about six parts, dealing with the entire Alpine system throughout the Pleistocene with especial reference to the topography resulting from ice action. In the two parts already issued Professor Penck discusses the general character of glaciers and of glacial deposits, and explains with great detail the glacial phenomena of the northern and eastern Alpine border region, particularly the area between the Iller and the Lech.

4. *Bacubirito, the Great Meteorite of Sinaloa, Mexico.*—An interesting account is given in vol. iv (pp. 67–74) of the Proceedings of the Rochester Academy of Science, by HENRY A. WARD, of a visit to the gigantic mass of meteoric iron discovered in 1876 in the State of Sinaloa, Mexico. This is perhaps the largest of all known meteorites; its weight is roughly estimated at 50 tons, and its only rival is the meteorite of Anighito, Greenland, to which a recent estimate has assigned a weight of 46½ tons. The three meteorites most nearly approaching these are those of Bemdego, Brazil, 5⅜ tons; of San Gregorio, Mexico, 11½ tons, and Chupaderos, Mexico, 15⅝ tons. The dimensions of the Bacubirito meteorite were measured, after extensive excavations of the soil in which it was nearly imbedded, as follows: length, 13 feet 1 inch; width 6 feet 2 inches; thickness, 5 feet 4 inches. The shape is extremely irregular, being compared to that of a ham; the cubic contents consequently could be only approximately estimated. In composition, an analysis by Whitfield has shown it to contain about 7 per cent nickel, and its structure is eminently octahedral. The exterior shows little oxidation and the pittings are clean and sharp in outline. It is to be hoped that the Mexican Government, which with admirable liberality has already transferred to the School of Mines, Mexico, five of her largest meteorites, may also undertake the similar protection of this unique mass.

5. *The Origin of Eskers;* by W. O. CROSBY. Boston Soc. Nat. Hist., vol. 30, No. 3, pp. 375–411.—It is an accepted truth among glacialists that eskers are formed either by superglacial or subglacial streams, and the large majority of geologists believe they are of subglacial origin. Professor Crosby has reëxamined the whole subject and concludes that streams flowing upon the ice sheet rather than those flowing under it are responsible for most of the esker ridges.

6. *Ueber Hussakite (Xenotim) und einige andere seltene gesteinbildende Mineralien;* by H. RÖSLER. Zeitschr. f. Kryst., xxxvi, pp. 258–267.—Prismatic xenotime (hussakite) has been identified in the heavy residues of a large number (52) of European rocks and kaolins amongst the crystals usually referred to zircon, from which it was distinguished in part by the application of the magnesium test for phosphoric acid; in part by the hepar reaction for sulphuric acid with soda on charcoal, but for the most part by the difference in the strength of the double refraction in microscopic preparations. Owing to the elusive nature of all these tests when applied to microscopic crystals in microscopic quantities, it seems desirable to carefully verify these identifications before conclusions of such far-reaching consequences be definitely accepted.

Contrary to the observations of Derby, who only identified prismatic xenotime in a single case in scores of residues examined and who found the octahedral forms almost invariably accompanied by monazite, the author finds, in the rocks examined, the prismatic forms of xenotime more abundant and widespread than the octahedral one and than monazite as well.

In addition to zircon, xenotime and monazite the author found anatase, regarded as secondary, in about half of the residues examined; dumortierite in two kaolins from 2-mica granite; chrysoberyl in seven kaolins (6 2-mica granites and 1 syenite) and one fresh 2-mica granite; staurolite in two kaolins from aplite, and andalusite in five kaolins from 2-mica granites.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *International Catalogue of Scientific Literature.* First Annual Issue. M. BOTANY, Part I, May, 1902. Pp. xiv, 378. D. CHEMISTRY, Part I, June, 1902. Pp. xiv, 768.—These two volumes of the first annual issue of the International Catalogue of Scientific Literature, commencing with the year 1901, have recently appeared. This Catalogue is published for the International Council by the Royal Society of London, being an outgrowth of the well-known Catalogue of Scientific Papers relating to the scientific literature of the Nineteenth Century, published by the same Society. In the form which the plan has finally taken, each complete annual issue of the Catalogue will consist of seventeen volumes, one for each of the sections of science separately recognized. The set will be sold to the public for £18, individual volumes costing, according to size, from ten to thirty-five shillings. The director is Dr. H. Forster Morley, whose address is at the Central Bureau, 34 and 35 Southampton st., Strand, London, W.C. Twenty-nine Regional Bureaus have been arranged for, which are to furnish the material for the Catalogue; for the United States, communications are to be sent to Prof. S. P. Langley, Smithsonian Institution, Washington.

The method of classification and indeed all the details of the entire plan have been very carefully worked out, but only the outline can be given here. Each of the volumes issued consists of three parts: (*a*) Schedules and indexes in four languages, English, French, German and Italian; (*b*) an author's catalogue; (*c*) a subject catalogue. The subject catalogue is divided into sections, each of which is denoted by a four-figure number between 0000 and 9999. These numbers follow one another in order but all are not used, space being left for such additions to the system of classification as may be found necessary in future years. In the case of the two volumes now published, the material for 1901 being yet incomplete, the first part will be followed by a second part in a few months; in future, however, when the organization is complete, it is planned to issue a single annual volume only for each subject.

The breadth and completeness of this great scheme for putting within the reach of every worker in science a catalogue of all original contributions on the subject in which he is interested, in whatever form or place published, is worthy of the century with which it commences and the Society under whose auspices it is published. It is to be hoped that the undertaking may not only receive all needed financial support, but also that editors and authors may inform themselves minutely as to the details of the plan, so that they may prepare subject-indexes for all papers at the time of their publication, thus diminishing very largely the subsequent labors of the collaborators.

2. *British Association.*—The annual meeting of the British Association for the Advancement of Science was held at Belfast during the week beginning September 10th. The meeting is described as having been very successful, about equal in numbers to that held in the same place in 1874, when the attendance was 1,951. The address of the President, Professor James Dewar, was of the highest interest (see Nature of Sept. 11), dealing, in addition to some general topics, with the subject of low temperature and the liquefaction of gases, to which he has personally contributed so much. We quote at length from the address in another place.

3. *Experiments in Aerodynamics;* by S. P. Langley. Second edition, pp. 115 with ix plates. Washington, 1902. (Smithsonian Contributions to Knowledge, No. 801.)—This volume is essentially a reproduction of the first edition of this interesting memoir, which was issued in 1901 and noticed in this Journal in November of that year (vol. xlii, p. 427). Since its first publication, machines made on the principles here described have actually flown, which fact gives a practical interest to the subject; a description of the heavy steel flying machines is promised for some time in the future.

4. *Elementary Physical Geography;* by William Morris Davis. Pp. x, 401, with numerous maps and illustrations (Ginn and Company.)—It is a pleasure to note the publication of a text-book which presents a subject in an interesting elementary form without the loss of scientific accuracy and a rational mode of treatment. Professor Davis's new text reduced from his "Physical Geography" is just such a book.

5. *The International Quarterly.*—The International Monthly, which since January, 1900 has had a highly successful career under the editorship of Mr. Frederick A. Richardson (Burlington, Vt.), will hereafter be continued as a quarterly with the same editorial direction. Each number will be more than double the size of the monthly, and will present articles of live interest by able writers at home and abroad. The September issue (pp. 1-214) of The International Quarterly begins vol. vi, of the series.

OBITUARY.

Professor Rudolf Virchow, the illustrious German anatomist, physiologist and anthropologist, the founder of cellular pathology, died at Berlin on September 5, in his eighty-first year.

Photograph by C. E. Taylor.

La Soufrière, St. Vincent, from Richmond Estate.
Local landslides along coast.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXXIII.—*Observations on the Eruptions of 1902 of La Soufrière, St. Vincent, and Mt. Pelée, Martinique;*[*] by Edmund Otis Hovey.

The chain of islands bounding the Caribbean Sea on the east, and known as the Leeward and Windward Islands, the Lesser Antilles or the Caribbean Islands, are almost wholly of volcanic origin, the most important exception to this rule being Barbados. From Grenada northward the chain of volcanoes extends in a grand curve for about five hundred miles, with its convex side toward the east, indicating a line of weakness in the earth's crust comparable with those which are outlined by the festoons of volcanoes along the northern and western coasts of the Pacific Ocean. The volcanic nature of these islands has been known ever since they first were explored, but only a few eruptions have been recorded during the past four centuries—the most important being those of La Soufrière on St. Vincent in 1718 and 1812, with Mt. Pelée on Martinique in slight eruption in 1851. Continuous solfataric action, which sometimes has been quite violent, is known in the crater of Mt. Misery on St. Kitts, the "Soufrières" of Guadeloupe and St. Lucia and the Boiling Lake of Dominica. Hot springs have been a feature of several localities on Martinique, St. Vincent and other of the islands.

La Soufrière, St. Vincent.

At least as early as April, 1901, earthquakes became more frequent and noticeable than usual in St. Vincent, but, with

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[*] The author was sent to the islands of Martinique and St. Vincent as the representative of the American Museum of Natural History, New York, to study the phenomena connected with the recent eruptions. The article here published is a condensation of the "Preliminary Report" prepared for the Museum authorities and published in the Bulletin of the Museum, vol. xvi, pp. 333–372, pls. xxxiii–li. The author's field work on the islands covered the period from May 21 to July 6, inclusive, and his Report and this article pertain almost solely to the personal observations made during that time.

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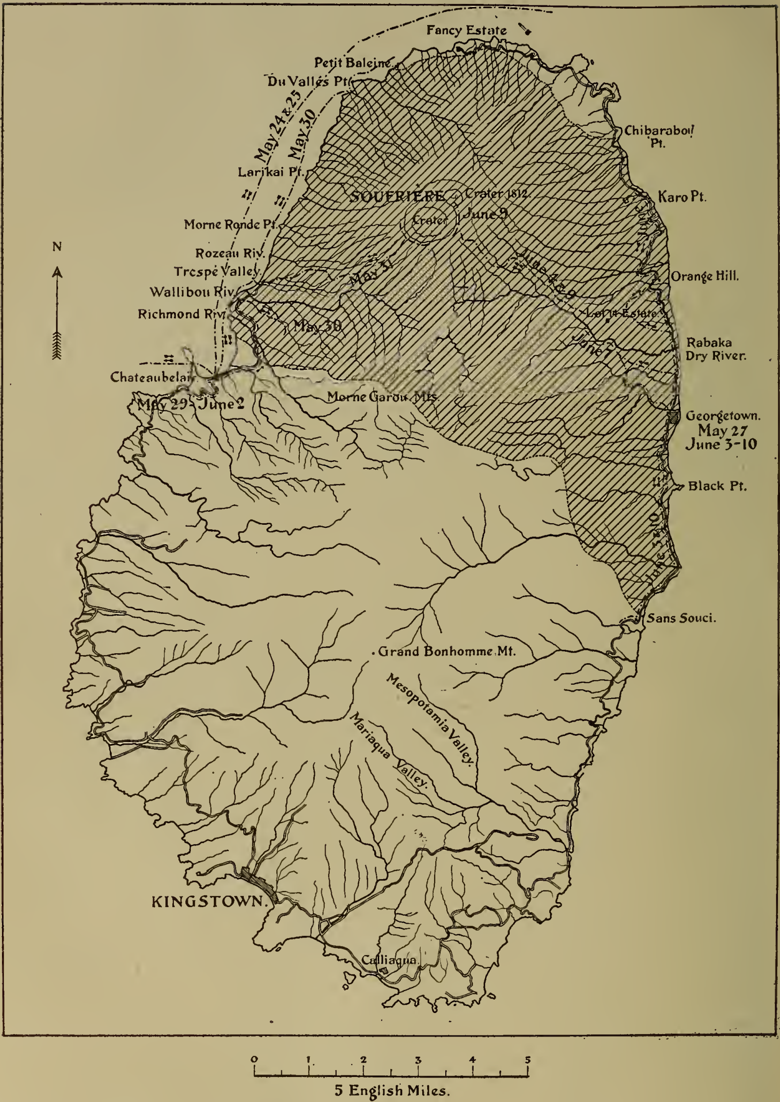

FIG. 1. MAP OF THE ISLAND OF ST. VINCENT, B. W. I.

The cross-lined area shows approximately the portion of the island which was devastated by the May, 1902, eruptions of La Soufrière. The violent outburst of September 3–4 deposited much additional material on the leeward (west) side, and extended the zone of devastation about four miles south of the boundary here indicated for that side of the island. The dot-and-dash lines show the principal routes traversed by the author while on and near the volcano.

the exception of Mr. F. W. Griffith, of Kingstown, no one seems to have connected them with an impending eruption of the Soufrière. In December of that year, however, the people living on the western slopes of the volcano began to feel anxious on account of the subterranean noises heard occasionally. By February, 1902, the rumblings had become so frequent that the inhabitants were very uneasy and began to leave the district, so that but one person was left within the fated area when the great eruption of May 7 occurred. The rumblings were less distinctly heard on the eastern or windward side of the island, and the warnings were not heeded so generally, because it was supposed that the prevailing winds would carry to westward any ejecta from the crater, in case of an eruption. The loss of life was confined to the windward side of St. Vincent.

The first ascent of the Soufrière, since the eruption of May 7, 1902, was made on Saturday, May 31, by Dr. T. A. Jaggar, Jr., George Carroll Curtis, T. MacGregor MacDonald* and myself with six porters. We went up from the site of Wallibou village, on the leeward (west) side, following the remains of the old trail to the rim of the crater at 2790 feet above the sea, an elevation obtained by taking the mean of the readings of three aneroid barometers.† We found the crater unchanged in diameter, as nearly as Mr. MacDonald could tell, and therefore to be about nine-tenths of a mile in diameter from east to west and eight-tenths of a mile from north to south, judging from measurements made on the map. The beautiful crater lake, for which the Soufrière was famous before the eruption, had disappeared of course, but there was a small lake of boiling water in the bottom of the pit, from the southeastern quarter of which steam was ascending in a strong column. See figs. 4 and 5, p. 351.‡ This column at intervals was carrying up quantities of black sand with it to moderate heights above the bottom of the crater. We estimated the surface of the boiling lake to be about 1600 feet below the point on

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*Mr. MacDonald is the owner, with his brother, of several estates on the leeward side of St. Vincent. One of these was destroyed in the May eruptions, and three others suffered the loss of their growing crops through the outburst of September 3. Mr. MacDonald had the presence of mind to remain in one of his houses, the Richmond Vale estate, from which there was an uninterrupted view of the upper portion of La Soufrière, and to take notes in detail of what happened on May 7 up to the time of the great eruption which took place at 2 P. M., when he fled for his life. His notes have been published in full in the Kingstown Sentry of May 16, 1902, and in the Century Magazine, vol. lxiv, pp. 638-642, August, 1902.

†All the altitudes recorded in this article were obtained by means of aneroid barometers, except as otherwise stated in the text.

‡For convenience of printing, the views illustrating this article have been placed together on pp. 351 to 358.

which we were standing, and 2400 feet below the highest point of the rim. The lake seemed to be shallow, judging from some nearly flat ground in the bottom of the crater northeast of the water. The surface of the old crater lake was 1930 feet (chart) above tide. Its depth in the center was 87½ fathoms, according to the statements of P. F. Huggins, engineer, of Kingstown, St. Vincent, who told me that he sounded it in 1896. His line was too short to reach bottom in the northwestern part of the lake.

Almost directly opposite the point where we first reached the rim was the saddle between the "Old" crater and the crater of 1812, apparently unbroken by the eruption. From the lower third of this nearly vertical rock-face there issued a strong stream of water which cascaded down the precipices and flowed across a rather narrow strip of nearly level ground in the bottom of the crater and emptied into the boiling lake. It seemed as if this stream must be the discharge of the waters now collecting in the crater of 1812, itself the possessor of a little lake before the eruption of the present year. The western side of the crater rim showed a gash on its western side, leading into the Larakai Valley, but the bottom of the gash was more than a thousand feet above the bottom of the crater. Mr. MacDonald said that the gash was there before the eruption took place, but that it seemed to him to have increased in size since the outbursts began. The gash is very much smaller than that in the southwest side of Mt. Pelée, and it does not seem to have had any appreciable, or, better, any determinable, effect in concentrating the force of Soufrière's volcanic hurricanes. Tremendous avalanches of rocks and earth descended the inner precipitous slopes of the crater at intervals during our stay on the rim. They made a great deal of noise, and probably occasioned some of the "groaning" of the volcano reported by the islanders.

On June 4 Jaggar, Curtis and I made an attempt at the ascent from the windward side. We reached the altitude of 3200 feet, but turned back without getting to the crater itself, on account of dense trade-wind clouds. On June 9 Curtis and I made our third ascent, alone, except for one guide, and reached the rim of the crater on the southeastern side two or three hundred yards beyond the spot at which we had turned back on the preceding occasion. For fifteen or twenty yards back from the edge of the rim in the ground there were crevices many yards long and up to three inches wide, which formed lenses with the edge itself and indicated the imminence of landslides into the crater. We pushed along the rim northward, until, at an altitude of 3550 feet above the sea, we stood between the large crater and the crater of 1812. The summit of the Soufrière east of the large crater and south of the small one is formed by a rather small plateau which slopes gently toward the southeast, closely analogous in position to the small high plateau on Mt. Pelée. This plateau was covered with a bed of dust, lapilli and bowlders which was ten and fifteen feet thick in places, and the trenches cut by recent rains made traveling very laborious, except near the edge of the crater.

In spite of clouds and rain, this visit, through occasional glimpses of the interior, enabled me to determine that the crater of 1812, which for nearly a century has gone by the name of the "New" crater, took no active part in the eruptions of May of the present year, a conclusion based on the following considerations: the saddle between the two craters appeared to be intact, confirming the observations made from the other side of the large crater; a knife-edge ridge which ran at a steep incline from the saddle to the bottom of the small crater and formed the pathway for descent into it before the eruption, was still there, and had on its slopes bare trunks of trees standing; in the bottom of the crater along the base of this ridge one could see talus slopes of dry (?) dust and lapilli which had slid and rolled down its sides; although the roaring of the steam and boiling water nearly half a mile below us in the large crater was obtrusively discernible, no sound whatever came from within the crater of 1812; the rim of the small crater showed less and less dust as one receded from the edge of the great crater. Samuel Brown, a ranger, or caretaker, on the Lot 14 estate on the southeast slopes of the Soufrière, who was our guide when we reached the small crater, told us that he watched the eruption of May 7 until the great outburst at two o'clock and that no cloud of steam or "smoke" rose from the small crater. Furthermore, at the time of my leaving the island, June 10, no column of steam had risen above that crater since May 7. Brown was at the sugar factory of the estate, three and one-half miles in a straight line east-southeast from the crater, a most favorable spot from which to observe what was going on at the summit of the mountain, and he saved his life by running into the rum cellar of the factory and closing the door and the window shutters just before the volcanic blast swept over the building. Inquiry in Georgetown found persons who had watched the eruption from the town and had noted the fact that no column of steam rose from the small crater.

The Soufrière, and, in fact, the whole of the island of St. Vincent, is made up of ancient lava flows alternating with volcanic fragmental deposits or tuff agglomerates.* These ancient

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* The alternation of lava beds and tuffs is well illustrated in fig. 5, p. 351.

agglomerates show that there have been many eruptions of the volcanoes of St. Vincent of the same character as that of 1902. They contain bombs as well as blocks. The beds of solid rock on the island show that many of the ancient eruptions were accompanied by extensive flows of molten lava. The porous agglomerates have suffered much from the decomposing action of percolating waters, and the lava beds show extensive alteration due to the same agency. Beautiful spheroidal weathering is common in the basalts of the southeastern part of the island and in the elevated beach conglomerates of the windward coast.

Although there are many ancient lava beds in the composition of the mountain, no *stream* of melted lava has issued from the Soufrière during the present eruption. The "bread-crust" bombs, however, which occur plentifully on the mountain sides, especially on the windward slopes, show that during the present eruption molten lava has been present in the throat of the volcano, and that many lumps of half-melted rock were thrown into the air. Besides the bombs, the volcano ejected blocks of ancient andesitic lava of several kinds and of varying degrees of coarseness of grain, and of all sizes up to masses six or eight feet across, and vast quantities of coarse and fine lapilli and dust. Most, if not all, of the blocks were thrown out at very high temperatures, as is shown by their cracked condition, though they were not actually fused. Although a few bombs, some of which were twelve to fifteen inches across, were found on the leeward side as far away from the crater as the site of Richmond village, three and one-half miles distant, by far the largest number of both bombs and blocks, as well as the largest specimens, were found on the windward side, bombs fifteen to eighteen inches in diameter being common in the bed of the Rabaka Dry River.

The area of devastation on St. Vincent is very large in proportion to the total area of the island. After plotting it out carefully on the British Admiralty chart and measuring the area with a planimeter, I find it to be forty-six square miles, practically one-third the entire area of the island. From much of this devastated area, however, the ashes are being washed off so rapidly by the rain that vegetation is already asserting itself, and within another year crops will be growing there again.*

Extensive landslides have taken place on the western side (see Plate VIII), removing a strip of coast, in places one

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* Newspaper reports and private advices from St. Vincent show that the area of devastation has been extended on the leeward side of the island by the tremendous eruption of September 3–4 about four miles south of the boundary indicated on the map herewith presented (fig. 1), while the whole western portion of the devastated area got a heavy additional coat of lapilli. The windward side did not suffer materially from this eruption.

hundred yards wide, continuously from the mouth of the Wallibou River to Morne Ronde village, a mile and a half to the north, and at intervals for two miles farther north. These landslides have left precipitous walls along the shore-line, and deep water is found where villages stood and prosperous plantations existed before the eruption. We had no sounding line, but our boatmen could not touch bottom with a twelve-foot oar three feet from shore on the site of Morne Ronde village. The sections left by the slides show that the land which has disappeared consisted of delta and coast-plain deposits, material which would easily be shaken from the more substantial lava flows and agglomerate beds by the vibrations due to the eruptions. The eastern, or windward, side of the island is not nearly as steep as the leeward, and landslides have not occurred there as features of this eruption. On the contrary, the windward shore-line from Black Point, a mile south of Georgetown, northward almost to Chibarabou Point, more than six miles distant, has been pushed out by the vast quantities of fresh lapilli which have been brought down from the slopes of the volcano by the rivers and the heavy rains, during and since the eruptions, and distributed by the ocean currents.

A large amount of material, too, was brought down by the Rabaka Dry River an hour in advance of the great outburst of May 7, which seems to have been due to the bodily discharge of a portion, at least, of the old crater lake into the headwaters of that stream. Survivors who attempted to cross the Rabaka Dry River toward noon of that day report that they were prevented by a torrent of "boiling hot" water and mud rushing down the valley, and that a wall of water and mud fifty or more feet high (they compared it with the height of a factory chimney) came out of the upper reaches of the river and swept out to sea. There was no heavy rain that day before the eruption took place, but the lake still was in the crater early in the day, according to the tale of a fish-woman who had ascended the mountain from Georgetown that morning on her way home to Chateaubelair. The trail led along the rim of the crater for half a mile. The woman reached the rim at nine o'clock and found that fissures had appeared in the ground and that the lake was at a higher level than usual and boiling. She rushed back to Georgetown to warn the people, but her tale was discredited. Mr. MacDonald's notes contain the entries: "12.55 P. M. Enormous discharge to windward side, color darker. 1 P. M. Tremendous roaring, stones thrown out to windward thousands of feet."* While this does not *prove* the bodily outthrow of the lake, it shows that there was

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* Century Magazine, vol. lxiv, p. 630, August, 1902.

a great outburst from the crater just in advance of the flood in the Dry River Valley.

It is evident that there was a blast or a series of blasts of hurricane violence from the crater of the Soufrière as well as from that of Mt. Pelée, as a feature of the eruptions of 1902. The effects were not so appalling, however, on St. Vincent as on Martinique, because no large city was destroyed there. The overturned trees constitute the principal evidence on the island of St. Vincent. They all point away from the crater, except for slight modifications due to local topography (see fig. 10). The blast extended radially in all directions from the crater, suggesting the explanation that some great volume of steam, rising from the throat of the volcano, could not find room for expansion upward, on account of the column of steam and ashes which had preceded it, and the ashes falling therefrom, and that it expanded with explosive violence horizontally and downward, following the configuration of the mountain. This accords with the testimony of Mr. MacDonald and other eye-witnesses of the eruptions, who say that they saw the clouds of "smoke" (dust-laden steam) rushing down the sides of the mountain with terrific speed. This dust-laden steam was able to do much work of erosion, as is shown by the horizontally scoured sides of some of the exposed cliffs and by the trunks and roots of trees. The roots particularly have been charred by the heat and have been carved into fantastic, pointed shapes, as if they had been subjected to the action of a powerful sand-blast. Erosion has not materially affected the original surface of the ground as yet, because almost everywhere one can find the living roots and charred blades of grass and other vegetation beneath the covering of dust and lapilli, the first of which acted as a protection against the heat of the rest. Now, however, the heavy rains take up vast quantities of the loose lapilli for use as a powerful scouring agent in attacking the denuded hillsides, and thus old valleys are being deepened and widened.

The particular feature of the May eruptions of the Soufrière was the enormous amount of dust* which was thrown into the air and distributed over a vast circle or ellipse the area of which cannot yet be calculated for lack of data. The British steamship Coya had an eighth of an inch of volcanic dust

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* The following chemical analysis is of dust from the May eruptions which I collected May 27 in a room in the Langley Park estate house, about one mile north of Georgetown, St. Vincent, in which twenty-one dead bodies were found after the eruption of May 7. The analysis was made by Dr. W. F. Hillebrand of the United States Geological Survey, to whom my acknowledgments are due, and is the unpublished analysis referred to in his article in the National Geographic Magazine for July (vol, xiii, p. 297) as emphasizing the greater amount of sulphur present in the ejecta of La Soufrière

from this volcano fall on her deck when she was two hundred and seventy-five miles east-southeast of St. Vincent. The steamer encountered the dust at 10.30 P. M., May 7, eight and one-half hours after the eruption of the Soufrière began, indicating transport against the prevailing surface wind at more than thirty-two knots per hour. Reports of vessels from the west (leeward) of the island are curiously lacking. The dust was spread like a gray mantle over the island, generally diminishing in thickness from the crater outwards, but collected in vast deposits in certain valleys on the sides of the mountain, where the conditions seem to have been particularly favorable. The chief of these beds were formed in the Wallibou, Trespé and Rozeau valleys on the leeward side, and in the valleys of the Rabaka Dry River and its tributaries on the windward slope, with by far the greatest thickness along the Wallibou and Rabaka Dry Rivers. In the valley of the Wallibou the deposits were not less than sixty feet deep in places, while in the Rabaka Dry River the fresh material filled a gorge which is said to have been two hundred feet deep before the eruptions began (see fig. 9). From a distance this deposit looks as if it were a glacier coming out of the mountains.

Such great accumulations of hot lapilli and dust retain their heat for a long time and they have given rise to secondary, or superficial, eruption phenomena of striking character and considerable interest. The river water and the water from the

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than in those of Mt. Pelée. The absence of chlorine is interesting as indicating fresh waters as the source of the steam of the eruptions.

SiO_2	55·08	
Al_2O_3	18·00	
Fe_2O_3	2·46	(Only approximate, because of effect of pyrrhotite, 0·91 %—see below.)
FeO	4·57	
MgO	3·34	
CaO	7·74	
Na_2O	3·45	
K_2O	0·65	
H_2O at 100° C.	0·66	
H_2O above 100° C.	1·39	
TiO_2	0·80	
ZrO_2	?	
CO_2	none	
P_2O_5	0·17	
SO_3	0·24	
Cl	none or faint trace	
S	(0·36) included in pyrrhotite below	
NiO	none	
MnO	0·21	
BaO	trace	
SrO	none	
Li_2O	faint trace	
Fe_7S_8 (?)	0·91	
	99·67	

tropical showers percolating through the beds have come into contact with the still highly heated interior, causing violent outbursts of dust-laden steam. We saw one of these outbursts from the Wallibou Valley send up a column of such vapor fully a mile in height. The action lasted for nearly an hour. The secondary eruptions illustrated by figures 7 and 8 took place on a clear, dry morning and must have been caused by the percolating river waters. On May 30 we witnessed the throwing of a dam across the stream and the formation of a temporary lake by a heavy secondary outburst of dust-laden steam from the lapilli-bed in the Wallibou Valley. This eruption is illustrated in fig. 7. After the eruption ceased the little lake soon rose to the top of the dam and quickly cut its way down to the old level, sending a "mud-flow" down the gorge to the sea. Such a lake in the valley of the Rabaka Dry River cut its new outlet through a narrow ridge of the old agglomerate constituting the wall of the canyon, forming as it did so a beautiful series of channel-bowls, pot-holes and scratched corkscrew channels.

When we first reached St. Vincent, the dust, especially that covering the Richmond estate, showed in marked manner the wind-drift surface so familiar in the case of freshly-fallen snow, and in many places these drifts were from three to four feet deep (see fig. 6). There were several heavy rains between May 24 and 29, so that the appearance of the surface was very different on May 30 from what it was when I first saw it. Its drifted character was not nearly as evident, and the beautiful dendritic drainage, which was already in evidence on May 24, had been greatly extended and intensified. Geological operations, which under ordinary conditions are performed so slowly as to be imperceptible, were being carried forward rapidly under our very eyes. One item of interest was the action of the Wallibou River itself under the influence of the loose dust and lapilli along its banks.* Its waters became so overloaded with sediment that they could only flow in pulsations, showing that intervals of time were needed by the stream to gather strength to force its way along with its load. On May 24 these waves or pulsations were from fifteen to forty seconds apart. Such mud streams carried large bowlders down the river bed to the sea.

When the great cloud of ejecta rose from the Soufrière at 2 P. M., May 7, the portion which was traveling eastward seemed suddenly to split, according to the accounts of eye-witnesses, when it was some distance beyond the island, and to send a part back to the land. This accounts for the fact that unprotected windows in the eastern side of houses in the

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* First described by the author in the New York Times, June 29, 1902.

devastated district along the windward coast were all stripped of their glass.

An official's estimate of the loss of life on St. Vincent by the eruption places the number of killed at 1350. The actual number of bodies buried was 1298, including those of the wounded who died in the hospitals. Almost all of the people who passed through the fury of the eruption and escaped uninjured had taken refuge in cellars the only openings into which were on the side farthest from the crater and were, moreover, tightly closed with wooden doors or shutters. The most striking example of such protection was at Orange Hill, on the windward coast, two and one-half miles north of Georgetown, where one hundred and thirty-two persons were saved unharmed in an empty rum cellar. This cellar, which is only partly underground, is part of a sugar factory situated on a rather flat divide between two ravines which may have tended to separate the volcanic storm somewhat, though the roof of the building over the cellar was demolished by the ejecta. The only openings into the cellar were a door and two windows on the side opposite the crater, and these were provided with heavy wooden shutters which were kept closed during the fury of the eruption. The experiences of the people in these cellars suggest the great desirability of constructing similar places of refuge for use in time of hurricane as well as of volcanic eruption.

The deaths on St. Vincent seem to have been due, principally, to the following causes: (1) asphyxiation by hot, dust-laden steam and air, (2) burns due to hot stones, lapilli and dust, (3) blows by falling stones, (4) nervous shock, (5) burning by steam alone, and (6) strokes of lightning. The last mentioned cause is perhaps somewhat doubtful, for though it is very generally named by the survivors, there has been no substantiation mentioned beyond the fact that there was a great deal of extremely vivid lightning during the eruption. The action of steam would account for burns received underneath the clothing where the clothing was not even charred. Sulphur dioxide, SO_2, and hydrogen sulphide, H_2S, were observed in troublesome quantities in the steam coming from the crater, and it is more than probable that these gases, especially the former, added very materially to the deadly character of the dust-laden steam. Not an autopsy was made on any of the hundreds of victims of the catastrophe, so that it never can be known definitely what part was played by these or other poisonous gases in the destruction of human life.

Under date of September 5, Wm. J. Durrant, druggist, of Kingstown, St. Vincent, writes me that great volumes of "smoke" and steam began rising from La Soufrière at 1 P. M. of September 3, but that the violent outburst did not begin until 9.30 that night. Three hours later the eruption was at its height and the last explosion occurred at 5.40 A. M. The roaring of the volcano from midnight onward was continuous and was terrifying even at Kingstown, while the electric display about the great column of dust-laden steam surpassed those of May 7 and 18. The matter ejected by this last eruption is described by Mr. Durrant as being "a heavy, black sand* of the coarseness of blasting powder, with plenty of pumice, but very few stones." Very little light-gray ash like that of the May eruptions fell this time. Richmond Vale estate received about eight inches of ash, Chateaubelair about six inches, Petit Bordel about four inches. Southward the coat of ash diminished to Peter's Hope, an estate on the west coast about ten miles southwest of the crater, where it ceased to be of importance. The beginning of this eruption was a mud-flow toward the site of Morne Ronde village.

Under date of September 26 Mr. T. MacGregor MacDonald writes me that three men, two brothers and a cousin by the name of Richards, visited the summit of La Soufrière August 19. From their accounts it was evident that relations within the crater had not changed materially from what we found on May 31. On September 17 Messrs. J. Adams and W. Cummings made the ascent to see what changes had been wrought by the tremendous eruption of September 3–4. They reported that the crater was filled up to about the level of the surface

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* A sample of the material thrown out by the eruption of the Soufrière September 3 was received from Mr. Durrant September 25 and has been examined under a hand-lens. It consists of fine and coarse volcanic sand and gravel, apparently for the most part comminuted ancient lavas of the volcano. The fragments from 3 to 15 millimeters across show the coarsely crystalline structure of the old lavas and many of them show that they are parts of weathered masses. Olivine, pyrite (pyrrhotite ?) and porphyritic crystals of feldspar, hypersthene and hornblende are abundant in these fragments and the separated minerals make up a large proportion of the particles about 2 millimeters in diameter. A comparatively large fragment (20^{mm} in diameter) shows phenocrysts of feldspar imbedded in dark brown and light brown scoriaceous glass which is apparently fresh. All the fragments and the particles of sand are coated with dust which seems to be as fine as any that fell during the May eruptions, so that the explanation of Mr. Durrant's statement regarding the relative absence of fine dust from the ejecta of September 3–4 may be that the wind carried most of such material northward and westward away from Kingstown, his point of observation. The cloud from this eruption of La Soufrière is reported to have produced darkness for about six hours on September 4 in Fort de France, Martinique.

The dust-coated sand is dark gray when dry, but is almost black when wet, justifying the description quoted from Mr. Durrant's letter. Comparison of this new material, however, with that collected by myself, May 23–June 10, indicates that there is no essential difference between the ejecta of the earlier and the later eruptions.

of the old lake (the one existing prior to May 7) with ash, and that there was a sloping surface from all sides down towards a depression in the middle. The slope was such that from almost any point they could have descended to the bottom. Steam was rising from several points, the most vigorous being from the spot most active on May 31. Around the central opening there was mud, and from the opening "fire" was being thrown up every two or three minutes, which fell back again, giving place to steam. There was an eruption during the night of September 17, and Mr. Cummings made another ascent on the 19th, when he found the crater cleared of ashes to the depth observed May 31 and with a small amount of water in the bottom, from and through which steam and "fire" were rising. The "fire" mentioned by Mr. Cummings must have been red-hot fragments of rock. A short violent outburst occurred about 6 P. M. September 21, lasting about ten minutes in its most vigorous stages.

LA MONTAGNE PELÉE, MARTINIQUE.

The destruction of human life overshadows every other consideration, in popular estimation, at least, when one speaks of the eruption of Mt. Pelée, Martinique, which took place May 8, 1902. The sweeping of between twenty-five and thirty thousand human beings out of existence almost in a moment presents a holocaust with but few parallels in the history of the world. The present eruptions of Pelée and the Soufrière will not, however, take first rank among those which have torn these and other Caribbean volcanoes, but they are extensive enough and are of such a character as to merit the study they have been and are receiving.

Mt. Pelée, like La Soufrière, gave warnings of the approaching catastrophe, but they were not heeded by the inhabitants of Martinique. The waters of the Lac des Palmistes became very noticeably warmer than usual several months before the eruption took place; rumblings were heard and steam began to issue from the old crater some weeks before dangerous activity began; a fortnight before the first great eruption took place the earthshocks were sufficiently strong to displace dishes on the shelves of the house of Mr. Prentiss, the American Consul in St. Pierre. The volcano became so threatening that some uneasiness was felt by the people dwelling on the slopes of the mountain, but the citizens generally were so deeply interested in a political contest in which race prejudice was playing an important and bitter part, that they paid little attention to the returning activity of the dangerous mountain on and near which they lived, until it was too late for them to escape with their lives.

The area of devastation caused by the eruptions of Pelée from May to July inclusive was less than that due to that of La Soufrière (compare maps, fig. 1, p. 320, and fig. 2, below.

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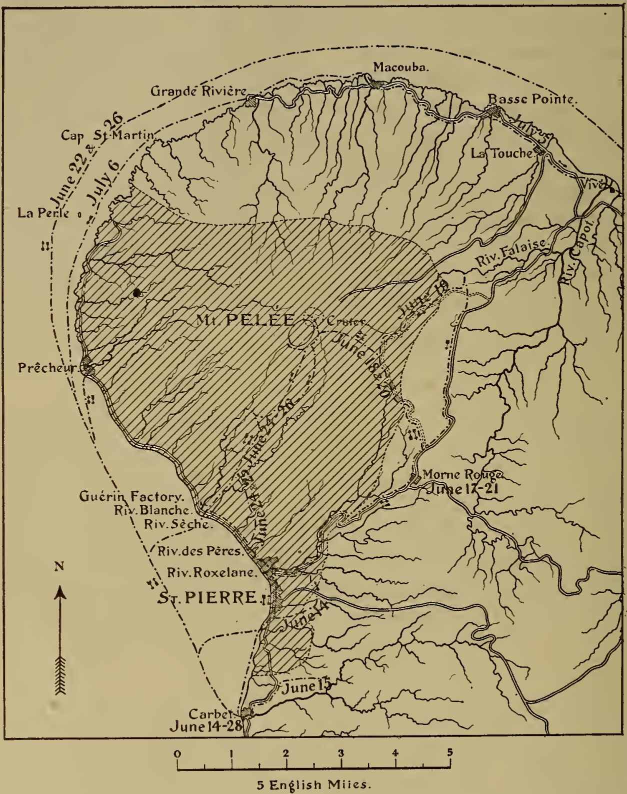

FIG. 2. MAP OF THE NORTHWESTERN PART OF THE ISLAND OF MARTINIQUE, F. W. I.

The cross-lined area shows approximately the portion of the island devastated by the eruptions of Mt. Pelée, from May 5 to July 6, 1902. The tremendous outbursts of August 25, 28 and 30 and September 3 extended the ruin greatly on the north, east and southeast sides of this area, so that nearly all of the region represented here, with the exception of a few square miles in the southeastern corner, now is included within the zone of destruction. The dot-and-dash lines indicate the principal routes traversed by the author while on and near the volcano.

Plotting the area on the Admiralty chart as well as possible, after inspecting all sides of the volcano, and measuring it with a planimeter, I find that thirty-two square miles of Martinique were laid waste by dust, lapilli, stones and "mud." The area is not as symmetrically disposed about the crater as is the case on St. Vincent, probably because the crater of Pelée is so much lower on the southwest than on the other sides and the great gash opening into the gorge of the Rivière Blanche, together with the configuration of the neighboring "mornes," or ridges, has given direction to all the violent explosions which have occurred. Although the whole island has received débris from some of the outbursts and dust has been scattered over a wide area, the district over which the vegetation was killed, at least temporarily, is included within a line beginning at the sea coast, about midway between St. Pierre and Carbet, though the palm trees along the coast at the base of the bluffs were scorched as far as Carbet Point itself. Passing inland about a mile, the line curves sharply to the north and east of north to the Roxelane River, then goes northeastward along this river and one of its tributaries, paralleling the main street of Morne Rouge within a quarter of a mile, swings then to the east of La Calebasse and rises somewhat on the northeastern flanks of Pelée, apparently passing along the south side of Pain de Sucre and then northwestward, leaving the island midway between La Perle Rock and Cap St. Martin. Much of this area is already springing into verdure again; the grass was already very noticeable on the hill slopes encircling St. Pierre by July 1, and green vegetation was to be seen even nearer the source of destruction. When I first arrived at Martinique (May 21) the line between the scorched and unscorched areas was strikingly sharp, and was still very noticeable six or seven weeks later. In many places the line of demarkation passed through single trees, leaving one side scorched and brown, while the other side remained as green as if no eruption had occurred.*

The material ejected by Pelée during this series of eruptions consists of dust in vast quantities,† fine and coarse lapilli, breadcrust bombs (see fig. 3) of all sizes from one inch to three feet and more across, and blocks of small and great size, the cracked condition of which shows that they have been highly heated. The freshly fallen ashes had a curious resemblance to snow, which gave a peculiar Alpine aspect to the

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* The tremendous eruptions of August 25, 28 and 30 and September 3 have extended the devastated area greatly on the northeast, east and southeast sides of the area of destruction indicated on the accompanying map. It now extends as far as Carbet, and includes Morne Rouge, but the reports thus far received do not clearly show whether it reaches quite to the coast on the north and northeast or not. The eruption of Mt. Pelée now must nearly if not quite equal that of La Soufrière in magnitude.

† One hundred and twenty tons of dust and lapilli were removed from the decks of the Roddam after her arrival in the harbor of Castries, St. Lucia, according to the personal statement of one of the agents of the line to which the steamer belonged.

mountain, and is noticeable in some of the photographs. No *stream* of molten lava has issued yet from the volcano as a feature of this eruption, though such flows were common in the early history of Pelée, as they were in that of St. Vincent's Soufrière. The bread-crust bombs prove, however, that much lava has been thrown out in the condition of half-melted masses. These bombs usually are more or less pumiceous in texture, and they show the "bread-crust" surface much more distinctly than do the more basic bombs of the Soufrière. The largest of the bombs observed was one fifteen feet long on the southeast slope of Morne Lacroix at an elevation of 3950 feet above the sea. The largest ejected block that we saw was one on the surface of the mud-flow between the rivers

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FIGURE 3.—"BREADCRUST" BOMB FROM MT. PELÉE.
Collected on the Sèche-Blanche plateau, three miles from the crater. The specimen is two feet two inches high.

Blanche and Sèche and not more than two hundred yards from the sea coast. Its dimensions are about 22 feet high, 30 feet long and 24 feet broad (see fig. 16), and it is of the light-gray andesitic lava forming one of the ancient lava beds near the summit of the mountain. When I inspected this block on June 25, I found it too hot on the surface to bear the hand upon it long at a time ; the great mass was cracked in several directions, and steam and sulphurous gases were emanating from the cracks. It seems certain that this enormous block was thrown out of the crater in a highly heated condition during the present eruption, but it may have reached the place where it now is partly through the agency of the great mud-flow on which it rests. Many other great bowlders, some of which are of nearly half the dimensions of the one just described, lie near by on this mud plain.

The area of distribution of the ejecta cannot be designated accurately yet for lack of data. The U. S. collier Leonidas received a quarter of an inch of dust on her deck from the great outburst of June 6 when she was 102 miles west of Martinique. It took the ship from 3 P. M. until nearly 6 o'clock to traverse the cloud of dust. This eruption began at 10.15 A. M. and was one of the heaviest of the whole series. I was in Georgetown, St. Vincent, at the time and felt the shock distinctly. From 3 o'clock onward that afternoon until after sunset heavy clouds of dust from the Pelée eruption passed over St. Vincent, much of it falling upon the island. The top of the cloud of dust as it passed over the mountains seemed to me to be about 6000 feet above the sea, so that the last deposits must have been made far south of St. Vincent. Kingstown is about 110 miles south of Mt. Pelée. The shocks or detonations from some if not all of the great outbursts were felt in St. Kitts and Trinidad, though not in some of the intervening islands.

Two illustrations of the force with which the bombs and blocks strike may be permitted here. On the sea coast near the Fort Villaret church in the portion of St. Pierre north of the Roxelane River there was a large distillery in which there were four big storage tanks constructed of quarter-inch boiler iron plates riveted together. These tanks look as if they had been through a bombardment by artillery, being full of irregular holes which vary in size from mere cracks at the bottom of indentations to great rents 24, 30 and even 36 inches across, while a strip several feet long was torn off from each of two. The direction of impact was essentially the same in all instances, namely, from the crater. The other illustration is found on the southeastern flanks of Mt. Pelée, along the trail leading from

Morne Rouge to the summit, where numerous spoon-shaped depressions occur in the rather loose soil of the mountain side, especially between the elevations of 2400 and 3000 feet above tide. These holes are of all sizes from 2 feet in diameter upward, the largest one which I saw being 40 feet long, 25 feet wide and 5 feet deep, but the depth had evidently been reduced by the sand which had been washed into it by recent rains. The longer axis of this depression was N. 50° W., pointing directly at the crater, and the longer axes of all the other holes observed were pointing toward the same center. The deepest part was on the up-hill side. On the down-hill side of each depression was found the cause of the phenomenon, and it was a bomb or ejected block from the volcano, which had struck the ground with a splash, throwing the earth in all directions and usually bounding or rolling out of the hole which it had made. Sometimes the blocks which did the work were found intact, but more frequently they had burst asunder after striking. All showed that they had come out of the volcano in a highly heated condition. Such splashes as these can be made experimentally on a small scale in any bed of stiff mud by means of well-directed stones.

Many stones must have fallen in St. Pierre, but they are so mingled with the rubble stones from the walls of the ruined buildings that usually they are not easily distinguishable therefrom. Great quantities of small, rounded fragments of yellow pumice are to be found now amid the ruins, the fine gray dust having been washed away to a considerable extent by the copious rains which have fallen since the great eruptions. Most of the pebbles of pumice were less than three inches in diameter. They are evidently from the old tuff agglomerate and must have been torn from the beds through which the volcanic vents pass and from the interior of the old cone. Stones fell all over the island in some of the eruptions.

Four ascents of Mt. Pelée, in the course of which the crater rim was traversed from the great chasm on the southwest along the southern and eastern edge more than two-thirds of the way around the circle, and the remainder also of the rim was clearly seen, enabled Curtis and me to form a reasonably definite idea of the center of activity and what was going on therein. Twice we followed the trail from Morne Rouge to the summit, which led us for a considerable distance along the right (southern) brink of the canyon of the Falaise River, and on the day intervening between these ascents we examined the gorge of the Falaise carefully from the point where the Morne Rouge trail to the summit strikes it nearly to its junction with the Capot River, a mile or more beyond the area of devastation. The upper reaches of the gorge certainly present the scene of desolation so graphically described by George Kennan,* but the "Falaise crater" mentioned by him and by Professor Heilprin† and indicated on Hill's map‡ can hardly be a true crater. We saw the same accumulations of volcanic ash in the gorge at an elevation of 1800 to 2000 feet above the sea (aneroid reading) that Heilprin and Kennan mention as forming a crater from which mud-flows were hurled down the gorge to the sea, and we saw steam issuing from them, but to us who had studied the phenomena on St. Vincent it seemed perfectly evident that the outbursts in the gorge of the Falaise were comparatively feeble examples of secondary or superficial eruptions of the same character as those which took place on such a grand scale from the ash-beds of the Wallibou and Rabaka Dry Rivers. This was the history of events in the Falaise and probably at Basse Pointe, Macouba, Grande Rivière and other places; and it was the history of some, but not all, of the mud-flows in the Prêcheur, the Mare, the Blanche, the Sèche and the Des Pères Rivers. Since the eruptions began there have been great floods in the Roxelane River, but it seems doubtful whether or not this stream has carried any true mud-flows down its gorge.

The actual crater is apparently somewhat oval in shape, with its longer axis stretching northeast and southwest. The highest point of the rim is on the northeast side and is what is left of the peak known as Morne Lacroix. By taking the average between the readings of our two barometers, we determined its altitude to be 4200 feet above the sea.§ It consists of ancient andesitic lava. Almost directly opposite this is the lowest point of the crater, where the great gash formed by the gorge of the Rivière Blanche occurs. The bed of andesite forming what may be considered the rim of the crater on the southeast side of the gash is 3350 feet above the tide, while the real bottom of the gorge where it issues from the crater is five or six hundred feet less in altitude. From this lava bed the rim rises rapidly (30° to 35°) to about 3750 feet above tide (see fig. 13), and then more gradually along the southern edge until 3950 feet is reached on the eastern edge. The northwest side of the southwestern gash is formed by a pinnacle of ancient lava which appears to be about 4000 feet above the sea, but may be higher. From this point the rim drops somewhat toward the north, but gradually rises again toward the east

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* The Outlook, vol. lxxi, pp. 773, 774, 26 July, 1902.

† McClure's Magazine, vol. xix, p. 363, August, 1902.

‡ National Geographic Magazine, vol. xiii, p. 260, July, 1902.

§ The French engineers located at Martinique are reported to have determined (by triangulation ?) that Morne Lacroix had lost 150 feet during the eruption, making its present altitude 4273 feet above tide.

until the point of rock on the northeast, already mentioned, is reached again. This great crater is about half a mile across, an estimate that is based upon the proportion which it bears to the height of the mountain, looked at from the sea, and from the fact that it took us twenty minutes to walk along the southern third of the rim from our first cairn to the Rivière Blanche gorge without stopping. The walking was not bad, considering the location of the route, and I should estimate the distance traveled in this time at not less than half a mile.

The breadth of the rim varies from a mere knife-edge on the south, north and northeast sides to a sloping plateau fifty to one hundred yards wide on the eastern side. This plateau is the site of the Lac des Palmistes, which was considered to be the old crater lake of Mt. Pelée. Studying this plateau carefully, we saw that it sloped gently southward and eastward from one side of a low divide running northeastward from Morne Lacroix across to a high ridge which paralleled the northern and northeastern sides of the crater. On the northwest side of this divide, the altitude of which was 3950 feet above tide, there is a shallow valley which rapidly changes into a gorge discharging into the canyon of the Prêcheur River. Heilprin's description* and his unpublished photographs show the existence on the plateau of a small lake-basin not more than five or six feet deep. He and his companion, E. E. Leadbeater, a New York photographer, state, furthermore, that this plateau and this portion of the crater rim were entirely or practically free from ash and dust deposit. When Curtis and I visited the spot, June 18 and 20, the surface was coated with a thick layer (more than four feet deep in places) of dust and ashes, probably from the great eruption of June 6. This materal had drifted into depressions to such an extent that we saw no indication of the existence of a lake-basin in this plateau. We had a perfectly clear and cloudless period when on the spot, and saw the topography with distinctness. I cannot think that the plateau, including the lake basin, ever has been a primary crater or center of eruption, though at the time of my visits the ground was hot, a scalding temperature being reached less than a foot from the surface, and steam was issuing from numerous crevices. This was the site of the Lac des Palmistes, but that lake was not located in the great ancient crater of Mt. Pelée.†

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* Op. cit., p. 360.

† The photograph of the Lac des Palmistes published by Dr. Emil Deckert on page 425 of the Zeitschrift der Gesellchaft für Erd-kunde zu Berlin for 1902 shows that body of water as it appeared in the rainy season of 1898. Deckert describes the lake as being but 2 meters deep and as lying in the middle of a morass or swamp upon a bed of lava. He regards this as a crater lake, though he mentions the fact that there is not and probably never could have been any crater wall on the east and north [south] sides. The

Judging from the account of the guide Romain,[*] from the "Notes relating to the history of the eruption of 1902," as translated in the Century Magazine[†] from the issue of Les Colonies for May 7, from the description by Lafcadio Hearn[‡] and from my own observations while on and near the mountain, the Étang Sec was the real crater lake of Mt. Pelée corresponding, though dry since the eruption of 1851, to the crater lakes of La Soufrière, on St. Vincent, Mt. Misery, on St. Kitts, and others. Its basin is said to have contained water until the eruption of 1851 drained it. The Étang Sec is stated to have been 700 meters (2300 feet) above the sea; its plain was estimated to be about 300 meters (986 feet) across, and the great circle surrounding it was judged to be about 800 meters (2628 feet) in diameter at top. This last estimate agrees closely with my estimate of the diameter of the present crater at top. The walls of the ancient crater must have risen almost precipitously from 1600 to 2100 feet above the Étang Sec, except on the southwest, where was located the great gorge through which flowed the waters of the Rivière Blanche, the sources of which were in the eastern side of the ancient crater.[§] Before the eruption which began last April, the crater of Pelée, except for the size of the great gash, must have been very much like the crater of St. Vincent's Soufrière and that of Mt. Misery, St. Kitts, as I saw it July 8 on my way home, and probably those of the other volcanic cones of the Lesser Antilles.

The whole interior of the crater was not seen entirely free from steam at any one time, but enough was observed to determine its character in its eastern, southern and western portions and to infer the shape of the remainder. The crater, like that of the Soufrière, is in the top of a broad, truncated

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eastern end of the "Somma" ring of Pelée bounds the little plateau on the north, but there is no cliff to the south; on the contrary, the plateau slopes off to the south into the head ravines of the Falaise River. It seems as if Deckert must have gotten his north and south points interchanged in his description. The two small craters of 1851 mentioned by Deckert (loc. cit., p. 426) are covered now, probably, by the inner cone, while the series of little craters in the gorge below those of 1851 must have become covered by the débris from the same cone, or have had the evidences of their existence destroyed by the tornadic blasts of the present eruption.

[*] The Century Magazine, vol. lxiv, p. 623, August, 1902. Translation from Les Colonies of May 5.

[†] The Century Magazine, vol. lxiv, p. 631, August, 1902.

[‡] "Through a cloud-rift we can see another crater-lake twelve hundred feet below, said to be five times larger than the Étang we have just left [the Lac des Palmistes, near the summit]; it is also of more irregular outline. . . . . It occupies a more ancient crater and is very rarely visited; the path leading to it is difficult and dangerous,—a natural ladder of roots and lianas over a series of precipices."—Two Years in the French West Indies, by Lafcadio Hearn, p. 288.

[§] See Romain, loc. cit.

cone of ancient tuff agglomerate alternating with lava beds. Some diametral enlargement has taken place, perhaps, during this eruption, though not enough to change the sky-line of the top to any great degree, except in the southwest side, where the old gash has been greatly widened, and perhaps deepened. The lower part of the outside of this old cone has an angle of slope of 20°, while the upper part is as steep as 30°, according to my determinations. Measurements of the inner slope gave values of 40° to 65° in the portion carved out of the old agglomerate, but the angles increased to 75°, 85°, and even showed great overhanging blocks on the eastern side where the old lava beds form the rim. In the western portion of the crater rises a cone of fragmental material, consisting of dust, ashes and large and small blocks and bombs. This cone is the scene of the greatest activity in the crater and it grew materially in size between the day when I first saw it, May 21, and July 6, when I got my last glimpse of it. It now entirely covers the site of the Étang Sec and partly fills the old crater, and probably more than compensates for the material torn and undermined from the old walls and thrown out by the eruptive action of the volcano. A large proportion of the activity of the volcano, aside from that of the great outbursts, has gone into the building of this cone. The accompanying profile

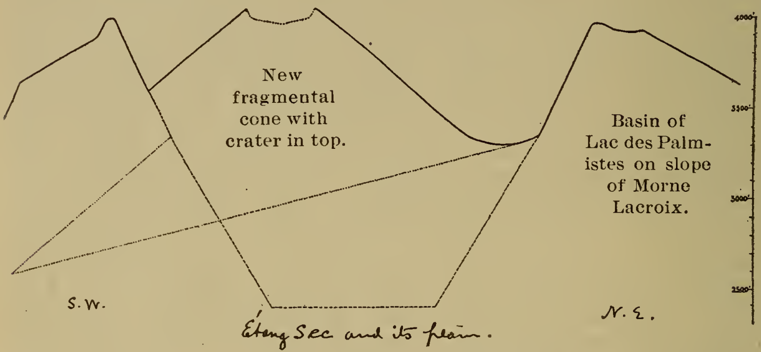

FIG. 2a. SECTION ACROSS SUMMIT OF MT. PELÉE FROM S.W. TO N.E. JULY 6, 1902.

Horizontal and vertical scales the same. Elevations estimated, except on northeast side. The shape of the crater in the inner cone is entirely inferential. The relation of the great southwestern gash to the fragmental cone is indicated by the dotted line. The broken lines complete the profile of the great ancient crater as it existed, probably, before the eruption of May 8, 1902. The fragmental cone was the scene of greatest activity, but there seemed to be another important center of eruption in the northeastern portion of the crater at the base of Morne Lacroix.

(p. 340) indicates the probable relationships between the inner cone and the old crater.

The illustration, fig. 14, gives the sight I obtained of the inner cone from the eastern side of the crater. At that time its top must have been just about on a level with or, perhaps, somewhat higher than the camera, which was 3950 feet above tide, by aneroid reading. The photograph shows that there was a depressed crater in the top of the inner cone. My measurements of the angle of slope of the southern side of this cone determined it to be 38° to 40°, but there were precipitous portions. The material which rolls and slides down the southwest side of this cone continues directly into the gorge of the Rivière Blanche. The steep-sided valley formed by the inner cone and the inner slopes of the crater-rim forms a continuation of the gorge of the Blanche and rises at a considerable angle from the southwestern gash to the base of the rocky precipice on the eastern side of the crater, where it may be 800 feet in depth. The valley probably continues around the northern side of the inner cone rising in a spiral, for it appears at an elevation of at least 3600 feet on the western side, between the rim of the crater and the cone on the northwest side of the great gash. The new fragmental cone rises, apparently, on the site of the new crater mentioned by Romain, a conclusion which seems to be in agreement with the account of the eruption of May 8 by M. Fernand Clerc as given by Kennan,* which is as follows: "About eight o'clock, with a rending, roaring sound, a great cloud of black smoke appeared suddenly on the southwestern face of the volcano near its summit, and rushed swiftly down in the direction of St. Pierre, . . ." Before this outburst, M. Clerc had been observing the great column of vapor rising from the other principal center of eruption, which is located in the valley within the great crater at the base of the high point of rock on the eastern edge (the remains of Morne Lacroix). At intervals columns of steam rise energetically from other parts of the crater valley.†

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* The Outlook, vol. lxxi, p. 683, July 12, 1902.

† Morne Lacroix is reported to have disappeared altogether and the crater to have extended greatly toward the east during the great outbursts which occurred from August 25 to September 3. This may indicate that the vent under the new inner cone above described has become partly clogged, and that the main activity has shifted to the vent mentioned (see p. 340) as being east of the Étang Sec at the base of the western face of Morne Lacroix. If this has taken place, as seems highly probable from the reported destruction of Morne Lacroix, the new inner cone acted as a dam in the great southwestern gash which played such an important part in the destruction of St. Pierre, so that the last eruptions came from a centrally located vent (like that of La Soufrière, St. Vincent) and the débris from the crater was distributed more symmetrically about the cone. The position of the great gash

The history of the present series of eruptions may be epitomized somewhat as follows: the gradually returning activity of the volcano began to make itself very manifest in the latter part of April, since visitors to the crater found warm water in the basin of the Étang Sec on the 25th of that month, and the lake was deep. Columns of dust-laden steam rose from an opening within the old crater on the east side of the Étang Sec and from one on the west side of the same basin, and cones rose about these openings. Water in large quantity collected in the old lake basin, assisted, perhaps, by a dam formed across the gorge by the ejecta from the western crater. The water was heated by the action of volcanic forces. On May 5 the heated waters of the crater broke through this dam and rushed, as a deluge of mud and bowlders of all sizes, down the gorge of the Rivière Blanche, and overwhelmed the Guérin sugar factory, which was situated at the mouth of the stream. On May 8 began the series of great explosions which have sent steam, laden with sulphurous gases, dust, ashes and stones, again and again over the southwest slope of the mountain with the violence of a tornado, several times reaching to St. Pierre and beyond. The author would explain the blasts in the same way as in the case of St. Vincent (see p. 326), but the great gash in the side of the crater of Pelée and the position of the neighboring ridges concentrated the force of the explosions in a certain direction and along a comparatively narrow zone—and the city of St. Pierre with its 26,000 inhabitants* and thousands of refugees lay in an amphitheatre, a regular *cul-de-sac,* directly in the path of the blasts.

There seems to be no crater or center of primary eruption in the gorge of the Blanche below the great crater, or in the gorge of the Sèche,† but there has been much secondary

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and neighboring cliffs with reference to the vent on the western side of the Étang Sec, which was the most active center of eruption in May, June and July, directed the blasts of the earlier eruptions toward St. Pierre and away from Morne Rouge. That directive factor having ceased to have force, through the growth of the inner cone and the (apparent) shifting of the center of activity to the eastern vent, Morne Rouge, a mile and a half nearer the crater than the middle of St. Pierre, came far within the area of destruction and received the full fury of an eruption.

* Population in 1895, 25,382, according to the Century Atlas.

† Prof. Angelo Heilprin has stated in his article in McClure's Magazine for August, 1902, and elsewhere, that eruptions have taken place from a crater located in the gorge of the Rivière Blanche some distance below the great crater. R. T. Hill has expressed the same idea in his extended article in the National Geographic Magazine (vol. xiii, pp. 251, 261) for July, 1902, and speaks of this as the center from which came the blast that destroyed St. Pierre, calling it the "Soufrière crater." He has recorded the matter on a map which was published on p. 260 of the National Geographic Magazine. Curtis was with Hill when the latter made the observations on which this map was based, and therefore knew the spot intended to be represented. Curtis and I stood on the brink of the gorge of the Blanche overlooking it on June 24, examined it again with field glasses from the rim

action along the lower portion of their courses, and much steam, with or without large quantities of dust, has been thrown high into the air when water has reached the heated interior of the vast beds of volcanic ash deposited there during this eruption. Mud-flows and torrents have been very numerous down the gorges of these streams and on the plateau between them. Some of these flows have come directly from the crater, especially in the case of the Blanche; others have originated on the exterior slopes of the old cone, while others have started in the heavy ash-beds in the gorges in the manner already described in connection with the Wallibou River, St. Vincent, and the Falaise River on the eastern side of Mt. Pelée. The surface of one of the mud-flows on the plateau between the Sèche and the Blanche is shown in fig. 17. Subsequent rain has washed the fine mud from the stones.

These streams of mud and stones present some characteristics which distinguish them clearly from the surfaces of undisturbed ash-beds. The most striking of these is the existence of curved folds or wrinkles transverse to the direction of flow of the stream, the folds varying in size with the size of the flow. The surface of an unmodified deposit of ash presents a drifted appearance like that of a field of snow or of dry sand on a sea beach, and the Richmond estate as illustrated in fig. 6 is a typical example. The plateau between the Des Pères and Roxelane Rivers, on which was located the Fort Quarter of St. Pierre, was covered with several feet of wind-drifted ash, and it was not a mud-flow or a series of mud flows which destroyed this portion of the city, as has been stated in several publications.

In addition to the showers of dry dust and ashes, there fell during the eruptions an immense amount of liquid mud which

of the crater, where we obtained a view directly through the gorge lengthwise, and repeated the examination from the crater rim on June 26. We could see no crater or center of eruption in the gorge of the Blanche below the great crater, though there has been much secondary or superficial eruption of steam from the ash-beds along the gorge.

I cannot agree with the distribution of the "zones of devastation" indicated on Hill's map or with the location of "mud craters" as the origin of the mud-flows of the Sèche, the Blanche, the Falaise and other valleys. It is well to separate the devastation into zones of "annihilation" and "singeing," in a general way, but the crater of the volcano should certainly be included within the former instead of being placed outside of the latter, as is done on Hill's map. The real location of the singe line of the May eruptions is nearly that of Hill's "ash line" and is indicated approximately on my map (p. 332), where it is called the limit of devastation. The "ash line" should be placed at some undetermined distance far beyond the shores of the island of Martinique. The existence of real "mud craters" on the slopes of Mt. Pelée seems very improbable, for the reasons given on pages 337 and 338 and elsewhere in this article. The mud-torrents of the Grande Rivière, which were among the heaviest of those experienced on the north and northeast side of the island, are not indicated on Hill's map.

had been formed within the eruption cloud through the condensation of its moisture. This mud formed a tenacious coating over everything with which it came in contact. That drops of mud, too, formed in the air and fell as a feature of the eruption is proven by the condition of the walls of the houses in Prêcheur, on which I found flattened spheroids of dried mud which could have formed only in the manner indicated. These flecks of mud were two, four and even six inches across, where two or more had coalesced. They occurred mostly on the northern and eastern walls of the houses. The testimony of the people as to the occurrence of rain during the great eruptions is conflicting, but the existence of this coating and these drops of mud proves that much aërial condensation of steam accompanied the outbursts.

During the latter part of our stay on the crater rim on June 24 the rain fell in torrents, and the deluge continued until we reached the foot of the outer cone on our return journey, the heaviest portion of the storm lasting for an hour or an hour and a half. Here we found the fumaroles sending out more steam than they did on our upward journey. When we crossed the Sèche River, we found a foot and a half of yellow, muddy water in place of the two or three inches which we had noticed there in the morning. We had not climbed out of the lowest gorge of the river before our attention was attracted by the heavy eruption that was taking place from the crater, and that was sending enormous clouds of dust-laden steam down the gorge of the Blanche to a point below the so-called Soufrière crater. Thunder-like noises nearer at hand had already made themselves heard and in another minute a wall of hot water, ten or fifteen feet high, swept with railroad speed over the place where we had crossed the river, and rushed on to the sea. The roar of the torrent was like that of a train, and the water dashing from side to side of the narrow gorge caused the ground on which we were standing to tremble like a ship when her propeller "races." The water was thick and as black as ink with its load of volcanic ash, and it transported with ease bowlders five feet in diameter which it had excavated from its banks. In many, if not most instances, these bowlders were the ejecta of the present eruption. To the left a stream of thick, yellowish mud was flowing down from the plateau of the Sèche-Blanche which we had left a quarter of an hour before and was cascading into the Sèche directly beneath us. Soon the black torrent cut into the ash-beds along its banks sufficiently to reach their still highly heated interiors and cause columns of steam to shoot hundreds of feet into the air. The steam columns carried great clouds of black and light-brown volcanic sand scores of feet upward. The hot area of the plateau also was sending skyward great columns of steam, and the whole formed a scene seldom witnessed, difficult to describe, and never to be forgotten. The next day we measured the gorge and found that the Sèche had deepened its channel at least ten feet in the loosely compacted recent ash during the hour which the flood lasted.

In this instance it seems evident that there was close connection between the heavy rain, the eruption, and the black torrent. Two explanations present themselves for consideration: (*a*) the crater may have thrown a mass of accumulated rainwater and ashes bodily over into the head canyon of the Sèche; (*b*) the rain which fell into the crater may have been the exciting cause of the eruption, but the mud-torrent may have been due to the soaking of the heavy coat of ashes on the steep outer slope of the old cone at the head of the Sèche until the resulting fluid mass slid off from the comparatively hard surface beneath and poured down the gorge of the river. There was plenty of water-soaked mud and ashes on the upper part of the mountain to supply the avalanche and some of it was on the verge of fluidity at the time of our visit, hence the latter explanation seems the more reasonable. The little tributary of the Sèche which empties into it on the southeast side close to our point of observation, did not show any corresponding torrent, because it does not head on the side of the great cone.

The mud-flows which have descended the Prêcheur River canyon have had ample collecting ground in the "Atrio del caballo," to use a Vesuvian term, on the north and northeast sides of the great crater, where the fine dust settles in vast quantities ready, when sufficient water has been added to it, to descend through a narrow gorge into the valley of the Prêcheur. When I was walking along the crater rim above the "Atrio" June 20, my footsteps started small mud-flows down the outer cone, so liquid was the mud at that time. The ordinary action of the volcano is to deposit dust of impalpable fineness on the inner face of the crater rim. When this deposit becomes thick, it is ready to be swept off by a copious rain and carried through the great southwestern gash, out of the crater and down the gorge of the Rivière Blanche as a mud-torrent or flow. There does not seem to the writer to be any need of locating "mud craters" at the heads of or along the line of the gorges which have been the courses which these torrents of liquid mud have followed to the sea.

Where the tuff agglomerate of the old (outer) cone had been freed from its coat of ashes, especially in its lower portion, i. e., from 1000 to 2000 feet above tide, it showed a smooth, somewhat fluted surface, the soft bowlders having been planed off even with the matrix. The whole showed striations parallel with the slope, so that the surface looked like the glaciated rock surfaces so common in northern latitudes. The planing and the striations seem to have been due to the scouring action of the ash avalanches in this part of their course. They ceased where the steep slope of the cone changed to the gentle slope of the plateau, and thus gave opportunity for the material of the avalanches to check its descent and pile up. The sides of the radial gorges on the flanks of Mt. Pelée show approximately horizontal striations. Near the stream-beds such striations occur on both sides of the gorges, and are due to abrasion by the sand and stones carried by the torrents. High above the stream on the bluffs facing the crater there are similar striations, but these must have been made by sand-blast action during the hurricanes of dust-laden steam, resulting from the explosions during the recent great eruptions. These striations extend to the very tops of bluffs rising 500 feet and more above the stream beds at their bases (see fig. 15).

Erosion seems not yet to have cut deeply into the old land-surface since or as a feature of the eruptions, because here and there all over the mountain side one can find undisturbed roots and charred grass still in place. The shore line from Ste. Marthe Point nearly to Cap St. Martin has been somewhat altered since the eruptions began, some of the river deltas having been built out by the new material brought down by stream and torrent, while others have been cut back by the waves. The most important example of the cutting back is near the mouths of the Sèche and the Blanche, where local land-slides have assisted the sea in forming nearly vertical bluffs from ten to thirty feet in height. These bluffs show sections of the old and the new material now composing the plain. The little ash island* which was formed near the mouth of the Rivière la Mare between May 8 and 23, and which was visited on May 23 by Mr. Curtis and two companions, had been washed away by June 14. The stone pavement laid on the beach of St. Pierre was cut into in places, perhaps by the return waves from the ocean accompanying the great outbursts.

The mud-flow which swept down the Grande Rivière reached the village of the same name at 4 A. M., May 8, four hours before the eruption occurred which destroyed St. Pierre. Three other great mud-flows have traversed this river: on May 11, June 6 and June 22, though no great eruption of Pelée took place on May 11 or June 22. The eruption of June 6 was one of the heaviest that occurred; this time the mud-torrent reached Grande Rivière village about an hour and a half before

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* Mentioned by Hill; The Century Magazine, vol. lxiv, p. 773, September, 1902.

the eruption took place. The flood of May 8 was the most violent and was three meters (about 10 feet) deep where the valley of the river opens onto the sea coast, according to M. Delsol Désiré, the mayor's deputy of Grande Rivière. He gave me the foregoing particulars in regard to these floods. The fine mud of these flows entered the buildings on the banks of the river as if it had been thick syrup. In one room that we examined the line of highest level was even with the top of an ordinary table, which would show that the mud was 30 inches deep in the room. At the time of our visit the deposit was nearly dry and it showed a shrinkage of but eight inches or 27 per cent. In another room the shrinkage was greater, showing that the mud there was thinner when it flowed in. Streams composed of such material as this would have great power in the transportation of bowlders. The sizes of the bowlders brought down by the mud-torrents and deposited on the flood plain of the stream above the village and in its old channel may be inferred from figure 18. Some of those measured were eight feet across. The bowlders seem to be from old deposits, since they have weathered surfaces. They show fresh abrasion along edges and at corners, due to their recent trip down the gorge. The mud is made up of gray material from the present eruption, together with a large proportion of yellow sand from the old beds through which the river runs. The vast amount of material brought down by the torrents has extended the delta plain fully five hundred feet into the sea and has pushed out the shore-line for several hundred yards on either side of the mouth of the river.

At Basse Pointe the history in regard to floods or torrents of mud has been similar. The principal disasters occurred on May 8 and 27, but the latter was the greater and most of the destruction was wrought on that occasion. Here too the deltal plain has encroached five hundred or six hundred feet on the sea and the ocean currents have spread the surplus material as a new beach for a long distance north and south of the mouth of the river, destroying the little artificial harbor of the town. Bowlders ten feet across were brought down and left in the town by the floods, and a deposit of sand, gravel and bowlders fifteen to eighteen feet deep rests upon the site of the old market place, which was at the mouth of the river.

The ruins of the city of St. Pierre presented a very interesting field of study, but mostly in the line of speculations as to the cause or causes of the terrible destruction of human life. The walls of the houses (see fig. 11) showed that one or more blasts of tornadic violence had swept over the city and that they came from the direction of the crater of Pelée, for the east and west walls—transverse to the direction of the crater from the city—were demolished more generally than the north and south walls. The direction in which most of the trees were felled indicates the same thing, but the trees in the angle of Morne Mirail, which rises behind the middle of the city, were thrown over at all angles progressively, showing that a vortex was formed there. As is indicated by the gradually decreasing degree of destruction in passing from the northern to the southern part of the city, the blast diminished in force as it progressed and expanded, but when it reached Ste. Marthe Point it still had strength enough to throw the statue of Notre Dame de la Garde from its pedestal. The statue, which is of hollow iron ten or eleven feet high, now lies on the edge of the bluff with its foot about fifty feet S. 10° W. from its original position on the pedestal, and directly in line with the crater.* The guns in the Ste. Marthe and Morne d'Orange batteries were thrown from their carriages in the same direction. More than once when I was on the rim of the crater or on the west flanks of the mountain I saw great clouds of dust-laden steam come out of the gash in the side of the crater with sufficient force to descend the gorge of the Rivière Blanche with great rapidity a full mile before rising in columns. It was not difficult to imagine that, if this happened when the crater was sending a steam and dust column only one or two thousand feet high, the action would be vastly greater and even like a hurricane in violence when the crater was in full eruption and was sending its ash-laden steam column from five to seven miles into the air.†

It does not seem necessary to call in any forces new or strange to the history of vulcanism to account for the phenomena attending the eruption of Mt. Pelée, or the destruction of St. Pierre and its people. The "flames" reported were perhaps the incandescent stones and bombs flying through the air; and these certainly would set fire to any combustible material upon which they fell. The officers of the French cable-repair ship Pouyer Quertier were eye-witnesses of the eruption of May 8 and describe the cloud as being black when it issued from the crater, but say that it became luminous as it approached the coast.‡ Several times at night during our stay we saw the inner cone of the crater outlined and streaked with

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* See Bul. Am. Mus. Nat. Hist., vol. xvi, pl. xlvi, fig. 2; and Nat. Geog. Mag., vol. xiii, p. 250, for illustrations.

† Lieut. B. B. McCormick, U. S. N., in command of the Potomac, was on his vessel in the harbor of Fort de France May 20 and made measurements of the angular distance to which the steam column rose during the great outburst that morning. The column subtended an angle of about 30° and the tug was thirteen and one-half nautical miles in a straight line from the mountain.

‡ Heilprin, loc. cit., p. 367.

lines of "fire" due to the rolling and sliding red-hot rocks and lapilli, and this light was reflected from the steam clouds above the cone. The existence of notable quantities of burning or inflammable gases in the discharges from the volcano seems to me to be as yet undemonstrated.

On two occasions, June 24 and 26, I went into the crater for a short distance beside the southwestern gash and several times was surrounded with heavy clouds of steam from within the abyss. The steam, which was warm, but not hot, when it reached me, contained much sulphur dioxide, SO_2, and at times some hydrogen sulphide, H_2S, but I could not detect the odor of any other gas. The sulphur gases made the atmosphere difficult to breathe, but the most uncomfortable sensation was due to the irritation caused by the fine, angular dust getting into the respiratory passages and the eyes. Such a mixture, raised to a high temperature, and containing a large amount of dust and a considerable percentage of sulphur gases, would be almost instantaneously fatal to life. It was a cloud like this that rolled over and enveloped St. Pierre for several minutes about eight o'clock in the morning of May 8, and must have caused most of the deaths. Some of the other causes of death were, (1) blows from falling stones which had been hurled out from the volcano, (2) crushing beneath falling walls and various objects (one man was found with his back broken by a sign which had fallen from over a store front), (3) burns due to hot stones and dust, (4) burns caused by steam alone and (5) by steam mingled with dust, (6) cremation in burning buildings, (7) nervous shock, (8) suffocation from lack of respirable air and, perhaps, (9) lightning. No autopsy was made on any of the thousands of victims of the disaster on Martinique, although men capable of performing such operations had the opportunity of making them within a very few hours after the eruption; hence there is no sure way of determining whether poisonous gases other than those mentioned played any part in the destruction of life. Immanuel Lédée, one of the survivors of the crew of the Roraima, told me that when the mucous membrane of his mouth, throat and nose sloughed off on account of the burning, it was found to be full of the fine black (gray) dust. He was taken to the hospital at Fort de France after the eruption. Samson Cil-Barice,* the prisoner who is the sole survivor of the persons within St. Pierre at the time of the eruption, told me in Morne Rouge on June 18 that it was the hot dry "sand" which sifted in through the window of his cell that caused his terrible burns.

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* This name is spelled very differently in the various accounts of the disaster. The spelling here adopted is that given me by my interpreter.

The term "stellar lightning" has been proposed by George Kennan for the particular form of electrical discharge characterizing the eruptions of Mt. Pelée. This expression, however, implies that the bolts shot out radially from a center in all directions at the same instant, whereas the shafts flew out successively in the different directions. Often they seemed to come from centers, but this appearance probably was due to the foreshortening of the line along which the successive flashes originated. The amount of electricity generated by the friction of the ascending column and the moving clouds of dust-laden steam against the surrounding atmosphere was very great, but much of the discharge seemed to be comparatively noiseless. At midnight of June 26 an eruption occurred which sent up a steam column to a height estimated at 12,000 feet above the top of the mountain. Much of this scintillating* lightning played about the column and the "mushroom" cloud above, but no sound of thunder could be heard from our sloop, which was at anchor off Carbet, seven miles distant. The same form of electrical discharge was observed in connection with the great outbursts of La Soufrière on St. Vincent. The electrical phenomena attending the September eruptions of Mt. Pelée are described as having been even more magnificent and terrifying than those observed in connection with the earlier explosions.

American Museum of Natural History.
October 11, 1902.

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* "Coruscating" is the excellent descriptive term applied by Dr. Jaggar to these discharges.

4

Photograph by E. O. Hovey.

La Soufrière. Southwestern part of Crater-rim.

5

Photograph by E. O. Hovey.

La Soufrière. Southeastern portion of Crater.

Photograph by J. C. Wilson.

The Richmond Estate, St. Vincent.
Wind-drifted surface of undisturbed ash-bed.

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7

Photograph by E. O. Hovey.

La Soufrière. Secondary outburst in ashbed of Wallibou River.
Dendritic erosion developing.

8

Photograph by E. O. Hovey.

La Soufrière. Mud-covered ridge at 1500 feet altitude. [Page 353.

9

Photograph by E. O. Hovey.

LA SOUFRIÈRE. ASH-FILLED GORGE OF THE RABAKA DRY RIVER.

New deposit is said to be 200 feet deep.

10

Photograph by E. O. Hovey.

LA SOUFRIÈRE. WINDWARD SIDE. TREES FELLED AND CARVED BY VOLCANIC BLAST.

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11

Photograph by E. O. Hovey.

RUINS OF ST. PIERRE, MARTINIQUE. MT. PELÉE IN BACKGROUND.

12

Photograph by E. O. Hovey.

RUINS OF ST. PIERRE, MARTINIQUE. VALLEY OF RIVIÈRE ROXELANE.

13

Photograph by E. O. Hovey.

Mt. Pelée. Southeastern part of Crater-rim at 3750 feet altitude.

14

Photograph by E. O. Hovey.

Mt. Pelée. Inner cone; from eastern edge of Crater at 3950 feet altitude.

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15

Photograph by E. O. Hovey.
MT. PELÉE. BLUFF IN CENTER OF VIEW SHOWS SAND-BLAST ACTION OF VOLCANIC TORNADO.

16

Photograph by E. O. Hovey.
MT. PELÉE. EJECTED BLOCK OF ANDESITIC LAVA ON SÈCHE-BLANCHE PLATEAU, 3 MILES FROM CRATER.
Dimensions 30′ × 24′ × 22′.

17

Photograph by E. O. Hovey.

MT. PELÉE. SURFACE OF "MUD-FLOW" ON SÈCHE-BLANCHE PLATEAU AT 800 FEET ALTITUDE.

18

Photograph by E. O. Hovey.

GRANDE RIVIÈRE. GREAT BOWLDERS BROUGHT DOWN BY MUD-TORRENTS OF MAY AND JUNE, 1902. Page 358.]

ART. XXXIV.—*On the Reflection of Electric Waves at the Free End of a Parallel Wire System*; by HENRY A. BUMSTEAD.

WHEN electrical waves are sent along two straight parallel wires, and a series of standing waves is formed by reflection from the unconnected ends of the wires, it is found that the distance from the ends (where one would expect to find a loop for electric force and a node for current) to the first node for electric force is less than a quarter wave-length as determined elsewhere along the wires; and the discrepancy always appears whether the measurements are made by means of a resonator or by the sliding bridge method of Lecher. This apparently anomalous behavior excited considerable attention among the earlier experimenters and writers upon this subject, and several attempts at an explanation, by means of special assumptions, have been made.* A more careful consideration of the question, however, shows that even with perfectly conducting wires, and without any modification of Maxwell's theory, or any assumption of the escape of charge into the air, a displacement of the current node beyond the end of the wires is to be expected theoretically and that its magnitude should be of the same order as that which is found experimentally.

The cause of the phenomenon is perhaps most easily seen by using Mr. Heaviside's ingenious device of considering electrical resistance in the guiding wires as approximately equivalent to a fictitious magnetic conductivity in the dielectric. Thus if the vectors **E** and **H** are the electric and magnetic forces at any point and **C** the total current, the fundamental equations of the field, in the form used by Heaviside and Hertz, are

$$\text{curl}\ \mathbf{H} = 4\pi\mathbf{C} \tag{1}$$

$$-\text{curl}\ \mathbf{E} = \mu\dot{\mathbf{H}} \tag{2}$$

C is the sum of the displacement and conduction current in the dielectric, so that

$$\mathbf{C} = \frac{K}{4\pi}\dot{\mathbf{E}} + f\mathbf{E}$$

where K and f are respectively the dielectric constant and conductivity of the medium. Equation (1) thus becomes

$$\text{curl}\ \mathbf{H} = K\dot{\mathbf{E}} + 4\pi f\mathbf{E} \tag{1'}$$

If we assume that the medium possesses also a *magnetic* conductivity, g, then (2) takes the entirely analogous form

$$-\text{curl}\ \mathbf{E} = \mu\dot{\mathbf{H}} + 4\pi g\mathbf{H} \tag{2'}$$

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* See Poincaré, Les Oscillations Électriques, arts. 110 and 125.

If now we are dealing with plane waves, propagated along straight and perfectly conducting guides parallel to the axis of z, then **E** and **H** are in planes perpendicular to z and cut each other orthogonally at all points. The actual form of the lines of electric and magnetic force may, of course, vary greatly with the shape and size of the guides, but, if we follow any plane in the wave, the line integral of **E** from one guide to the other is independent of the path, so long as we stay in the plane; and, with this understanding, it may be called the difference of potential between the wires, V. In like manner, the line integral of **H** about a closed circuit embracing one of the wires is a constant, and equal to $4\pi I$ where I is the current in the wire at this point. It should be observed that this current has nothing directly to do with the current **C** in (1), but is, from the present point of view, to be regarded merely as the line integral of the magnetic force.

The advantage in using the scalars, V and I, instead of the vectors, **E** and **H**, in treating plane waves, is apparent, since V and I vary only with the coördinate along the wire, z, and the problem reduces to one dimension. Equations (1′) and (2′) become, respectively,

$$-\frac{dI}{dz} = S\dot{V} + GV \qquad (3)$$

$$-\frac{dV}{dz} = L\dot{I} + 4\pi FI \qquad (4)$$

where S and L are the capacity and inductance of the system, G is the total electric conductance of the medium from one wire to the other, and F is the total magnetic conductance of the medium in circuits about the two wires following the lines of magnetic force; all these being measured per unit length along z.*

It is immediately apparent from these equations that the rate of dissipation of energy in a wave plane, whose thickness is dz, is GV^2dz due to the electric conductivity, and $4\pi FI^2dz$ due to the magnetic conductivity; and both take place throughout the plane.

The approximate equivalence of magnetic conductance in the medium and electrical *resistance* in the guiding wires is thus made evident. If we now have no magnetic conductivity in the medium, but a resistance, $\frac{1}{2}R$ per unit length, in each wire, where $R = 4\pi F$, we shall still have the same dissipation per second in the plane, viz: RI^2dz, and things will go on *approximately* as before. In fact, if we use one of the old theories, which ignore the action of the medium, to investi-

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* See Heaviside, Electromagnetic Theory, vol. i, p. 384, where, however, a different system of units is employed.

gate the propagation of electrical disturbance along resisting wires, we shall get exactly equations (3) and (4) with R in place of $4\pi F$. But on Maxwell's theory, as Heaviside has pointed out, the correspondence is not exact; for, with the resisting wires, we shall no longer have strictly plane waves, as the electrical force is no longer normal to the wires; moreover the dissipation of energy does not take place throughout the plane but in the wires alone, and, unless the distance between the wires is small in comparison with the wave length, we must expect to find noticeable differences between the approximate theory and the results of experiment.

It is in this lack of complete correspondence that the explanation is to be found for the apparent discrepancy mentioned at the beginning of this paper. To make the matter somewhat clearer, let us consider first the conditions when the ends are bridged. Let the perfectly conducting wires end normally upon a plate of infinite extent with perfect electrical conductivity; then, when any wave plane reaches it, the electric force will be instantly annulled throughout the plane, but the magnetic force will persist, and we must therefore have a reflected sheet with its electrical force in the reversed direction, and its magnetic force in the same direction, as in the incident sheet. This can occur since the two sheets are moving in opposite directions. Exactly at the plate we shall have a node of **E** and V, and a loop of **H** and I. If, instead of using the infinite plate, we bridge with a straight, perfectly conducting wire, we shall have nearly, but not quite, the same result; for now the electrical force is not instantly annulled throughout the whole plane, but only in the central portion; and the outlying tubes of electric force must travel inward toward the bridge with the speed of light, thus generating lines of magnetic force which surround the bridge and, in general, making the reflection a complicated one. But the most conspicuous effect will be a delay in the vanishing of the electric force and a consequent apparent shift of the potential node (or current loop) beyond the bridge. As, with circular wires of equal section, one-half the whole number of unit tubes in the plane lie within a circle whose diameter is the distance between the wires, we should expect this shift to be not far from one-half the distance between the wires. As a matter of fact, a displacement of the node beyond the terminal bridge of about this amount is always observed, but it excites no surprise, since even the most elementary considerations make it natural to add half the length of the bridge to the parallel wires, the middle of the bridge being, obviously, a center of symmetry. It is, however, frequently assumed that this correction would disappear if the bridge were a perfect conductor;[*] but the above considerations make it clear that this is not the case.

But an exactly analogous thing happens also when there is no bridge, when the simple theory would not cause it to be expected. Thus, suppose the wires to terminate in an infinite plate having no electrical conductivity but infinite magnetic conductivity; we now have reflection of the opposite kind to that in the previous case, for now the magnetic force will vanish while the electrical force will remain; and we shall thus have a node for **H** and I and a loop for **E** and V. If, instead of having the magnetically conducting plate, we cut the wires at this point, we have nearly the same effect; for infinite resistance in the wires is, as we have seen, approximately equivalent to infinite magnetic conductivity in the medium. But the result is not quite the same, for the effect of the termination of the wires is felt, at first, only in the parts of the wave plane near the wire; it is equivalent, not to an infinite plane with magnetic conductivity, but to a little ring of infinite magnetic conductance, immediately surrounding each wire. These little rings will immediately annul the magnetic force near the wire, but, as in the case of the wire bridge, the more distant tubes of force must come in with the speed of light and there is an entirely analogous delay and displacement of the apparent node beyond the ends of the wires. The shifting of the node should be about the same as in the previous case, as, in fact, it is found to be experimentally; if anything, it should be slightly less, for the imitation of a ring of perfect magnetic conductance by cutting the wire is probably closer than the approximation to a perfectly conducting bridge when a copper wire is put across the guides.

Yale University, New Haven, Conn.

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[*] E. g., Drude, Physik des Aethers, bottom of page 465.

ART. XXXV.—*The Upper Permian in Western Texas;*[*] by GEORGE H. GIRTY.

DURING the field season of 1901, as a member of a party under the direction of Mr. R. T. Hill, I examined a very interesting series of Carboniferous strata in western Texas. The route traversed was in part the same, though in an opposite direction, as that pursued by the expedition under Captain Pope in 1855, of which G. G. Shumard was a member. Our point of departure was El Paso, and we passed eastward, approximately along the thirty-second parallel, as far as the headwaters of Delaware Creek, in the Trans-Pecos region. There, finding that the old trail down Delaware was impracticable, we turned southward, meeting the railroad at Toya.

The region of special interest was the Guadalupe Mountains, where Shumard collected a number of species, subsequently described by his brother, B. F. Shumard, which indicated the existence at this point of a peculiar Carboniferous fauna, essentially different from anything known elsewhere in North America. Shumard gives the following section of the Guadalupe Mountains:[†]

1. Upper or white limestone	1,000 feet.
2. Dark-colored, thinly laminated and foliated limestone	50–100
3. Yellow quartzose sandstone	1,200–1,500
4. Black, thin-bedded limestone	500

The geologic series is finely exposed, and the order of superposition of the beds is obvious. The constituent formations are of rather unusual thickness and uniformity of composition. In fact, though we were able to make only barometric measurements, and though only the upper limestone was exposed in a continuous section, I believe that the thicknesses assigned by Shumard are too small. We measured 1,700 to 1,800 feet of the upper limestone, while the middle member, a yellow sandstone, must contain from 2,000 to 2,500 feet. Of the black limestone, which forms the lowest member of the section, probably not more than 500 feet are exposed, but the base was not seen.

Fossils were obtained from all these formations, but it is especially of those from the upper one that I desire to speak. The rock is a white limestone, sometimes stained yellowish or reddish in the lower portion, where it is also quite siliceous.

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[*] Published by permission of the Director of the U. S. Geological Survey.

[†] Acad. Sci. St. Louis, Trans., vol. 1, 1860, p. 280.

Horizons which are dolomitic also occur, and one of these is a pisolite. The highest beds seen are exposed on the summit of El Capitan, and contain *Fusulina elongata* Shumard in great profusion. The main fossiliferous horizon, however, was found about 1,000 feet below. Near this level crystalline calcite occurs in great abundance and in cleavage blocks of considerable size. The locality was difficult of access, and could only be reached by hard climbing, so that the collections obtained were less complete than might be wished. The above remarks relate to the "white Permian," which is peculiarly massive and shows little evidence of bedding. The hundred feet or more of brownish or gray limestone immediately below it, however, which represent Shumard's "dark Permian," are obviously stratified. From the "white Permian," chiefly at the locality mentioned, were obtained upward of 75 species, some of the more interesting of which I will mention. The fauna is very varied, and includes representatives from nearly all the invertebrate groups, though the brachiopods and pelecypods are most numerous in species and individuals.

Of the Protozoa we have *Fusulina elongata* Shumard, a species unique so far as I am aware, which probably attains a length of nearly 2 inches.

Sponges are remarkably abundant, and belong chiefly to the *Calcispongiæ.* The orders *Lycones* and *Pharetrones* are represented by a number of genera and species, most of which are probably new. In addition the genera *Mammillopora* and *Bothroconis* have been identified.

Though a species of *Lophophyllum* was found, coelenterates are rare, except for the group of *Hydrocorallinæ* similar to those described by Waagen from India. Both in these forms and those representing the *Calcispongiæ* the rock is crystalline and altered in such a way that the outlines of structures are partially obscured. The original difficulties attendant upon the study of these groups are therefore very much enhanced. Though of so widely different zoological affinities, such is the preservation in which they appear that in a number of cases I am not sure that some of the supposed *Hydrocorallinæ* are not calcareous sponges, and I even entertain similar doubts with regard to certain of Waagen's representatives of that group.

Of the echinoderms nothing appears in the collection, nor of the helminths.

The Bryozoa, except for a single group, are mostly few and of a character alien to our known Carboniferous faunas. They consist of *Fenestella* sp., *Acanthocladia ?* sp., a *Goniocladia* near *G. indica* Waagen, and a peculiar group of fistuliporoid Bryozoa much more like Mesozoic than Paleozoic types, which are more abundant in the "dark Permian" than in the white limestone whose fauna I am attempting to summarize.

The brachiopod fauna is abundant, and while of an undoubted Carboniferous facies, presents one which is apparently later and certainly different from that of our usual Carboniferous rocks. The following species were found:

Streptorhynchus near pelargonatus Schl.
Derbya n. sp.
Derbya sp.
Derbya Bennetti?
Meekella n. sp.
Chonetes n. sp. near trapezoidalis Waagen
Productus semireticulatus var.
Productus pileolus Shum. ?
Productus cora d'Orb. ?
Productus near Wallacianus Derby (2 sp.)
Spirifer Mexicanus Shum.
Spirifer n. sp.
Squamularia? Guadalupensis Shum.
Martinia n. sp. near elongata Waagen
Ambocoelia planiconvexa?
Spiriferina Billingsi Shum.
Spiriferina sp.
Spiriferina n. sp.
Seminula n. sp.
Hustedia? papillata Shum.
Pugnax n. sp.
Pugnax Swallowiana Shum.
Camarotoechia indentata Shum.
Camarotoechia sp.
Dielasma near truncatum Waagen (2 sp.)
Dielasma ?? sp.
Dielasma ? n. sp.
Hemiptychina near H. sparsiplicata Waagen
Spirigerella ? sp.
Lyttonia sp.
Richthofenia (several sp. ?).

Besides the forms listed are several new genera and species of terebratuloid shells, which, even in the comparatively few specimens in our collections, present a really remarkable differentiation. Many of the genera cited above are new to North America. Among these may be mentioned *Lyttonia*, *Richthofenia*, *Spirigerella*, and *Hemiptychina*, though in one case, at least, the generic reference is questionable. Many of the genera common to our other North American faunas are represented in part or wholly by species of peculiar types not found in them. An orbicular *Spiriferina* with short hinge line is one of these.

Of the pelecypods the following species were collected:

Aviculopecten (Pterinopecten ?) sp.
Aviculopecten ? sp.
Streblopteria (3 sp.)
Entolium ? (3 sp.)
Lima n. sp.
Euchondria ? sp.
Camptonectes ? (2 sp.)
Avicula n. sp.
Myalina ? near M. squamosa Sow.
Myoconcha n. sp.
Modiola ? sp.
Edmondia ? sp.
Cypricardinia ? sp.
Macrodon ? sp.
Axinus securus Shum. ?

The aspect of this fauna also is quite varied. The shells are as a rule small and preserved as internal casts, so that it is difficult in most cases to ascertain the characters of really generic value. There is a general absence of the types which characterize the Upper Carboniferous or even the Permian of the Mississippi Valley. The development of the pectinoid and mytiloid groups is rather striking. The genus *Myoconcha*, of which I seem to have virtual representatives, has not before been recognized in North America, and *Camptonectes* is new among our Carboniferous faunas. The latter is abundantly represented by individuals, and has every external appearance of belonging in the Mesozoic genus.

Gastropods are rare and in size generally minute. So far only the following have been found:

Pleurotomaria ? group of carbonaria (2 sp.)
Pleurotomaria ? (n. gen. ?) sp.
Worthenia ? sp.
Euconispira ? sp.
Orthonema ? sp.
Holopella ? sp.

But little need be said of the gastropod fauna, in which there is nothing striking, except the absence of our familiar Carboniferous species.

Of the cephalopods, at a horizon where novel and interesting ammonoid types might be expected to occur, only an imperfect and undetermined species of *Temnocheilus* has been found.

No Crustacea have yet been noted, except *Phillipsia perannulata* Shumard, which occurs in abundance in the "dark

Permian" below, but which is in this instance doubtfully identified.

From the "dark Permian," some of it in place, but most from float pieces probably belonging to that horizon, were obtained the following species:

Fusulina elongata Shum.
Sponges (of several types)
Lophophyllum (2 sp.)
Striatopora ? sp.
Acanthocladia sp.
Fistuliporoid Bryozoa of Mesozoic types
Crania ? sp.
Streptorhynchus ? sp.
Derbya sp.
Chonetes Permiana Shum.
Chonetes n. sp.
Productus Popei Shum.
Productus Popei var.
Productus semireticulatus var.
Productus, semireticulatus type (5 sp.)
Productus cf. Norwoodi Swal.
Spirifer sulcifer Shum. ?
Squamularia ? Guadalupensis Shum. ?
Spiriferina Billingsi Shum.
Hustedia ? papillata Shum.
Hustedia ? (2 sp.)
Pugnax ? bisulcata Shum.
Pugnax ? n. sp.
Pugnax Swallowiana Shum.
Camarotoechia indentata Shum.
Camarotoechia sp.
Dielasma perinflatum Shum. ?
Dielasma cf. truncatum Waagen
Aviculopecten sp.
Myalina ? near squamosa Sow.
Euomphalus n. sp.
Bairdia sp.
Phillipsia perannulata Shum.

This fauna requires little comment. Its relation to that of the "white Permian," nearly a thousand feet above, is obvious, yet each has an individual facies. In this fauna *Phillipsia perannulata* is abundant, and also the curious small fistuliporoids to which attention has already been directed. The Producti are for the most part of the *semireticulatus* type, small, and characterized by strong curvature and a deep median sinus.

The fauna of the yellow sandstone I will only hastily refer to. It contains *Fusulina elongate* Shumard and some brachiopods, chiefly Producti of somewhat different types from those above. The major portion of the fauna consists of pelecypods, many of which are different from those of the limestone, and are new species.

The black limestone at the base of the section is sparingly fossiliferous. A number of species were obtained, however, about 18 in all. This fauna is related to those above, especially to that of the "white Permian," and it also includes a species of *Richthofenia.*

These faunas are clearly pre-Mesozoic, though containing certain obvious Mesozoic relations. They are also different from any American faunas yet known, and are more especially related to the late Paleozoic faunas of Asia. Among related faunas may be mentioned that of China, described by Richthofen,* that of India, described by Waagen,† that of the Carnic Alps, described by Schellwien,‡ and, samewhat more remotely, that of the Palermo province, described by Gemmellaro,§ and the Permian of England, described by King.‖

Not only are these faunas very different from any known in America elsewhere, but they give evidence of being later in geologic time. For this reason I propose to give them a regional name which shall be employed in a force similar to Mississippian and Pennsylvanian. For this none more appropriate than one derived from the locality where they were first discovered can be found, and the term Guadalupian is suggested. The stratigraphic limits of the Guadalupian period will have to be determined on intrinsic evidence. At present it seems to include the whole section at the southern end of the Guadalupe Mountains, but the central fauna will be that of the "white" and "dark Permian" as described by Shumard.

I plan to resume field work in this region during the season of 1902, and hope to make important additions to the Guadalupian fauna, and to discover its relations with those which preceded and those which followed it. It is my purpose to more fully study and to describe this interesting fauna at an early opportunity.

Washington, D. C.

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* China, Richthofen, vol. iv, Berlin, 1883.

† Geol. Surv. India, Palæontologia Indica, Salt Range Fossils, vol. i, 1887.

‡ Die Fauna der Trog-Kofelschichten, K. K. Geol. Reichsanstalt, Bd. 16, Heft, 1, 1900.

§ La Fauna dei Calcari con Fusulina, Molluscoidea, Palermo, 1898-99.

‖ Mon. Perm. Foss. England, Paleontograph. Soc., 1850.

Art. XXXVI.—*The Reduction of Vanadic Acid by the Action of Hydrochloric Acid;* by F. A. Gooch and L. B. Stookey.

[Contributions from the Kent Chemical Laboratory of Yale University—CXII.]

Bunsen* and Mohr† have proposed to estimate vanadic acid by the action of concentrated aqueous hydrochloric acid, thus reducing it from the condition of oxidation represented by the pentoxide to that of the tetroxide, in accordance with the equation

$$V_2O_5 + 2HCl = V_2O_4 + H_2O + Cl_2,$$

and determining iodometrically the chlorine evolved.

In an attempt by Czudnowicz‡ to make use of this reaction by collecting in standard arsenious acid the chlorine evolved from the boiling mixture of hydrochloric acid and vanadic acid, and titrating the excess of the arsenious acid by iodine, accordant results were not obtained. On the other hand, Gibbs§ was able to determine with a fair degree of accuracy the small amounts of vanadium pentoxide found in the vanadio-tungstates and other complex combinations, by boiling with strong hydrochloric acid, collecting in potassium iodide the chlorine evolved, titrating the freed iodine with sodium thiosulphate, and calculating from the amount of iodine thus found the vanadium pentoxide corresponding to a change of condition from V_2O_5 to V_2O_4.

Milch‖ was unable to substantiate the work of Gibbs, and, obtaining in four experiments, upon approximately 0·2 grm., 0·5 grm., and 1·0 grm. of vanadium pentoxide, amounts of chlorine varying with the quantity of material handled and never exceeding one-fourth of the amount demanded by theory, was led to suppose that the degree of reduction was not constant, being larger in proportion as the quantity of pentoxide used was smaller. Milch concluded that while accordant results might be obtained by working with approximately similar amounts of material, the process afforded no ground for the calculation of the actual amount of pentoxide present.

Rosenheim¶ also tested the process, working with pure vanadates and pure vanadium pentoxide. Concentrated hydrochloric acid, of sp. gr. 1·19, was employed and care was taken to dry the distillation flask before introducing the materials, because even slight dilution of the acid lessened the evolution

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* Ann. Chem. (Liebig), xcvi, 265.

† Titrirmethode v. Aufl., 314.

‡ Ann. Phys., cxx, 17.

§ Proc. Amer. Acad., x, 250.

‖ Inaug. Dissert., Berlin, 1887, 10.

¶ Inaug. Dissert., Berlin, 1888; Ann. Chem. (Liebig), ccli, 197.

of chlorine in marked degree. Three stages were noted in the action of hydrochloric acid upon vanadic acid; the vanadic acid first dissolved to a solution of a deep brown color without perceptible evolution of chlorine; upon warming, the solution suddenly evolved chlorine and took on a deep green color; thereafter the evolution of chlorine became weaker, and the solution, giving off a small amount of chlorine on strong boiling, assumed a clear blue color. After this, further heating effected no change. It is recommended to raise the temperature gradually in order that the acid may not boil over into the receiver, and to keep this receiver cool so that iodine may not be volatilized by steam from the flask during the prolonged heating. In the experiments with ammonium vanadate, in which the heating was interrupted after the first violent evolution of chlorine, the iodine found in the receiver indicated, according to Rosenheim's figures, about 50 per cent of the vanadium pentoxide present; in three experiments longer continued the indications advanced about 6 per cent; and in three experiments continued presumably to the end—to the appearance of this blue color—the amount of pentoxide indicated were 61·77 per cent, 63·71 per cent, 61·89 per cent of the quantities actually taken, and further heating with another receiver until almost all the hydrochloric acid had been volatilized, resulted in no further progress in the reaction. Experiments with potassium vanadate, and with vanadium pentoxide resulted similarly. Rosenheim draws the inference that a titrimetric method based upon a theory of reduction from V_2O_5 to V_2O_4 by the action of hydrochloric acid, must lead to false conclusions, and suggests that his results lend probability to the supposition that an oxide of the formula $(V_2O_4)_2V_2O_5$ is formed, although the actual reductions observed by him are not quantitatively in accord with the formation of such a body —which implies a reduction covering about 66 per cent of the interval between V_2O_5 and V_2O_4. Rosenheim concludes that the whole method is to be rejected in quantitative estimations. An inspection of Rosenheim's tables, however, shows that the standards of the solutions of thiosulphate and iodine have been interchanged either in the printed record or in the calculation of results. In the latter event the actual indications of the process would be about 15 per cent higher than Rosenheim's figures, but still approximately 20 per cent below the theory of the reduction from V_2O_5 to V_2O_4.

In Holverscheit's* hands the process gave results most irregular and unsatisfactory. Ammonium vanadate was the material taken for the experiments, and the residue obtained by treat-

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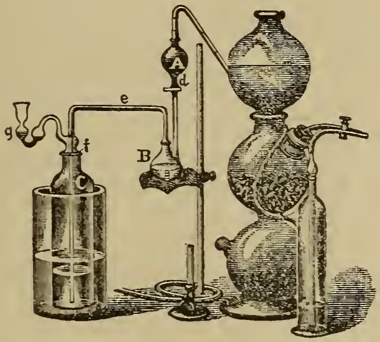
* Inaug. Dissert., Berlin, 1890.

ing this salt with potassium hydroxide and evaporating to expel ammonia, was boiled in a Bunsen distillation apparatus with concentrated hydrochloric acid. The solution, at first yellow, became green on long boiling. In some cases ebullition was kept up for 15 minutes. In working with amounts of material represented by 0·0585 grm., or 0·1171 grm. of V_2O_5 Holverscheit obtained from about 28 per cent to 39 per cent, or in the average about a third of the theoretical reduction, and, while noting the fact that by working with wholly concentrated ("ganz. konz. HCl") Rosenheim doubled this yield, ventures the opinion that it is scarcely conceivable that Gibbs obtained by boiling vanadic acid with hydrochloric acid and estimating the chlorine liberated, results even approximating the truth.

The green color of Holverscheit's residual solution shows, of course, an incomplete reduction—the consequence of the use of an acid which, as intimated, was not of full strength. Rosenheim, however, got the blue residual solutions characteristic of the condition of oxidation corresponding to V_2O_4. Why the deficiency in the chlorine indicated in the receiver in Rosenheim's experiments was so marked is not obvious, unless it be supposed that chlorine was lost from the apparatus in the sudden evolution which takes place when action begins. Our experience, moreover, shows that the liberation of chlorine begins as soon as the hydrochloric acid and vanadic acid come into contact. In our experiments upon the process, therefore, we have used a form of apparatus, shown in the accompanying figure, such that no chlorine can be evolved before the apparatus is connected and ready. For the retort we have used a Voit flask upon the inlet tube of which was sealed a stoppered funnel, while the outlet tube was sealed to a Drexel wash-bottle and this in turn was joined to Will and Varrentrapp bulbs. The Drexel bottle and bulbs used as receiver and trap



were charged with water containing 3 grm. of potassium iodide; the vanadate was introduced into the dry flask and the apparatus was adjusted. Hydrochloric acid was put in the stoppered separating funnel and, when all was ready, allowed to run into the flask. Connection was made between the funnel and a carbon dioxide generator, so that by passing carbon dioxide through the apparatus all danger of regurgitation might be avoided. Sometimes in the course of our work, too, a branched connection with the funnel tube was so arranged that either hydrochloric acid gas or carbon dioxide or both might, at pleasure, be sent into the apparatus. We have used in the experiments to be detailed ammonium vanadate either purchased in pure condition or made by precipitation with alcohol, or prepared from the oxychloride obtained by acting with chloroform upon ignited vanadium pentoxide. In each case the content in vanadium pentoxide was determined by ignition and confirmed by Holverscheit's* bromide process.

In Table I A are gathered results obtained by the use of the ordinary pure hydrochloric acid of the laboratory of sp. gr. 1·17; while in B of the same table are recorded results got by using acid of sp. gr. 1·20, specially prepared by saturation of the former acid kept cold by ice, with hydrochloric acid gas.

In these experiments, in which the precautions described to catch all the chlorine evolved were taken, the actual registration of chlorine amounts in the average to 92·62 per cent of the theory when the ordinary pure acid of the laboratory of sp. gr. 1·17 was used, and to 94·46 per cent when the specially concentrated acid of sp. gr. 1·20 was employed. While the error of these determinations would amount to a considerable figure when large amounts of vanadic acid are to be determined, it is obvious that a correction of, let us say, 6 per cent or 8 per cent upon the small proportions of vanadium pentoxide present in many of the complex salts to which Gibbs applied this method, would not change the significance of the analysis. Indeed, reference to the original shows that the formulæ deduced by Gibbs would in many cases apply as well to the corrected results as to the original figures. Thus it appears that, so far as concerns the special cases in which Gibbs used this method of analysis, the conclusion of Milch that the process affords no ground for the calculation of the amounts of pentoxide present, and Holverscheit's difficulty in supposing that results were even approximately true, prove to be unfounded, while Rosenheim's supposititious oxide disappears.

In the light of these results it is of interest to note the effect of a repetition of this treatment with strong acid of the residue

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* Inaug. Dissert., p. 48.

TABLE I.

NH_4VO_3 taken. grm.	HCl taken. cm^3.	V_2O_5 by calculation. grm.	V_2O_5 found. grm.	Error in terms of V_2O_5. grm.	Per cent.	Details of treatment.
				A		
0·0500	20 sp. gr. 1·17	0·0387	0·0348	0·0039	10·08	Boiled 5 minutes to blue color
0·1000	40 “ “	0·0765	0·0709	0·0056	7·32	“ “
0·1000	40 “ “	0·0765	0·0714	0·0051	6·67	“ “
0·1000	40 “ “	0·0765	0·0705	0·0060	7·84	“ “
0·3000	30 “ “	0·2295	0·2125	0·0170	7·41	Boiled to blue color
0·3000	25 “ “	0·2295	0·2179	0·0116	5·06	“
				B		
0·1000	30 sp. gr. 1·20	0·0765	0·0716	0·0049	6·41	Boiled to blue ; brown when re-saturated
0·1000	30 “ “	0·0765	0·0732	0 0033	4·31	“ “ “
0·1000	30 “ “	0·0765	0·0734	0·0031	4·05	“ “ “
0·1000	30 “ “	0·0765	0·0734	0·0031	4·05	“ “ “
0·1000	25 “ “	0·0765	0·0711	0.0054	7·06	“ “ “
0·1000	25 “ “	0·0765	0·0709	0·0056	7·32	“ “ “

TABLE II.

NH_4VO_3 taken. grm.	HCl taken.	V_2O_5 calculated. grm.	V_2O_5 found. grm.	Error. grm.	Details of treatment.
0·1000	10 $^{cm^3}$ sp. gr. 1·20	0·0752	----	----	Evaporated to dryness
	5* " "	"	----	----	" "
	5* " "	"	0·0737	0·0015	" "
					residue brown when treated with concentrated HCl.
0·1000	40 $^{cm^3}$ sp. gr. 1·20	0·0752	0·0700	0·0052	Boiled 15 minutes
	---- ----	"	----	----	Evaporated to dryness
	7* " "	"	----	----†	" "
	7* " "	"	----	----†	" "
	7† " "	"	0·0742	0·0010†	" "
					residue treated with KBr gave Br equivalent to 0·0001 V_2O_5.
0·1000	40 $^{cm^3}$ sp. gr. 1·20	0·0752	0·0699	0·0053*	Boiled 20 minutes
	Gas‡	"	0·0733	0·0029†	5 "
	Gas†	"	0·0751	0·0001†	5 "
					residue blue with concentrated HCl or with KBr gave Br equivalent to 0·0004 V_2O_5.

* Brown. † Blue. ‡ Green.

of the first action weakened by boiling. Plainly two methods of bringing about the re-treatment with strong acid are open: either the weak acid remaining after the boiling process may be wholly removed by evaporation and replaced by concentrated acid, or it may be cooled and re-saturated with gaseous acid. Table II contains the record of results obtained in both these ways.

These experiments show very clearly that several successive treatments with strongest hydrochloric acid, consisting either in the addition of the concentrated aqueous acid to the dry residue in successive portions, or in passing gaseous acid through the residual liquid cooled in ice-water, finally bring the residue to a condition of reduction in which the recharging of the liquid residue with gaseous acid produces no brown or green color but a clear blue. When this condition is reached the Holverscheit procedure produces no appreciable further reduction. The holding of the blue color when the solution cooled in ice-water is thoroughly charged with the gaseous acid, appears to be the best evidence of the complete reduction of V_2O_5 to V_2O_4; it is not sufficient that the boiled solution, in which the acid has been weakened, should be blue.

In the several manipulations of the repeated processes there is likely to be some mechanical loss of chlorine. For this reason, the direct titration of the residues by potassium permanganate in presence of a manganous salt was combined, as a control, with the determinations of the iodine set free by chlorine in the distillate, as shown in the experiments of Table III.

In these experiments we have again evidence that it is possible to effect the reduction of vanadic acid to within a few per cent of the amount present by a single treatment with concentrated hydrochloric acid, and that the amount of the reduction may be determined by titrating the residue with potassium permanganate. It is plain, therefore, that Gibbs' application of this mode of reduction and titration to the determination of the small proportions of vanadium pentoxide found in many of the complex salts studied by him is also justified.

The experiments show also that when the action of hydrochloric acid is sufficiently continued, ordinarily large amounts of vanadic acid may be completely reduced to the condition of the tetroxide; and the method of reduction is of special advantage in those cases which call for titration of the tetroxide by permanganate, since in such cases the use of Holverscheit's admirable method of reduction by hydrobromic acid is precluded.

TABLE III.

NH_4VO_3 grm.	Aq. HCl cm³.	V_2O_5 calculated. grm.	V_2O_5 found by chlorine in distillate. grm.	Error. grm.	V_2O_5 found by $KMnO_4$ as residue. grm.	Error. grm.
0·1000	25 sp. gr. 1·20	0·0765	----	----	0·0740*	0·0025 —
0·1000	25 " "	0·0765	----	----	0·0736*	0·0029 —
0·1000	25 " "	0·0765	----	----	0·0744*	0·0021 —
0·1000	30 sp. gr. 1·20	0·0765	0·0711	0·0054	----*	----
	Gas‡	----	0·0734	0·0031	0·0758†	0·0007 —
0·1000	25 sp. gr. 1·20	0·0765	0·0714	0·0051	----*	----
	Gas‡	----	0·0746	0·0019	----*	----
	Gas‡	----	0·0765	0·0000	0·0765†	0·0000
0·3000	25 sp. gr. 1·20	0·2295	----	----	----*	----
	Gas‡	----	----	----	----*	----
	Gas‡	----	----	----	0·2284†	0·0011 —
0·3000	25 sp. gr. 1·20	0·2295	0·2259	0·0036	----*	----
	Gas‡	----	0·2288	0·0007	0·2302†	0·0007 +
0·3000	25 sp. gr. 1·17	0·2295	0·2207	0·0088	----*	----
	Gas‡	----	0·2244	0·0051	----*	----
	Gas‡	----	0·2258	0·0037	----*″	----
	Gas‡	----	0·2269	0·0026	----*	----
	Gas‡	----	0·2281	0·0014	0·2293†	0·0002 —

* Residue after boiling was blue.

† Residue blue after boiling was still blue when re-saturated.

‡ Residue was cooled in ice-water and re-saturated with gaseous HCl.

JOHN WESLEY POWELL,

Founder and Director of the Bureau of Ethnology of the Smithsonian Institution, for thirteen years Director of the United States Geological Survey, died at Haven, Me., September 23d, in his sixty-ninth year.

Although well known locally for his scientific work and enthusiasm before the civil war, and acquiring military reputation in that war, he first came prominently before the scientific world and the wider general public by his daring exploration of the great Colorado Canyon in 1869, and since that date has been a conspicuous personage among American scientists for his zeal for science, his eminent administrative ability—shown in the organization and management of geographical and geological surveys and scientific bureaus—his broad grasp of scientific questions, his varied activities in the promotion of research in several branches of science, and by a charming personality.

He was born March 24th, 1834, at Mount Morris, then a small village in the Genesee Valley of Western New York. His parents were English, his father a Methodist clergyman who came to this country but a short time before the birth of his son. The requirements of his profession caused many changes of home, and the family moved to Ohio in his early childhood; eight years afterwards to Wisconsin; and again, when the boy was fifteen years old, to Illinois, which was young Powell's home until the breaking out of the civil war, in his twenty-seventh year.

The boy was an ardent lover of nature and the migratory home of the family during the days of his youth and early manhood gave him unusual facilities to see outdoor nature under many aspects, but the conditions of his environment were very unfavorable for obtaining a college or university training. He was fond of roaming, a keen observer, and in his studies was from the first strongly attracted to the natural sciences, especially such of them as could be pursued out of doors. He studied botany and geology and used every opportunity to learn these and the kindred sciences. He was for a while in the Illinois College at Jacksonville, later in Wheaton College and still later in Oberlin College in Ohio. Unable to attend any of these continuously, he alternated between teaching school and studying when and where the opportunity occurred. To him there was no continuing curriculum or studies available and, looking to an academic degree, he studied as the opportunities offered, now while teaching in some country or village school, then as a temporary student in some college, or, while roaming.

He made excursions and collected specimens which found their way into the museums of the several colleges and societies with which he had been connected. Some of these excursions are noteworthy. He journeyed to St. Paul on the Mississippi and across Wisconsin to Mackinaw. In 1856 he descended the Mississippi alone in a row-boat from the falls of St. Anthony to its mouth, making collections on the way. In 1857 he rowed the whole length of the Ohio River, from Pittsburg to its mouth, and in the fall of that year studied the geology and mineralogy of the Iron Mountain Region in Missouri. In 1858 he made a trip down the Illinois River to its mouth, and up the Des Moines River, returning, as usual, laden with specimens.

Meanwhile he had become a member of several local scientific societies as well as colleges. These institutions had given him much encouragement and some facilities in the prosecution of journeys, but this encouragement was moral rather than pecuniary and the necessary funds for the excursions—explorations we may call them—he was obliged to earn for himself by teaching during a portion of each year.

All this brought him into acquaintance with a great variety of people, scientific and otherwise, and the experience was rich in incident and adventure. I have some most pleasing recollections of the charming way in which he recounted some of these experiences to his intimate friends; of the enthusiasm and humor with which the stories were told, and the touches of philosophy with which they were embellished.

Such was the great university where he was educated. What a training it was for his future career! It often required as delicate tact, as careful diplomacy, as ingenious planning and skillful management, as enthusiastic argument and as persistent effort to carry out his plans to success, as it did later to deal with politicians in and out of congress and to successfully carry out the great works with which his name will be associated so long as science shall be studied. Those row-boat excursions on the gentler currents of the Ohio, Mississippi, and Illinois, were the forerunners of the daring one through the madly rushing waters in the great canyon, and the plans of the great Geographical and Geological Survey of the nation had their elements in these earlier trips.

His school changed when the great rebellion broke out. He enlisted as a private in the army and rose through the successive steps of lieutenant, captain, and major, in which office he lost his right arm at the battle of Shiloh. As soon as he recovered he returned to his post and continued in the service until the very end. He was made lieutenant-colonel and in the last days of the war received the commission of colonel, which he declined, not wishing to enter the profession of war, but the military title of major clung to him through life. His war experiences may here be considered as a sort of post-graduate study, following the gentler training of previous years, a schooling, both as private soldier and commander of a regiment, a training in the management of men in both field and office, and for bolder exploration.

The war over, he refused a lucrative civil position in his own town, as he already had a higher military one, and accepted a much less remunerative position as Professor of Geology, and Curator of the Museum of the Illinois Wesleyan University at Bloomington, which was followed later by a similar position in the Illinois Normal University.

In 1867, Professor Powell visited the Rocky Mountains of Colorado, taking with him his class in geology, for the double purpose of exploration and research, and for the instruction of his students in field work. He was practically the pioneer in the actual and practical introduction of extensive expeditions with students as a part of their college training for future field work, a phase of college instruction since so extensively practiced and which has been so rich in results.

Major Powell, on this excursion, became interested in the Colorado Canyon and its surroundings. For a century or more vague rumors of this region and its wonders had reached the outer world: stories of its awful and mysterious chasms, absolutely impassable and entirely preventing passage over the region. The stories became much more numerous and the information more definite after 1850, when the gold-seekers attempted to reach California; but curiously little was accurately known more than that the waters of the Rocky Mountains, from as far north as the 43d parallel, found their way through an awful canyon hundreds of miles in length to the borders of California and thence to the Gulf. It was reputed to be many thousands of feet deep. One and another had been on its brink here and there; that was about all, except the disappearance of luckless travelers who had by accident got into it at certain points.

In 1868 Major Powell organized a little party of mountaineers and others and explored a portion of the region, studied the problem, resolved on the exploration of the canyon, and finally went into winter quarters on the White River. From there he made further reconnaissances and other preparations for the bold work he had planned.

The transcontinental railroad, then under construction, had progressed far enough to bring in such supplies and appliances as were not otherwise obtainable, and in the early spring of 1869 the expedition left its winter quarters on White River and proceeded to where the Union Pacific Railroad crosses the Green River. Four small row-boats had been built in Chicago for the specially dangerous voyage and transported on the still unfinished railway to this place.

The small party consisted of but ten men. Their make-up is noteworthy. Of his nine companions, Major Powell describes four as having served in the army—in the war recently over; three were described as "hunters and trappers"—"Indian fighters" is incidentally mentioned; one as "a pensive young man;" and one was an Englishman "looking for a glorious trip."

With rations sufficient to last ten months, the little fleet started on its perilous trip on May 24th. The departure is briefly chronicled in the narrative. The people at the crossing turn out to see them start, he tells us, and "we raise our little flag, push the boats from shore, and the swift current carries us down." They disappear from the outside world and emerge from the mouth of the Grand Canyon August 29, and the next day arrive at the mouth of the Virgin River.

But not all of them. Only a few days earlier, the dangers of the passage becoming even greater than before, and a place occurring where it was thought they could get out of the canyon, ahead of them rapids or falls that seemed more dangerous than any before encountered, the dark abyss beyond visible but a short distance, three of the men resolved to leave the party while they could. They took out with them duplicate notes, that the results of the trip might not be lost with the party. They made their escape, and along the river below watched for fragments and traces of their abandoned companions.

Of the voyage itself and its brilliant success, of the results that grew from it, of the adventures and experiences encountered, I need not speak further. The subject forms a brilliant chapter in the annals of exploration and adventure in the interests of science.

Never was a bolder voyage planned and executed. I know of no equal in the annals of exploration and navigation. While comparisons between this and polar exploration are difficult, yet, there were in this features of the possibilities which seemed such eminent probabilities of disaster, and the dangers were of such a kind, as to deter the attempt. The disastrous end of the expedition, and the manner in which it would come about, seemed so plain that several of our enterprising newspapers published more or less minute accounts of its sad end; all of the party but one being lost was the most common plan of the tales; the nature of the dangers were such that one of the party had to be saved or no story written, except the disappearance of the party at an unknown time and place.

Some years later, while smoking an after-dinner cigar with some of his friends, he gave his reasons for his faith in undertaking it. I told him that for some years previous to his famous trip, I had been much interested in that canyon and had picked up all the rumors and information pertaining to it that I could, and being in Colorado while he was making the trip was intensely anxious as to his fate, for I thought it was a mad scheme; the canyon was a long and vastly deep one, cut mostly in strata lying relatively level, that owing to unequal hardness the erosion created waterfalls; that I had been reared in central New York where such waterfalls were especially numerous, cited Niagara and various other examples elsewhere; that this long and deepest canyon in the world was mostly in such rocks; that he embarked on the river at over 6000 feet elevation, to emerge some 500 or more miles below at nearly the sea level, the river having an average fall of ten or fifteen feet per mile and I had assumed that there must be great falls, and that the explorer must approach them from above.

He answered in substance, "Have you never seen the river? It is the muddiest river you ever saw. I was confident that I would find no considerable falls. Rapids I expected, of course, but not falls. I was convinced that the canyon was old enough, and the muddy water swift enough and gritty enough to have worn down all the falls to mere rapids. I entered the canyon with confidence that I would have no high falls to stop us, although there might be bad rapids, and I believed that we might overcome them in some way,—*and we did.*"

The next year he induced Congress to establish a geological and topographical survey of the Colorado River and its tributaries; it was placed under his direction and on it he was engaged much of the following ten years.

Incident to this, he became interested in the study of the arid regions and the problem of their improvement, also the impounding of the floods of the western rivers for the double purpose of controlling the floods and using the water for irrigation. The present hydrographic survey of the country is the outcome of his interest in this matter.

Between 1865 and 1875 many surveys in the western country were established, acting independently of each other, often in competition as well as rivalry, but not mutually helpful, and working under different departments of government.

Major Powell took an early and active part in the efforts that came up for a more satisfactory adjustment of these and their unification under a more rational system of operation. After much agitation, discussion and opposition, Congress finally, in

March, 1879, discontinued the separate surveys and established the United States Geological and Geographical Survey, under the Department of the Interior, and Clarence King was appointed Director.

Beginning with his first visit to the Rocky Mountains, Major Powell began ethnological and anthropological studies of the American Indians, for the Smithsonian Institution.

Ten years later, in 1876, Professor Henry, the then secretary, placed this along with other accumulated material pertaining to this subject in his hands, for arrangement and publication. The next year, his first volume of "Contributions to North American Ethnology" was published by the Geological Survey. Later followed five more of these quarto volumes under the same auspices.

With the establishment by Congress of the Geological Survey, the Bureau of Anthropology was also established in the Smithsonian Institution and Major Powell made Director, an office he retained twenty-three years and until his death, and the annual volumes of "Contributions" have continued in the same general form.

Mr. King resigned the directorship of the Geological Survey in 1881, and Major Powell was appointed his successor, retaining however the direction of the Ethnological Bureau, and for thirteen years he administered both offices, and both institutions were greatly widened in their work and improved in their methods under his administration.

In 1894 he resigned the office of Director of the Geological Survey and since then has devoted himself more to other work, ethnological, anthropological, psychological and philosophical.

Major Powell was endowed with an eminently philosophical mind, had great administrative ability, was rich in suggestions and fertile in originating and planning, in devising new work and methods and in improving old ones; had a personality of great force, persuasive in inducing men to do, and he inspired the confidence of those with whom he held official or social relations. He was a powerful advocate of reform in laws affecting the permanent welfare of the West and was for many years one of the most conspicuous personages in the scientific corps under the government. He was a member of the National Academy of Sciences and of other societies and clubs, and several colleges and universities conferred academic degrees upon him.

Major Powell was a faithful and genial friend, and his most interesting individuality made him many friends. He died of apoplexy. His wife and a daughter survive him.

Wm. H. Brewer.

New Haven, Conn.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Combination of Hydrogen and Oxygen.*—It is well known that many chemical reactions do not take place in the absence of moisture, but heretofore it has not been shown that the combination of hydrogen and oxygen could be prevented in this manner. By using a new method for preparing the gases, the electrolysis of barium hydroxide solution, H. BRERETON BAKER has succeeded in obtaining the mixture sufficiently pure and dry to withstand heating to redness without combination. Even when a coil of silver wire was heated to its melting point (over 1000°) in contact with the detonating gas it did not cause combination, but red-hot platinum wire and electric sparks produced explosions. The ordinary ignition-point of these gases is 600°. The interesting fact was noticed that when the tubes in which the experiments were made were subjected to only two days' drying in the presence of phosphoric oxide, instead of a period of ten days, which was employed for thorough drying, water was formed by heating and combination took place slowly without explosion. This is a result which is entirely different from what takes place, either with the moist or the perfectly dried gases. This behavior is explained by the hypothesis that without an electrolyte no chemical action is possible, and that since the water formed by the union of very pure gases is itself very pure, it is not sufficiently electrolytic to produce an explosion. During this investigation the important observation was made that hydrogen and oxygen combine slowly when exposed to direct sunlight if they are moist, but do not combine under this influence when they are perfectly dry. The exposure to sunlight took place outside a south window for four months, and the contraction of the moist mixture amounted to one twenty-third of its volume. On account of this result care was taken to dry the gases in darkness in preparing them for the experiments which have been described.—*Jour. Chem. Soc.*, lxxi, 400. H. L. W.

2. *Arsenic in the Animal Organism.*—Several investigators, especially Gautier, have recently arrived at the conclusion that minute quantities of arsenic exist normally in the animal organism, a fact which had been previously denied. The same conclusion has now been reached by BERTRAND after a series of very careful experiments. The human thyroid gland, thymus, skin, and other organs, have been found to contain arsenic, but Bertrand has avoided experiments with human tissues, because it is impossible to be sure that the individuals have not been subjected to treatment with arsenical medicines, or have not been otherwise contaminated with compounds of arsenic. He has also not attempted experiments with horses, because these animals are sometimes treated with arsenious acid. Investigations were

therefore carried out with the thyroid glands of calves and swine, then with the bristles of the latter animal, the horns of beeves, the feathers of geese, the hair and claws of dogs, etc. It was soon found that the horny and hairy products contained even more arsenic than the thyroid glands. The horns of oxen gave arsenic in the relatively enormous amount of 5^{mg} per kilo. Traces of arsenic were found in the hoofs, hide, and liver of a calf one month old, while larger quantities were evidently present in the corresponding parts of a heifer 18 months of age, although the horns of the latter contained less of it than those of more mature animals. It appears, consequently, that arsenic accumulates with the age of the animal. As a convincing proof of the normal occurrence of arsenic in an animal which had not breathed air contaminated by industrial fumes, the element was found in the thyroid glands of a seal which was captured in the vicinity of Spitzbergen.—*Bulletin*, xxvii, 847. H. L. W.

3. *Atomic Weight of Radium.*—By fractional crystallization of the greater part of the radiferous barium at her disposal, MME. CURIE has succeeded in obtaining about a decigram of radium chloride which appeared to be perfectly pure. Atomic weight determinations were made with this material with the result that 225 was found to be the atomic weight of the element, assuming that it is bivalent. Radium, therefore, appears to be a higher homologue of barium, with a place in the periodic table under barium and in a line with thorium and uranium. It is stated that pure anhydrous radium chloride is spontaneously luminous. —*Comptes Rendus*, cxxv, 161. H. L. W.

4. *Double and Triple Thiocyanates.*—A number of these compounds has been prepared by WELLS and his pupils. Most of the double salts contained cæsium as the alkali-metal, while ferric, lead, mercuric, cuprous, silver, thallous, magnesium, zinc, calcium and strontium compounds were obtained. It appears that the double thiocyanates are not generally formed in as great variety as the chlorides, bromides and iodides, but most of those obtained corresponded to known double halides. The calcium and strontium double thiocyanates, $2CsSCN \cdot Ca(SCN)_2 \cdot 3H_2O$. and $2CsSCN \cdot Sr(SCN)_2 . 4H_2O$ are of considerable interest, because double salts containing these alkali-earth metals as the negative constituent are very rare.

The triple salts show great variety in composition. Several of them crystallize remarkably well, and can be recrystallized from water. Fourteen of these compounds were obtained, belonging to seven different types, as follows:

I.	One salt, . .	$CsAgZn(SCN)_4 \cdot H_2O$
II.	One salt, . .	$Cs_2AgZn(SCN)_5$
III.	Five salts, analogous to	$Cs_2Ag_2Ca(SCN)_6 \cdot 2H_2O$
IV.	Four salts, analogous to	$Cs_3Ag_2Ba(SCN)_7$
V.	One salt, . .	$K_4Ag_2Ba(SCN)_8 \cdot H_2O$
VI.	One salt, . .	$CsAg_3Zn_2(SCN)_8$
VII.	One salt, . .	$CsAg_4Zn_2(SCN)_9$

The other salts belonging to type III have magnesium, manganese and nickel in place of calcium, and in one instance cuprous copper in place of silver. The replacements of barium by strontium and silver by copper give the other members of type IV. The four members of the latter type are isomorphous and resemble apophyllite in form.—*Amer. Chem. Jour.*, xxviii, 245. H. L. W.

5. *The Determination of Thallium in the Thallous State.*—To make this determination THOMAS adds auric bromide solution in excess to the warm thallous solution, then keeps the liquid warm for eight or ten hours, and finally filters off the metallic gold which is produced and weighs it. Three molecules of the thallous salt precipitate two atoms of gold. The test-analyses given are very satisfactory. The method will evidently be useful in analyzing substances containing both thallous and thallic compounds.—*Bull. Soc. Chim.*, xxvii, 470. H. L. W.

6. *Chemisches Praktikum*, von DR. A. WOLFRUM. 12mo, pp. 562. Leipsic, 1902 (Engelmann).—This volume is the first part, dealing with analytical operations, of a guide in laboratory work. The course is designed on a practical basis with the object of giving the student an idea of factory operations, and of encouraging the study of technical chemistry. This feature will doubtless appear still more conspicuously in the second part, not yet published, which will deal with chemical preparations. The volume under consideration covers a wide field of analytical chemistry in a very compact form. It embraces a course in quantitative analysis for the common metals and acid radicals, as well as the detection of the more important groups in organic compounds and the application of these tests to a large number of natural and artificial organic products. Quantitative analysis is presented in all its branches; not only the gravimetric and volumetric methods for determining inorganic substances are included, but also the quantitative determination of organic groups, gas analysis, molecular weight determination, toxicological analysis, and many methods of technical analysis. The methods appear to be well chosen, so that the book will be useful, not only to students pursuing courses in laboratory work, but also to analytical and technical chemists. H. L. W.

7. *Vacuum Thermo Element.*—PETER LEBEDEW discusses the advantages of enclosing a thermo element in rarified air. Kundt and Marbury have shown that a body loses heat less rapidly in a vacuum, and this fact doubtless lies at the root of the superior efficiency of a bolometer or thermo element in a vacuum. The author employs a thermo element of platinum constantin, diameter of the wire $d = 0{\cdot}025^{mm}$. The sensibility steadily increases and reaches its highest point at a pressure of $0{\cdot}01^{mm}$. It is believed that this method will allow measurements of electrical waves, which hitherto could not be made.—*Ann. der Physik*, No. 9, 1902. pp. 209–213. J. T.

8. *Electromotive Force of Ozone.*—In the course of an investigation on the possibility of converting the heat of deozonization

into electrical work, A. **Brand** determined the electromotive force of ozone. The electromotive force of the O_2 and the O_3 electrode of a Grove gas cell was measured against a normal mercury element (mercury covered with mercuric sulphide), in a normal sulphuric acid ($\frac{1}{2}H_2SO_4$ g. to the liter). It was found that the electromotive force with increasing proportion of ozone approached a limit which at 17° was 0·919; at 0°, 0·950 volt.—*Ann. der Physik*, No. 10, 1902, pp. 468–474. J. T.

9. *Influence of Electrification of the Air on Electric Sparks.*—The passage of electricity through a gas is such a complicated phenomenon and is influenced by so many conditions that it is difficult to frame a comprehensive theory of it. **Ernst Lecher** shows that a hitherto unknown condition results from electrifying the air or gas through which the electric spark is discharged. For this experiment two sources of electrification are employed. An induction coil produces the spark and a Holtz machine serves to electrify the dielectric. Many interesting phenomena result from this arrangement. The author believes that the phenomena are due to an ionization of the discharge space.—*Ann. der Physik*, No. 10, 1902, pp. 442–451. J. T.

10. *On a new Reaction between Electrostatic Tubes and Insulators.*—M. W. **de Nicolaiéve** believes that certain attractions and repulsions due to an electrostatic field set up in the process of electrolysis form a new phenomenon and confirm Professor Poynting's theory of the action of tubes of force.—*Phil. Mag.*, No. 19, July, 1902, pp. 133–138. J. T.

11. *A Magnetic Detector for electrical waves.*—In a communication to the Royal Society, of London, **Marconi** describes his magnetic detector. On a core of thin iron wires is wound a coil consisting of one or two layers of insulated copper wire, and over this and separated from it by insulating material is wound a second and longer coil. The ends of the inner coil are connected to earth and the aerial conductor; and the ends of the outer coil to a telephone. The iron core is magnetized by a permanent magnet at one end, which is rotated by clockwork so as to cause a continual slow change in the magnetization. The magnetization lays behind the magnetic force, owing to hysteresis; but when a high frequency current passes through the inner winding there is a decrease in the hysteresis. A sudden variation in the magnetization of the iron results, and this results in inducing a current in the coil connected to the telephone. This receiver is more sensitive than the coherer. Experiments have been carried out between points 135 miles apart. This detector seems to be Rutherford's magnetic detector.—*Nature*, July 31, 1902, p. 334. J. T.

12. *Radiations from Radioactive Substances.*—Professor **Rutherford** and Miss **Brooks** conclude from extended observations that radioactivity is a very complicated phenomenon. Both uranium and radium emit negatively charged particles with high velocities, similar in all respects to cathode rays. Uranium, radium and thorium emit rays which are not deflected by the

magnetic field and are absorbed by gases and thin layers of metal. These rays differ from one another in penetrating power. The emanations from thorium and radium differ greatly in their rates of decay of radiating power. The presence of emanations gives rise to a complicated phenomenon of "excited" radioactivity. Elster and Geitel have recently shown that a negatively charged wire in the open air, free from all possible contamination of radioactive substances, becomes strongly radioactive. This activity decays at a different rate from that due to thorium and radium and is of greater penetrating power.—*Phil. Mag.*, No. 19, July, 1902, pp. 1–23. J. T.

13. *Induced Radioactivity in Air.*—It has been shown by Elster and Geitel that a strongly electrified wire becomes after several hours strongly radioactive. The authors conclude that the atmosphere contains some radioactive substance which is attracted to the wire, and that this emanation is like that from thorium. Professor J. J. THOMSON, however, comes to the conclusion that it is not necessary to make this assumption and believes that negatively electrified surfaces may become radioactive without the deposition upon them of substances possessing radioactive properties. He found that a negatively electrified wire placed in a closed vessel, the enclosed air or gas being exposed to Rontgen rays, became radioactive. When the enclosed gas had been bubbled through air the effect was very large. Professor Thomson thinks that the ionizing power of the wire may be due to a kind of polarization which produces an electric field which makes the wire into a cathode emitting cathode rays of feeble penetrating power, which ionize the gas in the neighborhood of the wire. —*Phil. Mag.*, No. 21, 1902, pp. 352–367. J. T.

14. *Deviable Rays of Radioactive Substances.*—Professor RUTHERFORD and Mr. GRIER have discovered that uranium, thorium and radium all emit both deviable and non-deviable rays. They differ from polonium, which does not emit deviable rays. Uranium gives out more deviable rays than radium or thorium. The authors believe that most of the deviable rays are given out by a secondary product, produced by a disintegration of the uranium or thorium atom or molecule. These secondary products differ from the uranium or thorium in chemical properties.—*Phil. Mag.*, No. 21, Sept., 1902, pp. 315–330. J. T.

15. *Removal of Negative Electricity from the air by falling drops of water.*—A. SCHMAUSS shows that there is a possibility that each rain drop passing through higher layers of air rich in ions draws with it negative ions and conveys them to the earth. —*Ann. der Physik*, No. 9, 1902, pp. 224–237. J. T.

16. *The Elements of Experimental Phonetics;* by EDWARD WHEELER SCRIPTURE. Pp. xvi + 627. Charles Scribner's Sons. Yale Bicentennial Publications.—Valuable contributions have been made by Professor Scripture to the analysis of speech sounds by means of his ingenious apparatus for enlarging and tracing the curves recorded by the graphophone, and his experi-

ments are fully described and a large number of curves given in a series of plates at the end of the volume. The careful analysis of these curves leads to a number of most interesting and important results, and enables the author to arrive at a definite conclusion upon several controverted points, such as the action of the vocal cords, the theory of vowel sounds, the melody and rhythm of speech, the duration of long and short vowels, etc. In regard to the action of the vocal cords, the opinion is strongly maintained that they do not vibrate like stretched strings or membranes, but, at least in the chest register, act by alternately opening and closing the orifice between them, somewhat (one would judge) in the manner of a striking reed blown from the wrong side ; the mechanics of such a vibration is not altogether obvious, but, putting aside this difficulty, the hypothesis makes the cord tone consist of a series of puffs of air similar to those produced by a siren, and more or less explosive in character. Many of the curves appear to support this view. One of the consequences, however, which the author draws from this theory, and insists upon repeatedly (pp. 41, 94, 97, 263, etc.), cannot be accepted : it is that the cord tone, since it consists of such a series of explosive puffs, cannot therefore be resolved into simple harmonic (sinusoidal) constituents by the use of Fourier's Theorem. As a matter of fact, a series of explosive increments and decrements of the air pressure can be expressed by a Fourier expansion, even when the rise and fall are assumed to take place really instantaneously, that is, in a mathematically infinitesimal time, and for however small a fraction of the interval between two puffs the increased pressure endures; if the puffs are all alike and occur at equal intervals of time, then the lowest term in the Fourier series will have a frequency equal to the number of puffs in a second ; if they are not all similar the series will begin with a term of lower frequency, but in any physical case there can be no doubt that the expansion is possible, and any argument based upon the supposed non-harmonic character of the cord-tone will be fallacious. The convenience and utility of such an expansion in any given case is another question. In the discussion of the vowel sounds, some confusion is introduced by this erroneous assumption; but much experimental evidence is adduced in support of the theory of Willis, according to which the resonance tones characteristic of each vowel are fixed in pitch and have no necessary relation to the cord tone, and against Helmholtz's theory that the resonance tones are always harmonies of the cord tone.

Taken as a whole, Dr. Scripture's work is distinctly interesting as well as instructive ; it is written with spirit and enthusiasm, the illustrations are admirable, and the descriptions of apparatus and of experimental methods are so clear and detailed that it might well serve as a laboratory manual. To the student of phonetics it will of course be indispensable on account of the wealth of scientific material which it contains. H. A. B.

II. GEOLOGY AND MINERALOGY.

1. *United States Geological Survey.*—The following publications have recently been issued.

TWENTY-FIRST ANNUAL REPORT, PT. III. 644 pp., 68 pl., 104 figs.—This volume contains papers on general geology, ore deposits and the Philippines. Professor HOBBS's report on the Newark System of Pomperaug Valley, Conn. (reviewed in this Journal, vol. xiii, p. 70), occupies pp. 19–160. "The Laccoliths of the Black Hills" by Professor JAGGAR (pp. 163–303) is a description of the interesting intrusions of rhyolite and phonolite in western South Dakota and eastern Wyoming. The laccoliths are so numerous and the amount of erosion so varied that all parts of a typical intrusion—conduit, basement contact, wedge, flank, crest—are exposed in different parts of the region. These intrusions are assigned to the Eocene and are an effect, not the cause, of the great fractures and dome uplift of the Black Hills. "The fractures reached downward to a zone where molten rock was under pressure. The liquid shot upward into every ramification of the fracture system." ERNEST HOWE has made an extremely interesting series of laboratory investigations (pp. 291–303) imitating the processes of laccolith intrusion and consequent deformation of the invaded beds. Professor VAN HISE contributes a paper (pp. 313–434) on the "Iron Deposits of the Lake Superior Region" in which both the geologic and economic aspects of the area are discussed. The Arkansas Bauxite and the Tennessee white Phosphate deposits are described by C. W. HAYES, pp. 435–487. "The Report on the Geology of the Philippine Islands" (pp. 493–625) is by G. F. BECKER. It contains general descriptions of the rock types and formations, the mineral resources, a bibliography and a paper by K. MARTIN on Tertiary fossils.

TWENTY-FIRST ANNUAL REPORT, PT. IV. 741 pp., 156 pl., 329 figs. HYDROGRAPHY; by F. H. NEWELL, Hydrographer in charge. The tabulation and interpretation of stream measurements for 1899 has added much data which is essential if intelligent use is to be made of the water resources of the country. Work has been carried on in all parts of the country, and the descriptions (pp. 45–488) are so given as to render the facts directly useful to interested people. A special paper on the Geology and Water Resources of the Black Hills region (pp. 489–599) is written by N. H. DARTON. (Reviewed in this Journal, vol. xiii, p. 68.) "The High Plains and their Utilization," by WILLARD D. JOHNSON (pp. 609–741) is an interesting study of the topography, climate and history of the region including parts of Texas, Kansas, Nebraska, New Mexico, and Colorado. The causes of agricultural failure and the conditions necessary to success are discussed in the light of recently acquired knowledge of soil character, streams and underground water.

MONOGRAPH XLI.—Glacial Formations and Drainage features of the Erie and Ohio basins; by FRANK LEVERETT. (Held for review.)

BULLETINS. No. 179.—Bibliography and Catalogue of the Fossil Vertebrata of North America; by OLIVER PERRY HAY. Pp. 1–868. Washington, 1902.—The author has rendered an immense service to his fellow paleontologists in completing this list of all the fossil vertebrates described, up to the end of 1900, from all that part of the North American continent lying north of Mexico. The list of systematic names recorded reaches nearly 10,000; and the number of titles referred to in the bibliography is about 4600. The author estimates that there are over 40,000 citations recorded. The method of arrangement of the statistics and the mode of citations have greatly condensed the mass of material. The specific names are arranged according to their systematic order in the catalogue. A separate key is given of this catalogue, and under each scientific name in the catalogue are given all the citations recorded, but abbreviated to author's name, date, and a letter (A, B, C, etc.) standing for the separate papers of each author published during one year. In the Bibliography these letters mark the several papers whose titles are given in full. By this means the size of the volume is greatly reduced without omitting the important details called for by the user. A complete index of all the systematic names cited occupies the last 72 pages. The author deserves the gratitude of all paleontologists who may use this model catalogue of fossil vertebrates.
H. S. W.

No. 182.—A report on the Economic Geology of the Silverton Quadrangle, Colorado; by F. L. RANSOME. 258 pp., 16 pls., 23 figs. This is a complete and detailed report on the economic geology, of the ore deposits and mining operations of a quadrangle situated in the midst of the San Juan Mountains in southwestern Colorado. The first part of the report consists of a general description and discussion of the ore deposits and includes a chapter on the general geology of the region by Whitman Cross, while the second part consists of detailed description of special areas and individual mines. The area is covered with a complex of volcanic rocks consisting of a thick series of tuffs, agglomerates and lava flows. The ores occur in these rocks; either as lodes or as nearly vertical stocks of almost solid ore. The chief ore minerals carrying silver are galena, tetrahedrite, enargite, stromeyerite, bornite and chalcopyrite. Gold is present in the ore as native gold almost entirely, no important occurrences of tellurides being known. The ores were deposited from acid solutions for the most part in preëxisting openings and some of the deposits show the effects of descending surface waters in the secondary enrichment of their upper portions. W. E. F.

No. 188.—Bibliography of North American Geology, Paleontology, Petrology and Mineralogy for 1892–1900 inclusive; by F. B. WEEKS, 717 pp. This bulletin is a combination of bulletins Nos. 130, 135, 146, 149, 156, 162, 172 with the bibliography of the literature for 1900. The index (bulletin 189) is to be used in connection with this bibliography.

No. 189.—Index to North American Geology, Paleontology, Petrology and Mineralogy for 1892–1900 inclusive; by F. B. Weeks. 337 pp. The indexes contained in bulletins Nos. 130, 135, 146, 149, 156, 162, 172 are here combined. See above No. 188.

No. 190.—A Gazetteer of Texas; by Henry Gannett. 162 pp., 8 pls.—In addition to the gazetteer proper, Mr. Gannett gives a brief description of the topography, climate, character of the population, etc.

No. 191.—North American Geologic Formation Names: bibliography, synonymy, and distribution; by F. B. Weeks. 448 pp.—This volume is a valuable addition to the scientific registers of facts grown too bulky for memory. The author does not claim that every name that should appear in such a list is actually needed, but every name reported in a list of some five hundred official and serial publications which are given is mentioned. The author has made the list of special value to investigators by presenting the facts exactly as they were presented by the author of the name; thus throwing upon the user of the register the decision as to which name is entitled to first consideration as the proper name of any particular formation. When it is stated that the bulletin contains 448 pages, the indispensable nature of such a register, for the avoidance of further duplication of names, is apparent. We are pleased to see also that it is proposed to continue this list in the annual Bibliography and Index of North American Geology, which has become a feature of the Bulletins of the United States Geological Survey. H. S. W.

No. 192.—A Gazetteer of Cuba; by Henry Gannett. 113 pp.

No. 193.—Geological Relations and Distribution of Platinum and associated metals; by J. F. Kemp. 91 pp., 6 pls., 9 figs.

No. 194.—Northwest Boundary of Texas; by Marcus Baker. 50 pp., 1 pl., 5 figs.—An account of the surveys of western Texas from 1859 to 1900 is given and the present status of the boundary is discussed. "Our knowledge of the location of the west boundary of the panhandle is very imperfect," and Mr. Baker advises re-mapping the area.

Water Supply and Irrigation papers Nos. 57 (Alabama–Montana) and 61 (Nebraska–Wyoming).—Preliminary List of Deep Borings in the United States; by N. H. Darton.—A list of wells over 400 feet in depth has been compiled for each State —arranged alphabetically and accompanied by references to the literature.

2. *Iowa Geological Survey;* by Samuel Calvin, State Geologist. Vol. xii, Annual Report 1901, with accompanying papers. —Detailed geologic maps have been completed for fifty-three counties in Iowa, seven counties having been surveyed during 1901. The report on the Mineral Production in Iowa for the year (by S. W. Beyer) shows a substantial increase in coal and gypsum, but a decided falling off in the production of zinc. The

Geology of Webster County, by Frank A. Wilder, contains (pp. 138–224) an exhaustive study of the Iowa gypsum deposits, as well as those of other American and of foreign localities. The Geology of Henry County is written by T. E. Savage. Cherokee and Buena Vista Counties have been mapped by Thomas H. Macbride, who presents new facts regarding the limit of the Wisconsin drift and its effect on topography. The Geology of Jefferson County is by J. A. Udden, and that of Wapello by A. G. Leonard, Assistant State Geologist. Vol. xii is fully up to the high standard of previous volumes of the Iowa survey, especially as regards contributions to stratigraphy and glaciology.

3. *The Evolution of the northern part of the Lowlands of Southeastern Missouri;* by C. F. Marbut. University of Missouri Studies, vol. i, No. 3, 63 pp., 7 pls.—Southeastern Missouri consists of belts of lowlands enclosing belts and isolated areas of upland. As the result of field study (involving the making of a topographic and a geologic map), Professor Marbut finds the explanation of these belts as follows: The Mississippi River flowed west of (the present) Crowley Ridge, then between Crowley and Benton ridges and finally through Benton Ridge at Grays Point. These successive channels were abandoned in favor of small tributaries of the Ohio; "the Mississippi has been captured by the Ohio twice in succession."

The author's former paper on this region (Bos. Soc. Nat'l Hist., vol. xxvi, pp. 478–488) described Crowley Ridge as a *cuesta*, and this erroneous interpretation shows clearly the uncertain character of conclusions based on map study unaccompanied by field work. As Professor Marbut says: "To have determined the whole succession of events and the processes operating to produce them, would have been probably impossible by the methods of library study alone" (p. 39).

4. *Geology of the Potomac Group of the Middle Atlantic Slope;* by W. B. Clark and A. Bibbins. Bull. Geol. Soc. Am., vol. xiii, pp. 187–214, 7 pls.—A narrow belt of sand and clays, mostly unconsolidated and often ferruginous, form the basal element of the Atlantic Coastal plain. These sediments—called collectively the Potomac Group—are described in detail as regards their composition, fossil contents and economic importance. The relationship of the beds is given as follows:

$$\text{Cretaceous}\begin{cases}\text{Raritan}\\ \text{Patapsco}\end{cases}$$

$$\text{Jurassic (?)}\begin{cases}\text{Arundel}\\ \text{Patuxent}\end{cases}$$

In regard to the conflicting evidence of paleontology and paleobotany (see this Journal, vol. ii, p. 433, Dec. 1896), the authors think it essential to suspend final decision until more exhaustive investigations of the faunas and floras has been made throughout the entire Coastal region.

5. *Pleistocene Geology of Western New York*; by H. L. FAIRCHILD. Report of progress for 1900. 20th Ann. Rept. N. Y. State Geologist, pp. 105–139; pls. 9–41.—Professor Fairchild has made a special study of the Iroquois shore line between Richland and Watertown, and finds that the warping of the Ontario basin has occurred mostly since the extinction of glacial Lake Iroquois, and that "the rate of deformation has been much greater than the present rate." The territory between Syracuse and Oneida was studied with reference to the higher channels cut by overflow of glacial waters.

6. *Michigan Geological Survey*; ALFRED C. LANE, State Geologist. Annual Report, 1901, pp. 1–304, figs. 1–7, plates i–xv. —Besides the ordinary reports of progress for the year this volume contains a paper by B. E. Livingston on the Distribution of Plant Societies of Kent County, on the lines introduced by Dr. H. C. Cowles. Mr. F. B. Taylor presents an excellent graphic representation of the nature and distribution of surface deposits of Lapeer County (Plate VI). A detailed analysis of the local faunules of the Traverse (Devonian) formation of the northern part of the State is given by A. W. Grabau: the State Geologist publishes a geological map (scale 1 in. = 56 miles) revised up to 1902: an illustrated paper on Wave Cutting on the west shore of Lake Huron is contributed by C. H. Gordon. H. S. W.

7. *On Vertebrates of the Mid-Cretaceous of the Northwest Territory*; by HENRY FAIRFIELD OSBORN and LAWRENCE M. LAMBE. Geol. Survey of Canada. Robert Bell (acting) Director. Contributions to Canadian Paleontology, vol. iii (quarto). 81 pp., 22 pl. Ottawa, 1902.—Osborn and Lambe have contributed a second part to the quarto memoirs on Canadian fossil vertebrates, begun by the volume on the Cypress Hills species contributed by the late E. D. Cope, in 1891. Professor Osborn contributes the first paper on the *Distinctive features of the mid-cretaceous fauna*, in which he reaches the conclusion "*that the Belly River fauna is more ancient in character both as to the older types of animals which it contains and as to the stages of evolution among animals which are also represented in the Laramie.*" (p. 21.)

L. M. Lambe contributes the second descriptive paper:—*New genera and species from the Belly River series* (*mid-cretaceous*), in which are described thirty-four species, of which sixteen are new. H. S. W.

8. *Queneau on Size of Grain in Igneous Rocks*;* by ALFRED C. LANE. (Communicated.)—In this paper (a thesis for the master's degree) the author takes up the theory of grain proposed by myself in part 1 of vol. vi of the reports of the Geological Survey of Michigan, and successfully applies the same to the "Palisade" intrusive near New York, and, with very interesting re-

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* Size of grain in Igneous Rocks in Relation to the Distance from the Cooling Wall, by Augustus L. Queneau. School of Mines Quarterly, January 1902, pp. 181–195, Contributions from the Geological Department of Columbia University, vol. ix, No. 80. (This paper was briefly noticed on p. 70.)

sults, to the minette dike of Franklin Furnace, New Jersey. The mathematical foundation has also been worked out for him anew by Prof. Woodward, with accordant results, but whereas I treat the case where the country rock is appreciably heated up, he takes only the case in which the walls of the cooling body are kept at a constant temperature.

Unfortunately we have taken different initial temperatures, and otherwise the two methods differ so that the curves and numerical tables cannot be directly compared. The curves of falling temperature given in my paper are referred to the time, whereas in Queneau's paper the abscissas are laid off proportional to the square root of the time. The early stages of cooling are given, therefore, in more detail, but his remark at the bottom of page 188 as to the slopes of all the curves being equal, is erroneous. It applies to my curves, but not to his.* Queneau's results upon the minette of the Franklin Furnace are especially noteworthy; both biotite and apatite vary in size according to the distance from the margin. This shows clearly that these minerals are mainly not pre-intrusive. Moreover, the size of the apatite increases clear to the center, while the biotite has a zone of nearly uniform grain occupying nearly the middle two-thirds of the dike. The following inferences of theoretical interest, which, however, Mr. Queneau does not mention, may be drawn:

The apatite was formed early, much before the biotite, and probably before the dike had lost even one-tenth of its initial temperature. The dike therefore must have been largely viscous when the apatite formed, and the broken condition of the apatite mentioned by Queneau may well be attributed to a strain in the otherwise viscous magma.

The biotite was formed later, and supposing, as seems likely from the figure, that the breadth of the zone that has a markedly less grain than that at the center is about one-eighth of the width of the dike, we must infer that it was formed when the dike retained but little more than half its initial excess of temperature.

A small dike of diabase, a meter wide, shows in its feldspars that the temperature of its injection was not much above that of the formation of feldspar, at any rate.

When he discusses the Palisade trap sheet, however, Mr. Queneau neglects to mention that he does not carry his section clear across, nor does he state the thickness of the sheet, nor say

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* Some other minor mistakes in our papers are: on page 187, one column should be headed $x = \cdot 85c$, and line five above should begin with ·95c. I believe there are also some numerical mistakes in the body of the tables. The last column of the table on page 188 is erroneous, for instance. Also on page 191 the units for x are not in square but linear millimeters. In my table, when $m=7$ if $q = \cdot 92$, the entry should be ·74265, and if q is ·91 the entry should be ·73000. In my equation 11 an n has crept in that does not belong there, and on page 117, line 2, for (w) read $(2w)$. Also, in the plate, the decimal point for the horizontal unit is wrongly placed,—it should be $\log q = -0{\cdot}1$.

whether he continued the section until the grain appears uniform. From Kümmel's report for the New Jersey Geological Survey, 1897, p. 62, we learn that at one of the points—Fort Lee—the sheet is 950 feet thick, of which Queneau's section covered only about 100 feet. Of the grain, Kümmel says that while on the whole the trap is coarse-grained, near the contact it is fine-grained or occasionally slightly glassy, but this rapidly increases in size within a few feet of this shale, where coarsest tin tabular crystals of feldspar occur, two or three-eighths of an inch in diameter. The King's Point trap near Weehawken he estimates from 700 to 875 feet thick, and again Queneau can only cover the margin of varying grain (3449^{cm}, or 105 feet).

From his plates and figures it appears that, so far as he measured, the feldspars still steadily and uniformly increase in size, but the rate of increase of the King's Point augite drops decidedly between 23 and 34 meters. Thus the breadth of the zone of augite which was formed before the center cooled is not far from 100 feet, or about one-eighth of the total breadth. This would imply that the consolidation of the augite took place under conditions of temperature, etc., a little nearer those of the initial magma than those of the country rock, and that the feldspar was earlier formed. We may also infer from his equations of grain (as shown by investigations of mine as yet unpublished) that there is a contact zone of noticeable thickness in which the temperature was appreciably increased, and that while his data are consistent with Kümmel's observations, the grain of the augite at the center is not more than 5^{mm}, being probably about 3^{mm}—a result which it would be interesting to verify. Had we the thickness noted, and that of the contact zone if convenient, and a section representing the central belt, we could have a check on the theory, as well as on the accuracy of the observations; for the estimation of the grain is a difficult matter, and I doubt if an accuracy of 10 per cent can be obtained, though the divergence of Queneau's observations from his curves is no fair test, for he has done himself injustice, since the curve of linear grain of a great intrusive sheet with a contact zone, like the Palisades, ought not theoretically to be a straight line, but is enclosed by three straight lines as external tangents, which it will usually follow very closely, having only short easement curves near the points of tangency.

Queneau's statement that the zone of varying grain will vary inversely as the temperature of the country rock, is not mathematically accurate, and is probably intended merely as a rewording of what I say on page 111, that the hotter the country rock the less pronounced will be the zone of finer grain. But I may say that if we have the curve of grain located well enough to determine the three tangents just mentioned, we may infer the ratio of the temperatures of injection and consolidation, the thickness of the intruded sheet and the breadth of the contact zone appreciably affected, as well as a constant involving the diffusivity of the rock and the tendency of the particular mineral to crystallize. So that we may often give a shrewd guess at the size of the sheet from observations on the grain only at one side. I hope to take up this matter soon.

Geological Survey of Michigan, Lansing, Mich.

9. *Les Roches alcalines caractérisant la Province petrographique d' Ampasindava;* by A. Lacroix. (Nouv. Archives du muséum d' histoire naturelle. 4th Ser., Tome I, pp. 152, pl. 10, 4°, Paris 1902, Fascicule I.)—This work is based chiefly on specimens and observations collected by M. Villiaume, a colonial official. It is divided into three parts, the first being a description of the geology and rocks of Nosy Komba, an island off the northwest coast of Madagascar between the island of Nosy Bé and the bay of Ampasindava.* In this portion are described gabbros, nepheline syenites of various types, including dark basic varieties passing into the essexites. They are accompanied by acidic dike rocks, and there is described, in addition, the phenomena of the contact of these intrusive masses, both exomorphic and endomorphic. The second part relates to the occurrence and petrography of igneous rocks from portions of the mainland in this part of Madagascar and from Nosy Bé. In this are described granites with soda amphiboles, pulaskite, nordmarkite and laurvikite types of syenites, essexites, quartz bostonites, camptonites, phonolites, trachytes, monchiquites, ijolite, tinguaite, etc., etc.

The petrography of these rocks is given with the care and detail for which the author's works are so well known. A number of analyses enhances the value of the memoir, which adds greatly to our knowledge of this little known region. The appearance of Fascicule II, containing chapter iii, giving the general conclusions and resumé, will be awaited with interest by petrographers. L. V. P.

10. *Ueber mariupolit, ein extremes Glied der Elaeolithsyenite;* von J. Morozewicz (Tscher. Min. u. Petro. Mitt. Band xxi, s. 238, 1902).—On the north coast of the sea of Azov in Russia lies an area of crystalline rocks which is being investigated by the author. In the district of Mariupol a portion of this area, between gneiss and granite and comprising about 10–12 square kilometers, has been found to consist of eleolite syenite and pyroxenite. The investigation of this former rock shows it to consist of 73 per cent albite, 14 per cent of nephelite, 7·6 per cent of aegirite, 4 per cent lepidomelane and 1·6 per cent zircon. The mass analysis gave the following results :

SiO_2	ZrO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	H_2O	Sum.
62·53	1·08	18·72	3·26	0·34	0·16	0·08	0·54	0·79	11·77	0·68 =	99·95

In this the relation $K_2O : Na_2O :: 1 : 24$. The texture is variable, sometimes coarse, sometimes fine, and sometimes porphyritic. The feldspathic components are set through with aegirite needles.

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* (Stieler's Hand Atlas gives Ampassandava.)

Separate analyses of the mineral components are also given. To this rock of the syenite family composed almost solely of soda-bearing constituents, the author gives the name of Mariupolite.

L. V. P.

11. *Dahamit, ein neues Ganggestein aus der Gefolgschaft des Alkaligranit*; von A. Pelikan. (Denkschriften der mat.-nat. wiss. classe der K. Akad. der. Wiss. Wien, 1902. Bd. lxxi.)—In an article dealing with the petrography of a rock collection from the islands of Socotra, Abd el Kuri and Semha the author describes a dike rock of a chocolate brown color, compact texture, containing red phenocrysts of thin tabular feldspar. The microscopic study and the chemical analysis shows the rock to consist of 6·8 per cent riebeckite, 43·8 per cent albite, 2·8 per cent anorthite, 12·2 orthoclase, 31·5 per cent quartz. The chemical analysis by E. Ludwig gave

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	Sum.
74·02	13·56	1·93	1·09	0·23	0·56	5·80	2·06	1·05 =	100·30

The phenocrysts are albite or albite-oligoclase, containing the small amount of anorthite. The other components are mixed in the groundmass. The author suggests the name from the locality, Dahamis, and offers the fact that it differs from grorudite (quartz tinguaite) in containing riebeckite instead of aegirite, as a reason for the new name. He overlooks entirely, however, the fact that Osann (Tscher. Min. Mitt., vol 15, p. 435, 1895) has already described a dike rock consisting of alkali feldspars, quartz and riebeckite under the name of paisanite, the analysis of which also agrees in essential particulars with that above. The rock should be regarded as a variety of paisanite. L. V. P.

12. *Mineral Resources of South Dakota*; by C. C. O'Harra and J. E. Todd. South Dakota Geol. Survey Bull. No. 3, pp. 130; pl. 31.—The mineral wealth of the Black Hills has already been described by Professor O'Harra (this Journal, vol. xiii, p. 474). Professor Todd, State Geologist, gives a report (pp. 81–130) on the mineral Building Materials, Fuels and Waters of South Dakota.

13. *Note on a new occurrence of Native Arsenic*; by Nevil Norton Evans. (Communicated.)—During the past summer native arsenic was discovered in a calcite vein cutting the nepheline syenite at Montreal, Canada, by Mr. Edward Ardley, Museum Assistant at the Peter Redpath Museum, McGill University. The mineral appears to be pure arsenic, not more than traces of other elements having as yet been found in it. The vein has a maximum thickness, so far as has been seen, of two inches, and has already yielded about fifty pounds of the arsenic. A complete analysis, together with a detailed study of the occurrence, is being made by the writer, and will be published shortly.

McGill University, Montreal.

14. *The Inverness Earthquake of September 18th, 1901, and the Carlisle Earthquake of July, 1901*; by C. Davison. Quart.

Jour. Geol. Soc., vol. lviii, pp. 371–397, 2 pls.—The recent Inverness earthquake gives additional proof of the existence of a fault line reaching from Loch Ness to the sea and this region "appears to be in a stage of more rapid development than any other in the British Islands" (p. 396). The earthquakes of 1816–18, 1888, 1890, and 1900 were along the same fault.

The Carlisle earthquake has led to the recognition of a deep-seated fault (running N. 5° E) in a region where there is no surface sign of such a structure.

MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Beiträge zur chemischen Physiologie und Pathologie*, herausgegeben von FRANZ HOFMEISTER. II Band. 1902 (Braunschweig, F. Vieweg und Sohn. 15 M.).—This completed volume, of which the earlier numbers have already been reviewed in this Journal, brings evidence of the same high standard which characterized the first one. The Beiträge have now won a place in the permanent literature of physiological chemistry. Particular attention may be directed to the recent contributions on the products of proteolytic digestion and the studies on various proteids of animal and vegetable origin. L. B. M.

2. *Les Dirigibles;* by M. H. ANDRÉ. Pp. iii+346. Paris: Ch. Béranger, editeur. 1902.—This is a well arranged and useful hand-book of the theory and practice of aerial navigation as it is known at present. As indicated by the title, the larger part of the book is occupied with dirigible balloons, and much interesting and valuable information has been collected upon the various conditions of this difficult problem; the laws of the resistance of the air, so far as they are known, are applied to the determination of the proper shape and dimensions of the balloon itself, of the propellers, rudders, etc., and some consideration is given to the motors which may be employed; the very important question of stability also receives attention. The book concludes with a critical account of the various experiments which have been made with dirigible balloons from the celebrated attempts of Gifford in 1852 and 1855 to the recent achievements of Santos-Dumont. H. A. B.

3. *An Introduction to Physical Geography;* by GROVE KARL GILBERT and ALBERT PERRY BRIGHAM. D. Appleton & Co. 370 pages, 263 illustrations.—Gilbert and Brigham's Physical Geography is thoroughly scientific, up to date and attractive. It is a good introduction to out-of-door science of any sort.

1

FIG. 1.—BOWLDER TRAIN UPON THE SLOPE OF SHERMAN HILL
The view looks north-northwest along the train toward the crown of the hill.

2

FIG. 2.—SOUTHERN END OF THE TRAIN OF BASALT BLOCKS FROM SHERMAN HILL.
The view looks north-northwest along the train, Sherman Hill itself, distant a mile and a half, appearing between the two largest blocks.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXXVII.—*An Instance of the Action of the Ice-sheet upon Slender Projecting Rock Masses*;* by WILLIAM HERBERT HOBBS. (With Plate IX.)

THE present paper will discuss what seems clearly to be a case of degradational action by the ice mantle exerting its pressure in a lateral direction against steep and slender masses of projecting rock. The conditions are in some respects peculiar to the locality, which lies in an island-like area of Newark traps and arkoses within protecting walls of the crystalline schists—the Pomperaug Valley area of Connecticut. The preservation here of the Newark rocks from erosion, which has elsewhere so generally removed them, is a direct result of their deformation by jointing and their depression in the form of a composite crustal block along the marginal joint planes as fault walls.† This depression has been irregular in so far as the blocks of the smaller orders of magnitude within the larger composite block have been depressed by different amounts so as to produce a mosaic of small prismatic blocks. The present positions of basalt and arkose within the area are also dependent upon the high position of the main basalt flow in the local Newark series, and upon the low easterly dip (±20°) of the beds and flows previous to their dislocation. Their positions are further affected by the fact that the displacement by faulting was distributive largely within a marginal zone. As a result of all these conditions the dense resistant basalt now occupies the central portion of the depressed area and is bordered by the softer shales and arkoses.

Could the area have been visited subsequent to its deformation by faulting but previous to its degradation through the

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* Read before the Wisconsin Academy of Sciences, Arts, and Letters, at Milwaukee, December, 1901.

† The Newark System of the Pomperaug Valley. 21st Ann. Rept. U. S. Geol. Survey, Pt. III, pp. 1–160.

agencies of subærial and of ice erosion, we may believe that it would have presented an irregular surface not unlike that of a mosaic from which a local area of the back had become displaced and the overlying blocks allowed to slide down by small amounts while still restrained by their friction upon their neighbors. The effect of subærial erosion has been to etch out the marginal areas of soft sandstone and leave the basalt prisms of the central area in strong relief like the image of a cameo. The basalt itself discloses no marks of the subærial erosion, for the reasons: first, that it is intensely resistant; and, second, that its area is so small (six miles in length by two miles in greatest breadth) that no streams of any power have been developed upon it. It is not, however, to be assumed that no considerable degradational action has occurred within the area of the basalt masses of the valley, for the three upper members of the Newark series found in the Connecticut Valley area, which begins less than a score of miles to the east, are missing from the Pomperaug Valley series, and were doubtless removed by subærial erosion, while large thicknesses of the surrounding schists were being carried away.

Fig. 1. Schematic profile of basalt ridges of the Pomperaug Valley. Black, basalt; black spotted with white, amygdaloidal basalt; white, shale; white with black circles, conglomerate (where stippled, baked zone of contact); stippled area, drift and alluvium.

The work of the ice within the valley is revealed in the profiles of the basalt ridges. These ridges have generally fault scarps on their western and northern sides (which face in the direction from which the ice moved) and gentle slopes to the eastward and southward, conforming to the dip of the beds and flows of which they are composed. In these general outlines the action of the ice is not disclosed, but the caps of all the ridges seem to have been removed by an appreciable fraction of their height. This is brought out in the schematic figure 1 and in the author's report above cited.* That this degradational action by the ice is localized largely at the crests of ridges is also shown by the texture of the rock found at the crests when compared with that upon the flanks of the southern ridges. Dense and massive at the crest in correspondence with the lower beds of the flow, it is amygdaloidal and vesicular upon the southeastern flanks, where it doubtless represents upper layers of the flow.

* Loc. cit., pl. V, A.

Some clue to the manner of decapitation of the basalt ridges may be found in two trains of basalt blocks, one of which is represented in Plate IX. This train, which is the one of the greater interest, proceeds from the ridge known as Sherman Hill,* the extreme southwestern elevation of the

Fig. 2. Sketch map of the Pomperaug Valley showing the distribution of the terrace deposits and of basalt trains. W., Woodbury; S., Southbury; H., Hotchkissville: P.. Pomperaug; S. B., South Britain; W. O., White Oaks; S. H., Sherman Hill; R. H., Rattlesnake Hill; C. R., Castle Rock. The stippled area represents roughly the distribution of the terrace deposits, and the lines of larger spots the trains of basalt blocks; A., area of terrace excavated for railroad fill.

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* Sometimes considered a part of Rattlesnake Hill.

basalt within the valley. The position and direction of this train is brought out in fig. 2, which is a sketch map of the Pomperaug Valley. Upon the south-southeastern flank of Sherman Hill the train begins as a collection of irregular blocks of basalt, occupying a belt about one hundred feet in width and extending from the present low tower-like crest of the hill to the corner of the highway, where is the edge of the terrace floor of the valley and where the train appears to end abruptly. Within this portion of the train are a dozen or more blocks six to eight feet in diameter, and very many smaller ones. Fig. 1, Pl. IX is a view looking up the train from a point near the road corner toward the summit of Sherman Hill.

Lost in the terrace deposits of the valley the train is again picked up upon the south side of the valley so soon as the slope begins to rise above the level of the terrace. This locality is near and west of the road from South Britain over Georges Hill (see fig. 2) and just above the great fill upon the railroad. The sand and gravel for this fill was obtained from the area immediately north where indicated upon the map (A of fig. 2). Mr. Henry M. Campbell of South Britain pointed out to the writer a place where three large blocks of the basalt, one of them six feet or more in diameter, were unearthed and removed by blasting during the excavation of this section of terrace. The location would fall within the line of the train from Sherman Hill.

The blocks now in evidence south of the railroad fill are of special interest because of their location in the line of the train and because of their unusual size. Fig. 2, Pl. IX, which looks northwestward along the train, includes two of the largest. The hill from which they were separated is visible in the distance (more than a mile and a half away) between their tops. There are several blocks of this size (15 to 25 ft. in largest dimensions), some partially buried in earth along with many smaller blocks, but all located within a belt less than a hundred feet in width. The train does not appear to extend southward beyond this point, but no attempt has been made to follow it farther. The direction from Sherman Hill of these great blocks of basalt, which form a landmark in the valley, is S. 28° to 29° E., a value near that of the average movement of the ice over the higher points in the vicinity.

The conditions seem here to be best explained by assuming that from the pre-glacial surface produced by subærial erosion the faulted prisms of basalt projected in pinnacles above the softer sandstones, in part opposing to the ice stout walls and in part comparatively slender walls and towers. Sherman Hill, as indicated by the geological map in the report here cited, unlike practically all of the other ridges of the valley, opposed its long face and, therefore, its weakest direction to the ice mass, which was directed against its thin vertical walls. Owing in part to dip and in part to the manner of faulting, its western end (the present peak) projected above its general wall-like mass. This part also was unprotected by the higher mass of Rattlesnake Hill. In this way, it is believed, the great blocks which are now found over a mile and a half away and connected by the train with this elevation were separated from their parent mass.

Castle Rock, a prismatic block of nearly equal basal dimensions and now having a sheer cliff upon its northern face nearly one hundred feet in height, is located in the northeastern part of the area.* Like the west end of Sherman Hill its position left it unprotected by other masses from the northwest, where a considerable valley allowed the ice to sag well below the crests of the elevations surrounding the valley. The row of basalt blocks located southeast of White Oaks is believed to have been derived from this elevation much as the other train has been from Sherman Hill. The slender nature of the prism of Castle Rock, its considerable elevation above the general level, and its exposure upon the northwestern edge of the area all favor such an hypothesis. The direction of this train (S. 13° E.) would indicate that the long valley east of the basalt masses has modified the direction of movement of the lower portions of the ice mantle.

That the ice found a depression in the Pomperaug Valley, into which its substance sagged, is indicated by the present altitudes of the higher basalt ridges which have been decapitated, in comparison with those of the gneiss hills of the vicinity (the basalt ridges are some 200 to 300 feet the lower). It must be assumed that erosion in post-glacial time has been more effective upon the gneiss than upon the basalt, though this would doubtless be modified by the soft arkose members above the main basalt.

To ascribe these trains to the separation of blocks from the lee side of ledges due to the frictional action of overriding, is to leave unexplained their large size and the distance to which some have been carried, more especially, however, the restriction of the trains to ledges which the geological study shows to have been slender in form and with deep valleys northwest of them into which the ice could sink and act in a horizontal direction against their walls.

Professor Chamberlin has informed me that he has observed in Greenland an undoubted instance of such degradational action of the ice from lateral pressure upon rock walls.

University of Wisconsin, Madison, Wisconsin.

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* Loc. cit., fig. 41, p. 111.

Art. XXXVIII.—*On the New Species Melanochalcite and Keweenawite. With Notes on some other known species;* by George A. Koenig.

1. *Melanochalcite.*

For the material of this investigation I am indebted to Captain James Hoatson, of Calumet. I received it early in January of 1902, and informed that gentleman—about January 17th—that I had much reason to distinguish the black mineral as a new mineral species, for which I proposed the name *melanochalcite* (from *μέλας* and *χαλκός*).

Occurrence.—The material comes from the exploration shaft of the Calumet and Arizona Copper Mining Company, near Bisbee, Arizona. I am informed by Captain Hoatson that these specimens represent the character of the ore at a depth of 800 feet. All the mines in that district exhibit oxidized ores to a very considerable depth. Sulphides are rare. I had examined and assayed a number of samples for Captain Hoatson from time to time as the sinking of the shaft proceeded; all oxide ores, and of exceptional richness. No samples assayed under 10 per cent copper. Cuprite was always preponderating, sometimes mixed with much hematite; say, for instance, 30 per cent of the former to 70 per cent of the latter, as an extreme. Malachite and chrysocolla appeared sparingly; no azurite; whilst at the Copper Queen Mine, of the same belt, the silicate and the carbonates are in the foreground. The material under consideration in this paper differs from that of the upper shaft. The material before me presents hard spheroidal nodules, cemented together by a soft, brown-red, clayey material, easily removable. The nodules' nucleus is formed by granular cuprite, with occasional druses, the latter lined with octahedral crystals. This kernel is surrounded by a zone of pitchy-black mineral, a few millimeters in thickness. Upon this follows a banded green zone of chrysocolla and malachite. Thereupon follows white, or transparent, quartz. Within the quartz are smaller cuprite kernels, each with its aureole of black and green. Here the black material is thicker, but less pure as a whole. The purest substance is always thin, lying close to the cuprite. It passes into deep olive green; then light olive-green into the pure green of chrysocolla, or malachite. Thus the fracture-surface of a nodule is of striking beauty. The one before me, which served as model for the description, has an average diameter of 120 millimeters. The kernel is not centric, and rather oblong than circular. The black, green and white parts are massed chiefly on one side.

This material reminded me of the German "Kupferpecherz," which has been declared by eminent authorities as a mineral mixture of various bodies—chiefly chrysocolla and limonite. Dana places it under chrysocolla. I have analyzed such material coming from the Old Dominion Mine, Arizona, of a brown-black color. It was more the esthetic beauty of the present material which induced me to enter into its study, than the expectation of finding new facts. Absence of definite crystalline form is ever apt to call up a prejudice against the homogeneity or chemical integrity of bodies. In the present instance, additional reluctance was caused by thinness of the black zone. But since there was plenty of material, the question of obtaining a sufficient quantity of satisfactory substance could be answered by care and patience.

Physical Examination.—I picked out successively, and from different nodules, three portions of material—A, B, C. The sequence of the letters denotes the degree of scrutiny employed. "A" was intended for preliminary work, "B" for chemical orientation, and "C" for the final trial. At the beginning the chief care was the rejection of either red or green particles. But it was quickly discerned that among the dark material there was a lustrous and a dull portion; a banded and a bandless part. High luster and absence of band-structure go together; dullness and banding are yoked. Sample "A" was tainted somewhat by red, by green and by dull particles. Sample "B" was only contaminated by dull parts; but "C" was picked over several times, and contained only brilliantly-black material. This was time-consuming. It will be seen, however, from the analyses that the blemishes were rare even in "A" and "B." The black mineral is fairly hard—about 4; but it is exceedingly brittle. The cause of this brittleness lies, probably, in numerous microscopic fissures. As support for this opinion, I mention the long time required for the ceasing of air bubbles to rise, when the mineral was placed under water (specific gravity determination). And also the failure to obtain a thin plate by grinding; the plate going to small pieces long before translucence was reached. When the mineral is ground in a mortar it shows the disagreeable property of "smearing." The fine powder is coffee-brown in color. Some of the finest dust from sample "C," which had stuck to the mortar, was brushed upon a glass slide, imbedded in Canada balsam and examined under the microscope. It proved to be translucent, letting through yellow-brown light, one particle exactly as the other. The mineralogic uniformity and singleness of this material ("C") is undoubtable. In polarized light these dust particles behaved like an amorphous, or isotropic, body. The specific gravity was found to be

$\frac{1·5972}{0·3857}=4·141$ at 21 C. (material "C"). This number is rather under than above the true weight, because I wished to avoid boiling, in order not to interfere with the water-percentage of the material. To even up matters, the water used was saturated with air at 21 C. for both weighings.

Chemical Examination.—B. B. In closed tube the substance looses water and CO_2 and the coffee-brown powder turns to brown black. With the fluxes only copper reaction, except with microcosmic salt, when a fine skeleton of SiO_2 appears in a blue glass. The mineral is readily decomposed by HCl of all concentrations, even when in coarse fragments. If such a fragment be placed in 3 per cent HCl, and one observes with a pocket lens, one sees the margins of the splinter turn white. The white zone widens steadily, until nothing but a white mass remains, which occupies the entire space of the original black substance. And yet the percentage of SiO_2 is not quite 10. While this dissolution is progressing one sees a steady spray arise of minute bubbles of CO_2, very different from the big air bubbles arising from the microscopic capillary fissures. I consider this behavior as the essential foundation of my hypothesis regarding the constitution of the molecules of this mineral—to wit: *SiO_2 and CO_2 are simultaneously liberated*, whilst CuO and H_2O pass into the solution. The resultant SiO_2 is what I would call semigelatinous—not colorless and transparent, but white and translucent. It is readily dissolved by the water solution of NaHO. There is no cuprous chloride formed. The copper is altogether cupric.

Material "A."—preliminary analysis. Weight of substance taken, 0·5361 gr.

0·0671	loss by ignition.
0·0532	SiO_2
0·0010	Fe_2O_3
0·4188	Cu_2S

The sulphide was dissolved and electrolyzed, yielding 0·3277 Cu=0·4107 CuO, to which must be added 0·00015 CuO, obtained from the electrolyte by H_2S. Total, 0·4122 CuO.

In percentage:

$$\begin{array}{ll} CuO & = 76·72 \\ SiO_2 & = 9·91 \\ \left.\begin{array}{l} H_2O \\ CO_2 \end{array}\right\} & = 12·52 \\ Fe_2O_3 & = 0·19 \\ \hline & \ 99·34 \end{array}$$

Material "B." 0·5658 gr. The tenacity for water at increasing temperature was tested by exposing the powder, for two hours each, at the following temperatures:

0·0092 loss at 88 C.
0·0142 " 110 C.
0·0082 " 160 C.
0·0128 " 210 C.

0·0444
0·0451 loss at red heat.

0·0895 total loss.

CO_2 was not separately determined in this sample; but from the determinations in "C," when H_2O and CO_2 are nearly alike, the inference may be drawn that all the water is expelled at 210 C.

0·0500 SiO_2; 0·3415 Cu+0·0082 CuO from electrolyte by H_2S, 0·0008 Fe_2O_3.

CuO = 76·46
SiO_2 = 8·83
$\left.\begin{matrix}CO_2\\H_2O\end{matrix}\right\}$ = 14·20
Fe_2O_3 = 0·14

99·63

Material "C"—This having been proved irreproachable material, the analysis was made with great care. CO_2 and water were determined as follows: 0·5260 gr. of the fine powder was placed in a porcelain boat and the latter heated in a combustion tube to redness, whilst a slow current of perfectly dried and purified air passed through the tube. An "U" calcium chloride tube received the water and a Geissler Potash bulb received the CO_2. The increase of weight in the former was 0·0407 gr.; in the latter, 0·0378 gr., a total of 0·0785 gram. At the same time the weight in the boat decreased by 0·0766 gram. Hence there is here an error of 0·0019 gr., which may be evenly distributed between H_2O and CO_2, or may even be neglected altogether without affecting the result sensibly. The copper was precipitated electrolytically, and in this case H_2S found no residue of copper in the electrolyte. The latter being thereupon rendered ammoniacal, a flocculent precipitate fell, which, after filtering and ignition, showed by its color that it did not consist of iron oxide alone. It was found to be $ZnO+Fe_2O_3$. I had overlooked the zinc in the other analyses.

The percentages are:

$$\begin{array}{lrcl}
 & & & \text{Molecules.} \\
CuO = & 76·88 & : 79 = & 0·96583 \\
SiO_2 = & 7\ 80 & : 60 = & \left.\begin{array}{l} 0·12914 \\ 0·16295 \end{array}\right\} 0·29208 \\
CO_2 = & 7·17 & : 44 = & \\
H_2O = & 7·71 & : 18 = & 0·42833 \\
ZnO = & 0·41 & : 81 = & 0·00506 \\
F_2O_3 = & 0·07 & & \\
\hline
 & 100·04 & &
\end{array}$$

This unusual, and surely novel composition, may give cause for several interpretations. Roughly speaking, it might be an intimate mixture of copper carbonate, copper silicate and copper hydrate; but it may also be interpreted as the basic salt of an ortho-silico-carbonic acid $H_4(Si,C)O_4$, in which Si and C may replace each other within certain limits. A scrutiny of the three analyses shows a practically identical percentage of copper oxide. The percentages of SiO_2 and of the volatiles vary. As to SiO_2, we have 9·91 ("A"); 8·83 ("B"); 7·80 ("C"), a variation of about 1 per cent. In "A" we have 12·52 volatiles; in "B," 14·2; in "C," 14·88. These figures are evidently not due to accident, nor due to mechanical mixture. Unfortunately their significance was recognized only after it was too late for a determination of CO_2 in "A" and "B," for there was nothing, or too little, of the materials left. Notwithstanding this serious experimental deficiency, it seems to me that the logical comparison forces the admission of strength in my hypothesis. Admitted the existence of a complex $H_4(Si, C)O_4 . H_2O$ (and I can see no chemical reasons against it) in which hydrogen is wholly replaced by Cu, and H_2O partly by CuO and in which, moreover, Si and C are atomically interchangeable: but so that the percentage of Cu be constant, then a change in the percentage of Si_2O_2 must influence both the percentages of CO_2 and H_2O. Now, comparing "A" and "C," we find in the former 2·11 SiO_2 *more*, and 2·35 volatiles less than in the latter. 2·11 SiO_2 are equivalent to 1·53 CO_2, leaving 0·82 as that portion of the volatiles attributable to water, thus conforming with the hypothesis.

If the composition of melanochalcite be interpreted according to this plausible hypothesis, the figures of analysis "C" take the following shape.

$$\begin{array}{lr}
\text{Molecules } Si_2O_2 = & 0·12914 \\
\text{"} \quad CO_2 = & 0·16295 \\
\hline
 & 0·29209
\end{array}$$

These 0·29209 molecules require 2×0·29209=0·58418 molecules of CuO.

There are disposable 0·96583 CuO + 0·00506 ZnO, a total of 0·97089 molecules of basic oxides. Deducting from this total the requirements of the silico-carbonate, there will be left 0·97089—0·58418 = 0·38671 (CuO,ZnO) to constitute with the water, the hydroxide. But we have 0·42833 molecules of water; hence there is a surplus of the latter of 0·42833 − 0·38671 = 0·03762. This surplus, which amounts to 0·749 per cent, must be declared present as hygroscopic water. It is not determinable by experiment, since the substance lost at 87 C.—1·63 per cent, and since it is a well-known fact that boiling water converts the hydroxide $Cu(HO)_2$ into the oxide CuO.

Putting together these figures, we get:

Copper silico-carbonate 0·87627 : copper hydroxide 0·77342 = 1·000 : 0·882.

The formula of melanochalcite is:

$$Cu_2(Si,C)O_4 \cdot Cu(HO)_2$$

Paragenesis.—In regard to the forming of this mineral substance, one may conceive of at least two modes:

(1). Cuprite crystallizes first from a solution of copper carbonate, with the coöperation of a deoxidizing agent, and produces centers or nuclei. At a later period an oxygenated aqueous solution of silicon and carbon *meta-acids* invests these nuclei. In presence of an overwhelming basic substratum, the meta condition of the acid changes into the ortho state, and the melanochalcite molecules are formed rapidly, falling out in amorphous aggregates. As the crust increases in thickness the basic substratum's influence decreases and we find mixtures of melanochalcite aggregates with those of chrysocolla and malachite, because the ortho reverts to the meta state. The complex molecule $Cu_2(Si,C)O_4$ is no longer possible; and, shortly after, we have clear alternating bands of chrysocolla and malachite.

(2). One can conceive of an aqueous solution holding from the start all the constituents, excepting only oxygen, and from which the least soluble constituents, i. e., Cu_2O, will fall out first. But considering the great bulk of the latter compared with that of melanochalcite, chrysocolla and malachite, this view would seem less simple than at first. Both are purely hypothetical; no experimental facts are known to me outside of the formation of copper sulphides and arsenides. A large field of investigation is open here. The relative absence of native copper in these Arizona cuprite ores is surprising, because these ores are evidently neither metamorphic nor pseudomorphic; but appear to be automorphic, the same as the native copper ores of Lake Superior.

2. *Keweenawite.*

Occurrence.—In April 1901, driving the fifth level at the Mohawk Mine, Keweenaw Co., Michigan, southwestward from shaft No. 1 to shaft No. 2, a narrow cross vein was cut through, carrying domeykite and a reddish-metallic mineral having the color and general appearance of massive niccolite. Superintendent Fred A. Smith sent me some of the material. Being very busy at the time, I did not investigate this matter until June, after my vacation had begun. The examination revealed then my wrong, first impression, inasmuch as the substance showed copper, nickel, arsenic in the ratio of 2 : 1. Early in July I visited the mine and informed Superintendent Smith that I proposed the name *Keweenawite* for this undoubtedly new mineral species. I went under ground for the purpose of gaining some knowledge of the paragenesis of the arsenides for which this mine has now become famous. The large domeykite-mohawkite vein crosses the amygdaloid copper-bearing bed near the No. 1 shaft at an angle of nearly 45°. The arsenides in large shining masses sit mostly against the reddish amygdaloid, without the intervention of any selvage. There is little parallelism among the several minerals (the least soluble species forming the bordering fringe), which suggests the notion of the fissure having been filled by crystallization from a standing mother liquor. In the absence of parallelism, the mother liquor must have been in motion. The stoping operations on this vein between the second and third levels tend to show the vein as a system of flat lenses. One of them has been stoped out with a rich yield. I found the new vein to be about 1,300 feet from the large one just described, near shaft No. 2. The vein comes into the level very flat, almost parallel with the strike of the bed. It is thin, with a maximum width of 6 inches. The general character is very like that of the large vein; to wit, absence of parallelism. Sometimes calcite sits against the amygdaloid, sometimes quartz, or again either domeykite or keweenawite. The conditions under which the filling out of the vein took place must have been alike in both veins. I intended to analyze a large sample of the amygdaloid adjacent to the vein in order to learn whether the arsenic pervades the rock in minute quantities, to find proof or disproof of a lateral leaching. Thus far I have not done this, though the intention still exists. This is one of the reasons why I kept back the publication of the present notice.

Physical Properties.—I have observed the mineral only as a massive, very fine granular aggregate which is very brittle and shows flat conchoidal fracture. Hardness about 4, similar to that of domeykite. The color on the fresh fracture is pale pinkish brown. On exposure tarnishes to a deeper brown red; but is far more constant towards the atmospheroids than domeykite or mohawkite. I have now some specimens before me which have been exposed to the laboratory gases for over a year and still show the characteristic color, but slightly deepened. Specific gravity at 20° C. = 7·681 (with 3·140 grams of the mineral).

Chemical Characters.—B. B. melts easily to a globule. Gives vapors of arsenic. On continued blowing in oxidizing flame, a metallic globule is obtained. But if a borax bead be placed along the globule from the first, while the O. F. is acting, then a blue glass is obtained; later a brown glass, and ultimately a green glass, showing successively cobalt, nickel, copper. The qualitative behavior is thus identical with mohawkite. Dissolves in concentrated HNO_3 and even in HNO_3 (specific gravity 1·2).

A first preliminary quantitative determination gave Cu = 38·5; (Ni + Co) = 17·98; quartz = 4·52; no iron—the difference must be arsenic. This was very different from mohawkite.

A second analysis of the same sample, carefully made with O, 500 grams, gave

0·0249 insoluble
0·3760 $Mg_2As_2O_7$
0·2449 Cu_2S
0·0945 Ni + Co (by hydrogen)
0·0047 Co (by hydrogen).

From this follow the percentages.

Quartz	= 4·98			
As	= 36·96	: 75	= 0·493	
Cu	= 39·12	: 63	= 0·621	0·944
Ni	= 17·96	: 58·6	= 0·325	
Co	= 0·94			
Fe	= trace			
	99·96			

Thus the ratio obtains As : (Cu,Ni,Co) = 1,000 : 1,915 and again Cu : (Ni + Co) = 2 : 1 nearly.

It was assumed by me that this ratio between the metals would probably not be constant; but instead to a certain limit a replacement of each by the others, the same as was assumed for the mohawkite and has been fully proven by numerous analyses, I have made since.

Keweenawite = $(Cu,Ni,Co)_2As$.

This result was communicated to Superintendent Smith at my visit to the mine on July 6, 1901. The material had come from the sixth level. I collected material at the vein crossing on the fifth level. In appearance it was identical with the one just described. The analysis made with 0·5 gram samples gave the following data :

0·3379 Cu_2S
0·0487 Ni
0·0047 Co
0·3560 $Mg_2As_2O_7$
0·0039 quartz.

The percentages are :

Cu	= 53·96	: 63	= 0·856
Ni	= 9·74	: 58·6	= 0·182
Co	= 0·94		
As	= 34·18	: 75	= 0·456
Quartz	0·78		
	99·60		

The ratio (Cu,Ni,Co) : As = 2·27 : 1, is not so close to 2 : 1 as that of the first material, but still sufficiently so. The material, though freer from quartz, was not so faultless throughout as the first. There appeared certain pseudocleavages along which a thin olive-green film could be seen. Just to what extent this condition has to do with preponderance of the metals over the arsenic, I am not prepared to say. But on the other hand, this analysis shows unmistakably the replacement of copper by nickel, and vice versa.

A third analysis was made with another sample, the arsenic not determined.

Quartz	= 0·60			
Cu	= 40·72	: 63	= 0·646	0·992
Ni	= 19·42	: 58·6	= 0·346	
Co	= 0·82			
Fe	= trace			
(diff) As	= 38·42	: 75	= . .	0·515
	100·00			

(Cu, Ni, Co) : As = 1·128 : 1

In my paper on mohawkite (this Journal, December, 1900) I showed how an arsenide Cu_2As forms very easily when the vapors of arsenic act upon copper at red heat. This artificial Cu_2As shows the color and crystalline structure of chalcocite. The difference in color in keweenawite must, therefore, be owing to the nickel.

I give the specific gravity (l. c.) as 7·71, the calculated specific gravity as 7·75, whilst the keweenawite gives the gravity 7·681, which is very close indeed. Nickel and cobalt having nearly the same specific gravities and not much different from copper, this slight difference is readily accounted for.

3. *Mohawkite and Domeykite.*

During the past year I have made several more analyses of these two minerals from the Mohawk mine. The material was in part collected by me on the spot or sent to me by Mr. Fred Smith, to whom I wish to express my indebtedness.

The colors of these minerals seem alike to those of the fabled chameleon, and the identification by the eye is made very difficult, in fact impossible.

a. The mineral appears in form of large masses in calcite with a color equaling that of chalcopyrite; altogether unlike any previously seen domeykite or mohawkite. Mr. Smith states that it had this yellow color when it came up the shaft. It is exceedingly brittle, crumbling between fingers into blue and purple fragments. B. B. shows trace of cobalt and trace of antimony.

Cu = 70·56
As = 29·50

It is therefore domeykite.

b. Large iron gray mass, looks like arsenopyrite. B. B. gives strong cobalt reaction.

Cu = 67·86
Ni + Co = 3·32
As = 28·10
99·28

The mineral proves to be *mohawkite;* but the sum of cobalt and nickel is only one-third of that in my original mohawkite.

c. Mr. Knight, one of my students, picked up a specimen at the Mohawk mine, which seemed to be peculiar. It is tough, but not so much as what I have called mohawk-whitneyite, gray color and fine granular structure somewhat like algodonite in appearance.

B. B. reaction for antimony, no cobalt, no nickel.

Spec. gr. 8·378 — 8·364 (with 1·747 grams)
Cu = 80·72 : 63 = 1·281
As = 19·12 : 75 = 0·255
Sb = 0·84 : 120 = 0·007
100·68

$Cu : (As,Sb_6) = 4·9 : 1 = 5 : 1$

On the face of this result the establishment of a new species would seem indicated. But as I have expressed myself (l. c.), the higher ratios of these copper arsenides are either downright mixtures (grain very fine) or they pertain of the nature of alloys and hence all ratios are possible. In order to throw a little more light on this subject, a long sliver was knocked off the type specimen. On this sliver the mixture of two substances was discernible. The sliver was broken into three fragments and in each the copper was determined.

α (0·5063 gram) gives Cu_2S = 0·4836 per cent Cu = 76·2
β (0·500 gram) " " = 0·4743 " Cu = 75·76
γ (0·506 gram) " " = 0·5097 " Cu = 80·10

These differences would seem to bear out my statement. A straight ratio marks an accident rather than a necessity. In speaking of mixtures like these, it may perhaps be well to use the term *mohawk-algodonite*, as distinguished from true algodonite.

d. Mr. Rogers, another of my students, collected a specimen which did not quite correspond to anything I had seen before. It was much tougher than the preceding specimen. A fragment weighing 0·391 gram was dissolved and the copper determined. Arsenic by difference. Nothing insoluble.

Cu_2S = 0·4208, Cu = 0·3361 = 85·9
As = = 14·1

100·0

Ratio 7·25 : 1

It must be classified as *mohawk-whitneyite.*

e. Genuine Algodonite from the Champion Mine, on the South Copper Range.

I am indebted to Dr. L. L. Hubbard, the Superintendent, for the specimen. It presents a piece weighing about 400 grams, through which a drill-hole passes. The specimen was encountered on a cross vein, very narrow, similar to the occurrence at the Mohawk mine. The metallic mineral is intimately mixed with calcite. The fresh fracture is steel grey. Several fragments were digested with dilute HCl. The residue carefully washed and dried weighed 0·1968 grams. This quantity was dissolved in HNO_3 and boiled nearly to dryness in order to bring all the arsenic to the form H_3AsO_4. Only a trace of white insoluble material (quartz) was observed.

0·0683 $Mg_2As_2O_7$ = 0·0328 As
0·2063 CuO = 0·1645 Cu

Hence Cu = 83·53
As = 16·55 Cu : As = 5·96 : 1

100·18

f. Pulveriform chalcocite from the Champion Mine.

This very interesting material was also encountered in a small cross vein and recognized by Dr. L. L. Hubbard as something peculiar. Neither of us thought of chalcocite. It soils the paper or fingers like soft pyrolusite or graphite. An aggregate of small crystals, the largest less than 0·5$^{\mathrm{mm}}$ to microscopic individuals.

The dust appears under the microscope as made up of single hexagonal plates, or groups of plates, easily disengaged and reduced to individuals, perfectly opaque. I have since observed this same substance both at the Champion and Mass mine, dusting over groups of calcite crystals, either loosely or firmly imbedded in the calcite, causing the latter to look gray or black. It becomes bluish by tarnish. B. B. reacts for copper and sulphur only. The record of the quantitative analysis is lost; but I remember distinctly that the percentage of copper was close to 79.

g. Nodular nuggets found in the coarse material from the mortar at the stamp mill of the Baltic mine were singled out by Mr. William Vivian as whitneyite. If seen by themselves they look much like rounded native copper; but seen alongside of the latter a difference becomes noticeable even to the untrained eye. Compared with one another, on filed or ground surface, slighter differences appear. Held in a vise, a strong blow with a cold-chisel will break the whole in two. Native copper will not do this. The fracture is hackly; there are small geodes of calcite. Calcite is visible between the imperfect crystals of gray color. But the lens also reveals minute black globular bodies. These latter I succeeded in identifying as chalcocite. The material for analysis was extracted with diluted HCl. After extraction material weighed 0·4003 gram.

It gave: Insolubles = 0·0081; Cu_2S = 0·4575; $Mg_2As_2O_7$ = 0·0555

Hence: Cu = 91·33 : 63 = 1·450
As = 6·60 : 75 = 0·0888
Quartz = 2·20

100·13 Cu : As = 16·22 : 1

h. From Captain James Hoatson, of Calumet, I received a specimen showing quartz and what looks like native copper, at first sight. The supposed native copper is similar in color to the nodules just described; also similar in hardness and relative toughness. A filed surface shows a very uniform, dense texture, with a decided yellowish, brassy, color; but etched with HNO_3, the heterogeneous nature becomes visible even to the naked eye.

Two fragments gave:

Cu = 92·78	Cu = 93·96	1·4755	Cu : As = 18·8 : 1
As = 5·85	As = 5·74	0·0765	Cu : As = 19·3 : 1
98·63	99·70		

Two other fragments were detached close to the one whose composition has just been given.

They gave:

Cu = 96·2 and 94·5
As = 3·8 5·5 (by difference)
100·0 100·0

Here the ratios are Cu : As = 30·1 : 1 and 25·5 : 1. The figures show plainly that definite proportions cannot be looked for; but they indicate, as I look at it, that we must assume here conditions similar to those of pig iron, or of alloys. Further studies may give better light, especially in the direction of etching. In speaking of such alloys as these (*g*, *h*), I venture to propose the word "*Semi-Whitneyite*," to be used like Mohawk-Whitneyite, or Mohawk-Algodonite, meaning neither a species nor a variety; in the sense of a rock rather than of a mineral.

Chemical Laboratory, Michigan College of Mines,
Houghton, Mich.

ART. XXXIX.—*Studies in the Cyperaceæ;* by THEO. HOLM. XVII. Segregates of *Carex Tolmiei* Boott. (With figures in the text.)

SIMILAR to the prevalent distribution in the north the genus *Carex*, as represented in the Rocky Mountains of Colorado, does not attain its greatest development until the timber-line is reached, where conditions exist which are favorable to the development of *Carices.* From the timber-line with the low, open thickets of willows (*S. glaucops*) accompanying the water-courses, to the alpine slopes with the snow-banks, we meet with no small number of species over a relatively limited area. Those localities correspond, in many respects, with those of the north, and it is quite natural that we often find ourselves confronted with species that are, also, known to occur even in the polar-regions. Several of these alpine and subalpine *Carices* have been well recognized as being identical with certain northern, arctic and circumpolar, species, and we need only refer to such as: *C. nardina*, *incurva*, *festiva*, *rupestris*, *atrata*, *misandra*, etc., while others appear as indigenous only to the Rocky Mountains, e. g. *Carex filifolia*, *Engelmannii*, *elynoides*, *variabilis*, etc.

The mode of variation in alpine *Carices* corresponds well with that of northern species, indeed we have exactly the same variations exhibited by several of these, e. g. *C. alpina*, *atrata*, *rigida*, *misandra*, etc. And *Carex variabilis*, at least the plant from the Sphagnum-swamps at higher elevations in the Spruce-zone, varies so much, that we have observed forms that are absolutely analogous with the subarctic *C. anguillata*, *hyperborea*, *stans* and the various forms of *C. rigida*, even if they may not be looked upon as specifically distinct. We have collected a number of such forms of *C. variabilis* growing almost side by side, and possessing the same structure and shape of utriculus, besides the same color of squamæ, but varying in the length of bracts, peduncles and spikes, characters that are very prominent in *C. anguillata*, *stans* and *hyperborea;* in these species, however, the utricle offers such characters as seem to afford good evidence of their specific validity, as they were formerly established by Salomon Drejer, the most critical of Caricographers.

However, the ability to distinguish and recognize several of these species from the alpine regions depends to a large extent upon observations in the field as well as a thorough acquaintance with their homologues in other countries. And one of the species, which we intend to describe in the present paper, *Carex scopulorum*, offers an excellent example of analogous variation, which might have resulted in the establishing of several species, if it were not that we had the opportunity of studying the plant in its natural surroundings. It is a species that has, so far, been entirely misunderstood, and, strange to say, it has at various times been confounded with such species as *C. Tolmiei*, *rigida*, *vulgaris* and *pulla*,—to none of which it bears any close resemblance. It seems as if the mode of growth, the color, shape and direction of the utricle in this species has not heretofore been very critically examined. And the morphological structure of the rhizome with its floral and leafy shoots, besides the mere color of utriculus, its outline and direction, are characters of no small importance for distinguishing critical species, and are often much more constant than the number of stigmas, of spikes, distribution of sexes, etc.

Thus is the ramification of the rhizome in *Carex* either mono- or sympodial, the former being rare, but, as we have mentioned in a previously published paper,* it is characteristic of a number of allies of *C. laxiflora*, *digitata*, etc., to which it appears as absolutely constant, while the latter, the sympodial, is to be observed in most of the other *Carices*. The cæspitose and the stoloniferous growth is nearly always constant in the respective species, and such variations as have been noticed in a few cases, for instance in *C. vulgaris*, where a cæspitose rhizome changes into one that is stoloniferous, it appears to depend merely on the character of the soil, and is, therefore, of less importance.

Finally we may mention an additional character derived from the foliar organs at the base of the flower-bearing stem, which was first described by Elias Fries,† and which consists in these basal leaves being provided with large, assimilating blades or being merely scale-like with rudimentary or non-developed blades, at the time of the flowering. He gave the name "Phyllopodic" to the former, and "Aphyllopodic" to the latter. Besides the species with monopodial ramification, which are all "aphyllopodic," not a few species of those with sympodia belong to this same category. Such phyllo- and aphyllo-podic species are readily to be distinguished from each other, inasmuch as the character appears constant; low forms of the aphyllopodic *Carex macrochæta* exhibit in this wise an entirely different aspect from the phyllopodic *C. ustulata*, with which such dwarfish forms have often been confounded, as well as the aphyllopodic *C. cæspitosa* may be distinguished at once from the phyllopodic *C. vulgaris* and its allies. It is a feature which deserves much attention, but seems, so far, to have been

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* This Journal, vol. i, 1896, p. 348.

† Fries, Elias: Synopsis Caricum distigmaticarum, spicis sexu distinctis, in Scandinavia lectarum. (Botaniska Notiser, 1843, p. 97.)

overlooked or neglected by descriptive authors; as a matter of fact it constitutes one of the principal differences between *C. Tolmiei* Boott and our *C. scopulorum*, and the confusion would have been avoided had this particular point been duly considered.

In respect to the utricle, the peculiar dull, brown color noticeable in *C. stylosa* from Greenland and Alaska seems very rare, but is, nevertheless, also common to *C. scopulorum*, and constitutes, thus, an excellent distinction, and appears to be constant. A very prominent character may, also, be derived from the outline and direction of this same organ, the utricle, but it is very important to study this from life or from material preserved in alcohol. The utricle in *C. scopulorum* is turgid with the beak abruptly bent to the horizontal, a feature that makes the plant at once distinct from any of those to which it was formerly referred. But in regard to the other characters, such as the relative development of the spikes, their length, thickness, the peduncles, distribution of sexes, etc., several of these prove less constant and are, as we remember, often the principal foundation for the establishment of varieties, viz: *isogyna* (*C. dioica*), *epigejos* (*C. aquatilis*), *simplicior* (*C. paniculata*), *ramosa* (*C. teretiuscula*), *acrogyna* (*C. Pseudocyperus*), *remotiflora* (*C. vulpina*), *pendula* (*C. stricta*), *spinosa* (*C. hirta*), *anomala* (*C. acuta*), etc.

It, thus, appears as if there were a number of reliable points to be observed and by which one might determine obscure or imperfectly known species of the genus *Carex*, so as to place them in the sections where they naturally belong; but it is, nevertheless, a very difficult task to draw such distinction in so large a genus as that of *Carex*, when the supposed nearest related species are not at hand, but must be studied from the diagnosis alone. And in regard to *Carex Tolmiei* Boott it would seem absolutely fruitless to gather any knowledge about this particular plant from the latest descriptions published in this country, where the species is said, for instance, "to represent *C. vulgaris* Fr. on the western side of our continent," where the true *C. vulgaris* Fr. is amply represented and occurs with much the same variable habit as in the old world! Moreover the diagnosis of *C. Tolmiei* as reproduced in recent systematic works is so as to make it "specifically distinct" from the one established by Boott; in other words, the material has not been correctly identified, nor has the original diagnosis been carefully compared. Very little comfort is gained from consulting the larger herbaria, where we found, for instance, *C. atrata*, *Parryana*, *Raynoldsii*, *macrochæta*, etc., identified as Boott's *C. Tolmiei*.

Under such circumstances one feels obliged to consult the original diagnosis as a last resource, and it is, also, the safest method. We were in the present instance under the impression that our *Carex* from Colorado did belong to *C. Tolmiei*, judging from the very numerous references in literature and herbaria to the same plant from various parts of the Rocky Mountains, but our suspicion became aroused when comparing the diagnosis as written by Boott and reproduced by recent authors. Boott's comprehensive work is, of course, a great help, but it is, as may be said of all other monographs of large genera, far from infallible, and the writer is greatly indebted to Mr. C. B. Clarke of Kew for his kindness in loaning us one of Boott's own specimens of *C. Tolmiei*, and for calling our attention to certain points in the figured details, which are less correct. We have, thus, had the opportunity to compare one of Boott's specimens with his diagnosis, and have succeeded in acquiring a fuller knowledge of the plant than otherwise obtainable.

Most of the other species with which *C. Tolmiei* has been confused were already familiar to us; the remaining are evidently undescribed and will be treated as such, where sufficient material becomes accessible. But before we present the diagnosis of some of these segregates, we deem it necessary to give a few data concerning some external characters of the true *C. Tolmiei* Boott, by which it may be readily distinguished from its supposed allies.

The species *C. Tolmiei* of Boott is aphyllopodic, with the rhizome densely matted and with short stolons covered by a mass of fibers from the dissolved scale-like leaves, and the sheaths of the basal, proper ones, by Boott himself correctly described as: "Rhizoma horizontaliter repens, fibris lanatis." The relative large number of almost contiguous pistillate spikes is a striking feature, also the long and slender, setaceous peduncles of the lower spikes. The number of stigmas is constantly three, and the utricle is, as it appears, mostly two-nerved, granular above and often purplish spotted with a short emarginate or, sometimes, slightly bidentate beak. Among the specimens which we have examined of *C. Tolmiei* were several which answered very well to Boott's diagnosis of *C. nigella*: "A *C. Tolmiei* differt spicis paucioribus, masculis 2–3, perigynio bidentato majore, squamis lanceolatis mucronatis." However, we observed among typical *C. Tolmiei* utricles with bidentate beaks, and several with the scales mucronate. It, thus, appears as if *C. nigella* Boott may not be specifically distinct from *C. Tolmiei* Boott, and, moreover, Mr. Clarke has informed us that he has examined the very specimens in herb. Boott collected by Toulmie and labelled "*nigella*," and that he feels most inclined to consider them identical with *C. Tolmiei*, even that they were collected from "the same tuft" as this. It must, also, be borne in mind that

the republication of *C. nigella* (Ill. genus Carex, p. 194) was done after the death of Boott, and Mr. Clarke, therefore, thinks that Boott himself would have reduced it.

But whatever *C. nigella* may be, a distinct species, a variety or identical with *C. Tolmiei*, the latter itself cannot in accordance with Boott's diagnosis be confounded with any of the other species of this section, the *Melananthæ* Drej., among which we prefer to place it rather than among the *Microrhynchæ* Drej. Some authors, among which Boott himself, did think that the affinity should be looked for among the *Microrhynchæ* Drej., and he compared it with *C. rigida* Good., but was, nevertheless, well aware of the fact, that even if *C. Tolmiei* "has much the aspect and in some respects the habit of *C. rigida*, it differs from this in the number of spikes, the three stigmas, triquetrous achenium, etc." Following the suggestion of Boott, Professor Bailey places the species among the *Microrhynchæ*, in which he includes both Drejer's *Æorastachyæ* and *Melananthæ;* thus the section becomes very unlike that proposed by Drejer, and must be credited to Professor Bailey alone; the plant becomes, thus, associated with such species as *C. vulgaris*, *stricta*, *acuta*, *glauca*, *salina*, etc., a classification too unnatural to be acceptable. But then it is not so strange to understand how a number of very remote and very distinct species of no immediate affinity have been plunged together into one: "*C. Tolmiei*," the characters of which have gradually vanished in the systematic treatises of the genus in this country. And some of the plants which in this way have been united with *C. Tolmiei* are the species which we intend to describe in the following pages as independent species, and not by any means closely related to the original *C. Tolmiei* of Boott. These segregates of *C. Tolmiei* are:

Carex scopulorum Holm (figs. 1–6).

(*C. Tolmiei* Bail. non Boott var. *subsessilis* Bail. ex parte.)

Roots thick, very hairy; rhizome stoloniferous, densely covered with persisting (not fibrillose) scale-like leaves; culm from 10 to 40$^{\mathrm{cm}}$ in height, erect, rather coarse, triangular, more or less scabrous, the base surrounded by green leaves (phyllopodic): leaves shorter than the culm, relatively broad and flat, scabrous along the margins, otherwise glabrous; spikes very variable in number, from two to seven, the upper ones mostly contiguous: the terminal mostly purely staminate, sessile or short-peduncled, clavate, or sometimes androgynous or, though seldom, gynæcandrous,* the scales (fig. 4) oblong-lanceolate,

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* As to the distribution of sexes and number of spikes I find in 65 specimens of *Carex scopulorum* from various localities in Wyoming, Montana, and Colorado:

42 specimens with the terminal spike purely staminate.
17 " " " " androgynous (staminate above).
6 " " " " gynæcandrous (pistillate above).

obtuse, black or deep brown with thin, membranaceous margins, the midrib pale, not excurrent; lateral spikes mostly three, thick, erect or spreading, when crowded near each other (fig. 3), purely pistillate or the upper ones androgynous (fig. 2), at maturity almost squarrose, the upper sessile, the lower borne on short, stout peduncles; bracts not sheathing, with black auricles, only the lower ones leaf-like and about as long as the axillary spike; scale of pistillate spike (fig. 5) ovate, acute, black with pale, not excurrent midrib; utriculus (fig. 6) minutely granular above, mostly longer than the scale, thin in texture, shortly stipitate, turgid, with a short entire beak, abruptly bent to the horizontal, dull brown, often purplish spotted above, two-nerved; caryòpsis sessile, light brown, roundish in outline with both faces slightly convex; stigmas two, base of style persisting.

We found this species very abundant in the region of Clear Creek Cañon (Colo.), also near Leadville (Colo.); it grows in thickets of willows along creeks at an elevation of between 3,600 and 3,900 met.*

Carex prionophylla Holm (figs. 7–11).

(*Carex Tolmiei* Bail. non Boott var.)

Roots thick, very hairy: rhizome densely cæspitose with numerous persisting, very scabrous, reddish brown scale-like leaves; culms aphyllopodic, until 45^{cm} in height, erect, stiff, triangular, very scabrous and leafy to about the middle; leaves of sterile shoots as long as the culm, with long, tubular sheaths, as those of the culm, very scabrous along the margins besides on both faces of the blade and on the sheaths, the blade flat; spikes mostly five, contiguous, or the lowest one in some distance from the others; the terminal staminate, short, sessile; the scales (fig. 9) elliptical, black with pale, not excurrent mid-

24 specimens, some of the lateral spikes androgynous.
41 " all the lateral spikes purely pistillate.

33 specimens with in all 3 lateral spikes.
16 " " 2 " "
11 " " 4 " "
3 " " 1 " "
1 " " 5 " "
1 " " 6 " "

* Specimens examined: Wyoming: Head of Big Goose Creek, Big Horn Mts. (Fr. Tweedy); Sierra Madre Mts., Carbon County. Battle Lake Mt., 9,500 ft., scarce on a wet, shaded north-slope (A. Nelson); Little Goose Creek (A. Nelson). Montana: Old Hollowtop, near Pony Mt. (P. A. Rydberg and E. A. Bessey). Colorado: Marshall Pass, 12,000 ft. abundant in wet places, covering extensive areas (C. F. Baker); Silverplume (P. A. Rydberg); Headwaters of Clear Creek and the alpine ridges lying east of Middle Park (C. C. Parry); abundant along Quail Creek near Stevens' mine, in low thickets of *Salix glaucops;* Headwaters of Clear Creek; in swamps on Gray's peak; very frequent in swamps on Mt. Massive near Leadville (the author).

rib; pistillate spikes very short, about $\frac{1}{2}^{cm}$ in length, sessile, the lowest one subtended by a sheathless leaf-like bract, reaching to the base of the staminate spike, the other bracts scale-like, bristle-pointed; scales (fig. 10) ovate-acuminate, black with excurrent pale midrib; utricle mostly shorter and broader than the scale (fig. 11), rhombic-oval, compressed, stipitate, granular, brownish green with purplish spots, membranaceous, with a short, straight, emarginate beak, obscurely two-nerved; stigmas two with the style enclosed; caryopsis immature.

Habitat: Northern Idaho. Region of the Cœur d'Alene Mountains; near mountain streams; Divide between St. Joe and Clearwater River. Alt. 1,510^{m}. July 10, 1895; collected by John B. Leiberg.

Carex gymnoclada Holm (figs. 12–14).

(*C. Tolmiei* Bail. non Boott var. *angusta* Bail. ex parte.)

Roots thick, densely hairy; rhizome stoloniferous with shining, reddish brown persisting, scale-like leaves; culm from 28 to 44^{cm} in height, erect, slender, triangular, scabrous, leafless, phyllopodic; leaves as long as the culm, narrow, flat, scabrous along the margins; spikes few, mostly three, 1^{cm} in length, situated near the apex of the culm, but not contiguous; the terminal staminate or, sometimes, androgynous, short-peduncled; the scales (fig. 13) somewhat spathulate-oblong, deep brown with pale, not excurrent midrib; lateral spikes pistillate, mostly two, erect, sessile or nearly so; bracts not sheathing, with black auricles, the lower leaf-like and reaching to the staminate spike; scales of pistillate spike (fig. 14) elongated oval, black with pale, not excurrent midrib, shorter and narrower than the utricle; the utricle minutely granular, especially above, with a few prickle-like projections near the beak and around the orifice of this, membranaceous, rhombic-oval, stipitate, compressed, with a short, entire beak, yellowish green, obscurely two-nerved; caryopsis sessile, light brown, oblong; stigmas two, style flexuous within the utricle.

Habitat: Eastern Oregon, bogs of Hurricane Creek, 6,000 ft. alt. Aug. 28, 1900, collected by Wm. C. Cusick.

In considering these segregates of *Carex Tolmiei* Boott, *C. scopulorum* is at once distinguished by being phyllopodic, by its turgid utricle, the two stigmas, etc.; *C. prionophylla* differs from *C. Tolmiei* especially by its profuse, scabrous covering, its small spikes and two stigmas, and *C. gymnoclada* by being phyllopodic, besides by the spikes not being contiguous, by the structure of utriculus and the two stigmas. *Carex scopulorum* may be placed among the *Microrhynchæ* Drej., where it is somewhat anomalous, however, on account of the turgid

utricle; *C. prionophylla* shows some affinity to *C. cæspitose* L. of the same section, and *C. gymnoclada* may be placed with this near *C. vulgaris* Fr.

Brookland, D. C.

ART. XL.—*On the Chemical Composition of Dumortierite;* by W. E. FORD.

Introduction.—Dumortierite was first discovered near Beaunan, France, by Gonnard, who recognized it as a new mineral and named it after the palæontologist, Eugène Dumortier.* The mineral occurs at the original locality rather sparingly as fine grains or needles enclosed in pegmatite, associated with a gneiss. Sufficient material, however, was obtained for an analysis which was made by Damour† while the optical properties of the mineral were studied by Bertrand.‡ Dumortierite was next found near Harlem, Manhattan Island, New York, where it occurs in a pegmatoid portion of a biotite gneiss. The mineral from this locality was first thought to be indicolite, the blue variety of tourmaline. An analysis, however by Riggs, and a study of the optical properties by Diller proved that it was not tourmaline, but presumably a new mineral.§ Later it was shown by E. S. Dana to be identical with the dumortierite of the French locality.‖ A little later the mineral was discovered at Clip, Yuma County, Arizona, and two analyses of material from this last locality, together with one of the Harlem material, were made by Whitfield.¶

All of the five analyses thus far published show considerable variation in the composition of the mineral and none of them yield a satisfactory formula. The original analysis by Damour showed the mineral to be essentially an aluminium silicate containing a small amount of water. The presence of boron evidently was not suspected. The analysis, it should be stated, was made on a limited quantity of material, only 0·41 gr. being used. The analysis by Riggs of the Harlem dumortierite showed the presence of B_2O_3 and also a considerable amount of alkalies. The presence of alkalies has given rise to some question as to the purity of the material analyzed, while Whitfield ascribes the B_2O_3 to the possible presence of tourmaline. The amount of B_2O_3 found by Riggs was about 4 per cent; hence, since tourmaline contains only about 10 per cent of B_2O_3, it would be necessary, according to Whitfield's hypothesis, to assume the presence of over 40 per cent of tourmaline in the material analyzed, a supposition quite untenable, as indicated by the proportions of the other constituents found by Riggs.

The analyses by Whitfield of dumortierite from Harlem and Clip are discordant, since only a trace of B_2O_3 is reported in the Harlem mineral, while varying amounts, 4·94 and 2·62, are indicated in the two analyses of material from Clip. Of the Harlem material only 0·217 gr. was available for analysis and a

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* Bull. Soc. Min., iv, 2, 1881.

† Ibid., iv, 6, 1881.

‡ Ibid., iv, 9, 1881.

§ This Journal (3), xxxiv, 406, 1887.

‖ Ibid. (3), xxxvii, 216, 1889.

¶ Ibid., xxxvii, 216, 1889.

direct determination of B_2O_3 was not made. It is stated, however, that but the smallest trace of B_2O_3 was observed. It may here be noted that it is not especially easy to get a satisfactory qualitative test for boron in dumortierite, and without a quantitative determination one might easily be led to a wholly misleading conception as to the amount of B_2O_3 present; hence it cannot be assumed that the absence of notable quantities of boron in the Harlem mineral has been satisfactorily proved. It has been found, as will be shown in the course of this article, that the dumortierite from Harlem does contain boron, and it also occurs in notable quantities in the mineral from the original locality in France, as indicated by a distinct qualitative test made by fusing on platinum wire with potassium bisulphate and fluorspar; hence, boron seems to be an unfailing constituent of dumortierite.

All analyses thus far made agree in indicating that dumortierite is a very basic silicate of aluminium, yielding a small loss of weight on ignition, presumably water, but they show marked variations as regards boron. The present investigation was undertaken, therefore, with the idea of making a special feature of the boron determination and of establishing, if possible, the exact chemical composition of the species.

Material for Analysis.—It was possible to obtain material from three independent sources, Clip, Arizona; Harlem, New York; and San Diego Co., California. From the first locality material was obtained from specimens in the Brush collection, and also from an abundant supply of the mineral sent by Mr. Geo. L. English of New York. The dumortierite from Clip occurs as small columnar aggregates imbedded in a matrix of granular quartz, associated with a little magnetite and cyanite. Pure material was separated by pulverizing a large quantity of the rock and treating, first with potassium mercuric iodide in order to separate the quartz, then by suspension in barium mercuric iodide so as to obtain the mineral in condition of greatest possible purity. After separation in this manner the dumortierite was picked over carefully by hand and then allowed to stand for several days in hydrofluoric acid in order to remove any remaining traces of quartz which might be attached to the mineral. It may be stated that hydrofluoric acid in the cold has practically no action on crystals of dumortierite.

Material from Harlem was obtained from specimens in the Brush collection and rendered pure by the means described above. The material from San Diego Co., California, was obtained from some specimens which were sent to Prof. S. L. Penfield by Mr. E. Schernikow of New York. The general locality of the occurrence of this type of dumortierite has been confirmed by Mr. W. Tassin of the U. S. National Museum in Washington, who kindly sent a specimen for comparison with the material that was analyzed. The exact locality from which the mineral came could not, however, be learned. This material shows a marked difference in appearance from that of dumortierite from other known localities, as it has a pronounced lavender color rather than blue. The pleochronism of this type is analogous to other dumortierite, but ranges from deep lavender to colorless instead of from deep blue to colorless. The optical orientation of the crystals is the same as in the case of the dumortierite from Clip. It occurs in masses of considerable size, of radiating columnar structure, associated with granular quartz and a light colored mica from which it was easily separated by means of the heavy solutions, and thus obtained in a pure condition.

Method of Analysis.—The method of analysis presents no new features and need be only briefly discussed. The silica, alumina, and ferric oxide were determined as usual. Boron was determined by the Gooch method* using the precautions suggested by Penfield and Sperry, recorded in their paper on the Composition of Howlite† and by Penfield and Foote in their paper on the Composition of Tourmaline.‡ It was found that water could not be determined by simple loss on ignition and, accordingly, the method suggested by Penfield§ of igniting with a weighed quantity of lime, was employed. The loss on ignition in this case was found to be less than when the mineral was ignited alone. A somewhat different method of analysis had to be adopted in the case of the dumortierite from Harlem on account of the small amount of material available, and it is fully realized that the results are not to be looked upon as being as exact as those of the other analyses. The analysis was made on only 0·6 gr. of the mineral, which it was necessary to divide into two portions. In one of these, water was determined in the manner described above, and in the other boric oxide and the remaining constituents, silica, alumina and ferric oxide.

The results of the analyses are as follows:

Analysis No. I. Dumortierite from Clip, Arizona.
Specific gravity close to 3·319.

				Average.	Ratios.	
SiO_2	30·00	29·66	29·91	29·86	·497	
Al_2O_3	63·20	63·74	63·76	63·56	·617×6 =	3·702
Fe_2O_3	·23	·23		·23	·001×6	·006
B_2O_3	5·47	5·06		5·26	·070×6	·420
H_2O	1·45	1·38		1·41	·070×2	·140
				100·32		4·268

4·268 : ·497 = 60 : 6·99

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* Amer. Chem. Jour., ix, 23.

† This Journal (3), xxxiv, 220, 1887.

‡ Ibid. (4), vii, 97, 1899.

§ Ibid. (3), xxxii, 109, 1886.

Analysis No. II. Dumortierite from San Diego Co., Cal.
Specific gravity between 3·226 and 3·43.

		Ratios.	
SiO_2	30·58	·509	
Al_2O_3	61·83	·600×6 =	3·600
Fe_2O_3	·36	·002×6	·012
B_2O_3	5·93	·085×6	·510
H_2O	2·14	·119×2	·238
	100·84		4·350

4·350 : ·509 = 60 : 7·02

Analysis No. III. Dumortierite from Harlem, N. Y.
Specific gravity between 3·211 and 3·302.

		Ratios.	
SiO_2	31·24	·520	
Al_2O_3	61·26	·596 ×6 =	3·576
Fe_2O_3	·10	·0006×6	·004
B_2O_3	6·14	·088 ×6	·528
H_2O	2·09	·116 ×2	·232
			4·340

4·340 : ·520 = 60 : 7·19

Discussion of Analyses.—It would seem that the chief problem in arriving at a formula for dumortierite would be the determination of the rôles played by boric oxide and water, but the analyses indicate that these constituents are present in such variable proportions as not to yield definite ratios with the silica. In the first two analyses the ratios of $SiO_2 : B_2O_3$ are respectively 7 : 1 and 6 : 1, with percentages of H_2O increasing with increase of B_2O_3. It may be assumed, therefore, that the boron in the mineral has not the nature of an acid element, occurring in a definite proportion, but must be considered rather as having basic qualities, replacing aluminium as an isomorphous constituent. Moreover, there is no simple relation between the H_2O and the other oxides, which fact, taken with that of the small amount of water present and the difficulty with which it is driven off from the mineral, has led to the assumption that it, too, plays the part of a basic constituent in the composition of the mineral. That water does at times play such a rôle has been abundantly proven. The results of the analyses were, therefore, treated as follows: The ratio of each of the basic oxides was multiplied by a number which represented its equivalent in hydrogen, and in this way an expression for the acid from which dumortierite is derived was obtained. Thus treated Analysis No. I gives the ratio of $SiO_2 : H = 6·99 : 60$, No. II, 7·02 : 60

and No. III, 7·19 : 60, the ratios of all three being very close to 7 : 60. Analysis No. III shows the greatest variation from this ratio but the method of analysis which had to be employed in this case, as explained above, would account for a high ratio of the SiO_2. The ratio as given leads to an acid having the empirical formula, $H_{60}Si_7O_{44}$, and, on the assumption that the hydrogens are wholly replaced by aluminium, the formula becomes $Al_{20}Si_7O_{44}$ or developed as a basic orthosilicate, $(AlO)_{16}Al_4(SiO_4)_7$. In the foregoing formula it must be understood that boron and a little hydrogen replace a portion of the aluminium. In Analysis I, in which the ratio of $B_2O_3 : SiO_2 = 1 : 7$, the formula approximates very closely to $[AlO]_{16}Al_2B_2(SiO_4)_7$. The theoretical percentages corresponding to this formula are as follows:

SiO_2	29·83
Al_2O_3	65·20
B_2O_3	4·97
	100·00

It is of interest to note here a new occurrence of dumortierite. During the preparation of this article a blue mineral was sent to Prof. E. S. Dana for determination by Mr. R. M. Brereton of Woodstock, Oregon, and which was examined by the present writer. It proved to be dumortierite of a somewhat new habit. The mineral occurs in small spherules, about 1^{mm} in diameter, imbedded in a light-colored, fine-grained siliceous gangue. Each spherule when broken shows a radiated fibrous structure, and the mineral has a beautiful blue color. When the gangue is pure white a polished specimen of this material gives a very pleasing effect. This dumortierite shows the pleochroism characteristic of the blue variety. It was scarcely possible to obtain material sufficiently pure for analysis, but a decisive qualitative test for boron and approximate determinations of the other constituents left no doubt as to the identity of the mineral. The locality of this occurrence of dumortierite as given by Mr. Brereton is on the headwaters of the North Fork of the Washougal River in Skamania County, Washington.

The writer wishes to express his obligations to Messrs. English and Schermikow for the material which they gave for analysis and to Prof. S. L. Penfield for his constant advice and assistance.

Sheffield Laboratory of Mineralogy, Yale University, New Haven.

Art. XLI.—*Some Characteristics of Kau;*[*] by J. S. Emerson.

Of the Hawaiian group of islands, Hawaii is the largest, the most lofty and the most recent. The fires of its volcanoes are still burning, and from time to time new material is poured out over the surface of a land which is still in process of formation. Here is the place to study Nature in her workshop and see a world in making. But it is not of Hawaii as a whole that we propose to speak. It is made up of districts with characteristics marked and distinct from one another.

The Hilo-Hamakua-E. Kohala district, occupying the northeast side of the island, from Hilo Bay to Upolu Point, is the land of gulches and streams of water, of disintegrated rock and deep heavy soil.

The W. Kohala-Kona-W. Kau district, occupying the west side of the island from Upolu Point to South Cape, is the land of slowly disintegrating rock, almost without gulches and running streams. The extreme richness of its coffee lands is due to the fact that new soil is ever being formed, as wanted, from the loose mass of *aa* rocks, which contains every element needed for plant growth.

Puna is the district where frequent showers fall upon loose stone and sink out of sight, without forming gullies and streams, and where vegetation thrives without soil. Here the cocoanut tree grows in immense forests as nowhere else in this group.

Kau is unique, a district by itself; "*Kau ka maka lepo*"; Kau the dusty. That portion extending from South Cape to and including Kapapala Ranch, a distance of some thirty miles, contains all the land of any value for grazing or agriculture. Briefly described, it is a wide expanse of comparatively modern lava, forming a floor of rock upon which is spread a superficial covering of fine, light, reddish or yellowish dust of varying depth. In places the ephemeral mountain torrents have washed away this unstable soil and revealed the bed rock beneath, which has scarcely yet begun to disintegrate and ally itself with earth. This superficial coating of dust is distinct from the rocky stratum on which it rests, as the dust which the cleanly housewife removes is from the floor which she has swept. And such dust as that of Kau is found in quantity in no other district of these islands. In the olden days the natives of this section, when engaging in the popular pastime of *lehe kawa*, jumping from a high bank, often substituted a bath of this dust for the usual pool of water. An

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[*] Read before the Social Science Association of Honolulu, Oct. 14, 1895.

ordinary dirt road, unless properly covered with stone, is quickly worn down by constant travel. The wheels of loaded teams sink into the soil, which in time is blown away by the winds, or washed out by the heavy rains which occasionally fall.

From Waiohinu to Hilea the cane fields are mostly on the hills, where the soil is of great depth and remarkably free from rocks or stones, so that almost anywhere a crow bar or walking stick can readily be thrust down to its full length. On the low lands, however, the soil is usually shallow, with the bed rock frequently cropping out, or may be wanting altogether. The Hawaiian Agricultural Co. are more fortunate in the lay of their plantation, and have an extensive tract of about four thousand acres of rich cane land, not perched on isolated hills, but occupying two large valleys with the gentle slopes between them. These fields are somewhat scattered about, with unproductive areas between them, but as a whole they are far more compact and accessible than the fields from Waiohinu to Hilea.

Kau is not a well-watered district. It often suffers from prolonged drought, when the dry winds parch and destroy whole fields of young cane and raise clouds of dust from the newly plowed lands. When at length the long wished for rain comes, it sometimes pours down in such torrents as to cause great destruction of property. The light soil soon dries up again, so that the irregularity of the rains is the more keenly felt, while the cane stalks register the fact in the varying and irregular length and diameter of their joints. During these periods of drought great care has to be exercised to prevent any one from smoking in the fields or making a fire in the grass, for when a fire is once started, it is sometimes extremely difficult to prevent it from spreading under ground. The roots and other vegetable matter in the soil are consumed, while the mineral basis of the soil itself is so light and spongy as to allow enough air to enter to support combustion many inches below the surface. At times, when such a fire was supposed to be extinguished, it has burrowed its way unobserved, to show its presence at some other point where the surface would cave in and the ground itself seemed on fire. Mr. W. E. Rowell states that "one peculiarity of the soil on the Pahala plantation is the entire absence of any clay or anything adhesive in its composition, so that it does not stick to the shoes, however wet it may be."

At various points through the district it is possible to examine the record of the rocks and to see the character of the successive strata resting one upon another. It would appear from such observations that most of the strata represent ordinary lava flows, with but thin separating sheets of ash or earth. But Providence has most considerately anticipated the industrial wants of man at the present time, and above all these successive layers of rock has added this crowning layer of dust, which makes it possible to plow and plant a district whose formation is so recent. How different it might have been if this superficial layer had been *aa* or *pahoehoe* rock, as in Kona, requiring another ten thousand years to distintegate it sufficiently for farming purposes.

Between the South Point and the road from Kahuku Ranch to Waiohinu is a beautiful sketch of smooth grassy pasture. At various points near the Cape the writer has measured the depth of the soil to the bed rock, and recorded it as having an average thickness of about ten feet, separated into two layers of nearly equal thickness by a thin layer of whitish earth perhaps half an inch thick. One branch of the flow of 1868 traversed a portion of this plain from the vicinity of the Kahuku Ranch house half way to the Kaalualu landing. Flows of an earlier date have also covered other portions with a horrid mass of rock. But it is outside of the purpose of this paper to describe the various lava flows which cover much of the territory below the cane lands and the Kapapala Ranch.

The woods above the plantations are difficult, if not positively dangerous, to traverse on horseback, so much so that Mr. Julian Monsarrat, who knows the country well, pronounced the carrying of supplies through these woods to his workmen engaged in building a fence along their upper edge, as impracticable. The soft treacherous mud gives no foothold for man or beast. Consequently the supplies were carried a long distance around.

The Kau hills, Iholena, Puu Enuhe, Makanao and Kapuna, bear a most striking family resemblance to each other, so that the profile of one will serve pretty well for all. Captain Dutton in his Hawaiian Volcanoes speaks of them as "mere remnants of a large alluvial formation which was originally continuous," and the valleys which separate them as "valleys of erosion." In speaking of these hills he uses the following language: "The more we see of this country the more will the evidences accumulate that these buttes are silent witnesses of an extensive upheaval of this part of the island at an epoch not very remote." Again he says, "It is difficult to estimate with precision the amount of elevation attested by these terraces, but there are evidences still legible of several of them—one of them 1,200 to 1,400 feet high, another about 2,800, and perhaps, though more doubtful, a third at 3,400 feet." (See Dutton's Hawaiian Volcanoes, page 98.)

This theory, though advanced by a recognized authority on the geology of portions of the western United States, lacks the support of facts. It has not a single ledge of coral, a bed of shells, or a vestige of marine life of any sort on which to rest.

Until such proof of marine origin is found, we cannot accept the theory of upheaval as proven or even as a working hypothesis. To speak of the Kau dust as an "alluvial formation" only removes the question of its origin one step further back. Whence came it? The process of disintegration has scarcely begun in much of the Kau bed rock. The most casual study of its soil shows that it is not decomposed rock. It is totally unlike the soil of Hilo or Kona, and certainly was not washed down from the *aa* and *pahoehoe* of upper Mauna Loa.

Evidently it is a formation similar to that which covers a large portion of the slopes of Vesuvius and overwhelmed the ancient city of Pompeii. This volcanic ash is the evidence of a series of explosive eruptions in Kau on the grandest scale, probably far surpassing anything of a similar nature of which we have any evidence in this group. We must then look to the medium of the atmosphere rather than to the action of water to explain the remarkable distribution of this dust which has been sifted down on the ridges, as well as in the hollows, in a manner far more regular and uniform than could have been accomplished by the action of running water.

To locate the source or sources of this aërial eruption is a problem not yet fully solved, but some light may be thrown upon it. We need hardly look to Mokuaweoweo, the summit crater of Mauna Loa, as a source. For had such an explosion occurred there, the dust would also have been carried in the direction of Kona. But as a fact, neither in Kona nor on any side of the great dome of Mauna Loa is this dust found in quantity, until we reach the wood belt of Kau. Kilauea, the only remaining active volcano, may be looked to as a possible source with slightly greater probability. But between the district covered by the Kau dust and Kilauea lies the Kau Desert with an area of "many miles" of a totally different formation, while nothing is to be seen of the dust anywhere around the volcano. The writer has examined fissures in the Kau Desert to a depth of perhaps thirty feet and failed to see any of the *dust*. If then Kilauea were the real source of the dust eruption, the evidences of it have been covered most completely by these later eruptions.

The supposition is barely possible, but extremely improbable. Another possible source in this enumeration should not be overlooked. It is the vicinity of Puu o Keokeo, greatest of all the offsprings of Mauna Loa, with an elevation of 6870 feet; it appears to those who sail around South Point as another grand mountain, the rival of its mighty parent. It is located on the great fissure, or rift, in Mauna Loa, extending from Pohaku Hanalei to the vicinity of South Cape. This fissure, probably as old as the mountain itself, lies in the direction of the line joining Mauna Kea and Mauna Loa, the same as the line of the axis of Mokuaweoweo produced. The flows of 1868 and of 1887 seem to have escaped from the central shaft through this lateral rift in the mountain, and to have come to the surface at points on this line of least resistance. It is an axis of great volcanic activity, which has built up for itself the immense ridge of Mauna Loa which divides the geological district of Kau from that of Kona. About Puu o Keokeo as a center there is a large area cevered with pumice and gravel, quite similar to the so called Kau Desert, southwest of Kilauea. Manifestly it has been produced by explosive eruptions on a large scale. But as in the case of the vicinity of Kilauea, so here the peculiar Kau dust is altogether wanting. Further there is no sign of any such dust deposit at any distance, on the Kona side, of this area covered with pumice, while the entire portion of Kau covered with dust is at a distance of many miles in the opposite direction.

The conclusion seems forced upon us that we must look for the origin of this great eruption within the limits of the district covered by it. With this idea guiding us, we naturally look first to the immediate vicinity of the hills already mentioned, where the peculiar Kau soil attains its maximum depth. One cannot but be struck with the suggestion that Puu Iki marks a point on the upper rim of a vast extinct crater extending south to Kaiholena, possibly even to the great whaleback ridge on which Kapuna Trig. Station is situated, while the eastern rim, now largely washed away, would be marked by the hills Makanao, Puu Enuhe and Kaumaikeohu with the steep side hill just to the east of it. Everything seems to point to this locality as the source of the stupendous explosion, or series of explosions, which has rescued Kau from being a waste of unproductive rock and transformed it to so large an extent into a land of pastures and plantations.

If we admit that this is indeed the source of these eruptions, the whole problem of the distribution of the dust is greatly simplified. As would naturally be expected, the ejected matter has been deposited on all sides, but the action of the trade wind has carried the finer particles to a much greater distance to the south and southwest than in the opposite direction. So that we find the country about South Cape covered to a depth of ten feet, as before stated, with the finest dust, without any admixture of coarse material. The whole district west of Kaaluala landing has been tilted up on its western edge, along the line of the great fissure already alluded to, forming an extensive fault from the sea to the Government road just above Col. Norris' residence. The visible deposit of dust breaks off abruptly at the edge of this precipice. But according to native tradition the whole plane of Pakini at its base, on the Kona side, was formerly a rich field, cultivated with sugar cane and sweet potatoes. Since that time, however, various flows, among which are those of 1868 and 1887, have converted this garden into an uninhabited waste of *aa* and *pahoehoe.*

If, however, we examined the earth in the vicinity of the supposed center of eruption, we find a considerable admixture in places of stones, for example the so called Mud Flow of 1868 covered several hundred acres of good land to a depth of from ten to thirty feet with a heavy, red, clayey earth, abounding in stones, wholly unfit for cultivation, and producing a grass of such inferior character that even the cattle and horses shun it. This mud flow was simply a land slide. Kaapao pali was full of water and the great earthquake of April, 1868 loosened the superficial mass of earth and lubricated the rocky bed on which it rested. Gravity acting on a steeply inclined plane did the rest. Mr. Walton, the energetic and wide-awake manager of the Pahala plantation, has used his wits to good advantage in the search for water on the Kaapao pali and neighboring hillsides, and during the past few months has found enough, as I am informed, to irrigate five hundred acres of cane.

There are no traditions, so far as the writer can learn, relating to these great explosive eruptions. The only occurrence of the sort of which we have any historical information took place in 1790 at the volcano of Kilauea, which destroyed, as Dibble tells us, about 400 of the warriors of Keoua's army, one entire division. The sand, ashes, pumice and stones ejected at this time cover the country about the volcano for miles, and have been fully described by Dana and others.

The extensive area about Puu o Keokeo already alluded to is covered with material very similar to that of the Kau Desert. The "Alanui Umi," built early in the 16th century by King Umi, traverses this mountain desert from north to south. This road was made necessary by Umi's occupation with his court and warriors of the barren waste between Mauna Loa and Hualalai. When the political and military necessity for Umi's occupation of this strategic position ceased, he sought a more agreeable home, and spent the last years of his life at Kaawaloa, by the sea. The Umi road seems to have been little used since those days, save by the race of bird catchers and perhaps by the sandal-wood cutters of a later day.

Its very existence, however, is scarcely known to most of the dwellers on Hawaii. This ancient road is chiefly interesting to us at this moment as an evidence that no great explosive eruption has probably taken place in that portion of Hawaii for the past 350 years. It is pretty much in the condition in which Umi left it.

Some years since I had occasion to ride over a portion of this road, which was two or three feet wide and is still readily followed. So long as the mule kept to the old path he made good progress, but when he deviated but a few feet on either side, he sank down to his girth in the sand and pumice and floundered helplessly. It was most instructive to follow this path to the great natural amphitheatre on the southern slope of Puu o Keokeo, where the famous cock fights used to draw immense crowds to witness one of the great national games of Hawaii. The cock-pits or rather pens still stand, probably as Umi left them three and a half centuries ago. Had there been a shower of ashes or pumice from the vicinity of Puu o Keokeo during this interval, the old road and these cock-pits would have disappeared forever beneath the sands of the desert.

Since the above was written, Dr. A. B. Lyons of Oahu College has kindly furnished the following statement: "I have had occasion to examine the soil from some of the cane fields at Pahala. They were remarkable in several particulars. They contain a large proportion of organic matter, and yet could not be called peaty. They seemed rather sandy. They contain almost no clay. The mineral matter consists in fact of volcanic sand rich in olivine and very little decomposed—very similar in many respects to the sandy or gravelly soil of Punahou, which is made from recent volcanic sand. The abundance of lime in the soil confirmed also this view of its probable origin. Hawaiian soils composed of decomposed lava contain very little lime."

For the sake of clearness, a brief recapitulation and summing up of the argument with reference to the origin of the peculiar Kau soil may properly conclude this paper.

A district equal in extent to one-half the area of the Island of Oahu, 300 square miles, is covered with a soil quite unlike that of any adjoining district, and totally distinct from the very recent volcanic bed rock on which much of it rests. The entire absence of a single ledge of coral, bed of shells, or other positive evidence of marine formation, and the frequent occurrence of caves and caverns which remain unfilled with silt, together with the very porous character of the whole formation, discredits the theory "of an extensive upheaval of this part of the island at" any "epoch not very remote." On the contrary, this formation originated on dry land and has not been submerged. If this soil were alluvial it would show stratification. Instead of that it is blanketed like newly fallen snow upon the uneven contour of hill, plain and ridge.

If this formation were deposited at tide level, it would be interpenetrated by marine growths, animal and vegetable. But the evidence that such growth exists is conspicuously wanting.

But, finally, no better evidence as to the origin of this minute sand can be produced than its appearance under the microscope. Its mechanical features are sharp and broken as of volcanic sand, wholly unlike the rounded and worn features of beach sand. In short, the positive testimony of chemical analysis and microscopic examination shows that the mineral portion of this soil is volcanic sand, not the wash from any higher level of decomposed rock. This necessitates the theory of explosive eruptions on a scale of magnitude proportional to the extent of territory covered, which would have been greater but for the ocean which abruptly terminates it along the entire coast from Punaluu to South Cape, and a precipice on the southwest, beyond which all trace of this soil has been effectually covered up by flows of lava. Further, three great centers of volcanic activity, viz., Kilauea, Mokuaweoweo and the vicinity of Puu o Keokeo to the northeast, north and west respectively of the district in question, have covered extensive areas about them with other formations, so that it is impossible to locate the original limits of this unique formation in those directions. At the same time, the evidence is very strong, if not conclusive, that neither of these three volcanic centers was its source, while every consideration points to the great crater-like area below Puu Iki.

This locality is so little known and so difficult of exploration that we are unable to point out the exact location of the center of explosion. The unstable character of the material ejected would tend in a measure to cover up its source, which from the nature of the case could not be as sharply defined as that of a flow of *aa* or *pahoehoe*, whose birthplace is marked with solid rock.

As to the time when these remarkable explosions occurred, it may be observed that the only event of this character in these islands, of which we have any definite information, took place at Kilauea a little over one hundred years ago, as already stated. From the fact that the old cock-pits near Puu o Keokeo and the ancient road leading to them remain as they must have been left by King Umi 350 years ago, it seems quite evident that no explosive eruptions on a large scale have taken place during that interval either from the summit crater of Mauna Loa or from the great lateral rift which has been so active in building up the immense ridge which marks its southwest slope. The conclusion therefore is evident that the eruption which produced the Kau dust under discussion was earlier than the beginning of the sixteenth century. Though we may not locate the time of these eruptions as definitely as the place, yet the fact that they form the last of a long series of distinct strata, each of which represents a considerable interval of time, shows that they must have occurred at a period very recent in the growth of the island. On the other hand, the entire absence of any tradition relating to them and the occurrence in several places of *aa* and possibly *pahoehoe* flows from Mauna Loa of limited extent and of uncertain age superimposed on this formation, make it probable that the stupendous convulsions of Nature which gave birth to this crowning feature of the district and prepared it for the support of man in an advanced stage of civilization, occurred many centuries ago, probably before the advent to these shores of its first Polynesian inhabitants.

ART. XLII.—*The Titrimetric Estimation of Nitric Acid*; by I. K. PHELPS.

[Contributions from the Kent Chemical Laboratory of Yale University—No. CXIII.]

IN the methods for the quantitative estimation of nitric acid which depend upon its reduction with a ferrous salt and the determination of the amount of oxidation produced, scrupulous care is necessary that the atmosphere in contact with the ferrous salt while the nitrogen dioxide is present shall be free from oxygen. This fact was recognized by Fresenius,* who modified the original process of Pelouze† by filling the flask with carbon dioxide or hydrogen at the outset. Eder‡ used carbon dioxide similarly. Holland's method,§ roughly described, consists in boiling, until the air is expelled, the solution of the nitrate in a flask provided with a doubly bent exit tube, rubber-jointed and fitted with a pinch cock, then admitting through the tube as the flask cools a mixture of ferrous salt and strong hydrochloric acid, heating the mixture on a water bath, and, finally, titrating the resulting ferric salt with stannous chloride.

All of these methods give results which are higher than the theoretically expected—those which use carbon dioxide on account of the oxygen invariably present in the gas as ordinarily produced in the laboratory, and Holland's process possibly because of the slow leakage through the rubber connections during the long heating, or because the nitrogen dioxide, which is not driven out completely from the solution of the iron salts, acts somewhat with the atmospheric oxygen during the titration.

Another series of methods has depended upon the determination of the nitrogen dioxide evolved, usually by direct measurement as nitrogen dioxide. Among these may be mentioned the methods of Schloessing,‖ Reichart,¶ Schulze and Wulfert,** Tiemann,†† Wildt and Scheibe,‡‡ Warington,§§ Boehmer,‖‖ Kratschmer,¶¶ Wilfarth,*** Morse and Linn.,††† Berger,‡‡‡ and Roberts.§§§ In general, these methods give results lower than demanded by the theory—in many cases, on

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* Ann., cvi, 217; Zeit. anal. Chem., i, 32.

† Ann. de Chim. Phys. [3], xx, 129.

‡ Zeit. anal. Chem., xvi. 267.

§ Chem. News, xvii, 219.

‖ Ann. de Chim. Phys. [3], xl, 479.

¶ Zeit. anal. Chem., ix, 26.

** Ibid., ix, 400.

†† Anleitung zur Untersuchung von Wasser von W. Kubel. Zweite Auflage von F. Tiemann, 55.

‡‡ Zeit. anal. Chem., xxiii, 151.

§§ Jour. Chem. Soc., xxxvii, 468; xli, 345.

‖‖ Zeit. anal. Chem., xxii, 20.

¶¶ Ibid., xxvi, 608.

*** Ibid., xxvii, 411.

††† Amer. Chem. Jour., viii, 274.

‡‡‡ Chem. Zeit., xix, 305.

§§§ This Journal, xlvi, 126 (1893).

account of the solubility of the nitrogen dioxide in the ferrous solution used as a reducer and, in other cases, on account of the solubility of that gas in the solution of sodium hydroxide over which it is measured. Further there is the effect of oxygen upon the nitrogen dioxide; if present in the measuring burette in the proportions found in air, it will not give any appreciable effect in moderate amounts, as was observed by Roberts; but if it is present while the gas is in contact with the ferrous solution, the nitrous or nitric acid formed will be taken up by the solution, and, should the oxygen be introduced continuously, as an impurity in carbon dioxide furnished by a Kipp generator, the iron salts will never be free from oxidized nitrogen. If, however, the oxygen is present in some other proportion of dilution than that of the air—as, for example, in the proportion in which it dissolves in aqueous solutions—it will produce an error no matter whether it comes in contact with the gases of the ferrous solution or those of the collecting burette: in the example taken, the proportion of oxygen being greater than that in the air, the error produced is one of deficiency. The effect of oxygen has been recognized before. For example, in his process of determining nitrates by reducing them with ferrous salt and hydrochloric acid in an atmosphere of carbon dioxide (furnished by the action of hydrochloric acid on marble), boiling the ferrous solution completely to dryness, collecting the gases over mercury, absorbing the carbon dioxide by sodium hydroxide solution and the nitrogen dioxide by repeated treatment with a concentrated solution of ferrous salt, Warington found that, when the carbon dioxide was made as free from air as possible by using marble boiled in water and hydrochloric acid also boiled and adding a little cuprous chloride to the acid, the results were decidedly better.

The estimation of the amount of oxidation of a ferrous salt may be accomplished with a simpler apparatus than that required when the nitrogen dioxide is measured, and the purpose of this article is to put on record such a method, following most nearly the procedure of Holland. The apparatus used consisted of a 250^{cm^3} flask closed with a rubber stopper carrying in two perforations the inlet and exit tubes. A stoppered funnel of 50^{cm^3} capacity with its tube constricted at its lower end was used as the inlet tube; and a glass tube of $\cdot 8^{cm}$ internal diameter, enlarged just above the stopper to a small bulb (to prevent mechanical loss of the solid contents of the flask during the boiling) and bent twice at right angles, served as the exit tube.

The analysis was made as follows: A solution of ferrous sulphate, mildly acidified with sulphuric acid, was made of about one-fifth normal strength and standardized against standard decinormal arsenious acid solution by treating portions of it, measured from a burette (and weighed as a check on the burette readings) with an excess of decinormal iodine solution, adding about 3 grms. of Rochelle salt in solution, neutralizing with acid potassium carbonate and adding in succession 15^{cm^3} of a saturated solution of acid potassium carbonate, starch paste and then standard arsenious acid solution to the bleaching of the starch blue, and, finally, titrating to color with the iodine solution. For the determination of nitric acid, the pure potassium nitrate of commerce was used. In the smaller amounts, the nitrate was taken in a solution of known strength measured from a burette and in the larger amounts as the dry salt. Where the solution of nitrate was used, it was measured into the flask, the stem of the separating funnel being completely filled with water, and the exit tube of the flask reaching to the surface of mercury which was placed in a test tube to the depth of about three centimeters. The nitrate solution was then boiled to small volume, an amount of the standardized ferrous sulphate solution known to be in excess introduced into the separating funnel, the exit tube plunged a centimeter or two deep into the mercury (which is readily accomplished by changing the position of the flask on the wire gauze provided that the gauze is depressed well at the center and the flask is set well up on the higher part at the beginning of the operation), and then the flame withdrawn until diminution of pressure sufficient to draw the ferrous solution into the flask is made evident by the rise of the mercury in the exit tube. By applying and withdrawing the flame and by regulating the rate of inflow of the solution, the ferrous salt may be introduced without admitting air and the funnel washed carefully with an amount of concentrated hydrochloric acid nearly enough to equal the total volume of the liquid in the flask. After the pressure has been restored in the apparatus by heating the flask, the exit tube is again raised to the surface of the mercury and the solution in the flask boiled to a volume of 10–15^{cm^3}. The excess of acid is then nearly neutralized with sodium carbonate solution, the carbon dioxide evolved assisting in maintaining the pressure in the apparatus so that the condensed liquid in the test tube which may contain oxidized nitrogen dioxide is not returned to the iron solution ; the flask is cooled and the ferrous salt remaining determined by iodine as previously described or by a standard solution of potassium permanganate. In case permanganate is used, the contents of the flask are diluted with 600^{cm^3} of water, 2–3 grms. of crystallized manganous chloride,* and titrated to color with potassium

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* Gooch and Peters, this Journal, vii, 461 (1899).

permanganate. In the experiments where the dry salt was used, the air was expelled from the apparatus by boiling 10^{cm^3} of water to small volume in the flask, arranged as previously described, the ferrous sulphate solution introduced and concentrated by boiling to a volume of about 20^{cm^3} so that the amount of acid used may not be so large; then, the nitrate, dissolved in a small amount of water, was allowed to flow in and was finally washed in, as before, with an amount of concentrated hydrochloric acid, which approximates in volume that of the liquid contents of the flask.

Experiments numbered I–VIII, inclusive, of the following table show the results of a series of experiments made as described above.

	KNO_3 taken. grm.	Oxygen value of ferrous salt taken. grm.	Oxygen value of ferrous salt found. grm.	Error on oxygen. grm.
I	0·0500	0·01823	0·00621	0·00015 +
II	0·0500	0·01865	0·00681	0·00003 —
III	0·0500	0·01954	0·00768	0·00000 ±
IV	0·1000	0·02881	0·00507	0·00001 +
V	0·1000	0·02822	0·00441	0·00008 +
VI	0·2500	0·06453	0·00512	0·00009 +
VII	0·5000	0·13394	0·01524	0·00005 +
VIII	0·5000	0·12210	0·00340	0·00005 +
IX	0·0500	0·01720	0·00747	0·00214 —
X	0·0500	0·01550	0·00389	0·00026 —
XI	0·0525	0·01550	0·00318	0·00014 —
XII	0·1000	0·02765	0·00432	0·00040 —

Experiments numbered IX and X were made to determine whether the long boiling in the previous experiments is actually necessary; for in the work by Fresenius as well as that of Eder, directions are given merely to boil the hydrochloric acid solution of the iron salt with the nitrate until the color of the dark compound of the nitrogen dioxide with the ferrous salt wholly vanishes and is replaced by the clear color of the ferric salt, which means an active boiling of not longer than five minutes in the experiments recorded in the table. Experiment IX was made exactly like the similar ones above it in the table, except that the boiling was interrupted after the dark colored ferrous compound with the nitrogen dioxide was completely broken up; and experiment X similarly, except that the boiling was continued for five minutes after the complete disappearance of the dark color. Obviously the period of boiling allowed by Fresenius and Eder is not enough, but since the main error incidental to these processes is an error of excess due to oxygen present, as already stated, it will readily appear how this second error, which is one of deficiency and hence correcting the first error, may have been overlooked.

Ferrous ammonium sulphate has been recommended by Austin and Chamberlain* and by Rosa† as more convenient, stable, and sensitive than the crystalline ferrous sulphate. It would seem possible that nitric acid might act as an oxidizing agent on the ammonium salt, and certainly nitrous acid (if it were produced, as might be, as an intermediate product in the reduction of nitric acid to nitrogen dioxide) would act according to the equation,

$$NH_4Cl + HNO_2 = HCl + 2H_2O + N_2.$$

Such an action either of the nitric acid or nitrous acid would produce an error of deficiency. Experiments XI and XII were made to test this point, being made exactly like those numbered I–VIII, except that 1 gram of crystallized ammonium sulphate was added with the ferrous salt. The results show slight but appreciable losses.

The concentration of the hydrochloric acid in this operation does not allow of much diminution under these conditions, where immediate reduction of the nitric acid without any volatilization is a necessity,—a fact which has been recognized before by Roberts and obviated under the conditions there used.

Thus it would appear—

First. That the method outlined above is capable of yielding very accurate results, affording as it does an easy and complete means of shutting out oxygen from the nitrogen dioxide while that gas is in contact with the ferrous salt.

Second. That prolonging the boiling only until the dark colored compound of nitrogen dioxide with ferrous salt is broken up, results in the incomplete reduction of the nitric acid.

Third. That ammonium salts must be absent, if the highest accuracy is desired.

*Amer. Chem. Jour., v, 209.

† Gazz. chim. ital., xv, 295.

Art. XLIII.—*The Clays of the Boston Basin*;* by Robert Marshall Brown.

The problem of the correlation of the clays of New England has never been solved. Numerous papers have been published, in which various clay beds have been described and in part discussed. Some of the writers have ventured to correlate the clays of neighboring sections. No one has yet undertaken the solution of the entire problem. Not enough light has been cast upon the subject for a general discussion. The isolation of clay beds in the same neighborhood with no evidence to show whether they are parts of the same deposit or disconnected deposits of the same time or unrelated beds, offers little of interest. Similarity of clay itself cannot be taken as good data for correlation, unless by chance some unique peculiarity of composition is discovered. Ordinarily, the zest to further search is furnished the student of clays by the constant excavations that are made in the streets for the laying of pipes, the opening of new clay pits, the extension of the old, and the removal of the cover of the clay for various purposes. All new exposures which furnish interesting evidence in any direction should be recorded. By the accumulation of such evidence, it is believed that in time a correlation of the clays of New England and beyond may be safely attempted. For this reason, the writer of this article desires to place on record some of the results of this field study on the clays about Boston, with a few observations that arose during the process of the investigations.

Field Work.—Near Chelsea Street, between the cities of Everett and Chelsea, Massachusetts, extensive excavations, during the fall of 1901, revealed the clays. A hill, drumlin-like in appearance, of no great height, and half a mile long, with a trend a little south of east, parallel to the drumlins of the neighborhood, was in part removed. An almost complete cross section of the hill was exposed. The core of the hill is an igneous rock (fig. 1). The rock does not extend to the southern slope, however. Here a clay and sand interior was found. Both clay and rock was capped by a thin layer of till. The relation of the clay to the rock was unknown, as neither the quarrying of the rock to the north nor the removal of the clays to the south showed the contact. The first appearance of the south end of the hill in the process of removal of the material showed an anticline in the clay. The stratification of the beds was emphasized by the interlamination of thin layers

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* This paper is a part of a thesis presented in the course on Glacial Geology at Harvard College, under Prof. J. B. Woodworth.

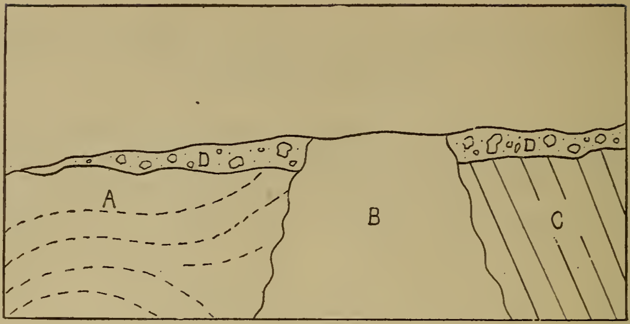

Figure 1.—Chelsea Street, between Chelsea and Everett, Mass. A. = Clay, B. = Talus, C. = Rock, D. = Till. Dotted lines in clay represent sand.

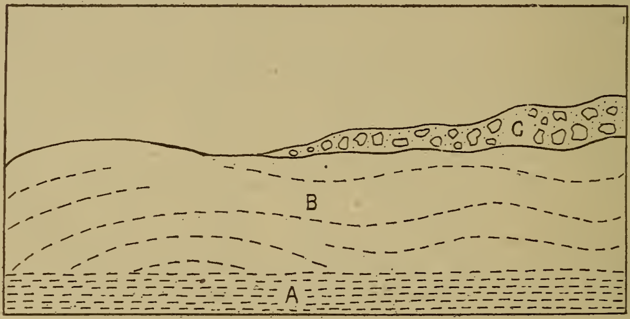

Figure 2.—Chelsea Street, between Chelsea and Everett, Mass. A. = Sand, B. = Clay, C. = Till. Dotted lines in clay represent sand.

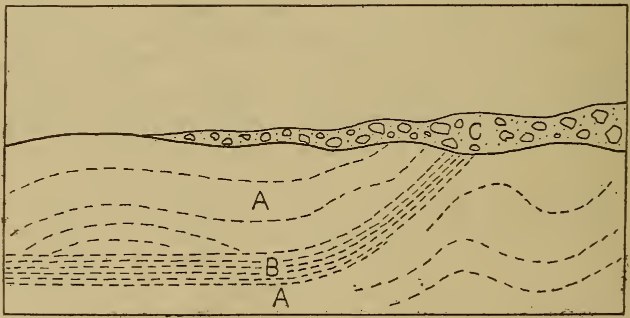

Figure 3.—Chelsea Street, between Chelsea and Everett, Mass. A. = Clay, B. = Sand, C. = Till. Dotted lines in clay represent interstratified sand.

of sand in the lower portions of the clay and by dark bands, probably of vegetable matter, in the upper portions. Below the clay was a bed of sand, and above a thin layer of till which ran out towards the south (fig. 2). The disappearance of the till was due probably to the removal of the material in a previous excavation further to the west. Before a second visit to the pit was made enough material had been removed to yield a better section (fig. 3). The bed of sand at the bottom of the clay (shown in fig. 2) proved to be a stratum of sand 14 inches thick, underlain by more clay. The sand was of fine texture, similar to our beach sands, and homogeneous throughout. A single small slate pebble was the only break in the uniformity of the sand bed. At the same time enough of the talus had been removed to show the sand bed extending to the edge of the till and there cut off before the deposit of the till. To the north the clay was much more crumpled, and the interstratified sands were, as a general rule, thicker than the layers above the thick sand bed. The till averaged 18 inches in thickness, was made up of coarse and fine material, and extended over the entire section of the hill remaining. The slope of the hill was very gradual and the question of the slipping of the till over the clays was negatived by the rolling surface of the clay as well as by the slope.

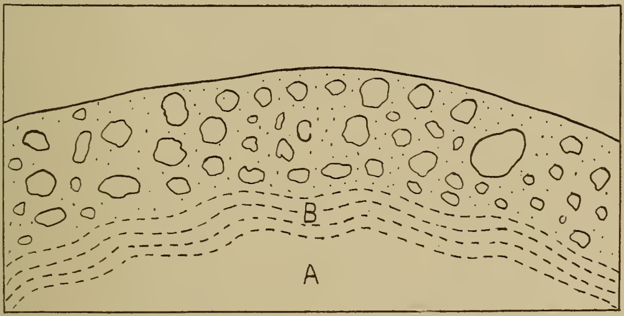

Figure 4.—Cross-section of end of Drumlin in Revere, Mass. A. = Clay, B. = Sand and Clay, C. = Till.

In seeking for other instances of the same thing, a section across the trend of a drumlin at the junction of Shirley Avenue and Nahant Avenue in Revere, Mass., was found. The drumlin had the northwest—southeast position of the drumlins of the district. The core of the drumlin was clay (fig. 4). Above the more solid bottom clay was a thickness of about three feet, made up of alternating layers of sand and clay, the sand increasing upwards. Over the sand was 14 feet of till.

The till contained bowlders of varying sizes; the largest over a foot in diameter. Thickly intermixed as a part of a till was a great deal of clay. The clay itself, below the layers of sand, was homogeneous and contained no foreign matter. The bottom of the clay was seen in one instance only, and the clay rested in that case on gravels. This exposure was at a distance from the two mentioned above.

Clays in Literature.—An early mention of the clays was by Edward Hitchcock.* His conclusion stated that nearly all of our clays are in the Tertiary formation. At the same time he is frank in admitting that he has no evidence bearing on the matter, and that his result was reached solely by analogy. The European plastic clays resting on the chalk was the basis of his reasoning. In the Geology of New Hampshire many cases are instanced by Upham† where clays overlie till. This is especially true of the Winnipiseogee Lake beds. His explanation is quoted: "The ice-sheet probably remained in a high mountain-like mass over these lakes after it had disappeared on each side from the basin of Ossipee Lake and from the lower part of the Pomigewasset valley. As the melting continued, the drainage over this area was frequently obstructed because the ice-sheet retreated from the lines of watershed towards the middle of these hydrographic basins. The water seems then to have melted large open spaces beneath the ice near its margin in which beds of clay and sand were deposited. This would occur at the various heights and in the situation where these beds are found, and the till which overlies them is shown by its material to be that which was contained in the ice-sheet and fell upon the surface when its melting was completed. We thus see how these deposits came to be spread over the slopes of the hills, thinly covered by large boulders and till. The frequent accumulation of such deposits in other parts of the state was prevented by unobstructed drainage from the melting ice. This modified drift over-laid by till does not therefore appear to bear testimony to a warm interglacial period, or even to any retreat and subsequent advance of the ice."

Emerson‡ reports clay resting upon till in the "Northampton Lake" deposits. In a few localities he observes till over clay, and, furthermore, explains the contortions of the clay beds by ice moving over them. In the succession of events a minor advance (being the third) of the ice is considered to explain these phenomena. Shaler§ publishes a section at Weewocket,

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* Report on Geology, Mineralogy, Botany and Zoology of Massachusetts. 1883, 36.

† Geology of New Hampshire, iii, 136.

‡ Monograph 29 U. S. G. S., p. 697. § Bulletin 53 U. S. G. S., p. 16.

Nantucket, in which is shown a till deposit over clay. Professor Shaler at another time,* in summing up the facts of the clays, suggests that they are reconcilable with the supposition that there were several clay-making periods, each marking a retreat of the ice, followed by a readvance. The clays about Boston were studied by Marbut and Woodworth.† Sections of drumlins in Somerville have been published by them showing the clay beneath the till. Professor Woodworth,‡ in the correlation of the deposits along the coast of New England, places the Mystic clays in the second of three glacial epochs.

Discussion of Relation of Clays to the Glacial Period.—The points that must be explained are as follows:

1. The position of the clays beneath the drumlins in Chelsea and Revere. 2. The considerable amount of clay that makes up a constituent part of the till of the drumlins. 3. The distortion of the clay-beds.

Only one conclusion can be reached in regard to the first of these. The clays must have been deposited before the advance of the ice which formed the drumlins. The clayey composition of the drumlins in the neighborhood points to the same conclusion. In a pit recently opened in the flank of a drumlin situated near Hyde Park, Massachusetts, enough clay was found on the floor to give an aspect of a clay bed. This clay had washed out of the exposed till during the storms, and collected at the bottom of the pit. A little digging exposed a few inches of clay only, and further examination explained the origin of the clay. The per cent of clayey material appears to be too large to be produced by the natural process of grinding, during or just previous to the formation of the drumlins. It seems just, under the circumstances, to presuppose a reservoir of clay from which the drumlins drew their supply. Local advances of the ice have been offered as an explanation for the position of the clay under the drumlins as well as the large percentage of clay in their composition. Emerson considered such an event in the "Northampton Lake" area. While a local advance of the ice after the last general retreat has been proven along the line of the chain of lakes—Fresh Pond, Spy Pond, the Mystic Lakes, etc.,—it is not consistent to extend this local advance over an area large enough to account for the drumlins of Revere and Chelsea. The local advance would then grow to a general invasion.

The distortion of the clay-beds offers some additional testimony. No explanation has been given for the folding of the clays that has been more satisfactory than the thrust of the

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* 17th Ann. Rep. U. S. G. S., p. 969.
† 17th Ann. Rep. U. S. G. S., p. 989.
‡ 17th Ann. Rep. U. S. G. S., p. 987.

advancing ice. The agent of this work has also been considered a local advance, but again the widespread occurrences of these folds indicate the general event rather than a limited one.

Where the surface has been planed off, as in fig. 3, the ice was supplied with its clay, which it deposited in the drumlins of the harbor and the harbor vicinity. The beds must have been developed previous to the ice advance. Upham's explanation, cited above (dated 1883), cannot be considered as applicable for the Boston district, as he demanded a valley slope by means of which the water was held against the side of the glacier so that the warmer water might undermine the edges of the ice. It is not easy to conceive how clays of any amount could be deposited under the ice by such a supposititious theory. There seems to be evidence strong enough to support the belief that some of the clays of the Boston Basin were deposited before the last general advance of the ice; are therefore inter-glacial in origin.

New Bedford, Mass.

Art. XLIV.—*A New Form of Calcite-Sand Crystal;* by Erwin H. Barbour and Cassius A. Fisher.

Until quite recently the knowledge of calcite-sand crystals was confined to a very few occurrences, that of the well-known "Fontainebleau limestone" being the most important;* here the crystals are rhombohedral in form (−2R). A few years since sand-calcite crystals of different type from those of Fontainebleau were found on Devil Hill, in the Indian Reservation, Washington Co., South Dakota. During the winter the writers have added still another locality, partly in western Nebraska and partly in Wyoming, which yields a third form of sand crystals, namely combinations of acute and obtuse rhombohedrons, constituting a group similar to and quite as interesting as those from Devil Hill, though smaller in size.

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Fig. 1. Pen drawing of a scalenohedron with rhombohedral terminations illustrating the theoretical form of the sand-lime crystal shown in figure 2.

Fig. 2. Photographic reproduction of a sand-lime crystal, nearly natural size, the type found at Devil Hill, Indian Reservation, Washington County, South Dakota.

Crystals from Devil Hill, South Dakota.

The sand-calcites from Devil Hill, which is the base of the Arikaree sand, vary from single to double, triple, quadruple and multiple crystals, up through clusters and concretions to solid sand-calcite rock, which though solid and compact reveals on fracture, and especially on weathered sections, the indistinct hexagonal outlines of its component crystals.

In point of size they vary from a quarter of an inch (6^{mm}) to

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*Lassone, Mem. d l'acad. royal, Paris, 1775, p. 65. Haüy, Traite de Mineralogie, vol. 1, p. 424, 1882. See also Dana, Syst. Min., p. 266.

those exceeding 15 inches (28^{cm}). The average crystal, of which there are myriads to be dug out of loose sand, has a length of two and one-half to three inches (6 to 8^{cm}). (See figs. 1 and 2, which are somewhat reduced.) They are barrel-shaped with rounded ends, and have been described by Penfield and Ford* as hexagonal pyramids, but to the writers a study of the form of the faces and a measurement of the angles seems to show that they are a combination of scalenohedron and rhombohedron.

Analyses.—Analyses of four crystals were made by Woodruff and Warner, who determined the average percentage of sand to be 63·81, leaving 36·19 soluble matter, as shown in detail in the accompanying table.

	Weight of crystal.	Per cent sand.	Per cent of soluble matter.
Crystal No. 1	$129·57^{gr}$	63·07	36·93
“ “ 2	$80·36^{gr}$	63·55	36·45
“ “ 3	$33·40^{gr}$	64·22	35·78
“ “ 4	$30·65^{gr}$	64·40	35·60
Average of the above		63·81	36·19
Large concretions		61·88	38·12
Sand crystal rock		63·43	36·57
Average of four radiate sand-lime concretions, Sioux County, Nebraska		58·89	41·11

Crystals from Goshen Hole Region, Wyoming.

The new crystals, which also consist of sand cemented by calcite, are very similar in color, texture, and in general appearance to those from Washington County, South Dakota, differ from them in being a combination of acute and obtuse rhombohedrons. They show greater uniformity of size, varying but little from one and one-half inches (40^{mm}) in length, by seven-eighths inch (21^{mm}) in thickness (figs. 3, 4). Apparently they occur much more sparingly than the others, although the field remains to be fully explored.

They show the same tendency to become doubled, clustered, concretionary, and massive to such an extent that descriptions already written of the one kind serve well for the other. If the crystals happen to be particularly small, the size of the sand grains is relatively so large that the exact outline of the

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* Penfield and Ford, Siliceous Calcites from the Bad Lands, Washington County, South Dakota, this Journal, vol. ix, 1900, pp. 352–4, 1 plate, 4 figures.

See also Barbour, Sand-Crystals and their relation to certain concretionary forms, presented before the Geol. Soc. of America, Dec. 27, 1900, printed in Bulletin of the Society, vol. xii, pp. 165–172, pls. 13 to 18, April 16, 1901.

crystal is obscured, and yet to the collector in the field, at least, the identity is plain. The less obvious forms occur in great masses and over wide areas, and pass for concretionary sand. Their extent may be judged better from the fact that they may be traced from the Indian Reservation of South Dakota to northwestern and western Nebraska and eastern Wyoming, as far west, at least, as Bates Hole, which is practically the extent of the Arikaree formation. Without a knowledge of the actual sand crystals these obscure forms would ordinarily be unrecognizable. In the case of the new forms as in the case of the older ones they are the result of crystallization in a sand bed saturated with water bearing calcium carbonate in solution. The lime in crystallizing out followed some one of the forms common to calcite and in the process cemented the sand, together making a sand-calcite crystal. The crystal proper is calcite. The sand may be viewed as an accident incident to the crystallization of lime in a sand bed. A chemical analysis shows that those from western Nebraska do not differ essentially from those of South Dakota, as shown by analyses of Mr. Willis Warner (Univ. Nebr. 1901).

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Fig. 3. Drawing of a crystal showing combination of acute and obtuse rhombohedrons, the theoretical form of the actual crystal shown in figure 4.

Fig. 4. Sand-lime crystal, natural size, type found west of Mitchell, in the Chadron sandstone near the North Platte River, on the Wyoming-Nebraska line.

Analysis of Sand Crystals from Goshen Hole Region.

	Per cent of sand.	Per cent of lime and soluble matter.
Sand crystal	63·63	36·37
Sand concretion	62·54	37·46

Analyses of the above in full as furnished by Mr. Warner are as follows:

Crystal: silica, 49·32; phosphorus, ·011; iron, $Fe_2O_3+Al_2O_3$, 14·21; lime, $CaCO_3$, 33·27; magnesia, $MgCO_3$, 3·14; undetermined, probably manganese, ·049.

Concretion: silica, 47·94; phosphorus, ·01; iron, $Fe_2O_3+Al_2O_3$, 14·52; lime, $CaCO_3$, 34·24; magnesia, $MgCO_3$, 3·25; undetermined, probably manganese, ·04.

Distribution and Geologic Range of Sand-Calcite Crystals.

The distribution of sand crystals is very wide though they are little known and seldom recognized from the fact that the more obscure forms pass for concretionary sand and receive no attention. They have been personally observed at and around Devil Hill, in the Indian Reservation of South Dakota; in Sioux County, Nebraska; in the North Platte region in Nebraska, at Goshen Hole, Bates Hole, and intermediate points in Wyoming.

The larger crystals present no such disparity between the component sand and gravel grains and the crystal itself as do the lesser ones, hence their forms are defined and perfectly apparent. Such forms are restricted and very local in area. Those at Devil Hill occur in enormous quantities along about 100 yards of exposure. The total extent of the bed, which is but a mere remnant of the original, is scarcely one acre. Those from the region of the North Platte river, at or near the Nebraska line, seem to be even more local, and are very scattered in number. The same seems to hold true of those in the Goshen Hole country, which may be classed with the North Platte region, both producing the same crystalline forms shown in figure 4, though differing in horizon. There are but the three above named localities known in this country which produce these crystals. In France, at Fontainebleau, the crystals are similar in physical properties to those from the Great Plains though differing crystallographically, inasmuch as they are simple unmodified rhombohedrons.

In vertical range these forms occur in greatest numbers in the Arikaree, though found as low as the Chadron sands at the base of the Oligocene. In the basal sands of the Laramie of Wyoming occur numerous examples of the obscure or concretionary type.

		Locality of sand-calcites.
Tertiary	Miocene (Arikaree)	Devil Hill, S. D. Sioux Co., Nebraska Goshen Hole, Wyoming Bates Hole, Wyoming
	Oligocene (Chadron sand)	Mitchell region, Nebr.
Cretaceous	Laramie	South of Buffalo, Wyoming Obscure crystals or concretionary sand

University of Nebraska, Lincoln, Nebr.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Transformation of Carbon into Diamond.*—It was shown by Pepys, in 1815, that an iron wire heated to redness in contact with diamond was converted into steel. Dr. ALBERT LUDWIG now claims that under great pressure in an atmosphere of hydrogen this reaction is reversed, and also that carbon fused in the electric arc in absence of iron, under the same conditions of pressure, is likewise converted into diamond. In carrying out the experiments, pressures as high as 3100 atmospheres were used. A spiral of iron wire was embedded in powdered retort-carbon and heated by an electric current in a highly compressed atmosphere of hydrogen. In a few moments the resistance, which was slight at first on account of the conductivity of the carbon, rose to that of the iron spiral. This indicated that the carbon in contact with the spiral had become non-conducting, and careful examination showed that on some of the pieces of carbon were brilliant, minute crystals, possessing the hardness, specific gravity, and refraction of the diamond. The greater part of the carbon contained in the iron spiral had also been converted into diamond. The crystals had the characteristic irregular surface shown by the diamonds produced by Moissan by the sudden cooling of molten iron. To produce diamonds without the use of iron, it was found necessary to use much higher temperatures and actually fuse the carbon under very high pressure. Thus fused it was shown to be a non-conductor, and hence was considered to be molten diamond. Under the pressure employed this fusion took place very easily in the electric arc, and there were thus obtained spherical masses, of the size of peas, having the great hardness and crystalline structure of carbonado. It is the intention of the author to develop the process for the commercial manufacture of diamonds. —*Chemik. Zeitg.*, xxv, 979. H. L. W.

2. *An Iodometric Titration of Thiocyanic Acid.*—It has been shown by Rupp and Schied that sulphocyanides are oxidized in sodium bicarbonate solution, according to the equation,

$$HSCN + 4I_2 + 4H_2O = H_2SO_4 + 7HI + CNI,$$

but starch cannot be used as an indicator in applying this reaction on account of the presence of cyanogen iodide; and, moreover, the yellow color of the latter compound makes the method applicable only to small quantities where the disappearance of the iodine color is used. It has been found by Meinecke, however, that in acid solutions the following reaction takes place: $CNI + HI = I_2 + HCN$. THIEL has now used the facts which have been stated for devising a very convenient method for making this titration. The thiocyanate is first treated with an excess of iodine solution in the presence of sodium bicarbonate, enough water being used to dissolve the latter. The reaction is complete in four hours at ordinary temperature. Then an excess of hydrochloric acid is added, and the excess of iodine is determined at once by means of sodium thiosulphate solution, with the use of starch as an indicator. The final result corresponds to the equation,

$$HSCN + 3I_2 + 4H_2O = H_2SO_4 + 6HI + HCN.$$

The experimental results obtained were extremely accurate, and the author advises the standardization of volumetric thiocyanate solutions by this method.—*Berichte*, xxxv, 2766. H. L. W.

3. *Iodine Pentafluoride.*—This compound was prepared, probably in an impure condition, by Gore in 1871 and by MacIvor in 1875, by the action of iodine upon silver fluoride. MOISSAN has now prepared it by allowing fluorine gas to act upon iodine. Combination takes place with evolution of heat and the product is a colorless liquid boiling without decomposition at 97°, and solidifying at 8°. In the solid state it resembles camphor. The liquid fumes in the air, and when poured into water it is decomposed without violence into hydrofluoric and iodic acids according to the equation,

$$2IF_5 + 5H_2O = I_2O_5 + 10HF.$$

The fluoride possesses great chemical activity; most elementary bodies decompose it, and it enters into reactions with a great number of compound substances. When its vapor is heated to the neighborhood of 500° it decomposes, showing the color of iodine vapor.—*Comptes Rendus*, cxxxv, 563. H. L. W.

4. *Separation of Manganese from Magnesium, Zinc and Aluminum.*—To effect these separations DIETRICH and HASSEL precipitate the manganese as higher oxide in dilute sulphuric or nitric acid solution by means of ammonium persulphate. For quantities of manganese corresponding usually to ·1^g MnO or less they used 5^{cc} of dilute sulphuric acid (1 : 10) and 15–20^{cc} of a ten per cent solution of ammonium persulphate. In the separation from magnesium the total volume of the liquid was 150–200^{cc}, while in the other cases, where the quantities of zinc and aluminum oxides present were about the same as that of the manganese oxide, a volume of 400–500^{cc} was used. The precipitations were made in solutions heated upon the water-bath and frequently stirred, and the heating was continued for about two hours in order to decompose the excess of ammonium persulphate. The manganese precipitates, after filtering and washing, were ignited directly, and Mn_3O_4 was weighed. The test analyses gave very satisfactory results. It seems probable that this method will find useful application in mineral and rock analyses, in which, by the usual methods, the separation especially of manganese and aluminum presents some difficulties.—*Berichte*, xxxv, 3266. H. L. W.

5. *Plasticity and Adhesiveness of Glass at Ordinary Temperatures.*—That glass possesses a certain amount of plasticity when not heated has been known for a long time, but it has not been shown definitely that this plasticity is sufficient to produce adhesion similar to the welding of metals. PICCARD has now

made experiments which indicate that the thin cracks extending from ·05 to ·1^{mm} below the scratch made by the glass-cutting diamond may be healed to a considerable extent in from one to three days by gentle pressure. The experiments were conducted by comparing the loads required to fracture freshly scratched pieces of glass and those which had been slightly bent for several days in such a way as to press together the ruptured surfaces.—*Berichte*, xxxiv, 3635. H. L. W.

6. *General Principles of Physical Science;* by ARTHUR A. NOYES. 8vo, pp. 172. New York, 1902 (Henry Holt & Co.).—The purpose of this volume is to present the principles and laws of physics and chemistry which lie at the basis of the modern science of theoretical chemistry. The treatment is non-mathematical to a great extent. The two main chapters of the book treat respectively of the general principles relating to matter and to energy.

The book forms the first part of a work on the general principles of chemistry, which has had to be discontinued. It is to be hoped that Professor Noyes will continue the work in the future. H. W. F.

7. *Lehrbuch der Allgemeinen Chemie;* by Dr. WILHELM OSTWALD. 2 vols. Leipzig, 1902 (Engelmann).—The last section of the second part of volume ii has just appeared. A third part is to appear in the future. This work is by far the most comprehensive which has yet appeared in the field of physical chemistry and probably comes as near treating the whole subject as it is possible to do. It is to be regretted that volume i and the first part of volume ii are already out of print. H. W. F.

8. *The Spectra of Hydrogen and Reversed Lines in the Spectra of Gases;* communicated by JOHN TROWBRIDGE.—In a previous paper* I described the spectra produced by powerful condenser discharges through Geissler tubes filled with hydrogen. A fairly continuous spectrum was obtained between the HH lines and the red end of the spectrum which was traversed by reversed lines. In that paper I expressed the hope of being able to obtain quartz tubes. This hope has been realized. Through the kindness of manufacturers† working under the direction and according to the method of Professor Shenstone of Clifton College, England, I have obtained suitable tubes, and the results given by such tubes are so remarkable that they seem worthy of a preliminary paper.

The tubes are eight centimeters in length; with a capillary four centimeters in length and about two millimeters in diameter. On account of the difficulty of inserting platinum terminals in quartz, I had the ends of the tubes ground smooth; and the glass blower of the laboratory prepared glass bulbs in which suitable electrodes were inserted. These bulbs were luted to the ends of the quartz tubes. In certain cases where metal plates were luted directly to the ends of the quartz tubes I employed silicate of soda as a luting agent; and after this had hardened I applied on the outside of the joint a hard preparation of pitch and shellac.

The glass bulbs were covered with other bulbs which allowed

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* This Journal, vol. xiv, p. 1.

† Baird and Tatlock, London.

a current of water to circulate from the upper end of the tube to the lower. The great heat, however, was excited in the capillary of the tube. Quartz prepared by the method of Professor Shenstone possesses the property of resisting changes of temperature in a remarkable manner. One of these quartz tubes can be heated to a white heat and plunged into water without cracking. Such tubes, therefore, are very valuable for the experiments I have been conducting on gases at high temperature.

They also possess the great advantage over end-on tubes of glass provided with quartz window, that the capillary can be placed close to the slit of the spectroscope ; thus giving a very intense light and a broad spectrum. Moreover, the quartz is not melted by the intense heat. A photograph of gaseous spectra can be obtained with a single discharge and a very narrow slit ; with tubes filled with hydrogen excited by a difference of potential of twenty thousand volts, condenser ·3 microfarads, an extremely intense light is obtained. This light is dazzling white with a bluish cast. It has more than three times the actinic effect of the same quantity of electricity discharged between magnesium terminals. Viewed with a strait vision spectroscope, the spectrum appears continuous, and even photography fails to reveal bright lines between the HH lines and the red end of the spectrum. In the region, however, beyond the limit set by the absorption of the glass Geissler tubes there are both bright lines and dark lines. The principal reversed lines are at wave lengths 2889·70 ; 2549·89 ; 2528·60 ; 2524·29 ; 2519·3 ; 2516·21.

These lines correspond with the lines of silicon volatilized by the spark in air. It seems that we have in this phenomenon another instance of selective solarization mentioned in my previous paper. The strongest metallic lines or gaseous lines are not those which show the strongest reversal. For instance, the calcium line at approximately 4227 is strongly reversed, while the stronger 3968, 3933 do not show a reversal, except with much stronger and longer continued discharges.

A careful inspection of the negatives shows that the reversals of the metallic lines occur when they fall on bright gaseous lines or bands. In the same way a bright gaseous line falling on a continuous spectrum can show a similar reversal. We can express this in symbolic language as follows : let A represent the intensity of the line and B the amount of the previous action of light on the photographic plate, then the reversal appears to be proportional to AB.

It seems probable that there are similar reversed lines running through the solar spectrum and I hope to detect them.

This investigation shows that the presence of dark lines in the spectra of stars does not imply necessarily the presence of reversing layers of a colder state of the gases ; for such reversal may arise from photographic action on the plates which are used. Moreover a gas may show a continuous spectrum to the eye, or even when photography is employed with glass tubes and glass lenses ; while with quartz tubes such as I have employed a large region in the ultra violet is shown to be traversed by both dark and bright lines and bands.

Jefferson Physical Laboratory, Harvard University.

9. *A New Holtz Machine.*—The influence electrical machine in many respects has been found to excel the induction coil for the excitation of X-ray tubes. H. Wommelsdorf describes a new electrical machine which he calls the condenser machine. It consists of many discs similar to those now used in the Holtz machine. There is a large condenser action between the glass plates which are provided with suitable sectors. We have thus a row of condensers; one set of plates or coated layer remaining fixed while the intervening plates revolve.

A small model, 30^{cm} high, 28^{cm} long and with a breadth of 22^{cm}, affords a larger quantity of electricity than the largest Holtz machine, and this new machine promises to be of the greatest use in the excitation of X-ray tubes.—*Ann. der Physik*, No. 11, 1902, pp. 651–659. J. T.

10. *Electrical Conductibility of Metals and their Vapors.*—Hon. R. J. Strutt finds that (1) Mercury vapor is an insulator, while liquid mercury is a conductor. Since the liquid and saturated vapor are indistinguishable above the critical temperature, one or both of these must undergo a remarkable change of electrical properties as that temperature is approached.

(2) Attempts to predict the critical temperature of mercury seem to lead to results altogether inconsistent with one another.

(3) Attempts to observe the critical temperature of mercury and arsenic in quartz tubes have failed. In both cases experiment proves that the critical temperature lies above a dull yellow heat.

(4) Up to a full red heat the conductivity of saturated mercury vapor remains of quite a different order of magnitude from that of the liquid, the latter being ten million (10^7) times as great as the former. But on the other hand, the conductivity of the saturated vapor is immensely greater than that of the vapor at atmospheric pressure. For the former was found to have a resistance of 10^7 times that of the liquid, the latter more than 4×10^{14} that of the liquid. Thus the vapor at atmospheric pressure has a resistance about 4×10^7 times that of the saturated vapor, both at a full red heat. It need scarcely be said that this ratio is of quite a different order from the ratio of the densities of those vapors. It seems likely that as the critical temperature is approached the vapor begins to conduct freely, while the liquid changes its electrical character to a much less extent.

(5) The conductivity of saturated arsenic vapor at a bright red heat is of the same order as that of mercury, and obeys Ohm's law, at all events up to an electromotive intensity of more than 100 volts per cm.—*Phil. Mag.*, Nov., 1902, pp. 596–605. J. T.

11. *Ionization of Nuclei Produced by Violent Agitation of Dilute Solutions;* communicated by C. Barus.—Discharging the nuclei produced by violent agitation of dilute solutions, in a steady stream at once into a tubular condenser, the following deflections

of the electrometer (with very light needle) were observed at intervals of half a minute: Charge +, 14·4, 10·5, 6·5, 3·4; time rate 7·5. Charge −, 21·5, 20·0, 18·2, 16·2, 14·2, 12·2; time rate 4·0. Charge +, 18·3, 14·5, 10·4, 6·7, 3·3, ·9; time rate 7·6. The surprising result is thus obtained that the electric current is constant while the initial charge of the inner coating of the condenser (the outer being earthed), at nearly 20 volts, gradually quite vanishes.

In explanation it may be assumed either that the number of ionized nuclei at constant ionic velocity varies inversely as the potential difference, or far more simply, it seems to me, that the velocity of the nuclei is independent of the potential gradient, each nucleus retaining its own specific velocity in the presence or the absence of an electric field, while the number of nuclei is appreciably constant—the point of view taken in my earlier work (Smithsonian Contributions, 1901). The difference of current for positive and negative charges follows from the known excess of negative nuclei. The initial ionization is of the same order as that of the phosphorus emanation.

12. *Handbuch der Spectroscopie*; by H. Kayser. Vol. ii, 698 pp., 4 tables, 57 figs. (Leipzig, S. Hirzel).—The appearance of the second volume of this work gives further assurance of the thorough treatment of the whole subject of spectroscopy which we may expect from this eminent worker in the field. In the present volume, the first chapter is devoted to emission and absorption, with the history, development and proofs of Kirchoff's law. The chapter on radiation of solids furnishes an exhaustive discussion of the various laws which have been formulated connecting the emission with the absolute temperature, the distribution of the energy in the spectrum, and the attempts to apply the results in the measurement of temperature. Under radiation of gases, the sources of energy and the production of ether vibrations in general are discussed. This is followed by a detailed treatment of the spectra of compounds and of the different spectra given by the same substance under varying conditions. The succeeding chapters deal, respectively, with the influence of pressure, temperature and the nature of the electric discharge upon spectra; the appearance of spectral lines, their broadening, and reversal; Doppler's principle and its applications, in the discussion of which the author has been assisted by Dr. H. Konen; the general relations which have been discovered among the lines of the spectra of individual elements and of those of Mendeleeff's groups. The concluding chapter brings up to date the work which has been done upon the vibrations of light in the magnetic field. Prof. C. Runge has assisted in the development of the Zeeman-effect in accordance with the modern ionic theory.

Evidently no effort has been spared in making the references to the literature of every subject discussed as complete as possible up to 1901. The volume is replete with suggested problems of research, to stimulate which is one of the purposes which the author hopes the book may serve. D. A. K.

II. GEOLOGY AND NATURAL HISTORY.

1. *United States Geological Survey.*—The following publications have been received:

MINERAL RESOURCES OF THE UNITED STATES FOR THE CALENDAR YEAR 1901; by DAVID T. DAY. 973 pp.—For the second time the annual mineral production exceeds $1,000,000,000. The important metals except iron and zinc have decreased in output and value. 1,408 ounces of platinum were produced in 1901 compared with 400 in 1900. Building materials, clays and abrasions show greatly increased production. For the first time in the United States arsenious oxide was manufactured at Seattle, and rutile was produced on a large scale—in Nelson Co., Va.

BULLETIN No. 195.—Structural details in the Green Mountain Region and in Eastern New York; by T. NELSON DALE. 10 pp., 4 pls., 8 figs. Some interesting examples of structures in metamorphic rocks are described and well illustrated. These details have been collected since the publication of Professor Dale's previous papers on this region (16th Ann. Rept., Pt. I, pp. 549–570, 19th Ann. Rept., Pt. III, pp. 199–217).

BULLETIN No. 203.—Bibliography and Index of North American Geology, Paleontology, Petrology and Mineralogy for 1901; by F. B. WEEKS. 144 pp.

2. *Geological Survey of Kansas—Special Report on Mineral Waters;* by E. H. S. BAILEY. Vol. vii, pp. 25–333, 38 pls.—Kansas is well supplied with marketable mineral waters. Mr. Bailey describes and gives the analyses of some 87 springs and wells separated into groups according to their mineral content. He also discusses the medicinal value of the various waters and the industrial uses of the brines. Dr. W. R. CRANE contributes a chapter (pp. 323–333) on the Geological Distribution of mineral springs and wells.

3. *A Quantitative Chemico-mineralogical Classification and Nomenclature of Igneous Rocks;* by WHITMAN CROSS, J. P. IDDINGS, L. V. PIRSSON and H. S. WASHINGTON (Jour. of Geol., vol. x, No. 6, pp. 555–690, 1902).—In this work is presented an entirely new system for the classification and nomenclature of igneous rocks, a result which the authors believe is to be best attained by the coöperation of several workers agreeing on fundamental principles. Originally the late Prof. G. H. Williams was also one of the collaborators.

The authors state that after many attempts to modify and use existing systems this was perceived to be impossible if one should evolve at the same time a comprehensive and rational one based on recent investigations and knowledge. Thus through repeated trials the present system was gradually worked out, and with its evolution has gone hand in hand the calculation of thousands of analyses by which it has been tested and its formation in part controlled. It is a *chemico-mineralogical* system based on its own principles, and as its concepts of rocks are in great part new it demands a new nomenclature.

What the authors propose is as follows: All igneous rocks are classified on the basis of their *chemical composition;* all rocks having like chemical composition are grouped together.

The definition of the chemical composition of a rock and of a unit of classification is expressed in terms of *certain minerals* capable of crystallizing from a magma of a given chemical composition, and the expression is *quantitative.* For this purpose the rock-making minerals are divided into two groups, the one of the more siliceous alkali-and calcic-aluminous ones, the other of the ferro-magnesian minerals. The first group is called mnemonically the *salic* group; the second one, the *femic* group. From this category the aluminous augites and amphiboles and the micas are excluded for reasons given.

To completely classify a rock by this system its chemical composition must be known by chemical analysis or approximately so by physical or microscopic optical methods indicated by the authors. Rocks once determined become types by which similar rocks may be approximately classified.

Since a given magma may crystallize into quite different mineral combinations according to the different conditions attending its solidification, it is necessary to select a certain set of salic and femic minerals as uniform standards of comparison. These are the ones ordinarily formed, but aluminous augite and hornblende and micas are excluded. In practice, the molecular composition of a rock obtained from its chemical composition (determined as mentioned above) is computed into amounts of these standard minerals and its place in the system is then easily determined.

The *standard mineral composition* of a rock is called its *norm,* and this may be quite different from its *actual mineral composition* or *mode.* Methods are given for obtaining the latter and indicating its relation to the former.

On the relative proportions of these two groups of standard minerals the rocks are divided into five *Classes,* accordingly as one or the other of these two groups alone constitutes the norm or is *extremely* abundant; whether one or the other is *dominant;* or whether the two are present in about *equal* proportions. *These Classes* are then divided into *Orders* on the relative proportions of the minerals forming the predominant group in each case and in the middle group on the relative proportion of the salic minerals. So in the preponderantly salic classes the orders are based on the relative proportions of quartz, feldspars and feldspathoids.

The *Orders* are divided into *Rangs* on the chemical character of the basic oxides in the minerals in the preponderant group in each case; thus if these were feldspathic, as to whether they are alkalic, alkali-calcic or calcic. The lowest division or *grad* obtains only in the three intermediate classes and results from the consideration of the relative amounts of the minerals forming the subordinate group in each case. Where necessary there are subclasses, suborders, subrangs and subgrads.

Texture is considered of minor importance and is taken into account after the chemical and mineral composition.

Nomenclature. The system demands a new nomenclature and this has been provided for according to a definite system. As proposed it consists of three parts, substantive names for the magmatic units, implying the chemical composition and the *norm*; then two sets of adjective terms to qualify these nouns, one referring to the *mode* and the other to the *texture*.

The magmatic name consists of a root, geographical in all cases except for the names of the five classes, and of a suffix. The suffixes are chosen so that they vary in a definite way with the division of the system to which the magmatic name belongs. Thus for Class, Order, Rang and Grad, the letters *n*, *r*, *s* and *t* in alphabetical order are used with the vowel *a*, giving in English *ane, are, ase, ate.* For subclass, suborder, etc., the vowel is *o*, giving *one, ore, ose* and *ote.*

In the geographical roots, so far as possible those in present use are retained, advantage being taken of their connotation as to magmatic character.

The authors propose a nomenclature for field use based on purely megascopic characters.

The work concludes with a discussion of methods of calculating mineral composition from chemical composition and the reverse, and presents tables to aid such calculations. L. V. P.

4. *Petrography and Geology of the Monzoni region in Tyrol.*—The exhaustive study of this area, so long known and so much investigated as to be perhaps rightly called a classic one, has recently received a new impetus, apparently from the suggestive work of Brögger (ii Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtirol). A number of shorter articles by various authors have appeared describing new types of rocks or various phases of its geology. Quite recently, however, more important memoirs on the geology and petrography of the region, the one by Romberg (Geologisch—petrographische Studien im Gebiete von Predazzo i and ii, (Sitzber. d. K. preuss. Akad. d. Wiss. Berlin, 1902, phys. mat. class. 675), the other by Doelter (Tscher. Min. and Petro. Mitt., vol. xxi) have been published. The various authors have not entirely agreed among themselves regarding various points and this has led to a stimulation of interest in their work. As a result many new analyses and descriptions of important rock types have been given. It is shown that the forecast of Rosenbusch on theoretical grounds, regarding the existence of nephelinitic and other alkaline types, was correct, and in general a considerable amount of new information, of value to systematic petrography, has been developed by these excellent studies. L. V. P.

5. *Gesteinskunde für Techniker, Bergingenieure etc.*, von F. Rinné. (8°, 206 pp., 4 pls., 235 figs. Geb. Jänecke.) Hanover, 1901.—In this excellent and well written little volume is given a general survey of the subject of petrology from the modern standpoint, with especial reference to its use by beginners and those desiring some knowledge of the subject for technical purposes. It is also a good introduction to the science for workers in other fields in

geology. Some optical mineralogy is introduced and the use of the microscope indicated. A further advantage is that a considerable amount of physical geology, in so far as it relates to the subject, is brought in. A great help will be found in the numerous well executed half-tones of photographs, especially those of rock sections showing texture, etc. A more careful selection of more modern and better executed analyses of rocks and more of them, would have been of advantage. The volume is well printed and in convenient form. L. V. P.

6. *The Terlingua Quicksilver Deposits, Brewster County, Texas.* The University of Texas Mineral Survey, Bull. No. 4, pp. 74.—These deposits are of quite recent development and are as yet only worked in a small way by means of open pits. They are located in the center of an extensive area of Cretaceous sedimentary rocks, which have been much faulted and into which igneous rocks have been intruded. The ore deposits are found within the sedimentary rocks and usually at a short distance from some igneous intrusion. The chief ore mineral is cinnabar, with which is associated some iron oxides and large amounts of calcite. The ore occurs in vein formations of a number of different types, none of which are very wide and most of which vary considerably in their richness. It is thought that the veins and their ore contents will be found to continue in depth. The ore is treated near the mines in furnaces similar to those in use in California. The total output of the district up to the end of 1901, is estimated at 3,700 flasks of mercury, of which 3,000 flasks were produced during the year 1901. W. E. F.

7. *Notes on New Minerals.*—BAUMHAUERITE is a sulpharsenite of lead having the formula $4PbS \cdot 3As_2S_3$. The analysis made by H. Jackson gave the following results:

	Found.	Calculated.
Pb	48·86	48·75
S	24·39	24·61
As	26·42	26·64
	99·67	100·00

The specific gravity was determined as 5·329. It is monoclinic in its crystallization, having the axial relations,

$$a : b : c = 1·136817 : 1 : 0·947163\ ;\ \beta = 82^\circ\ 42\tfrac{3}{4}'.$$

The crystals closely resemble those of dufrenoysite and jordanite in appearance. They may be distinguished from dufrenoysite by the marked oblique development of the zone 100—001, and from jordanite by the absence of twin striations and by the color of the streak. The mineral is described by R. H. SOLLY and named in honor of Dr. H. Baumhauer, Professor of Mineralogy in the University of Freiburg.—*Min. Mag.*, xiii, 60.

A new analysis of material from the original locality has been made by G. T. PRIOR and shows KILLRICKENITE to be identical with the earlier described geocronite. The important difference between the new analysis and the original analysis is in the finding of arsenic. No determination of arsenic was made in the first analysis and its presence was evidently not suspected. Prior's results are as follows:

Pb, 68·49; Sb, 9·13; As, 4·59; S, 17·20; total, 99·41.

These results yield the formula $5PbS(Sb, As)_2S_3$, which is the accepted formula for geocronite.

An analysis of MIERSITE by Prior gave the following results:

		Atomic ratios.
Ag	38·17	·353 or 4
Cu	5·64	·090 " 1
I	56·58	·446 " 5
	100·39	

which yield the formula, 4AqI . CuI. The specific gravity of the mineral was determined as 5·640.

MARSHITE was also analyzed by Prior and gave the following results:

		Atomic ratios.
Cu	32·35	·513
Ag	1·19	·011
I	65·85	·520
	99·39	

which yield the formula CuI. Specific gravity = 5·590.—*Min. Mag.*, xiii, 60.

COOLGARDITE.—This mineral was discovered by A. Carnot at Kalgoorlie. It is steel-gray to yellow-gray in color, is practically devoid of cleavage and breaks with a conchoidal fracture. Its formula is $(Au,Ag,Hg)_2Te_3$ and it is, therefore, related to coloradoite (Hg_2Te_3) and melonite (Ni_2Te_3). The following are Carnot's analyses:

	I.	II.	III.
Au	23·15	27·75	37·06
Ag	16·65	13·60	4·71
Hg	3·10	3·70	3·70
Cu	·10	·25	·88
Fe	trace	trace	·90
Te	56·55	53·70	51·13
Sb	·20	·15	1·20
Total	99·75	99·15	99·58

– *Geol. Surv. W. Australia*, Bull. No. 6, p. 18.

COLORADOITE occurs freely and in large pure masses at Kalgoorlie. A new analysis of pure material is of interest: Hg, 50·40; Au, trace; Ag, ·12; Te, 49·48; total, 100·00. Specific gravity, 9·21.

The formula for coloradoite calculated from these figures is Hg_2Te_3, requiring: Hg, 51·7 per cent.; Te 48·3 per cent. The previously accepted formula based upon analysis of small and impure specimens was HgTe, requiring: Hg, 61·6 per cent.; Te, 38·4 per cent.—*Geol. Sur. W. Australia,* Bull. No. 6, p. 27.

STIBIOTANTALITE, a tantalo-niobate of antimony, Sb(Ta,Nb)O4 is found in the stream works at Greenbushes. The exact crystalline form of the mineral has not been determined for it occurs in water-worn pebbles with a very smooth bright surface. It is brittle, with a subconchoidal to granular or occasionally fibrous fracture. Its hardness is 5 to 5·5, and specific gravity 6·4 to 7·4. Its luster is adamantine to resinous; color, various shades of yellow and brown, also gray. It is subtranslucent to opaque. Its composition is shown by the following analysis by Goyder: Sb_2O_3, 40·23; Bi_2O_3, ·82; NiO, ·08; Ta_2O_5, 51·13; Nb_2O_5, 7·56; total, 99·82.

A hydrated variety of this mineral occurs also, resembling it in color, but having a rough surface. Its formula would appear to be $2Sb(Ta,Nb)O4 \cdot 7H_2O$. Before the blowpipe stibiotantalite is practically infusible and colors the flame greenish-gray. It is reduced to metallic antimony by fusion with potassium cyanide. In the closed tube the anhydrous mineral gives no sublimate; the hydrous, a sublimate of water. After mixing with sulphur it gives in the closed tube a sublimate which is black when hot and brownish red on cooling. It is soluble in hydrofluoric acid; this solution on adding a little potassium fluoride and evaporating somewhat, deposits on cooling a felt-like mass of colorless crystals of potassium fluotantalite. If some of the solution in hydrofluoric acid be poured into a platinum dish and a piece of pure zinc be dropped into it, a black stain immediately develops on the plate. Stibiotantalite is decomposed by fusion with potassium bisulphate.—*Geol. Sur. W. Australia*, Bull. No. 6, p. 42.

HISTRIXITE, an apparently new sulphide of antimony and bismuth, is described by W. F. PETTERD. It occurs in radiating groups of crystals which are orthorhombic, with acute but indistinct terminations and are striated longitudinally. It is slightly sectile with a hardness of about 2. Luster eminently metallic. Color and streak, steel-gray. The mean of two analyses is:—S, 23·53; Bi, 56·00; Sb, 9·70; Cu, 6·49; Fe, 5·31; total, 101·03. which gives for the formula, $7Bi_2S_3,2Sb_2S_3,5CuFeS_2$.—*John Vail, Gov. Printer, Tasmania.*

PETTERDITE, a new oxychloride of lead. This mineral, which was found at Zeehan, Tasmania, was described by Mr. W. H. TWELVETREES. It occurs in thin hexagonal plates of a white color. Fracture is irregular, luster dull, hardness 1·5 to 2, specific gravity 7·16. The analysis made by Mr. O. E. White of Hobart is as follows:—PbO, 74·04; As_2O_5, 2·60; P_2O_7, 2·10; Sb_2O_6, ·50; Cl, 20·00; total, 99·24.—*John Vail, Gov. Printer, Tasmania.* W. E. F.

8. *Gold in Meteorites.*—At the September meeting of the Royal Society of New South Wales, Prof. LIVERSIDGE exhibited under the microscope particles of a malleable yellow metal, insoluble in nitric acid, which have all the appearance of gold obtained from certain Australian and European meteorites (siderolites). The presence of gold in meteorites bears upon the presence of gold in "meteoric" dusts, and it is also of great interest in connection with the presence of gold upon the earth and in sea-water,

inasmuch as meteorites and the dust of meteorites are constantly falling upon the earth, to the extent of probably many million tons a year. Further information upon the question of the presence of gold in meteorites is promised in a subsequent paper.

9. *Triassic Ichthyopterygia from California and Nevada;* by JOHN C. MERRIAM. Bulletin of the Dept. of Geol., Univ. of Cal., vol. iii, No. 4, pp. 63–108, pls. 5–18.—A valuable contribution to Paleontology, based chiefly upon saurian material from the upper Triassic of Shasta County, California, collected in 1891 by field parties from Stanford and California universities.

The great value of the monograph under review lies in the carefully executed plates and in the accurate measurement and description of the bones of a hitherto little known group of extinct reptiles. Collectively, the several specimens described afford an excellent generic definition of *Shastasaurus*, the anterior part of the skull and the distal ends of the paddles being practically the only portions of the skeleton which now remain unknown. Prof. Merriam has met with the great, though by no means rare, good fortune to find in his collected material nearly as many species of *Shastasaurus* as individuals, seven examples offering more or less complete descriptions of five new forms, *S. perrini, osmonti, alexandræ, careyi,* and *altispinus,* although none of the new acquisitions have been identified with the type species *S. pacificus,* which was described by him in 1895 (this Journal, vol. iv, p. 56). The type species is shown to differ from *S. perrini* in regard to certain posterior dorsal vertebræ and the pubis. None of the other new species, however, are represented by these parts, and therefore cannot well be differentiated from the type. The author wisely states: "At the present time we cannot determine definitely the relations of *pacificus* to the better known species, and it is not impossible that when the other parts of the skeleton of those forms are better known it will be found that some one of them should be included in *pacificus.*" In view of this lack of comparison and the urgent need of simplicity, the doubt naturally arises whether the purpose of classification would not have been better served by uniting, provisionally at least, one of the new forms with the type species.

Accompanying the discussion of *Shastasaurus* is a careful revision of Leidy's genus *Cymbaspondylus* from the middle Triassic of Nevada, which is shown to be closely related to *Shastasaurus.* The family Shastasauridæ is proposed to embrace these two genera, distinguished as they are from the Mixosauridæ, Ichthyosauridæ, and Baptanodontidæ, by the peculiar articulation of their dorsal ribs, the form of the pelvic girdle, and their long-spined chevron bones. In a postscript, Prof. Merriam states that a good collection of saurian material has just been obtained from the middle Triassic of Nevada. When these specimens have been properly worked out, another contribution is promised by the author. This will be awaited with great interest, and it is confidently hoped that further investigation will yield as satisfactory results as the monograph before us. G. F. E.

10. *Zoological Results based on material from New Britain, New Guinea, Loyalty Islands and elsewhere*, collected during the years 1895, 1896, 1897; by ARTHUR WILLEY. Part VI (August, 1902), pp. 691–826, 8 pls., 33 figs.—Dr. Willey is to be congratulated upon the completion* of a valuable series of zoological papers. The present volume contains the results of a study of the development of the Pearly Nautilus. The interesting "personal narrative" (pp. 691–734) is illustrated by photographs of the natives who carry on the Nautilus-fisheries on the different islands, and who came in contact with Mr. Willey during his visits to the archipelago (1894 and 1897) in search for the eggs of species of *Nautilus*. The "special contribution" (pp. 736–826) is prefaced by a complete review of the bibliography of nautilus since the first description with figures of the external characters by Rumphius, 1705, and of the animal by Bennett, 1831. Many new and interesting facts are mentioned. It was found by observation that the color markings on both the shell and animal "exerted a protective influence"; that the "wart-like gibbosities" on the upper surface of the hood form a shield for protecting the aperture of the shell when the animal is in retraction, and not a foot for locomotion. The studies of the anatomical characters show the relation of the *Nautilus* to the dibranchs, but with reference to the other cephalopods opinions will differ. It is, however, one whose external shell is probably primitive as compared with the internal shell of *Spirula*. No definite opinion is given as to whether the many similarities in anatomy between the *Nautilus* and diotocard prosobranchs (*Haliotis*, *Fissurella* and *Pleurotomaria*) are of the nature of affinity or convergence, but an interesting figure (15) is given showing a shell with a median groove and shell-slit similar to *Pleurotomaria*. K. J. B.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The following is a list of papers read before the National Academy at the meeting in Baltimore, Nov. 11–12.

S. L. PENFIELD: A possible explanation of the difficult solubility of certain compounds containing fluorine and hydroxyl.

GEORGE E. HALE: The spectra of stars of Secchi's fourth type.

T. C. MENDENHALL: Biographical memoir of Henry A. Rowland.

W. K. BROOKS: The embryology of Salpa cordiformis.

CASWELL GRAVE: The occurrence of reef corals near Beaufort, N. C.

D. H. TENNENT: The Trematode parasites of the oyster.

H. N. MORSE: The preparation of cells for the measurement of osmotic pressure.

R. W. WOOD: A substance with remarkable optical properties, and screens transparent only to ultra-violet light.

J. B. WHITEHEAD: On displacement currents.

L. A. PARSONS: On the spectrum of hydrogen.

LEWIS BOSS: A new system of positions for standard stars, with notes relative to its bearing upon sidereal astronomy.

H. F. OSBORN: Complete skeleton and restoration of the Cretaceous fish *Portheus molossus* Cope. A new small dinosaur from the Jurassic or Como

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*See this Journal, vii, 79, 322; viii, 398; x, 89; xi, 330.

beds of Wyoming, apparently a bird-catcher. New or little-known elephants and mastodons of North America.

A. Agassiz: On elevated Oceanic Islands in the Pacific.

2. *American Association for the Advancement of Science.*—The next meeting will be held in Washington, Dec. 29 to Jan. 3, inclusive. This is the first time the Association has met in the winter.

3. *Smithsonian Institution, Annual Report for 1901;* by S. P. Langley, Secretary. Pp. lvii + 739, 71 pls.—The last report of the Smithsonian Institution shows that increased appropriations means increased volume of important work. Fifty articles by well known specialists tell of the latest progress in the principal branches of knowledge.

4. *United States National Museum.* Bull. 51, 168 pp. List of Publications 1875–1900, by Randolph I. Geare.—The National Museum has issued a complete list of its publications, arranged both as a chronological record and as a subject and title index.

5. *British Museum — Catalogue of the Collection of Birds' Eggs;* by Eugene W. Oates. Vol. ii, 400 pp., 15 colored plates. —Descriptions are given of 15,000 specimens of eggs belonging to the *Carinatœ.* Ten orders and 726 species are included in the list.

6. *United States Coast and Geodetic Survey;* O. H. Tittman, Superintendent:

Annual Report 1901. 423 pp., 46 illustrations, 4 maps in pocket.—The superintendent of the Coast Survey reports the inauguration of the survey of the Philippine coast line and the establishment of a suboffice for the publication of charts and notices to mariners. Parties were also at work in Porto Rico, the Hawaiian Islands and Alaska. Perhaps the most important field work now in hand is the measurement of the 98th meridian. Mr. A. L. Baldwin reports on the Measurement of Nine Bases along the 98th Meridian (pp. 241–302); and Mr. J. F. Hayford, inspector of geodetic work, describes the present state of the triangulation along this meridian in Kansas and Nebraska. The measured arc will cover 23° of latitude within the United States; the Mexican government is expected to extend it 9° southward, and it is possible to extend it far northward.

The Eastern Oblique Arc of the United States and Osculating Spheroid; by Chas. A. Schott. Special Publication No. 7, 394 pp., 38 illustrations, 2 maps in pocket.—The second long arc measured by the Coast Survey extends from Calais, Maine, to New Orleans, La. The line is 2612·3 kilometers in length, covering 23° 30′ 57″, and is unique in that it is the first one which utilizes on a grand scale a measurement oblique to the meridian. The work was begun in 1833 and the field work finished in 1898. The Eastern Oblique Arc intersects the Transcontinental Arc of the 39th parallel in Maryland and Virginia. With the measurements along the 98th meridian well under way and two long arcs already completed, the Coast Survey may well feel proud of its contributions to geodesy.

7. *United States Naval Observatory*, CAPTAIN C. H. DAVIS, U. S. N. Superintendent. Publications, Second Series, Vol. II. ZONE OBSERVATION WITH THE NINE-INCH TRANSIT CIRCLE, 1894–1901; by AARON N. SKINNER, assisted by FRANK B. LITTELL and THEO. I. KING. pp. xxviii, 525.—This volume embodies the results of observations made, in accordance with the suggestion of Dr. A. Auwers of the Astronomische Gesellschaft, on stars to the ninth magnitude, inclusive, between the parallels, —13° 50′ and —18° 10′.

8. *Bureau of American Ethnology.*—The following volumes have recently come to hand:

NINETEENTH ANNUAL REPORT; by J. W. POWELL, Director. Pt. I., pp. xcii + 548. 79 pls., 48 figs. An exhaustive report on the Myths of the Cherokee Indians has been prepared by James Mooney, (pp. 3–548).

BULLETIN NO. 26—KATHLAMET TEXTS: by FRANZ BOAS. 261 pp., 1 pl.

9. *Ostwald's Klassiker der Exakten Wissenschaften.* Leipsig, 1902 (Wilhelm Engelmann).—The following are recent additions to this valuable series:

Nr. 129. Allgemeine Methode partielle Differential gleichungen zu integriren; von Johann Friedrick Pfaff. Pp. 84.

Nr. 130. Pangeometrie; von N. J. Lobatschefskij (Kasan 1856). Pp. 95.

Nr. 131. Experimental-Untersuchungen über Elektricität (xiv und xv Reihe); von Michael Faraday (London 1838). Pp. 48.

Nr. 132. Über die Continuität der gas förmigen und flüssigen Zustände der Materie, und Über den gas förmigen Zustand der Materie; von Thomas Andrews (London 1869). Pp. 81.

Nr. 133. J. H. Lambert's Abhandlungen zur Bahnbestimmung der Cometen. Pp. 148.

10. *Hodgkins Gold Medal Awarded.*—The second Hodgkins Gold Medal has been awarded to J. J. Thomson of Cambridge, England, "for his investigations on the conductivity of gases, especially on the gases that compose the atmospheric air." The committee of award consisted of Mr. Richard Rathbun, Chairman; Doctor A. Graham Bell, for Electricity; Doctor Ira Remsen, for Chemistry; Doctor Charles D. Walcott, for Geology; Professor E. C. Pickering, for Astronomy; Doctor Theodore N. Gill, for Biology; Professor Cleveland Abbe, for Meteorology; Mr. William H. Holmes, for Anthropology, and Mr. S. W. Stratton, for Physics.

OBITUARY.

Dr. OGDEN NICHOLAS ROOD, Professor of Physics in Columbia University, died November 12 at the age of 71. (A sketch of the life and work of Professor Rood will appear in this Journal for January.)

Dr. ROBERT C. KEDZIE, for forty years Professor of Chemistry at the Michigan Agricultural College, died November 7, at the age of 79 years.

Dr. ROBERT RUBENSON, Director of the Central Meteorological Institute of Sweden, died Oct. 14, aged 73.

JOHN HALL GLADSTONE, "one of the founders of physical chemistry," has died in London at the age of 75.

INDEX TO VOLUME XIV.*

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* This Index contains the general heads, BOTANY, CHEMISTRY (incl. chem. physics), GEOLOGY, MINERALS, OBITUARY, ROCKS, and under each the titles of Articles referring thereto are mentioned.

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SAPPHIRE BLUE

of the true shade is to be found in the popularly named "False Sapphire" or **CYANITE** from the far-famed St. Gothard. A trip by our collector and considerable work done for us yielded some superb specimens. This locality has been known for over half a century, but like many others in Switzerland, is quite unworkable, save during two months of the year, and rarely visited even then. Thus the specimens are not new—just vastly superior to those in the large museums, all of which have the early specimens, but are fast replacing them with the later ones.

Months of expert work were devoted to the careful removal of the Paragonite matrix, exposing the transparent blue crystals associated with lustrous dark brown Staurolites, often in parallel and penetrating habits. This is mentioned in some of the mineralogies, which likewise add "rarely terminated." Yet we have perfectly terminated Cyanites six inches long, penetrating the length of a Staurolite. This peculiarity, together with the contrasting blues and browns standing out on the pearly background, affords one of the most striking combinations to be seen in any collection.

The stock of really fine specimens is limited and rapidly diminishing. 50c. to $15.00.

Detached Crystals, 25c. per dozen to $1.00 each.

Terminated Crystals, 50c. to $2.00 each.

OTHER SWISS MINERALS.

We secured by exchange the few duplicates left in one of the oldest of European collections. Among them were the following historical things of high value: *Eisenrose, Sphene, Octahedral Rose Fluor, Acmite, Apatite, Green Fluor, Smoky Quartz, etc., etc.*

EDUCATIONAL COLLECTIONS.

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WITH PLATE IV.

NEW HAVEN, CONNECTICUT.

1902.

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SAPPHIRE BLUE

of the true shade is to be found in the popularly named "False Sapphire" or **CYANITE** from the far-famed St. Gothard. A trip by our collector and considerable work done for us yielded some superb specimens. This locality has been known for over half a century, but like many others in Switzerland, is quite unworkable, save during two months of the year, and rarely visited even then. Thus the specimens are not new—just vastly superior to those in the large museums, all of which have the early specimens, but are fast replacing them with the later ones.

Months of expert work were devoted to the careful removal of the Paragonite matrix, exposing the transparent blue crystals associated with lustrous dark brown Staurolites, often in parallel and penetrating habits. This is mentioned in some of the mineralogies, which likewise add "rarely terminated." Yet we have perfectly terminated Cyanites six inches long, penetrating the length of a Staurolite. This peculiarity, together with the contrasting blues and browns standing out on the pearly background, affords one of the most striking combinations to be seen in any collection.

The stock of really fine specimens is limited and rapidly diminishing. 50c. to $15.00.

Detached Crystals, 25c. per dozen to $1.00 each.

Terminated Crystals, 50c. to $2.00 each.

OTHER SWISS MINERALS.

We secured by exchange the few duplicates left in one of the oldest of European collections. Among them were the following historical things of high value: *Eisenrose, Sphene, Octahedral Rose Fluor, Axinite, Apatite, Green Fluor, Smoky Quartz, etc., etc.*

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yrus Adler,
ibrarian U. S. Nat. Museum.

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WITH PLATES V–VII.

NEW HAVEN, CONNECTICUT.

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ITALIAN MINERALS

MANY IMPORTANT RARITIES.

Ten months were spent by our collector in visiting the principal mineral collections and several of the most important localities. A large number of historical specimens were thus secured, which cannot be duplicated even by the mos tempting exchanges that can be personally offered. But few good minerals are now coming from the mines of the peninsula, and the high values placed upon examples of the old finds are steadily rising. The following are all good typical examples of their kind, extra choice crystallizations being especially noted.

PIEDMONT

Piedmontite, Violan, Diopside, Idocrase, large Hessonite crystals of unusually fine quality.

BAVENO

(At lower prices than foreign collectors pay at the quarries.)

Bavenite, a very rare new species, Babingtonite, rare, Orthoclase in Baveno and Manebach twins, Fluorite.

CARRERA

Limpid Rock Crystal on Marble.

PORRETTA

A large assortment of the well known cavernous Quartz Crystals, many showing moving bubbles, Calcite in neat groups of primitive rhombs.

ELBA

A large lot of Tourmaline crystals including excellent terminations. Red, green and white. A few vari-colored. Cookeite, Ilvaite, Pollucite. We maintain the old scale of prices on this consignment in spite of a great advance in Italy.

BELLISIO SOLFARE

Sulphur in brilliant transparent crystals of different types from the Sicilian and of finer quality. Selenite, perfectly limpid and flawless crystals of unrivalled lustre, offering the most highly prized specimens of this mineral known. Grouped with the Sulphur and isolated. A remarkably beautiful but rare occurrence.

CAPO DI BOVE

Nephelite in groups of sharply defined hexagons. Gismondite crystals of characteristic habits. Breislakite, Hauynite.

MONTE SOMMA

"What's in a name" is answered for the mineralogist in the following list. Of some of them we obtained but one specimen, and at the best got but a sadly limited supply. All are old and quite a number are of the original meagre find from which Prof. Scacchi made the descriptions:—

Granuline
Neociano
Euchlorite
Humboldtilite
Cuspidine
Meionite, large xls
Erythrocalcite
Dolerophanite
Neochrysolite
Nocerite
Aphthitalite, fine crystals
Belonesite with Cryphiolite
Séméline
Facellite, fine group of crystals
Melanothallite
Sodalite, well crystallized
Thermonatrite
Humite
Hydrodolomite
Hydrocyanite

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1902.

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Neociano
Euchlorite
Humboldtilite
Cuspidine
Meionite, large xls
Erythrocalcite
Dolerophanite
Neochrysolite
Nocerite
Aphthitalite, fine crystals
Belonesite with Cryphiolite
Séméline
Facellite, fine group of crystals
Melanothallite
Sodalite, well crystallized
Thermonatrite
Humite
Hydrodolomite
Hydrocyanite

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WITH PLATE VIII.

NEW HAVEN, CONNECTICUT.

1902.

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GUANAJUATO

Several recent shipments direct from the "Andreasberg of America" afford a large choice of the more recent finds of this famous district. Prices average lower than formerly, generally 50c. to $3.00 or $4.00 for the best cabinet specimens. Small study specimens at 15c. to 40c.

Hematite in hexagonal prisms. New and rare. Small but marvelously sharp and brilliant, coating a volcanic rock suggesting the Vesuvian examples, but of different crystalline habit.

Rose Apophyllite in handsome groups. Beautiful white and colorless crystallizations. Also detached crystals.

Hyalite. Clear masses of pearly lustre in twisted and botryoidal forms. Attractive and typical.

Fire Opal in large pieces.

Octahedral Fluor showing interesting modifications.

Quartz Crystals containing moving bubbles.

Amethyst in groups of unrivaled richness and depth of color.

Stilbite. Delicate cream-colored groups. Crystals symmetrical and well defined.

STUDY SPECIMENS

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