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[FOURTH SERIES.]

Art. I.—*The Relative Activity of Radium and the Uranium with which it is in Radioactive Equilibrium;** by J. H. L. Johnstone and B. B. Boltwood.

Although the matter has been under consideration and discussion for a number of years, the genetic relationship between the earlier members of the uranium family of radio-elements is still a matter of considerable uncertainty. It is generally conceded that both ionium and actinium are products of the radioactive disintegration of uranium, but the exact point of origin of actinium and its immediate parentage have remained somewhat obscure and uncertain.

The work of Boltwood[1] on the relative α-ray activity of uranium minerals and the uranium which they contained demonstrated a constancy of relationship between the radioactive constituents of the older minerals and clearly indicated a close genetic relation between uranium and actinium. His determination of the activities of the more stable α-ray products relative to the activity of the associated uranium showed a simple and direct relation to exist between the products ionium, radium and polonium, but showed an abnormally low value for

* The experimental results given in this paper and the general theoretical conclusions are taken from a dissertation on the "Relative Activity of Uranium and Radium" presented on April 27, 1916, by J. H. L. Johnstone in fulfillment of the requirements for the degree of Doctor of Philosophy in Yale University. The chief reason for the delay in publication was the entry of Dr. Johnstone into active military service with the Canadian forces in May, 1916. The work was carried out in the Sloane Physical Laboratory of Yale University.

[1] This Journal, 25, 269, 1908.

the ratio in the case of the actinium series, which could only be explained on the assumption that actinium originates as a branch product and belongs to what may be termed a collateral branch of the ionium-radium-polonium family.

The values obtained by Boltwood in the course of his experiments showed that the activity of the uranium was about 2·2 times that of the radium with which it was in equilibrium, although at that time the range of the α-particle from uranium was supposed to be about 2·7 cm., which is less than that of the α-particle from radium. Since the ionizing power of an α-particle is nearly proportional to the range, and since, on the basis of the disintegration theory, an equal number of α-particles are emitted per second by each of two radioactive products in equilibrium with one another, it was necessary to assume that either the uranium atom emitted two α-particles simultaneously, which was improbable, or that two distinct α-ray changes existed in ordinary uranium. Neither of these assumptions, however, completely obviated the difficulty.

The fact that uranium actually did emit twice the number of α-particles to be expected on theoretical grounds was subsequently demonstrated by Geiger and Rutherford[2] and by Brown[3] who counted the number of α-particles emitted per second from a film of pure uranium oxide and a similar film of uraninite of known composition. Using the scintillation method, Marsden and Barratt[4] made a careful examination of the α-radiation from uranium and concluded as a result of their experiments that ordinary uranium consists of a mixture of two successive α-ray products in equilibrium with one another. Attempts to measure the separate ranges of the α-particles emitted by these two products were made by Foch[5] and Friedmann.[6] By the use of a better method of measurement, in which the Bragg ionization curves for a uranium film were compared with the corresponding curves obtained with polonium and ionium, Geiger and Nuttall calculated the ranges of the α-particles from uranium to be 2·5 cm. and 2·9 cm. (at 0°C.).

[2] Phil. Mag., 20, 691, 1910.
[3] Proc. Roy. Soc., A 84, 151, 1910.
[4] Phys. Soc. Proc., A 23, 367, 1911.
[5] Le Radium, 8, 101, 1911.
[6] Wien. Ber., 120, 1361, 1911.

Numerous unsuccessful attempts have been made to reduce the specific α-ray activity of uranium. In one experiment conducted by the authors about two kilograms of pure uranium nitrate were subjected to fractional crystallization and a least soluble "head" fraction weighing about twenty grams was obtained after about forty operations. The specific α-ray activity of the uranium in this material did not vary by as much as one per cent from the specific activity of the uranium in the original nitrate. This shows that the two components are so closely allied chemically as to be inseparable, a conclusion which is supported by all the other known facts at our disposal.

We may outline, therefore, the progressive disintegration of the uranium atom, considering for the present only the products emitting α-rays, as taking place in the following manner: the parent element, uranium I, produces the product uranium II. This in turn produces ionium, which disintegrates to form radium, followed successively by radium emanation, radium A, radium C and polonium. When these are all present in equilibrium proportions, as is the case in a non-emanating, old, radioactive mineral, then certain comparatively simple relations will exist between the α-ray activities of the different constituents. It has been shown by Geiger[7] that the ionizing power of an α-particle is proportional to the two-thirds power of its range. The ionization produced by equal numbers of α-particles emitted by two different radio-elements will therefore be proportional to the two-thirds power of the ranges of these particles. In a series of successive products in equilibrium, each product emits the same number of α-particles in unit time. The relative ionization (and therefore the relative activities) due to each of these products should therefore be proportional to the two-thirds power of the range of the respective α-particles.

This relation has been shown[8] to hold quite closely in the case of radio-thorium and its α-ray products, and also in the actinium and the radium series of products. The chief object of the work described in the present paper was to apply the same methods to the case of the

[7] Proc. Roy. Soc., A 83, 505, 1910.
[8] McCoy and Viol, Phil. Mag., 25, 333, 1913; McCoy and Leman, Phys. Rev., 4, 409, 1914; ibid. 6, 185, 1915.

uranium-radium series with the expectation that the results would throw some light on the obscure relations of the earlier members of the series.

The Radioactive Measurements.

The determinations of the radioactivity of the different solids examined were carried out in an electroscope which has already been described.[9] In the present experiments a telemicroscope was used for observing the position of the gold-leaf. The natural leak of the instrument was small and over a period of about six months varied from 0·4 to 0·7 scale divisions per minute. Before and after each series of measurements the sensibility of the electroscope was determined by measurements of the activity of a standard reference film of pure uranoso-uranic oxide. This film was carefully preserved throughout the entire period of the measurements here recorded and all the results given in this paper are given in terms of this film as the standard.

The method of preparing the radioactive materials for measurement was essentially the same, with certain modifications, as that described by Boltwood. The material to be examined was ground as finely as possible in the form of a thin paste with pure ethyl alcohol in a small agate mortar. A sheet of aluminium $7{\cdot}5 \times 9$ cm. and 0·01 cm. thick was first carefully cleaned with liquid soap and distilled water and was then placed in a drying oven at 65°C. for 15 minutes. It was placed in a desiccator over sulphuric acid for half an hour, and then weighed on a sensitive chemical balance. The paste of material and alcohol was then thinly spread on the surface of the aluminium with a small camel's-hair brush.[10] The coated plate was placed in the oven, cooled in the desiccator and weighed as before. The weight of the films could be determined in this manner with an accuracy of one per cent. The solid material adhered quite strongly to the plate and showed no tendency to fall off even when the plate was inverted.

The measurements of radium emanation were made with a gold-leaf electroscope having an air-tight ioniza-

[9] Boltwood, this Journal, 25, 272, 1908.

[10] The brushes used were carefully cleaned in advance by long immersion in alcohol and subsequent washing in fresh quantities of the same liquid.

tion chamber with a capacity of about three liters. The separation and collection of the radium emanation, its transfer to the electroscope and the measurement of its radioactivity were carried out according to methods which have already been described.[11]

Ratio of the Activity of a Uranium Mineral to the Activity of the Contained Uranium.

The relation of the activity of the parent element, uranium, associated with equilibrium amounts of all of its disintegration products, to the activity of the parent element alone, is a fundamental quantity of great importance to any consideration of the relations existing between the individual products themselves. The actual progenitor of the series is uranium I, but this can not be isolated from its invariable associate and isotopic product, uranium II. The combined effect of these two elements when mixed in equilibrium proportions can be determined, however, and this can be compared with the activity of a similar mixture containing all the other disintegration products in equilibrium proportions.

Such a mixture is furnished by a pure, primary, unaltered uranite. A mineral containing a low proportion of thorium is preferable since a correction must be made for the activity of the thorium products present. A specimen of uraninite from Spruce Pine in the possession of the authors was considered to fulfill all the necessary requirements. It consisted of essentially unaltered material selected with much care from a considerably larger quantity. It contained less than 0·2% of silica and residue insoluble in dilute nitric acid. A determination of the uranium content was made by one of the authors and by Ledoux and Co. of New York City.[12] The mineral contained 1·9% of thorium oxide.

In determining the activity of uranium a very pure specimen of uranoso-uranic oxide was used. This had been prepared from a specimen of especially pure uranium nitrate obtained by fractional recrystallization of a much larger quantity (see p. 3). The oxide was made from the nitrate with all the precautions which have been

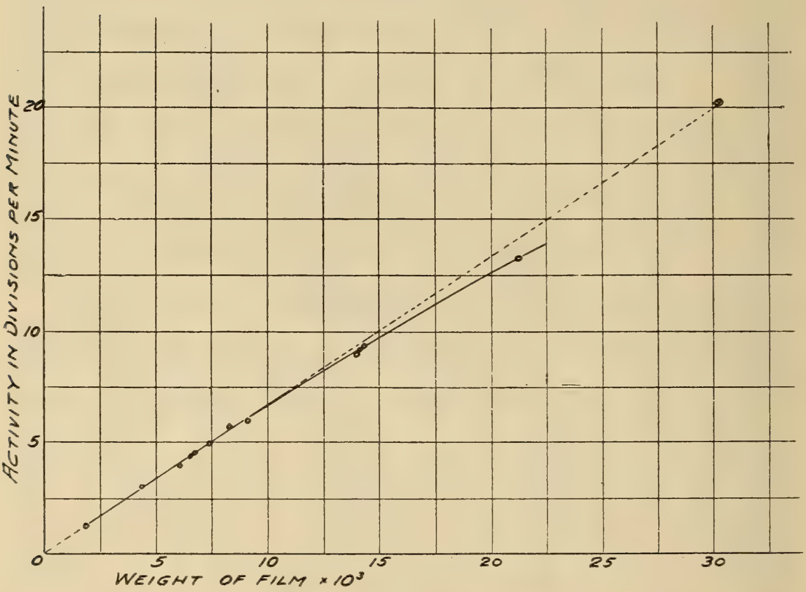
[11] Boltwood, this Journal, 18, 378, 1904; Phil. Mag., 599, 1905.

[12] The authors wish to express here their obligation to Ledoux & Co. for this favor and to state their appreciation of the value of this carefully conducted analysis.

mentioned in an earlier paper.[13] It is very important to note that this oxide was used as a standard in the analytical determination of uranium (both volumetric and gravimetric) in the mineral, so that the analytical determinations and radioactive measurements are in direct accord with one another, although it was assumed for purposes of calculation that the uranoso-uranic oxide contained 84·8% of uranium.

It has been found by McCoy[14] that considerable ab-

Fig. 1.



sorption of the radiation takes place in the film itself when its thickness is appreciable. In earlier work by one of us[15] it was shown that by the use of thin films any necessity for an absorption correction could be avoided. To further demonstrate this fact a series of films of uranoso-uranic oxide weighing from 0·0019 g. to 0·04 g. were prepared and their activities were measured. The results are given in table I and are shown graphically in Fig. 1. In films weighing not more

[13] Boltwood, this Journal, 25, 278, 1908.
[14] Jour. Am. Chem. Soc., 27, 391, 1905; Phys. Rev., 1, 393, 1913.
[15] Boltwood, this Journal, 25, 176, 1908.

than ten milligrams the absorption of the α-radiation was negligible. In all cases where values of importance were to be derived the weight of the films used was less than this maximum, so that no correction has to be made in the results for absorption of the radiations.

The average of the first eight values in the fourth column of table I is 666, which denotes that the average activity of the eight lighter films was 666 divisions per minute per gram of uranium oxide. This corresponds to an activity of 785 (viz. 666/0·848) divisions per minute per gram of uranium.

Table I.

Film Number	Weight of oxide in grams	Activity Div./Min.	Activity / Weight
20	·00187	1·24	663
19	·00432	2·91	673
15	·00566	3·77	666
18	·00653	4·37	669
21	·00740	4·95	668
22	·00832	5·56	662
14	·00898	5·95	662
23	·00653	4·38	670
25A	·01405	8·89	633
8	·01380	8·94	648
25B	·01440	9·30	645
26	·02150	13·45	624
24	·04350	25·96	596

The specific activity of the uraninite was determined by the measurement of four films weighing from approximately 2 to 6 milligrams. The results are given in table II.

Table II.

Film Number	Weight gram	Activity in divisions per minute per gram
27	0·00387	2627
28	0·00240	2655
29	0·00588	2627
30	0·00170	2600

These results give the mean value for the specific activity of the uraninite as 2624 divisions per minute per gram.

As already stated the mineral contained 0·019 gram of thorium oxide (and other thorium products in equilibrium with this) per gram of mineral. The above value for the specific activity of the mineral includes the increment due to the thorium products which must be eliminated. To accomplish this measurements were made of a series of films prepared from a specimen of thorite containing 52 per cent of thorium oxide and 0·37 per cent of uranium. The results are tabulated in table III.

Table III.

Film Number	Weight gram	Activity per gram in divisions per minute
39	0·0056	511
40	0·0076	515
42	0·00776	514
		Av. 513

The activity of the uranium and its radioactive products contained in the thorite will closely equal

$$\frac{2624}{0{\cdot}73} \times 0{\cdot}0037 = 13{\cdot}3 \text{ divisions per min.}$$

Correcting the specific activity of the thorite by this number and dividing the remainder by 0·52 (the weight of thorium oxide per gram) we obtain 960 divisions per minute as the activity of one gram of thorium in equilibrium with its products. We may now correct the value found for the activity of the uraninite by an amount equal to the activity of the thorium components ($960 \times 0{\cdot}019$) and obtain the value 2606 divisions per minute per gram of mineral for the uranium series of products which it contains and a value of 3570 divisions per minute per gram of uranium present (2606/·73).

The uraninite, however, contained less than the full equilibrium amounts of the uranium-radium products because of the fact that in the finely divided form in which it was used it spontaneously lost a small proportion of its radium emanation. The loss of this and the absence of the proportionate amounts of radium A and radium C would cause a deficiency which must be corrected for.

The relative proportion of radium emanation lost by the films of uraninite was determined by the method described by McCoy and Leman.[16] It was found to be 9·1 per cent. In applying the correction, the value for the ratio of the activity of the radium products (radium emanation, radium A and radium C) to the activity of the radium with which they are in equilibrium, as found by McCoy and Leman, namely 4·11, was made use of, as was also the ratio of the activity of radium to the activity of the uranium with which it is in equilibrium (0·49) which was derived in the course of the present investigation (see p. 12).

The correction has the following form,

$$3570 + (785 \times 4{\cdot}11 \times 0{\cdot}49 \times 0{\cdot}091) = 3715,$$

which gives an activity of 3715 divisions per minute per gram of uranium as the activity of the mineral due to uranium and its products in a complete state of equilibrium.

From this final result we are able to calculate the value sought, namely, the ratio of the activity of the uranium with its equilibrium amounts of disintegration products to the activity of the uranium (uranium I + uranium II) alone.

This is $3715/785 = 4{\cdot}73$, which is in good agreement with the value 4·69 found earlier by Boltwood.

Ratio of the Activity of Radium to the Activity of the Uranium with which it is Associated.

If the transformation of the atoms of uranium I into atoms of uranium II takes place directly without the production of any side products, and the transformations uranium II—ionium—radium proceed in the same direct manner, then the relative activities of the three members—uranium I, uranium II, radium—should be proportional to the two-thirds power of the ranges of the α-particles emitted by the respective elements, namely, the activities should be proportional to

$$(2{\cdot}37)^{\frac{2}{3}},\ (2{\cdot}75)^{\frac{2}{3}},\ (3{\cdot}13)^{\frac{2}{3}}$$

where the numbers in parentheses are the ranges at 0° C. of the α-particles from uranium I, uranium II and radium, respectively. Any departure from this proportionality will indicate an irregularity in the mode of

[16] Phys. Rev., 6, 185, 1915.

transformation and may serve to suggest the nature of the changes which are actually taking place. If the transformations are all simple the activity of the uranium (consisting of an equilibrium mixture of uranium I and uranium II) should be to the activity of the radium in the proportion

$$(1{\cdot}78 + 1{\cdot}96) : 2{\cdot}14 = 1{\cdot}00 : 0{\cdot}57.$$

An experimental determination of this ratio was carried out in the following manner:

A quantity of radium was separated from Colorado carnotite and was carefully freed from other radioactive substances which can be separated by chemical operations. Since carnotite is free from thorium the specimen of radium obtained did not contain any appreciable amounts of mesothorium or other products. A solution of this radium in dilute hydrochloric acid was then prepared and its approximate strength in radium was determined by the emanation method. Using this first solution as a basis, two other solutions (denoted hereafter as solutions B and C) were prepared which contained about 0·025 g. of barium chloride and $2{\cdot}4 \times 10^{-8}$ g. of radium in 10 cc. of solution. The quantities of radium were so chosen that the radium films ultimately obtained would have activities of the same order of magnitude as the activities of the uranium films with which they were to be compared.

An accurate determination was then made of the emanation in equilibrium with the radium in 10 cc. of the radium-barium solutions. The results were recorded in terms of the leak produced in the emanation electroscope in divisions per minute.

The results were

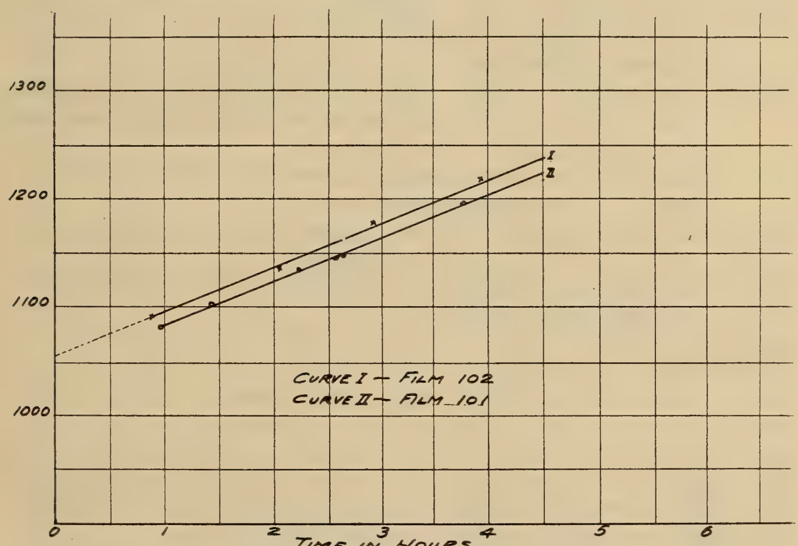
For 10 cc. of Solution B............81·7 div. per min.
For 10 cc. of Solution C............71·0 div. per min.

The radium emanation in equilibrium with the radium contained in one gram of the uraninite was also determined and was found to correspond to 853·5 divisions per minute in the same electroscope. Since the uraninite contained 73·0% of uranium, the radium in equilibrium with one gram of uranium in the mineral was equivalent to a leak of 1170 divisions per minute. The quantity of radium in 10 cc. of solution B, therefore, was the same as that in equilibrium with 0·0698 g. of uranium, and in 10 cc. of solution C with 0·0607 g. of uranium.

The α-ray activity of the radium itself was determined in the following manner:

Portions of solutions B and C 10 cc. in volume were taken, and the barium and radium present were precipitated as sulphate under standard analytical conditions. The precipitates were removed and ignited as promptly as possible and the time at which the ignition was carried out was noted. The weight of the precipitate was determined and the material was quickly ground to a

FIG. 2.



fine powder with ethyl alcohol. Films of this material were then prepared in the manner already described and the activity of these films was measured in the α-ray electroscope. Measurements of the activity were continued over a period of 6 to 7 hours and the increase with the time (due to the growth of the emanation and other active products) was noted at definite intervals.

Preparatory to the precipitation of the sulphates the radium-barium solutions were kept at a temperature slightly below the boiling point for a period of four hours in order to remove any emanation *as formed* and to permit the other products (radium A, radium C) to completely disintegrate. The activity of the material forming the films was therefore due to radium alone at the time of ignition, and this activity could be easily determined from the data available. The variation of the activity with the time for two typical films is shown in figure 2, where the zero time is taken as the moment of ignition. By a simple extrapolation of the curve the initial activity could be obtained with accuracy.

The calculation of the ratio of the activity of the radium to the activity of the uranium was made by the use of the following equation, where

x = the required ratio.
Em_1 = the activity of the equilibrium amount of emanation from one gram of uraninite in div. per min. (in the emanation electroscope).
Em_2 = the activity of the equilibrium amount of emanation from 10 cc. of radium-barium solution in div. per min. (in the emanation electroscope).
U = the activity of one gram of uranium oxide in div. per min. (in the α-ray electroscope).
R = the initial activity of one gram of radium-barium sulphate (in the α-ray electroscope).
w = the weight of sulphate precipitated from 10 cc. of the radium-barium solution.

The value of x is given by,

$$x = \frac{W \times Em_1 \times R \times 0{\cdot}848}{0{\cdot}73 \times Em_2 \times U}$$

The advantage of this method of calculation lies in the fact that the question of either radium or uranium standards is not involved in the final value.

The results obtained from the measurement of the radium films are given in table IV.

Table IV.

Solution	Film Number	Film Weight	U	R	W	Em_1	Em_2	X
B	101	0·00926	710[a]	1040	0·0278	853	81·8	0·493
B	102	0·00711	710[a]	1050	0·0278	853	81·7	0·497
B	103	0·00819	710[a]	1030	0·0277	853	81·7	0·487
B	104	0·00667	710[a]	1025	0·0274	853	81·8	0·480
C	110	0·00548	710[a]	1025	0·0237	853	71·0	0·478
C	113	0·00300	710[a]	1050	0·0237	853	70·0	0·495

Mean value of $x = 0{\cdot}488$

a The value here given is based on a different sensibility of the electroscope from that which it possessed in the case of the values given in table 1.

The value obtained by Boltwood[17] for this ratio (0·45) is somewhat lower than that given above. When the experimental conditions are taken into consideration, however, the agreement is as good as might be expected. A determination has also been made by Meyer and Paneth[18] who compared the radiation from a known quantity of radium with the ionization produced by the α-particles from one gram of uranium. They obtained a value of 0·57 for the ratio. Aside from other objections to their method, the manner in which they obtained the uranium salt used as a standard is open to the most serious criticism. Comparatively crude uranyl nitrate was subjected to purely chemical methods of purification, methods which are generally recognized as unsuitable for obtaining a pure uranium product. Very little, if any, weight can therefore be attached to their determination of the value of the ratio.

Discussion of Results.

As already pointed out, if the entire series of transformations from uranium I, through uranium II and ionium, to radium is a simple and direct one, the value to be expected for the uranium-radium ratio is approximately 0·57. The value found in this investigation is 0·49, which is lower by an amount far in excess of the probable experimental error. The result suggests that the number of radium atoms which disintegrate with the emission of α-particles in the unit time is less than the number of atoms of uranium I or uranium II which disintegrate in the same period. This indicates either (*a*) that a series of branch products is split off from the main series before the radium atom is produced, or (*b*) that radium itself disintegrates in a complex manner, a larger proportion (but not all) of the atoms being transformed with the emission of α-particles. Unless the accepted values for the ranges of the α-particles from uranium are greatly in error (which appears to be rather improbable) the progress of transformation from uranium I to (and including) radium is at some point irregular and is accompanied by the production of a collateral series. This conclusion is supported by the occurrence of actinium and its products in association

[17] This Journal, 25, 269, 1908.
[18] Wien. Ber., 121, Abt. IIa, 1912.

with radium in uranium minerals, and by the impossibility of tracing the origin of actinium to any point in the series subsequent to radium.

We will now proceed to a consideration of the two alternatives, (*a*) and (*b*) mentioned in the preceding paragraph. As a preliminary to this the relative activities of the other members of the main-line series can be calculated from the ratio experimentally determined for the uranium and radium. Geiger's equation is employed

$$I = Nk\,R^{\frac{2}{3}}$$

and the results obtained are given in table V. The calculations are made on the assumption that the simplest (1:1) relation exists between all the products following and including ionium.

Table V.

Element	Range of α-particle in cm. (at 0°C.)	Relative Calc.	Activity Found
Uranium I	2·37		
Uranium II	2·75	1·00	1·00
Ionium	2·95	0·46	
Radium	3·13	0·49	0·49
Emanation	3·94	0·57	
Radium A	4·50	0·62	
Radium C	6·57	0·80	
Radium F	3·64	0·53	
	Sum =	4·47	
Relative activity of actinium and actinium products as determined experimentally by Boltwood.[19]	=	0·28	
	Total =	4·75	
Total activity as determined (p. 9)			4·73

The *very* close agreement between the total activities as calculated and as found is purely accidental and merely indicates that the value given for the activity of the actinium products by difference (4·73–4·47 = 0·26) is practically the same as that suggested by Boltwood as a result of his experiments.

The ranges of the α-particles from uranium, radium and each of the actinium products and also the value of the two-thirds power of the range are given in table VI.

[19] This Journal, 25, 297, 1908.

Table VI.

Element	Range at 20°	$R^{2/3}$
Uranium I	$R_1 = 2{\cdot}54$	1·87
Uranium II	$R_2 = 2{\cdot}95$	2·05
Radium	$R_3 = 3{\cdot}36$	2·24
Radioactinium	$R_4 = 4{\cdot}29$	2·64
Actinium X	$R_5 = 4{\cdot}34$	2·66
Actinium emanation	$R_6 = 5{\cdot}66$	3·18
Actinium A	$R_7 = 6{\cdot}37$	3·44
Actinium C	$R_8 = 5{\cdot}24$	3·01

Applying the data available we may calculate what proportion of the total number of atoms of uranium II would have to be assumed to disintegrate in a mode leading to the production of actinium in order that the ratio of the activity of the actinium products to the activity of the radium would have the value 0·28/0·49 indicated in table V. There are five actinium products emitting α-rays as compared with a single α-ray change in the case of radium, and if equal numbers of atoms of each of the elements were disintegrating in unit time the ratio of the activities would be[20]

$$(2{\cdot}64 + 2{\cdot}66 + 3{\cdot}18 + 3{\cdot}44 + 3{\cdot}01) : 2{\cdot}24 = 6{\cdot}6 : 1.$$

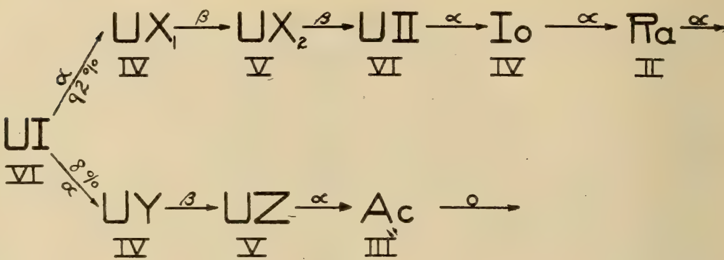
The observed ratio is, however, 0·28 : 0·49. If 100 atoms of uranium II are assumed to disintegrate in unit time of which x disintegrate to form actinium, we have the relation

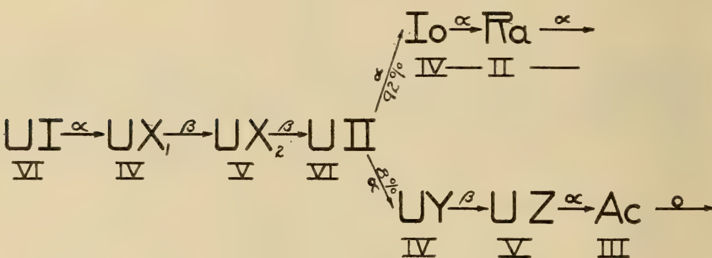
$$\frac{14{\cdot}9\,x}{(100 - x)\,2{\cdot}24} = \frac{0{\cdot}28}{0{\cdot}49}$$

which gives a value for x of approximately 8. So that, if, out of every one hundred atoms of uranium II disintegrating, a total of eight atoms changed into actinium and the remaining 92 changed into ionium (and ultimately radium) the observed relations would exist between the activity of the radium and the activity of the actinium products in a mineral.

Based on considerations of this character a number of attempts have been made to devise a scheme of transformation which will satisfactorily indicate the successive changes undergone by the uranium atoms. The most plausible of these have been proposed by Soddy and Cranston[21] and are given on the following page.

[20] Table VI.
[21] Proc. Roy. Soc., A 94, 384, 1918.

(I) 

(II) 

It is not proposed to discuss these schemes in detail or to consider at any length certain minor points involved to which exception might be taken. It is, however, difficult to understand just what is implied by the dual transformation with the expulsion of α-particles in both cases which is suggested for U I in the first scheme and for U II in the second. It would appear that the loss of an α-particle in each case should lead to the production of one and the same kind of matter, namely, to a single product and not to two different products to be designated as U X_1 and U Y in one example and as Io and U Y in the other. The main point under consideration is, however, whether either of these schemes give us a clue to the explanation of the relative activities of uranium and radium as they have been found in our experiments, and it may be stated that they do not, since the first scheme would suggest a ratio of 1/·55 for the relative activities of the uranium and the radium while the second scheme would imply a ratio of 1/·53 for the same quantities.

In order that Scheme I might satisfactorily apply to the ratio as found by experiment it would be necessary to assume that about 26 out of every 100 atoms of U I were transformed in the mode leading to the production of actinium. This in turn is contradicted by the relative activity of the actinium products in an equilibrium mixture.

In order to fulfill the conditions involved in Scheme II it would be necessary for 14 out of every 100 atoms of uranium to be transformed in the mode leading to the production of actinium. Nor is there any apparent advantage gained by assuming that the transformation of either U I or U II into the first member of the side series is accompanied by the expulsion of a β-particle instead of an α-particle.

It might, however, be assumed that the branching of the series takes place at some other point, as at radium, for example, and that 86 per cent of the radium atoms disintegrate with the emission of α-rays to form the emanation, etc., while 14 per cent disintegrate (emitting β-rays) to form actinium. Direct evidence of the emission of β-rays by a specimen of radium has been obtained by Hahn and Meitner.[22] Under these conditions the α-ray activity of ionium would be proportional to the uranium radiation and would equal 0·53. The activity of the actinium series would equal 0·56 and the activity of the radium + emanation + radium A, C and F would be 3·01 (the sum of the values given in table V). The sum of all of these together with uranium is 5·10 for the total activity of the uranium series (as in uraninite). There are, however, serious objections to the assumption that the side branch arises at radium, aside from the fact that the values mentioned are widely different from those found in Boltwood's experiments and the value found in the present experiments for the total activity of the uranium products.

The most significant objection is presented by the agreement of the value found for the disintegration constant or radium by Rutherford and Geiger[23] and the value of this constant found by Miss Gleditsch.[24] The Rutherford and Geiger estimate was based on the number of α-particles emitted per second by the radium C in equilibrium with one gram of radium. If only eighty-six out of every hundred of the radium atoms disintegrate to form radium C, then this estimate would be 14 per cent too low. The method employed by Miss

[22] Physik. Zeitschr., 10, 741, 1909.
[23] Rutherford, Phil. Mag., 28, 326, 1914.
[24] This Journal, 41, 112, 1916.

Gleditsch depended on the production of radium from the ionium in equilibrium with a known amount of radium and was measured in terms of the fraction of the total equilibrium amount which was produced in a known period of time. This would have given the true value for the disintegration constant irrespective of the mode of disintegration. These two methods would therefore have given different and not similar values if the collateral series had originated at radium.

Among other objections may be mentioned the experiment made by Soddy[25] who examined a specimen of radium salt containing 13·2 mgs. of radium which had been sealed for a period of 10 years. No evidence of the presence of actinium was obtained. Paneth and Fajans[26] examined a specimen containing 180 mgs. of radium which had been sealed for six years, but were unable to detect the presence of any actinium products. We may therefore dismiss the possibility of the side chain splitting off at radium as highly improbable in the light of our present knowledge.

The possibility that the collateral series originates at ionium may also be considered. The fact that the experimental evidence is all opposed to the emission of a β-radiation by ionium is in itself a decided objection to this view. Moreover, it would require (uranium taken as unity) an activity of 0·56 for the actinium products, an activity of 0·46 for ionium, and an activity of 3·01 for radium and its products, with a total activity of 5·02. Paneth and Fajans[27] have directly attacked this problem by seeking for the presence of actinium in a strong preparation of ionium-thorium which had been undisturbed for four years. They were unable to discover the presence of any actinium products. Lacking any support, therefore, the supposition that the collateral series arises at ionium is untenable at present.

These circumstances compel a return to a consideration of the earlier members of the series, to U I and U II, in the hope of being able to find there an explanation of the conditions indicated by our experiments. At first sight it might seem that the conditions would be satisfied

[25] Nature, 91, 634, 1913.
[26] Wien. Ber., 123, IIa, 1627, 1914.
[27] Wien. Ber., 123, IIa, 1627, 1914.

by assuming that what we now call uranium consists of three radio-elements, a parent element and two isotopic products in equilibrium, all emitting α-rays. But if these are present in relative amounts of the same approximate order of magnitude (*i. e.*, 100, 92, 92, etc.) then the α-rays emitted by at least one of them would have to be of exceedingly short range and small ionizing power and the rate of change of this substance would be excessively slow. It is not impossible, but it does not seem probable, that ordinary uranium may consist of what we know as U I and U II, both radio-elements in the main line of descent, and a third isotope which is a product in the collateral actinium series. But the difficulties here are not inconsiderable aside from the fact that the existence of such an isotope is somewhat difficult to imagine. If present in amounts proportional to the actinium this product would have to emit comparatively long range (7·2 cm.) α-particles and would therefore have a very short life period. Such a conclusion does not seem at all probable in the light of our present knowledge.

It is not impossible that the values accepted for the ranges of the α-particles from uranium are considerably in error and that this is the reason for the lack of agreement between theory and experiment. But until some more definite data have been obtained there seems to be little justification for abstruse speculation on the genetic relationship in the earlier stages of the uranium series.

Summary.

The relation of the activity of radium to the activity of the uranium with which it is in radioactive equilibrium has been redetermined. The results obtained indicate that if the activity of uranium is taken as unity the activity of the radium is equal to approximately 0·49.

The total activity of uranium mixed with equilibrium quantities of its disintegration products has been compared with the activity of the uranium alone, and the former has been found to be 4·73 times the latter.

A critical examination has been made of the various theories which have been proposed to explain the genesis of radium and actinium from uranium. None of these theories appears to satisfy the necessary requirements.

Art. II.—*The Devonian of Central Missouri (III). The Cooper Limestone;* by Darling K. Greger.

Under the name of Cooper marble this formation was described by G. C. Swallow in 1855 in his detailed reports on Cooper and Marion counties. These reports give a clear and concise description of the lithologic characters of the formation, but having failed to find it fossiliferous in the localities studied, Swallow tentatively correlated it with the so-called Onondaga of Montgomery and Warren counties. Apparently, however, he was never entirely satisfied with the disposition made of the formation, since we find him stating, in his general discussion of the rocks of Missouri, that there is a "mere possibility" that the Cooper marble may be, in part at least, equivalent to the Trenton.

This formation is best developed in Cooper and Pettis counties, where it attains a thickness of approximately 25 feet. Limited outcrops occur, however, in Boone, Moniteau and Marion counties, but in these it seldom reaches its maximum depth.

The writer has traversed all the streams in the counties above named and examined every known outcrop of the formation, and in 1916 at the Twenty-ninth Annual Meeting of the Geological Society of America, announcement was made of the discovery of a distinctive fauna in no wise related to the Devonian faunas heretofore found in Missouri. The fossils of the Cooper are for the most part new and undescribed species, brachiopods are most abundant, but the large *Turbonopsis providencis* (Broadhead) may be taken as the guide fossil, its distribution throughout the formation being quite common.

The stratigraphic position of the Cooper may be better understood from the following sections through Pettis county eastward to Boone, where it thins out and finally disappears.

Section in Pettis county: The following measured section, made in the near vicinity of Pinhook Bridge, 7 miles northeast of Sedalia, Pettis county, is considered typical, since it gives a complete view of the lower and upper contacts, both of which are marked by pronounced unconformity.

	ft.	in.
Mississippian, Chouteau limestone.		
No. 10. Yellowish, gray and blue, thin-bedded limestones and shale	70	
No. 9. Sandy shale, blue to green, sometimes quite soft		8
Unconformity.		
Devonian, Cooper limestone.		
No. 8. Heavy bed of limestone, blue, with very small limpid calcite crystals	8	4
No. 7. Heavy bed of limestone, similar to above, lighter in color	4	10
No. 6. Brown, somewhat platy limestone	6	2
No. 5. Light brown, gritty limestone, fossiliferous	3	
No. 4. Blue-gray, very compact limestone		8
No. 3. Drab, gritty, porous limestone	2	
No. 2. Sandy conglomerate, much blue and black, oolitic chert		14
Unconformity.		
Ordovician, St. Peter sandstone.		
No. 1. White, friable sandstone, with rounded grains	3+	
Water's edge.		

The only fossils found in the Cooper at this locality are *Favosites* sp., *Turbonopsis providencis* (Broadhead), *Lunulicardium grande* Miller and Gurley, and *Gomphoceras* sp. These were found only in No. 5 of the section.

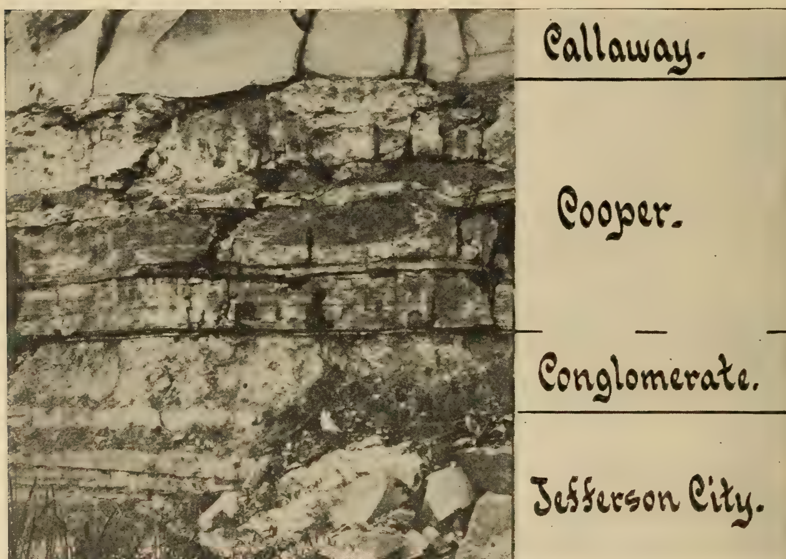
Section in Cooper county, on La Mine River, Sect. 4, Twp. 46, Range 19:

	ft.	in.
Mississippian, Chouteau limestone.		
No. 7. Yellowish, impure limestones and shale	50	
No. 6. Compact limestone, gray, buff and blue	30	
No. 5. Thin layer of blue-green shale		8
Unconformity.		
Devonian, Cooper limestone.		
No. 4. Heavy-bedded, gray, brown and drab limestones	45	
No. 3. Conglomerate, white sand with gray and black, oolitic chert	2	
Unconformity.		
Ordovician, St. Peter sandstone.		
No. 2. White, friable sandstone, with rounded grains	25	
Unconformity.		
Ordovician, Jefferson City formation.		
No. 1. Gray and buff, dolomitic limestones	20+	

The Devonian interval is represented in No. 4 of this section by 45 feet of typical Cooper limestone; fossils are rare here, three specimens of the ubiquitous *Tur-*

bonopsis providencis (Broadhead), and a fragmentary *Gomphoceras* sp. being the only forms recorded.

Section in Boone county, Sect. 28, Twp. 47, Range 13 West: Exposures of the Cooper in Boone county are confined to the Missouri River bluffs in the vicinity of Providence. The locality where the following section was measured is probably the most interesting exposure of Devonian rocks in Missouri, there being four marked unconformities (= disconformities) within a vertical distance of less than 20 feet.



Callaway-Cooper-Jefferson City unconformities, Sect. 15, Twp. 47, Range 14 West, Moniteau Co.

	ft.	in.
Mississippian, Chouteau limestone.		
No. 6. Yellow, shaly limestones and thin beds of shale..	60	
No. 5. Thin sandy layer, blue and green, sometimes quite soft		7
Unconformity.		
Devonian, Craghead Creek shale.		
No. 4. Gray, sandy shale	4	
Unconformity.		
Devonian, Callaway limestone.		
No. 3. Brown, earthy limestones, fossiliferous......	3	
Unconformity.		
Devonian, Cooper limestone.		
No. 2. Gray and blue, heavy-bedded limestones, fossiliferous	12	
Unconformity.		
Ordovician, Jefferson City formation.		
No. 1. Buff, dolomitic limestones......	9+	

In this section the basal conglomerate of the Cooper is absent, as also is the St. Peter sandstone. The three Devonian formations are replete with their characteristic fossils. The Cooper, No. 2 of the section, contains an abundance of *Turbonopsis providencis* (Broadhead), *Favosites* sp. with occasional specimens of *Lunulicardium grande, Loxonema* sp., and *Gomphoceras* sp.

Section in Moniteau county: Exposures of the Cooper limestone in Moniteau county are confined to the Missouri River bluffs and a small area along Splice creek near the town of Lupus. The following section was measured in Sect. 15, Twp. 47, Range 14 West, along the river front:

		ft.	in.
Mississippian.			
No. 7.	Light gray, crinoidal, Burlington limestone....	15	
No. 6.	Yellowish, shaly limestones and thin beds of shale, Chouteau	65	
No. 5.	Sandy shale, blue-green, soft in places.........	1	
Unconformity.			
Devonian, Callaway limestone.			
No. 4.	Gray and brown, gritty limestones, fossiliferous.	10	
Unconformity.			
Devonian, Cooper limestone.			
No. 3.	Bluish, compact limestones, alternating thick and thin beds, fossiliferous.......................	8	
No. 2.	Very sandy conglomerate, blue and black oolitic cherts	3	
Unconformity.			
Ordovician, Jefferson City formation.			
No. 1.	Brown and buff, dolomitic limestone...........	5+	

No. 4 of this section carries a typical Callaway limestone fauna, the more abundant species being *Syringothyris occidentalis* (Swallow), *Athyris fultonensis* (Swallow), *Atrypa reticularis* Linnæus, along with some undescribed corals. The 8 feet of blue and drab close-grained limestone, represented by No. 3 of the section, is the Cooper limestone, and in addition to the characteristic *Turbonopsis providencis* (Broadhead), *Lunulicardium grande* Miller and Gurley, and *Favosites* sp., the following forms occur here:

Cyathophyllum sp. (common), *Spirifer lupusensis* sp. nov. (common), *Schuchertella altirhynchus,* sp. nov. (common), *Stropheodonta cooperensis* sp. nov. (common), *Camarotœchia splicensis* sp. nov. (rare), *Martinia* sp. cf. *glanscerasi* (White) (not common), *Martinia* sp. cf. *sublineata* Meek (common), *Platyceras* sp. nov. (rare), *Loxonema* sp. (rare), *Conocardium cooperensis* sp. nov.

The Cooper limestone in Marion county: Only the eroded, upper beds of the Cooper limestone were examined in this county, notably along See creek, North river, and less extensively along South river. In all the exposures studied, the Cooper is covered unconformably by the Saverton shale, which varies in thickness from 3 to 45 feet in a distance of less than one mile. Swallow and more recent workers in the county failed to detect the presence of fossils in the formation, but the writer found an abundance of the following species:

Turbonopsis providencis (Broadhead), *Gypidula marionensis* sp. nov., *Cranæna marionensis* sp. nov., *Stromatopora* sp., Bryozoa, 2 species, gen. et sp. indet., *Conocardium cooperensis* sp. nov.

Fossils are nowhere so abundant in the Cooper limestone as they are in the overlying Callaway and Craghead formations, but careful search in any of its outcrops will bring to light many of its characteristic species, *Turbonopsis providencis* frequently being found on the bedding planes of layers that elsewhere seem entirely devoid of fossil remains, and often occurring in colonies of quite large individuals, some of which measure 5 inches in diameter. The genus *Martinia* is represented by two species and they are restricted to the Cooper, in fact, the genus is not known to occur elsewhere in the Devonian of Central Missouri. The larger of the two species is not to be distinguished from the *Martima glansecerasi* (White), of the Otis beds of Iowa, while the smaller, transverse and more abundant form bears a striking resemblance to *M. sublineata* (Meek), described from the region of Great Slave lake, British Columbia.

A complete list of the fossils of the Cooper limestone is given below; description and illustrations of the fauna will appear elsewhere.

Bryozoa, 2 species, gen. et sp. indet., *Stromatopora* sp., *Favosites* sp., *Cyathophyllum* sp., *Spirifer lupusensis* sp. nov., *Schuchertella altirhynchus* sp. nov., *Stropheodonta cooperensis* sp. nov., *Camarotœchia splicensis* sp. nov., *Gypidula marionensis* sp. nov., *Cranæna marionensis* sp. nov., *Martinia* sp. cf. *glanscerasi* (White), *M.* sp. cf. *sublineata* (Meek), *Conocardium cooperensis* sp. nov., *Lunulicardium grande* Miller and Gurley, *Turbonopsis providencis* (Broadhead), *Platyceras* sp. nov., *Loxonema?* sp., *Gomphoceras* sp.

Fulton, Missouri.

Art. III.—*The Athabaska Series;* by F. J. Alcock,[1] *Geological Survey of Canada.*

In the northern interior portion of Canada are found several large and many smaller areas covered by a sandstone formation which has been described by a number of members of the Geological Survey of Canada. In two seasons work in northern Alberta and Saskatchewan the writer was able to secure some additional information regarding this interesting series.

Discovery.

In 1888 Mr. R. G. McConnell[2] made a traverse along the south shore of Lake Athabaska from the mouth of the Athabaska river as far eastward as Point William. At several places he found outcrops of a granular siliceous sandstone to which he gave the name Athabaska sandstone. No fossils were found in it, nor its contact with other formations observed, but from its general character and position he placed it in the Cambrian.

In 1892 Mr. D. B. Dowling,[3] acting as assistant to Mr. J. B. Tyrrell, made a reconnaissance survey of the south shore of Lake Athabaska and found that the sandstone extends along the whole southern coast of the lake, with a few outcrops on the shore itself, and forms an escarpment to the south. The formation was traced as far eastward as Wollaston lake. Its southern limit was not determined.

In his exploration journeys in 1893 and 1894 on the Doobaunt, Kazan and Ferguson rivers, Mr. J. B. Tyrrell[4] found many small areas of a red altered feldspathic sandstone or arkose which he correlated with the Athabaska sandstone of McConnell. In places it passes into a coarse conglomerate and in other places is represented by red arkose.

[1] With the permission of the Director of the Geological Survey of Canada.

[2] McConnell, R. G.: Report on a portion of the district of Athabaska, Geol. Surv. Canada, Part D, Ann. Rept., vol. 5, 1889-90-91, page 51.

[3] Tyrrell, J. B.: Report on the country between Athabaska Lake and Churchill River, Geol. Surv. Canada, Part D, Ann. Report, vol. 7.

[4] Tyrrell, J. B.: Report on the Doobaunt, Kazan and Ferguson Rivers, and the North-West Coast of Hudson Bay, Geol. Surv. Canada, Part F, Ann. Report, vol. 9, 1896.

Areal Distribution.

The large known areas covered by the Athabaska Series are three in number. The first and largest is that in which it was originally described and named, extending along the south shore of Lake Athabaska to Lake Wollaston, a distance of 250 miles, and with a width in a north and south direction of probably 100 miles. The second is a large V-shaped area surrounding Doobaunt lake, having a length of approximately 200 miles in a north-east direction, and with a width varying to a maximum of about 100 miles. The third region where the series is exposed is north of lake Athabaska, where it forms a number of smaller areas. The regions studied by the writer include the first and more particularly the third of these areas.

Lithological Character of the Series.

In the large area lying to the south of Lake Athabaska the dominant rock type is a sandstone consisting practically entirely of quartz. Varieties of different degrees of coarseness are found. A very common type is one consisting of well-rounded quartz grains from two to five millimeters in diameter, scattered through a finer grained matrix of rounded quartz particles with diameter varying from ·2 to ·6 millimeters. Another variety consists of a white sandstone made up entirely of these smaller grains. Still another type contains well-rounded quartz pebbles up to three inches in diameter scattered irregularly among grains of varying degrees of coarseness.

In places the sandstone is very hard, in places weak and friable. The color varies from white to yellow, weathering reddish. The beds vary in thickness from a few inches up to two feet; irregular joint-planes cause them to break into blocks some of huge size.

In the areas north of Lake Athabaska the series is dominantly red in color, although gray and yellow beds are found locally. The rock types found in these localities consist of sandstone, arkose and conglomerate, with interbedded flows and sills of diabase. The largest of these areas is north of the Beaverlodge lakes; smaller areas are found north of Spring and Maurice points, on a peninsula and some islands east of Black bay, and along the shore of Lake Athabaska between Sand and Big points.

Conglomerates are in greatest abundance towards the base of the formation, in many places resting unconformably on the truncated edges of an older quartzite series. The bowlders are well rounded and range in size up to 18 inches in diameter. They consist of quartzite, granite-gneiss, vein quartz, and a few small bowlders of iron formation. Where the series rests on quartzite, this forms the dominant type of bowlder, and where it rests on granite, the latter is the most abundant type. The conglomerates show but a limited amount of sorting, bowlders of various sizes being associated together in a sandstone matrix. East of Beaverlodge lake alternations of fine red sandstone and conglomeratic beds form the lower portion of the series.

The finer-grained portions of the series consist of sandstone and arkose. Portions of the former show incipient quartz enlargements and approach a true quartzite. In places considerable quantities of feldspar are present, and the rock becomes a true arkose. North of the Beaverlodge lake this variety becomes a red, hard, well-cemented, thick-bedded rock. A characteristic feature seen in nearly every outcrop is the presence of well-rounded, quartz pebbles averaging about an inch in diameter, which are found sparingly throughout the series. In some massive varieties of the rock they are abundant enough to mark the bedding planes. In places the rock is so well cemented that it breaks directly across these quartz pebbles.

A local outcrop referred to this series consists of a red breccia made up of angular fragments of quartzite firmly cemented by a fine-grained matrix consisting of quartz, iron ore, chalcedony and sericite. Some of the smaller quartz particles are rounded, but the majority are subangular and were clearly not transported far.

West of Beaverlodge lake, the series forms hills, which rise to a height of 200 feet above the lake. The top of these hills consist of diabase and basalt outcropping in bands parallel to the strike of the series. The coarse-grained diabase has the relationship of intrusive sheets, but two of the bands consist of amygdaloidal basalt representing surface flows. The amygdules consist of calcite and vary up to 1½ inches in diameter. In the Doobaunt area Mr. Tyrrell found dikes and masses of both acid and basic eruptives, diabases and quartz-porphyries, traversing the sandstone and conglomerate beds of this series.

Structural Features.

Bedding.—Bedding is for the most part well-marked throughout the series, the beds varying in thickness from a few inches to two feet. Locally it is marked by color banding, usually alternations of red and yellow. In places, however, the texture is so uniform that the only way of detecting the bedding planes is by the way the rock breaks into slabs. These vary in size up to those which measure ten feet across; besides those occurring with outcrops in place, many are found on the sand plains north of the lake.

Cross-bedding.—The series is extensively cross-bedded, in all the areas studied. South of Lake Athabaska the prevailing type consists of diagonal layers bounded sharply above and below by horizontal beds. The maximum length of the diagonal fore-set beds observed was three feet. At the eastern end of the lake the slope of the fore-set beds is uniformly to the south-west indicating a source of supply from the north-east.

In the areas north of Lake Athabaska, the same type of cross-bedding is dominant. In the small outcrops between Sand and Big points, however, a more irregular type is presented, showing curved and fore-set beds, irregularly truncated by other curved beds above. This type, however, is on a smaller scale, and is much less abundant than the variety first described.

Sun-cracks.—Sun-cracks are not at all common throughout the series; in some fine-grained beds north-east of Beaverlodge lake, some excellent examples were found. The outlines were polygonal, averaging about four inches in diameter, with the filling of sandstone standing up as prominent ridges. Mr. Tyrrell also mentions finding sun-cracks in certain beds of Athabaska sandstone in the Doobaunt lake area. The reason why they are not more prevalent is evidently due to the coarse clastic nature of the series which is unsuitable for their development.

Rain-prints.—Rain-prints are not common; south of Stone river one layer in some fine-grained beds afforded a few unmistakable examples, but aside from this no others were seen.

Ripple-marks.—Ripple marks were seen in fine-grained beds in several localities. Near Fair point is an outcrop where the ripple-marks were symmetrical, vary in width from two to four inches measured from east to west, and with a height of one-half inch. Similar markings were found in the Beaverlodge area. Abundant ripple-marks were found by Mr. Tyrrell in the sandstone in Baker lake.

Clay-balls.—South of Stone river a number of round impressions filled with clay were found in the sandstone. These vary in size from one to two inches in diameter, and are very thin. Their method of occurrence was found to be the same in every case, for they were only observed in the plane between the fore-set laminæ and the top-set laminæ of the underlying stratum.

Folding.—South of Lake Athabaska the series lies horizontally, or with but very slight local dips. Its thickness here as shown by barometric measurement is over 400 feet. In the region of the Beaverlodge lakes north of Lake Athabaska, the series, however, is folded into a gentle syncline in which it was found to secure a determination of the thickness. Over 8,000 feet of interbedded conglomerates, arkoses and sandstones are exposed here. This syncline has a maximum dip on the limbs of 40° and pitches to the north at an angle of 20°. In the other areas north of Lake Athabaska the series lies practically horizontally.

Faulting.—In the outcrop of the series near Fair point excellent slickensided surfaces are preserved, which shows the existence of faulting on some scale. Friction breccias are present in an older quartzite series, but although they were developed after the metamorphism of this series it is unknown whether or not they were developed in post-Athabaskan times. Just to what extent the Athabaska series was faulted is, therefore, at present unknown.

Jointing.—Jointing is marked throughout the series, causing it to break into huge angular slabs. South of Stone river vertical jointing in an east and west direction keeps the front of the escarpment vertical while at right angles to this direction large crevasses mark a second joint system. The intersection of these two sets of planes produces blocks of sandstone ten to twenty feet across containing several hundred cubic feet of material. In places these blocks stand out as vertical pillars in front of the escarpment.

Intrusion.—The series is traversed, as has already been mentioned, by dykes and sills of diabase of contemporaneous age. At the eastern end of the lake on both the north and south shores, moreover, are to be found intrusions of a foliated norite. Along the contact of the norite in one locality on the north shore is found a quartzite, which, if it represented Athabaska sandstone metamorphosed by contact action, shows that the latter is older than the norite intrusion. No decisive evidence was seen by the writer to establish this, however.

Age of the Series.

The age of the Athabaska series has called forth considerable discussion. Careful search in all the localities where it is found has failed to reveal any fossils in it whatever. It is, however, very probably older than the Ordovician, for nowhere has the latter in this region been found to be cut by diabase dikes or sills, such as intrude the Athabaska series. Whether it is to be referred, however, to the Cambrian or to late Pre-Cambrian has, however, been the chief grounds for debate. The greater lithological resemblance, however, to the Keweenawan sandstones of the Lake Superior region, and its association with diabase intrusives and extrusives render it probable that it is to be correlated with these rather than placed in the Cambrian.

Origin of the Series.

The structural features displayed by the series points to a continental rather than a marine origin. The features in favor of such an interpretation may briefly be summarized.

The dominant feature of the series is its clastic character throughout. Limestones are absent and shales which form the large proportion of marine sediments are at a minimum. On the other hand many deposits of known continental origin consist dominantly of clastic materials as for example the Newark Series of the eastern United States, the Siwalik beds of India, and the Old Red Sandstone of Great Britain.

The great areal extent of the Athabaska series and its great thickness also strongly point to a subaerial origin. Great areas of marine sandstones of limited thickness may be found, for currents and longshore drift will transport materials for long distances, and an advancing or retreating shore line during the period of deposition would tend to increase the areal extent, but under such conditions a great thickness of sand could not be deposited over an extensive area. On the other hand a thick deposit of limited area might accumulate under marine conditions, as for example where streams from a mountainous region dump their load into deep water producing what might be termed a submarine alluvial fan, but such deposits must necessarily be very limited. In the formation of continental deposits a change of base-level affects all the rivers of the region and when aggradation begins in one it begins in all; as a result, subaerial deposits of practically any extent and thickness may be produced.

The character of the bedding is significant. The series is uniformly thick-bedded in contrast to the regular thin-bedded strata characteristic of marine deposits. The presence of so much conglomerate at various horizons and the alterations of sandstone and conglomerate are also much more easily explained as fluviable than as marine deposits.

The feldspathic character of portions of the formation is to be noted since it has been shown[5] that not only are feldspar fragments sorted out by rivers in their progress to the sea, but also wave action after the material has reached the sea tends further to sort out and remove the feldspar and other destructive minerals. The presence of the feldspar, therefore, not only indicates a subaerial origin, but a climate during its deposition unfavorable for decomposition.

The evidence of basic amygdaloidal and vesicular lava flows interbedded with arkose is an indication of the deposition of this portion of the series under subaerial conditions.

Many of the structural features point to the same conclusion. Rain-prints, sun-cracks and clay-balls are all more characteristic of continental rather than marine deposits. Though not abundant in the Athabaska series, their presence in beds capable of forming and preserving them is suggestive. The cross-bedding displayed is also characteristic of water-laid, torrential deposits. Local breccias are also best explained as deposits of such a character.

Conclusion.

If we assume, therefore, that the Athabaska series is of subaerial origin, then in Athabaska times, the region must have been a land area with, however, an entirely

[5] MacKie, Wm.: The Sands and Sandstones of Eastern Moray, Trans. Edinburgh Geol. Soc., vol. 7, pp. 148-172, 1897.

different type of topography from that which obtains in the region today. The great thickness of the series makes it necessary to postulate a down-warping basin or basins with adjacent country of considerable relief from which clastic material could be derived. The coarse conglomerates and local breccias suggest torrential deposits carried but a short distance; the greater part of the series, however, was certainly transported distances measured in miles. Fluviatile deposition on broad flood-plains in intermontane basins seems to best represent the conditions under which the series accumulated.

The climate prevailing at the time the formation was laid down may also be inferred. The prevailing red color is due to the oxidation of iron and indicates conditions of partial decay of granitic materials with regular periods of exposure to the atmosphere. Such a condition is met with in a semi-arid climate in which periods of rain alternate with periods of drought during which a thorough oxidation of the iron is accomplished.

The conditions of deposition may, therefore, be summarized as follows:—broad subsiding basins between mountains of considerable relief; a semi-arid climate, in which erosion and disintegration proceeded rapidly, loading up the streams to their ultimate capacity; torrential floods in which the coarser materials were spread out over the river flood-plains, followed by dry seasons in which the sediments were exposed to the air, and their iron content oxidized. The farther the materials were transported, the more would the feldspar content be sorted out, until finally the detritus would consist of practically quartz grains only. Progressive subsidence and rapid erosion would eventually give rise to a thick series with all the features characteristic of the formation.

Late Pre-Cambrian time in North America was apparently marked by wide areal extent and conditions favorable for the accumulation of subaerial deposits. Rocks similar to the Athabaska series are found on the east arm of Great Slave lake, along Coronation gulf, and the Coppermine river, on several of the Arctic islands, and in the Labrador peninsula. The subaerial character of the Keweenawan rocks of the Lake Superior region, and of the Belt formation of Montana points also to the dominance of continental sedimentation in late Pre-Cambrian time. It is probable that in no subsequent period has North America had a greater areal extent.

Art. IV.—*Italite, a new Leucite Rock;* by Henry S. Washington.

Introduction.—Zirkel was the first, in 1867, to discover with the newly introduced microscope that many basalts contained microscopic leucites,[1] and he gave the name "leucitite" to such basaltic rocks which contained no feldspar. The term was generally adopted, and is now the recognized name for feldspar-free effusive rocks, that are composed essentially of leucite and augite in about equal parts. Thirty years after Zirkel's observation, Dr. Whitman Cross[2] suggested that "the term leucitite be reserved for the rock that has not yet been discovered, * * * * consisting essentially of leucite, with all other minerals of subordinate importance." A similar suggestion was also made for "nephelinite."

Leucite rocks are not very commonly met with, and, up to the present, no occasion has arisen to put Cross' suggestion to a practical application. It is, however, the purpose of this paper to put on record, and to describe briefly, such a true "leucitite," in Cross' sense of the term, that is, an effusive rock composed almost wholly of leucite. The name "leucitite," through long usage, has come to connote the presence of augite, along with the leucite, in almost equal amount, and with small quantities of magnetite, apatite, and possibly nephelite, so that rocks called leucitite are highly femic, and fall mostly in salfemane. The name is one of our many heritages from the early days of petrography, when the occurrence of rare or unusual minerals was considered a leading factor in rock nomenclature, and long before the importance of the recognition of the quantitative relations of the mineral constituents of a rock had begun to receive recognition. Under the circumstances, it is inadvisable to follow Cross' suggestion, and to redefine the old term "leucitite." It is better, in that it is less likely to lead to confusion, to bestow a new name, and the one here proposed is *italite,* in honor of the country whose lavas are so famous for their abundance in leucite, and where, appropriately enough, the new and long sought-

[1] F. Zirkel, Zs. D. Geol. Ges., 1868, p. 97. Cf. Zirkel, Basaltgesteine, Bonn, 1870, p. 44.

[2] Cross. This Journal (3), 4, 137, 1897.

for rock has been discovered. A more precise definition will be given on a later page.

The rock was first brought to my attention in October, 1919, by Baron Dr. G. A. Blanc, of the University of Rome, and Ing. F. Jourdain, who had discovered it during the preceding summer on the west slope of the volcano of Rocca Monfina, north of Naples. These gentlemen stated that the rock formed apparently a flow, not a mass of tuff, more than a hundred meters long and of considerable thickness. As I was on the point of leaving Rome for Washington, I had no opportunity to visit the locality, but Signori Blanc and Jourdain very generously gave the specimen shown me, and also their permission to publish the results of my study of it. They also kindly promised to send me more material and fuller notes on the occurrence of the rock. For this courtesy and generosity it is a pleasure to express my most sincere thanks. The present note is to be supplemented by a more complete description and by additional analyses, when I shall have received more material and fuller notes on the occurrence. What remains of the specimen has been deposited in the Petrographic Reference Collection of the U. S. Geological Survey.

Megascopic characters.—My specimen of the rock (which weighed only about 80 grams), is almost white, though with some yellowish stains, because of superficial weathering, but the interior is fresh, as the analysis and the microscope show. One side is formed by a smooth, slightly warped surface, such as is common with blocks that have resulted from cracking during the solidification of very viscous lavas.

It is rather coarsely granular, composed almost wholly of spheroidal crystals of leucite, of fairly uniform size, from 3 to 5 mm. in diameter. These are water-clear, with conchoidal fracture and the somewhat greasy luster that is characteristic of many Italian leucites. The grains show few, if any, crystal faces, as if their growth had been more or less limited by mutual interference, so that they are equantly anhedral. In irregular spaces between them is a small amount of an aphanitic, light gray substance, of dull luster, which was at first taken for kaolinitic decomposition products, but which the microscope shows to be glass. This glass acts as a cement between the leucite crystals, which are, however, very loosely attached, so that the rock is very friable and the leucite crystals are easily detached and the specimen is readily crumbled to fragments between the fingers.

Some small (up to 1 mm. long), sharp prisms of black pyroxene are seen, that lie for the most part in the cement, but also a few in the leucite crystals; and there are fewer, smaller black grains of what proves to be a garnet. No other constituents are visible in the small specimen in my possession.

Although anticipating the description of the microscopical characters, it may be said here that, while the specimen suggests a tuff in its mineral composition and friability, yet the warped surface just mentioned, and especially the presence of glass as a cement and the occurrence of pyroxene prisms partly in the glass and partly in the leucites, with the texture as seen under the microscope, leave no doubt that the specimen is from a flow, and not a fragment of one of the somewhat consolidated leucitic tuffs, which have been reported from this volcano. Indeed, it may be suggested that such masses of "tuff," or at least some of them, are in reality flows of this highly leucitic lava, which has been mistaken for tuff because of its highly friable character.

Microscopical characters.—Unfortunately, only one thin section, and this not a large one, was available for study, two others having gone to pieces because of the friability of the material.

The largely predominant and anhedral, though generally equant, leucite crystals are perfectly clear and are obviously extremely fresh. They show the characteristic twinning in a most remarkable way, almost the whole area of most of the crystals showing between crossed nicols very numerous, differently oriented, sharp lamellæ, in some cases very thin, in others broad. Indeed, among the numerous leucite lavas of which I have studied thin sections, I can recall none that shows the twinned structure so beautifully.

The leucites are almost free from inclusions, and it may be remarked specially that there is none of the zonal or radial arrangement of small inclusions that is usually so characteristic of this mineral. As inclusions occur some small, anhedral pyroxenes and a few grains of garnet (melanite), with rare, small, slender prisms of apatite. A small area in one of the leucite crystals is crowded with minute (0·01-0·05 mm.) spheroidal inclusions, each of which is composed of glass containing still smaller granules of a colorless, birefringent substance, of rather high refractive index.

Pyroxene is not abundant, and occurs mostly between the leucite crystals, but to some extent partly in these and partly in the glass. It is an "ægirite-augite," or rather an acmite-diopside, as a recent study of the ægirite group (soon to be published) by Dr. Merwin and me has shown to be true of most of the so-called ægirite-augites. The crystals are subhedral, generally with some prismatic planes. The color is a rather dark yellow-green, and the mineral is but slightly pleochroic, varying from a greenish yellow, Ridgeway's[3] "oil-green" (27*k*) to a greenish yellow-green, Ridgeway's "grass-green" (33*k*). The extinction angle is about 40°; $\alpha = 1{\cdot}710\text{-}1{\cdot}715$ and $\gamma = 1{\cdot}752$; and $2V = \text{ca. } 70°$, these data having been kindly determined by Dr. Merwin, to whom I am much indebted for this and other determinations. It was not practicable to isolate sufficient pyroxene in a pure condition for a satisfactory analysis, so that study of its chemical composition must be deferred until more abundant material is in my hands.

In decidedly less amount than the pyroxene prismoids are small anhedral grains of a deep red-brown, isotropic mineral, with the high refractive index, $n = 1{\cdot}94$, as determined by Merwin. A partial analysis, made on a very small amount of material, shows that this is a titaniferous melanite, similar to that found in lavas elsewhere, as at Tavolato and Frascati at the Alban Volcano. It will be discussed, and the analysis given, at the close of this paper.

There are a few small, thick tables of a dark, reddish, pleochroic biotite, most of them in the ægirite, some small grains of magnetite, and the rare colorless apatite prisms mentioned above. No hauyne nor noselite was seen.

A colorless glass base occurs in small amount, interstitial between the leucite crystals. It shows no perlitic cracks, but contains some small, spherical bubbles, and occasionally (in patches) small (0·05-0·10 mm.) black, opaque, rounded grains, that are probably magnetite, as the glass near them in places is stained yellow. For the most part the glass is crowded with very minute (0·001-

[3] R. Ridgway, Color Standards and Nomenclature. Washington, 1912.

0·010 mm.) sub-spherical grains of a colorless, birefringent substance, that is similar to that seen in the leucite. These microlites are arranged in long lines, like streptococci, some of the lines being straight and more or less parallel, while others are curved.

Mode.—As only one small, and probably not representative, thin section was available, no attempt was made to determine the mode by Rosiwal's method. But from consideration of the figures given by the norm and by separations with heavy solution and the magnet, the mode is estimated to be approximately as follows:

Leucite	90
Hauyne	2
Melilite	2
Pyroxene	4
Melanite	1·5
Biotite	0·2
Magnetite	0·2
Apatite	0·1
	100·0

It is to be supposed that the hauyne and melilite, neither of which is visible in the section, form the glass, the amount of which is estimated at about 4 per cent. The presence of hauyne, melilite, and melanite is quite in accord with the mineral composition of other highly salic and potassic Italian lavas, which frequently carry small amounts of these minerals.

Chemical composition.—For the chemical analysis, 18 grams (about one-fourth) of the specimen was crumbled to fragments over a large sheet of paper, and the *whole* was reduced to powder and thoroughly mixed. It is thought that it represents fairly well the composition of the specimen, though, of course, a larger sample from much more material would be preferable for such a coarse-grained rock. The analysis was made according to the usual methods, the alkalies and sulphur trioxide being determined in duplicate. The results are shown in Column 1 of the Table, there being also given some other analyses of highly leucitic rocks.

ANALYSES OF ITALITE AND OTHER LEUCITE ROCKS.

	1	2	3	4	5	6
SiO_2	51·02	54·17	51·65	50·25	51·20	47·39
Al_2O_3	22·21	10·16	21·60	21·41	21·21	14·79
Fe_2O_5	1·48	3·34	0·85	1·76	2·38	3·10
FeO	0·57	0·65	3·12	1·82	3·67	5·08
MgO	0·14	6·62	1·07	0·31	1·99	6·77
CaO	2·31	4·19	4·29	4·48	5·42	11·61
Na_2O	1·67	1·21	4·30	5·16	2·11	1·49
K_2O	17·94	11·91	11·60	11·32	10·63	6·93
H_2O-	0·11	0·52	0·26	0·62	0·28	0·77
H_2O+	0·82	1·01		0·34	0·10	0·28
CO_2	*none*	0·49	*n. d.*	0·32	*none*	*none*
TiO_2	0·57	2·67	0·65	0·57	0·74	1·41
ZrO_2	0·06	0·22	*n. d.*	0·02	0·03	0·04
P_2O_5	0·02	1·59	*n. d.*	0·12	0·36	0·45
SO_3	0·76	0·16	*n. d.*	1·05	*trace*	*none*
Cl	0·08	0·06	0·07	0·18	*n. d.*	*n. d.*
$(Ce,Y)_2O_3$	*trace*	*n. d.*	*n. d.*	*n. d.*	*n. d.*	0·05
MnO	0·01	0·06	*n. d.*	*n. d.*	*n. d.*	*n. d.*
BaO	0·20	0·59	*n. d.*	0·13	0·33	0·15
SrO	*n. d.*	0·18	*n. d.*	*trace*	*n. d.*	0·04
	99·97	100·21*	100·20	99·86	100·45	100·35
Less O	·02	·17	·01	·04		
	99·95	100·04	100·19	99·82		

* Includes $F = 0·36$, $Cr_2O_3 = 0·05$, NiO and Li_2O traces.

1. Italite (I. 9. 1. 1.). Near San Carlo, Rocca Monfina. Washington analyst.
2. Orendite (III. 5. 1. 1). Leucite Hills, Wyoming. Hillebrand analyst. W. Cross, this Journal, 4, 130, 1897.
3. Leucite sanidinite (II. 7. 2. 2). Monte Somma. Pisani analyst. Lacroix, C. R., 144, 1249, 1907.
4. Tavolatite (I. 7. 1. 3). Tavolato, Alban Hills. Washington analyst. Rom. Comag. Region, 51, 1906.
5. Vicoite (leucite tephrite) (II. 6. 2. 2.). Monte San Antonio, Rocca Monfina. Washington analyst. Rom. Comag. Region, 92, 1906.
6. "Leucitite" (III. 7. 2. 2.). Mte Jugo, Bolsena Volcano. Washington analyst. Rom. Comag. Region, 124, 1906.

At the first glance this analysis is seen to be very remarkable. It is composed almost entirely of silica, alumina, and potash; with small amounts of ferric oxide, lime, and soda; and with very small amounts of the other constituents. The percentage of silica is about 4 per cent below that in leucite, while the percentages of alumina and potash are about those in this mineral. The very high figure for K_2O is the most striking feature, being higher by 50 per cent than any yet recorded. The next highest (11·91) is found in orendite (2), one of the peculiar rocks of the Leucite Hills, which is composed in great part of leucite and orthoclase, with subordinate biotite and diopside. Similar to this as regards potash (though with differences in silica, alumina, etc., as may be seen in the table), are a leucite sanidinite from Monte Somma (3), a tavolatite from the Alban Hills (4), and a vicoite from Rocca Monfina (5). The analysis of a typical, so-called "leucitite" is given in (6); for comparison. This contains only about 32 per cent of modal leucite, and about 50 per cent of augite.

The amount of soda is about that shown by most Italian leucites. The preponderance of ferric over ferrous oxide and the rather high lime are to be noted and, among the minor constituents, the rather high figures for SO_3 and BaO. The common occurrence of noselite (and hauyne) in Italian leucitic lavas has already been mentioned, and SO_3 is present in all the lavas of the Leucite Hills. It has been pointed out elsewhere[4] that barium shows a tendency to be associated with magmas that are high in potash, as is well seen in the leucitic lavas of Italy and of Wyoming. In the present rock it may be assumed to be present in the leucite. As the literature furnishes no analysis of leucite in which BaO has been determined, this determination was made on a crystal from Vesuvius; the amount found was 0·08 per cent. It is therefore reasonable to suppose that it is present in the leucite of the italite, though in larger amount than in the leucite of Vesuvius.

Classification.—The data for the classification of the italite specimen according to the Quantitative Classification are given in the calculated norm, shown below.

Anorthite	2·78	2·78	
Leucite	82·62		92·12
Nephelite	4·83		
Kaliophilite	0·47	89·34	
Thenardite	1·42		
Diopside	0·86	3·99	
Wollastonite	3·13		
Magnetite	0·23		6·56
Ilmenite	1·06	2·57	
Hematite	1·28		

Norm of Italite. Rocca Monfina.

The rock therefore falls in Class I, Persalane (C. I. P. W.); order 9, laurentare (Adams); rang 1, congressase (Adams), and subrang 1: the symbol for the specimen analysed is I. 9. 1. 1. 2). This perpotassic subrang has

[4] H. S. Washington, Roman Comagmatic Region, Carnegie Publication No. 57, p. 188, 1906; Trans. Am. Inst. Min. Eng., 1908, p. 754.

been hitherto unrepresented, and may be called *monfinose.* As will be seen from a comparison of the norm with the mode given on a previous page, the mode is essentially normative, as deviations from the normative minerals are of negligible amount. Using the adjective *monfinal* to denote the modal and textural (motexal) characters the rock may be called monfinal monfinose in the Quantitative Classification.

In the qualitative or modal classifications also this rock has been unknown up to the present. Though it is, in reality, what might logically be considered a typical "leucitite," yet, as has been explained above, this name has a different connotation, so that the bestowal of a new name is called for. That proposed is *italite,* meaning thereby an effusive, porphyritic rock, composed almost entirely (80 per cent or more) of leucite crystals, with minor amounts of pyroxene, glass, and possibly other components.

Formal description.—In my paper on The Roman Comagmatic Region[5] there were given formal descriptions of the various rock types, which were modeled on those used in botanical and zoological publications. These aimed "to give a concise, but complete, description of the type, both qualitative and quantitative, which may be regarded as standard." It is thought that the use of such formal descriptions will aid greatly in comprehending the description of a rock; will render more precise our ideas of what is intended to be meant by any rock type or name; and will hasten the general recognition of that important factor in rock classification and description—the quantitative relations of the several constituents of rocks, whether chemical or mineral. It is, therefore, my intention to publish such descriptions hereafter, whenever the occasion may arise. The technical terms used (for brevity) are those suggested by C. I. P. W. in their various publications, and which will also be found in Volume I of "Igneous Rocks" by Iddings. It will be noted that these formal descriptions may be used whether the so-called quantitative classification be adopted or not.

ITALITE. MONFINAL MONFINOSE (I. 9. 1. 1.).

Megascopic characters.—Light gray or white, equigranular or persemic, rather coarse-grained, may be somewhat friable.

[5] Carnegie Publication, No. 57, p. 15, 1906.

Leucite anhedra, 80 per cent or more, equant, about 3-5 mm., usually containing few inclusions. Pyroxene, in small black prisms, and garnet, in small black grains, not more than 5 per cent each. Interstitial glass cement, about 5 per cent, may be present, and negligible amounts of other minerals possibly present.

Microscopic characters.—Percrystalline, megaporphyritic, persemic, mediophyric.

Leucite: megaphenocrysts, 80 per cent or more, usually clear, twinned, few inclusions, not necessarily regularly arranged. Pyroxene: acmite-diopside, 5 per cent or less, usually prismoids and about 1 mm., green, pleochroic. Melanite: 5 per cent or less, small anhedra. Biotite, magnetite, apatite: 1 per cent or less of any may be present. Base: about 5 per cent, glass, usually colorless, with or without microlites.

Chemical composition.—Approximately that given on page 37 above. *Type specimen* from near San Carlo, Rocca Monfina Volcano, Italy.

Garnet in Italite.

Titaniferous melanite.—By means of a magnet 0·0639 gram of the small grains of garnet was isolated from 5·25 grams of the rock powder, practically entirely free from pyroxene and magnetite. It was sufficiently pure, at least, to establish the general composition and character of the mineral, and a partial analysis was made of this portion, with the results given below. Because of the very small amount of material available, ferrous and manganous oxides, the alkalies, and water could not also be determined. The sodium carbonate melt was colored a decided blue-green and, judging from the depth of this in connection with the amount of substance, it was estimated that about 0·10-0·20 (or possibly more), per cent of MnO was present.

SiO_2	29·7	·496	·604
TiO_2	8·7	·108	
Al_2O_3	8·1	·080	·227
Fe_2O_3	23·6	·147	
MgO	0·7	·017	·532
CaO	28·8	·515	
	99·6		

Analysis of melanite from italite, Rocca Monfina.

These constituents and percentages show that the mineral is unquestionably a garnet, even though the molecular ratios do not conform strictly to those of the garnet formula. This is to be attributed in part to the serious errors that are almost unavoidable in the analysis of such a small amount of material as was at my disposal, and in part probably to the presence of some FeO, which would reduce the apparent amount of R_2O_3 and, with the MnO known to be present, would increase that of RO. The ratios would thus approximate more closely to those of garnet, 3 : 1 : 3.

This garnet is certainly quite high in titanium, which is for the most part, if not presumably entirely, present as TiO_2. In its high titanium it resembles the melanite of Beaver Creek,[6] Frascati[7] and the Perlerkopf,[8] and the schorlomite of Magnet Cove,[9] but differs from the melanite of East Rock, near New Haven, Conn.,[10] which contains none. It may be called a melanite, the name usually given to the andradites (lime-iron garnets) found in alkalic effusive rocks.

Optically, it is perfectly isotropic, showing no anomalous double refraction. The refractive index, 1·94 (Merwin), is higher than that of any garnet yet recorded, so far as search of the literature reveals. Those that come nearest to it in this respect are the melanite from Syssersk (n(Na)=1·8893) determined by Osann, and that from Frascati (n(Na)=1·8566) determined by Wülfing.[11]

As it was thought that the determination of the refractive indexes would be of interest in connection with the presence of titanium in these minerals, Dr. Merwin made several determinations on specimens that were kindly put at our disposal.[12] The results were as follows:

	n	TiO_2
Melanite, Rocca Monfina	1·94	8·7
Melanite, Beaver Creek, Colorado	1·95	5.08
Schorlomite, Magnet Cove, Arkansas	1·94	16·90
Ivaarite, Kuusamo, Finland	2·01	18·98
Melanite, East Rock, New Haven	1·86-1·88	none

[6] Larsen, Journal Wash., Acad. Sci., 4, 478, 1914.
[7] Knop, Zs. Kr., 1, 62, 1877. [8] Uhlig, Zs. Kr., 53, 204, 1914.
[9] Koenig, Proc. Acad. Sci., Phila., 1886, 355.
[10] E. S. Dana, this Journal, (3), 14, 215, 1877.
[11] Rosenbusch-Wülfing, Mikr. Physiog., I, part 2, p. 18, 1905.
[12] The specimens from Beaver Creek (collected by E. S. Larsen), Magnet Cove, and Kuusamo, were given by Dr. Foshag of the U. S. National Museum, from its specimens; and that from East Rock, out of the Brush Collection, by Prof. Ford.

It will be noted that the garnet of Beaver Creek, and Magnet Cove, which contain (the former variably) considerable titanium, show indexes much like that of the Rocca Monfina mineral; while the ivaarite of Finland, which is almost black and opaque, and has the largest amount of TiO_2, shows the highest index. The melanite of East Rock, in which Dana could detect no titanium, is distinctly birefringent, and therefore the low temperature form of garnet,[13] and shows the lowest refractive index. As will be recalled by all students of mineralogy at Yale, this melanite occurs in crevices in the "trap," not as a constituent of the rock itself, so that the fact that it is the low temperature form, and consequently birefringent, is not surprising.

Vesbite (*melilite italite*).

While this paper was being written, Dr. A. F. Buddington, of the Geophysical Laboratory, called my attention to a specimen of melilite that he had obtained from Ward's Natural History Establishment. The melilite cystals are in crevices and small cavities in an "ejected block" from Monte Somma. While it is, in general, not very satisfactory to describe a rock type from such a specimen, yet, in this case, the rock is so very peculiar and so strikingly like my specimen of italite, that it seems to merit description.

The rock is light gray, holocrystalline, and very clearly an effusive igneous rock, and not a metamorphosed block. It is rather coarsely granular, made up for the most part of grains of very light gray leucite, of irregular but generally equant form and closely packed together, these grains measuring from 3 to 5 mm. in diameter. With them is a white mineral in smaller amount, the melilite revealed by the thin section. Very small and fairly abundant black prismoids of pyroxene are scattered through the leucite, and give the grayish color to the specimen. The rock is somewhat vesicular, and tabular, white melilite crystals occur in the vesicles, most of the cavities showing signs of some weathering of their contents.

Thin sections show that the rock is made up of nearly 75 per cent of clear, fresh leucite, in closely packed anhedra, some of them spheroidal and others quite ir-

[13] Cf. H. E. Merwin in C. W. Wright, U. S. Geol. Survey, Prof. Paper No. 87, p. 107, 1915.

regular through mutual interference during growth. It is interesting to note that the leucite forms a granular aggregate, quite analogous to its occurrence in the intrusive missourite, discovered by the late Prof. Pirsson.[14]

The leucite shows the twinned structure well, but not as remarkably as does the italite of Rocca Monfina. There is no regular arrangement of inclusions. The leucite is perfectly clear and unaltered.

Scattered through the rock, and especially included in the leucite, are many rather small crystals of augite. These are mostly euhedral, showing prism and pyramid planes. They are of an olive-yellow color, not pleochroic, with some tendency to zonal structure, the extinction angle about 45°, and in general quite like the typical augites of most of the Italian leucite rocks. They carry no inclusions, and the augite is, with the magnetite, evidently the first mineral to crystallize.

Interstitial between the leucite grains, and evidently the last mineral to crystallize, is considerable melilite, which forms thick, tabular subhedra, with well-marked basal cleavage, and showing the characteristic blue-gray between crossed nicols. This mineral will be described in detail later by Dr. Buddington. With this fresh melilite, and apparently an alteration product, are similar forms of what looks like melilite, but which does not give the blue-gray color, though it has also extinction parallel to the base. This is usually fringed on the edges with narrow strips of a finely granular decomposition product, of high birefringence, that resembles hydronephelite or ranite.

There are very few small magnetite grains, an apatite prism here and there, but no biotite, olivine, melanite, nor mineral of the hauyne group was seen. There is no glass, and evidently the melilite takes its place, though not so markedly interstitial as is the glass in the italite proper.

From examination of the norm and the thin sections the mode is estimated to be approximately as follows:

Leucite	60	(60)
Melilite	23	(18)
Pyroxene	16	(20)
Magnetite	1	(2)
	100	

[14] This Journal, (4), 2, 315, 1896; U. S. Geol. Survey, Bull. 237, 115, 1905.

As some of the melilite crystals in the crevices were included in the material analysed, the mode given in the first column is too high in melilite, and a presumably more correct one is given by the figures in parentheses.

For the chemical analysis a thick slice was made through the center of the specimen, and the melilite crystals in the cavities, and the lining of these, were removed so far as possible, though they could not be wholly avoided without unduly reducing the quantity of material. The analysis furnished the following results:

SiO_2	45·49	H_2O+	0·93
Al_2O_3	17·66	H_2O-	0·05
Fe_2O_3	0·81	TiO_2	0·13
FeO	1·45	P_2O_5	0·16
MgO	4·27	SO_3	none
CaO	16·72	Cl	0·03
Na_2O	1·66	MnO	trace
K_2O	11·44		
			100·80

This analysis is remarkable in its high potash and lime. Both the silica and alumina are distinctly lower than in italite, the oxides of iron are about the same in their total amount, though in inverse proportions, magnesia is decidedly higher, while the percentage of soda in both is identical. Two features of interest among the minor constituents are the figures for TiO_2 and SO_3. The higher titanium in the italite is evidently connected with the presence of the titaniferous andradite, which is wanting in the other rock. In this latter not a trace of SO_3 could be detected, and but little more than a trace of Cl, showing the absence of minerals of the sodalite group.

The norm of the rock is calculated to be:

Anorthite	6·95	Olivine	8·81
Leucite	47·70	Calcium orthosilicate	23.22
Nephelite	7·67	Magnetite	1·16
Kaliophilite	3·95	Ilmenite	0.30
		Apatite	0·34

It is clear that most of the normative anorthite and olivine go into modal augite; a small amount of each, with a little of the nephelite, going into the melilite. As melilite has a ratio of bases to silica slightly greater than 2 : 1, the orthosilicate ratio, some silica will be thus liberated, which would go to form leucite out of the kaliophilite. The relations of norm and mode can, however, be best studied after the melilite has been analysed, which it is hoped to do soon.

As to classification in the quantitative system, the figures of the norm and of the analysis place this rock in dosalane, in the perlenic order (but close to the border of the feldolenic order), in the domalkalic rang, and the dopotassic subrang. The position is indicated by the symbol II″. (8) 9. (1) 2. ″2. No rock has yet been found that falls in this rang and subrang of lappare, and, though it is transitional as regards order and rang, and intermediate as to subrang, the rock is so unusual that one may be permitted to violate one of the rules of nomenclature and give a name based on this rock. That which is suggested for the rang is *vesbase,* and that for the subrang is *vesbose,* both derived from the name given to the rock.

It is clear that the rock has no exact analogue in the prevailing systems of classification. Although it is much like italite, it is so much higher in melilite and pyroxene as to merit distinction from this, though it might be designated as a melilite italite. It also resembles the olivine-melilite-leucite venanzite of Sabatini[15] (euktolite of Rosenbusch),[16] but this contains so much olivine, melilite, and pyroxene as to fall into dofemane. Mineralogically, also, it resembles cecilite ("melilite leucitite"), but this contains much more augite and less leucite, and is structurally much finer grained and otherwise different.

Though the rock is essentially a melilite italite, the name *vesbite*[17] is suggested for it, meaning an effusive rock (in this type rather coarse-grained), composed essentially of 60-70 per cent of leucite, and about 20 per cent each of augite and melilite.

The chemical relations of *vesbite* to the salic italite on the one hand, and to venanzite, cecilite (melilite leucitite), albanite ("leucitite"), and missourite on the other, all of these last rocks being distinctly femic, are shown in the accompanying table.

[15] Sabatini, Boll. Com. Geol. Ital., 1898.

[16] Rosenbusch, Sb. Akad. Wiss. Berl., 1899, p. 110. Cf. this Journal, 7, 399, 1899

[17] This name is derived from Vesbius, a Latin variant name of Vesuvius.

	1	2	3	4	5	6	7	8
SiO_2	51·02	45·49	41·43	45·99	44·69	47·20	47·39	46·06
Al_2O_3	22·21	17·66	9·80	16·56	14·57	17·66	14·79	10·01
Fe_2O_3	1·48	0·81	3·28	4·17	5·56	3·51	3·10	3·17
FeO	0·57	1·45	5·15	5·38	3·69	4·50	5·08	5·61
MgO	0·14	4·27	13·40	5·30	5·83	4·20	6·77	14·74
CaO	2·31	16·72	16·62	10·47	11·68	9·52	11·61	10·55
Na_2O	1·67	1·66	1·64	2·18	2·37	2·25	1·49	1·31
K_2O	17·94	11·44	7·40	8·97	8·62	7·63	6.93	5·14
$H_2O\pm$ ...	0·93	0·98	1·11	0·45	0·71*	1·29	1·05	0·73
TiO_2	0·57	0·13	0·29	0·37	1·03	1·19	1·41	0·73
P_2O_5	0·02	0·16	none	0·56	1·16	0·58	0·45	0·21
MnO	0·01	trace	n. d.	n. d.	0·15	n. d.	0·27	trace
Incl	1·10	0·03	....	0·25	....	0·23	0·27	0·60
	99·97	100·80	100·12	100·65	100·06	99·76	100·34	99·57

* $H_2O+ = 0·60$, $H_2O- = 0·11$.

1. Italite, Rocca Monfina. Washington analyst.
2. Vesbite, Monte Somma. Washington analyst.
3. Venanzite, Pian di Celle, Umbria. Rosenbusch, Sb. Akad. Wiss. Berl., 1899, p. 110.
4. Cecilite, Capo di Bove. Washington analyst. Rom. Com. Region, p. 139.
5. Cecilite, Laghetto, Alban Volcano. Washington analyst. Unpublished.
6. Albanite, Arcioni, Alban Volcano. Washington, Rom. Com. Region, p. 113.
7. Albanite, Mte. Jugo, Bolsena Volcano. Washington analyst. Rom. Com. Region, p. 124.
8. Missourite, Highwood Mts., Montana. Hurlburt analyst. Pirsson, this Journal, 2, 321, 1896.

Cecelite is the old name of Cordier[18] for the melilitic "leucitites," and is the name which it has been proposed[19] to revive for these rocks. The name *albanite*[20] is proposed to replace the old name "leucitite," implying an effusive rock composed in approximately equal parts of leucite and augite, with only accessory and negligible amounts of plagioclase, melilite, olivine, magnetite, etc.

Geophysical Laboratory,
Carnegie Institution of Washington,
April 17, 1920.

[18] Cordier, Description des Roches, Paris, 1868, p. 117. Cf. C. R. VIII Cong. Geol. Int., Paris, 1901, p. 1051.

[19] Washington, Rom. Com. Region, 1906, p 140.

[20] This name has been given to a "bituminous material from Albania" (Cf. L. J. Spencer, Min. Mag., 16, 352, 1913), but, in view of its application to a mineral of very indefinite characters, it would seem to be allowable to use it for a rock type. The root is already in use for the name, albanose, of the subrang III. 8. 2. 2.

Art. V.—*The Late Lower Cretaceous at Federal Hill, Maryland;* by Edward W. Berry.

Federal Hill, situated on the peninsula between North West Branch and Middle Branch of Patapsco River which is terminated by historic Fort McHenry, is an erosion remnant of Cretaceous rising about 90 feet above tide and famous in local paleobotanical annals for the large flora contained in its sandy clays. These fossil plants were fully described[1] in 1911 from materials collected during the opening and grading of streets more than a generation ago. The surface of Federal Hill Park has been in turf for many years so that no opportunities for additional collecting have been afforded.

Some years ago in the construction of the Key Highway a small cutting was made at the eastern end of the Park exposing a few feet of fossiliferous deposits. This proved to be of considerable interest from the light which it shed on the conditions of deposition. The horizon can be located from the following old section:[2]

	Feet
Patapsco formation.	
Argillaceous sand with silicified wood	6
Carbonaceous clay with siderite	1
Sandy clay with ferruginous streaks and crusts	34
Bluish clay with logs of lignite	7
Dark blue laminated clay	3
Gray sandy clay with plants	2
Argillaceous sand	2
1 inch ferruginous band.	
Patuxent formation.	
White sand and clay with reworked clay balls in places	85
All but about 15 feet below tide.	

The horizon from which the recent collection of plants was made is just above the Patuxent contact in the old section quoted above. The indicated environment is a sandy flood plain with a characteristic poor soil flora. There apparently was not enough humus to furnish a true soil since neither the clay laminæ nor the sands are carbonaceous. The prevailing plant growth was a small

[1] Berry, E. W., Maryland Geological Survey, Lower Cretaceous, Baltimore, 1911.

[2] Idem., p. 75.

species of Equisetum with occasional ferns and possibly a few conifers and dicotyledons, although the bulk of the species recorded from this locality amounting to a total of thirty and including a Marchantites, an Equisetum, a Sagenopteris, 9 ferns, 9 conifers, 1 monocotyledon and 8 dicotyledons, represent fragments of nearby vegetation of a more fertile soil that were washed or blown into the basin of sedimentation. That the equisetum grew in abundance at this place is shown by the profusion of the tuber-bearing underground stems in place in the argillaceous gray sand. This tuber-bearing stratum is immediately overlain by a thin layer of brownish clay containing a variety of leaves and fragments of foliage of different sorts and very large numbers of the aerial stems of the equisetum, and it is a significant fact that these prostrate stems are arranged in a subparallel manner as if they had been laid flat by flood conditions and then buried by the fine silt when the flood waters backed up or became slack. This process appears to have been repeated many times, perhaps seasonally, since there are a succession of these alternating tuber-bearing and prostrate stem-bearing layers. A fragment of the tuber-bearing layer and the character of the aerial stems are shown in the accompanying figures. (Figures 3, 4.)

Among the other plants found here which serve in a measure to confirm the flood plain character of the deposits, or at least their stream-border character, are the Sagenopteris which appears to have had a habit of growth like that of the existing water-fern Marsilea, the two species of Nelumbites-Lower Cretaceous prototypes of the existing Nelumbo, and the monocotyledonous plant, illogically named Plantaginopsis by Fontaine, which was certainly a semi-aquatic marsh plant with a habit that I have compared with that of a modern Ericoaulon.

An interesting dicotyledonous plant common at this locality is *Celastrophyllum latifolium* Fontaine. I have for a long time been interested in the angiosperms of the Potomac Group, and the recent discussions of Bailey & Thompson[3] as to whether the vessel-less angiosperms Tetracentron, Trochodendron and Drimys were primitive or specialized by reduction has stimulated a new interest

[3] Thompson, W. P., and Bailey, I. W.; Mem. N. Y. Bot. Garden, vol. 3, pp. 27-32, pl. 2-4, 1916. Bailey, I. W., and Thompson, W. P., Annals of Botany, vol. 32, pp. 503-512, pl. 16, 1918.

in these Lower Cretaceous foliar remains. I have nothing definite to put forward at the present time beyond calling attention to the remarkable resemblance between the leaves of the existing Tetracentron, Cercidophyllum and Trochodendron, and the Patapsco dicotyledons that have been described as Populus, Populophyllum and Celastrophyllum. For example the seedling leaves of Cercidophyllum exhibit the closest similarity in size, form and venation to *Populus potomacensis* Ward. Not only could additional comparisons be made but it is noteworthy that like remains occur in the Lower Cretaceous of Portugal and Sakhalin Island (Ainuian series) showing that whatever their true nature they were elements in the Holarctic radiation of early Cretaceous dicotyledons. An additional feature exhibited by the *Celastrophyllum latifolium* and shown in the accompanying figure, is the enclosure of the growing point of the twig within the petiole of the latest formed leaf. This habit is also shown in the form from the Albian stage in Portugal which Saporta described as *Adoxa proetavia*.[4] This again is a feature exhibited by the existing Trochodendraceæ and also by certain Piperaceæ, and would seem to be one that might legitimately be considered as primitive or at least as indicative of relationship.

A novelty in the present collection is a new species of liverwort, which may be described as follows:

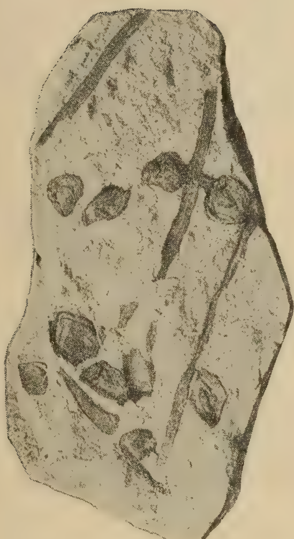
Marchantites Sewardi sp. nov.

Vegetative body or frond laminar in form, thalloid, without traces of fruiting bodies. The linear, slightly undulate margined segments fork repeatedly in a dichotomous manner and show a thickened midrib-like portion medianly (Figure 2). These rather poorly defined impressions agree closely with recent thalloid Hepaticæ of the genus Marchantia and are therefore referred to the genus Marchantites Brongniart (Tableau, p. 12, 1849). They are poorly preserved but not uncommon in certain layers where their remains cover slabs of an area of several square inches. Fossil species of Hepaticæ are such rare fossils that remains of this sort are of the greatest interest even when poorly preserved. None are certainly known from the Paleozoic but at least two species have been described from the Jurassic, namely

[4] Saporta, G. de: Fl. Foss. Portugal, p. 187, pl. 34, fig. 5, 1894.

1

2



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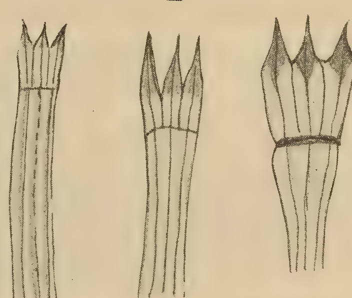

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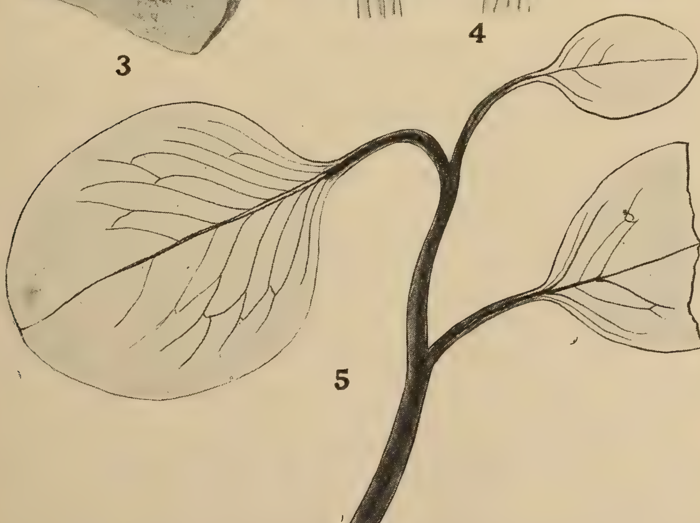


5

Marchantia oolithius Fliche & Bleicher[5] and *Marchantites erectus* (Leckenby) Seward[6], and the last named author has described *Marchantites Zeilleri*[7] from the English Wealden.

The Patapsco form is very much like the Wealden species *Marchantites Zeilleri* and may possibly be identical with it despite the difference in age and the geographical remoteness of the two. I have ventured to name the American form in honor of Professor Seward who has done so much to elucidate the Mesozoic floras of the Old World. Beginning with the Eocene a considerable number of Tertiary forms of liverworts, some showing traces of their fruiting organs, have been found.

The Johns Hopkins University,
Baltimore, Md., U. S. A.

[5] Fliche & Bleicher: Bull. Soc. Sci. Nancy, ser. 2, tome 5, p. 67, fig. 1, 1881.
[6] Seward, A. C.: Jurassic Flora, pt. 1, p. 49, pl. 19, fig. 2, 1900.
[7] Seward, A. C.: Wealden Flora, pt. 1, p. 18, pl. 1, fig. 3, 1894.

EXPLANATION OF FIGURES.

Fig. 1. Ruffordia acrodentata (Fontaine) Berry.
Fig. 2. Marchantites Sewardi Berry, sp. nov.
Fig. 3. Tubers of Equisetum Burchardti (Dunker) Brongniart.
Fig. 4. Nodes with leaf sheaths of Equisetum Burchardti, X 3.
Fig. 5. Twig of Celastrophyllum latifolium Fontaine.

ART. VI.—*Triassic and Jurassic Formations in southeastern Idaho and neighboring regions;* by GEORGE ROGERS MANSFIELD.[1]

INTRODUCTION.

In the course of the Geological Survey's examination of the Idaho phosphate field two areas have been studied in considerable detail. The first is the Fort Hall Indian Reservation; the second is a group of seven quadrangles ranged along or near the state line northward from the southeastern corner of Idaho. The southernmost member of the group is the Montpelier, a 30-minute quadrangle. The other six are 15-minute quadrangles, namely, Slug Creek, Crow Creek, Lanes Creek, Freedom, Henry, and Cranes Flat. The location of these areas and of other districts mentioned below is shown in fig. 1.

Triassic and Jurassic rocks are exposed in most of this country. During the progress of the work, and with increasing knowledge, changes in the classification and nomenclature of these rocks became necessary. It is the purpose of the present paper to discuss these changes, leaving in large measure the details of the formations themselves to a forthcoming extended report[2] on the same quadrangles above mentioned.

TRIASSIC SYSTEM.

Occurrence and subdivisions.—The Triassic system is well developed in southeastern Idaho and is exposed in much territory, particularly in the Montpelier quadrangle and the four quadrangles to the north. In the Henry and Cranes Flat quadrangles it occupies smaller areas.

In the seven quadrangles three formations or groups, aggregating 5,350 feet in thickness, are distinguished and assigned to the Lower Triassic series, namely the Woodside shale, Thaynes group, and Timothy sandstone. In addition, three other formations of uncertain age and with a combined thickness of 520 feet are considered provisionally Triassic. These are respectively the Higham grit, Deadman limestone, and Wood shale. In the Fort Hall Indian Reservation the Thaynes group is

[1] Published by permission of the Director of the U. S. Geological Survey.
[2] Mansfield, G. R.: The geography, geology, and mineral resources of part of southeastern Idaho, U. S. Geol. Survey Prof. Paper (in preparation).

composed of three formations[3], but these subdivisions cannot well be differentiated throughout southeastern Idaho.

The Nugget sandstone, which overlies the Wood shale and was formerly considered Triassic or Jurassic, is now referred to the Jurassic.

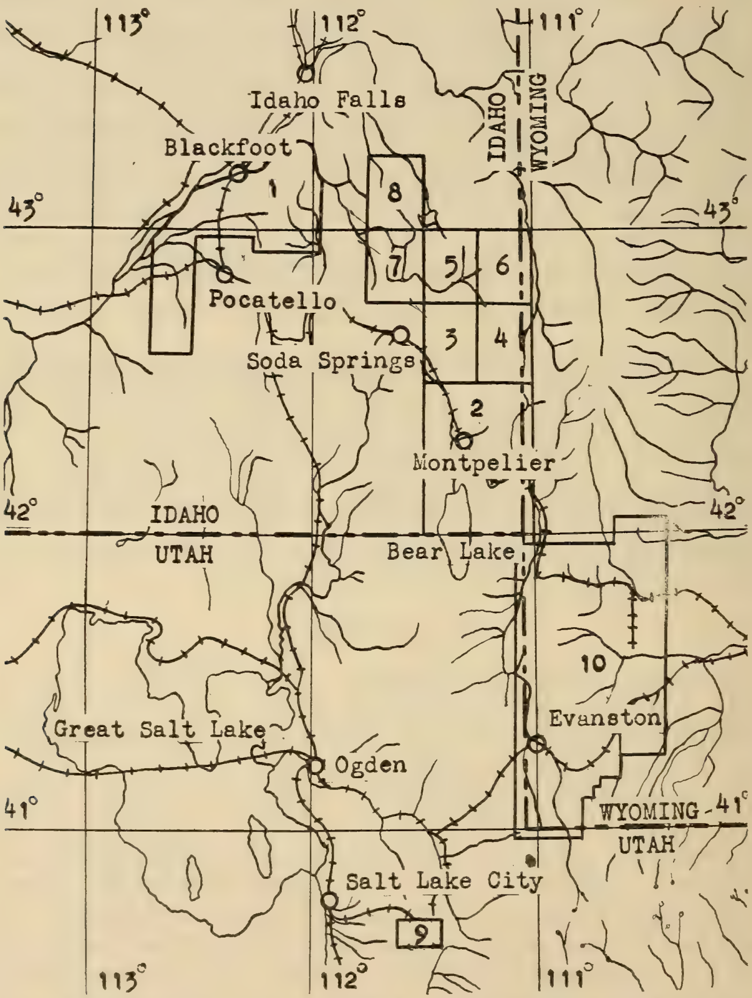


FIG. 1. Index map: 1, Fort Hall Indian Reservation; 2, Montpelier; 3, Slug Creek; 4, Crow Creek; 5, Lanes Creek; 6, Freedom; 7, Henry; 8, Cranes Flat; 9, Park City District; 10, Southwestern Wyoming (Veatch, Prof. Paper 56).

[3] Mansfield, G. R.: The geography, geology, and mineral resources of the Fort Hall Indian Reservation, Idaho, U. S. Geol. Survey Bull. 713, in press.

Stratigraphic correlation.—In figures 2 and 3 a tentative correlation is attempted of the stratigraphic units employed by different authors in the discussion of Triassic and Jurassic formations in northeastern Utah, southeastern Idaho, and southwestern Wyoming.

Schultz, whose field work in western Wyoming was completed before the classification here presented was made, uses the name Ankareh in several publications[4] for strata corresponding with the Ankareh of Boutwell (fig. 2) or with the red beds of Veatch's Nugget (fig. 3). In the last two publications named he indicates an unconformity at the base of the Ankareh.

Review of Nomenclature.

Hayden Surveys.—Although both Triassic and Jurassic rocks were recognized in southeastern Idaho by the Hayden Survey parties, it was not then possible to differentiate clearly the one group from the other, hence both were included in the so-called "Jura-Trias." Three subdivisions were recognized, namely, (1) a lower series of arenaceous limestones characterized by the occurrence of the fossil ammonite, *Meekoceras,* and called the "Meekoceras beds"; (2) the red beds, a series of red sandstones and shales classed with (1) as Triassic; and (3) a series of limestones, shales, and sandstones with Jurassic fossils. The last series was subdivided into two formations. The doubt as to the nomenclature was caused by the apparent intermingling of Triassic and Jurassic faunas.[5] This broad grouping is still applicable in a general way to the region.

Park City district, Uutah.—In his original studies of the Park City mining district Boutwell described the Woodside shale and Thaynes formation. The faunal content of the Thaynes was found to agree with that of the "Permo-Carboniferous beds" of the Fortieth Parallel Survey and the Woodside, almost nonfossiliferous but lithologically related to the Thaynes, was grouped with that formation rather than with the underlying Park

[4] Schultz, A. R.: Geology and geography of a portion of Lincoln County, Wyoming: U. S. Geol. Survey, Bull. 543, p. 49, 1914.

Idem: A geologic reconnaissance for phosphate and coal in southeastern Idaho and western Wyoming, U. S. Geol. Survey Bull. 680, p. 25, 1918.

Idem: Oil possibilities in and around Baxter Basin in the Rock Springs uplift, Sweetwater County, Wyoming, U. S. Geol. Survey Bull. 702 (in press).

[5] Peale, A. C.: Report of the Green River Division, U. S. Geol. and Geogr. Survey Terr. for 1877, pp. 621-629, 1879.

City formation, which was correlated with the "upper Coal Measures limestone" of the Fortieth Parallel

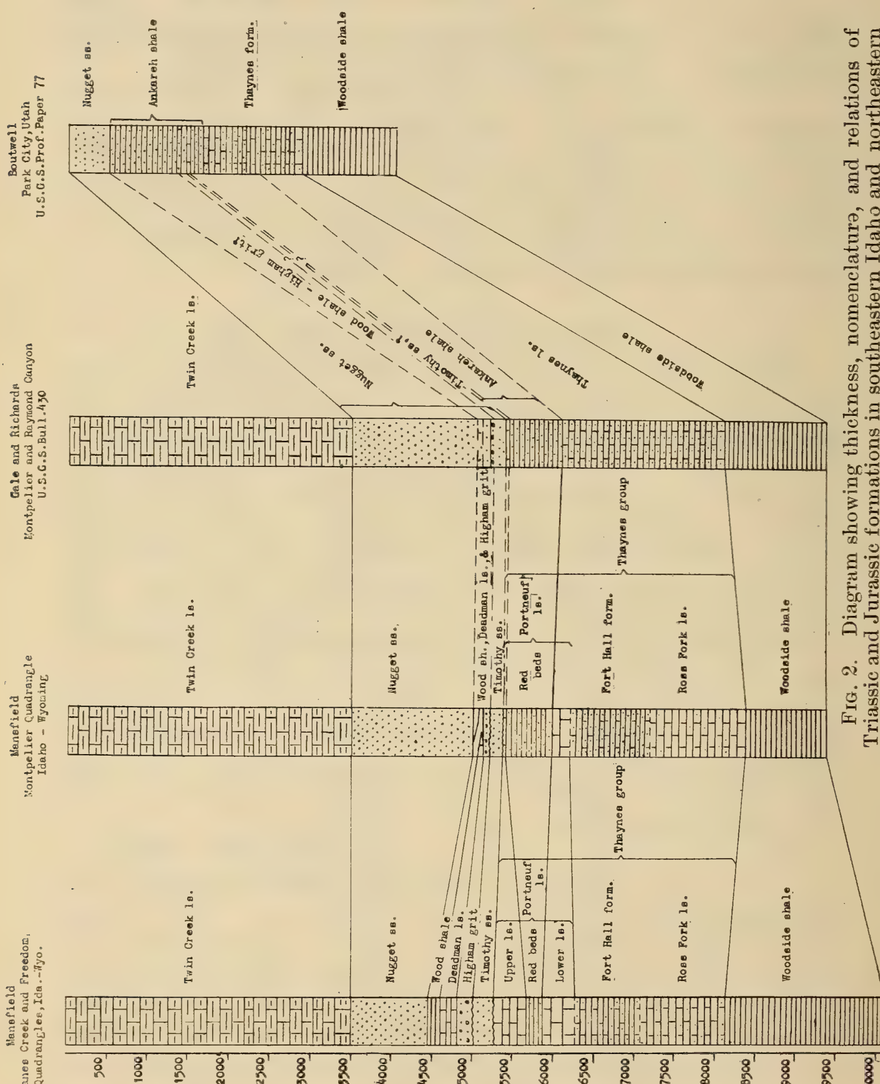


Fig. 2. Diagram showing thickness, nomenclature, and relations of Triassic and Jurassic formations in southeastern Idaho and northeastern Utah.

Survey. To the red beds above the Thaynes, Boutwell gave the name Ankareh shale.[6] In later work[7] he cor-

[6] Boutwell, J. M.: Stratigraphy and structure of the Park City mining district, Utah, Jour. Geol., vol. 15, No. 5, pp. 434-458, 1907.

[7] *Idem*: Geology and ore deposits of the Park City district, Utah: U. S. Geol. Survey, Prof. Paper No. 77, pp. 42-59, 1912.

related the Woodside and Thaynes with the Meekoceras zone of southern Idaho (the Lower Triassic of Hyatt and Smith[8]) and restricted the name Ankareh shale to red beds between the Thaynes formation and a light-colored

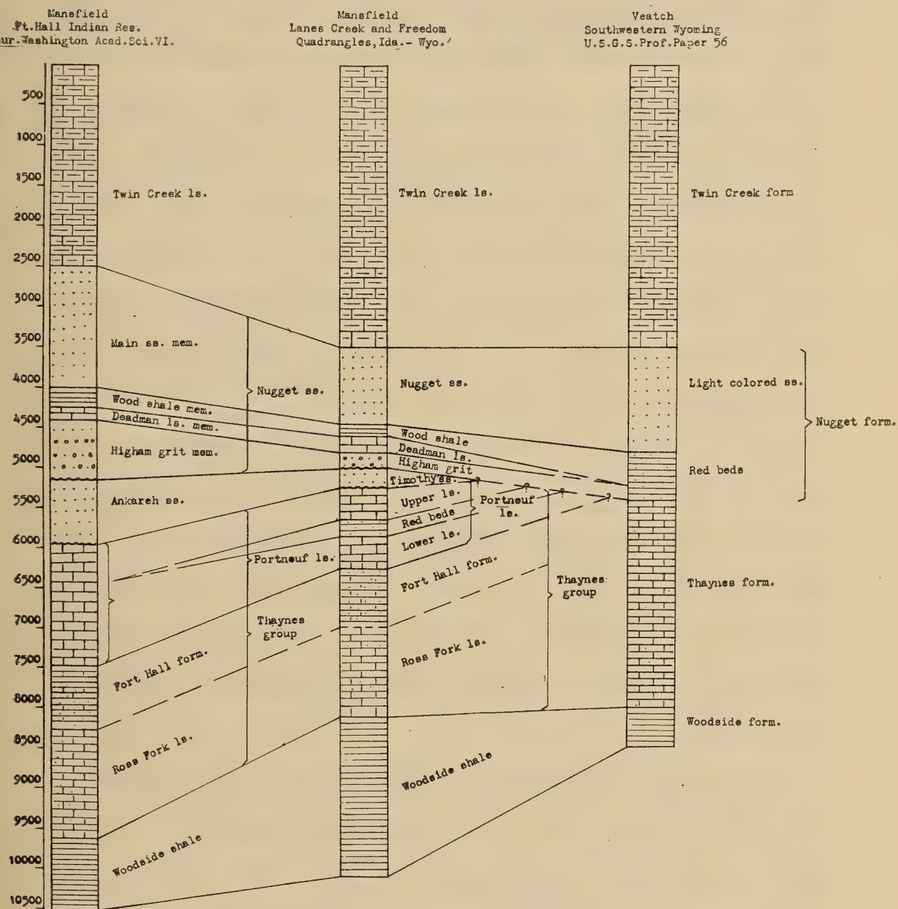


Fig. 3. Diagram showing thickness, nomenclature, and relations of Triassic and Jurassic formations in southeastern Idaho and southwestern Wyoming.

sandstone, which he had formerly included in his term Ankareh, but to which he now gave the name Nugget sandstone, using Veatch's name for similar beds in southwestern Wyoming. Boutwell's Ankareh and Nug-

[8] Hyatt, A., and Smith, J. P.: The Triassic Cephalopod genera of America, U. S. Geol. Survey, Prof. Paper No. 40, pp. 17-19, 1905.

get, which he correlated with King's Triassic, doubtless correspond in the main with Peale's "red beds," for in the Park City district, as in the region of Peale's studies, the red bed formations are overlain by strata containing marine Jurassic fossils. Thus the stratigraphic limits of the Triassic system in the Park City district and in southeastern Idaho appear to be essentially the same.

The Woodside in the Park City district is chiefly a red shale without fossils, and about 1,180 feet thick. The Meekoceras fauna does not appear to be present in the Thaynes there, the boundary between the two formations being indicated by the change from the shaly, non-fossiliferous beds below to the sandy, calcareous and fossiliferous beds above. The Thaynes formation is 1,190 feet thick. The Ankareh is also distinguished from the Thaynes on lithologic grounds by the change from the calcareous beds below to the siliceous beds above. The Ankareh is composed mainly of red shales that in places are sandy through considerable thicknesses. It includes a number of well-marked beds of coarse gray sandstone 20-55 feet thick and at the base lies a coarse massive sandstone that immediately overlies a thin limestone. A few fossiliferous grayish-blue limestones are intercalated in the formation, apparently 200 feet or more above the base. The thickness of the formation is 1,150 feet and the top is defined by the massive white sandstone of the overlying Nugget, which is 500 feet thick and includes with the sandstones intercalated reddish shales.

Southwestern Wyoming.—In his report on southwestern Wyoming, Veatch distinguished the Woodside and Thaynes formations and correlated them with the "Permo-Carboniferous." The red beds above the Thaynes were all grouped by him in a single formation, the Nugget, which is overlain by the marine Jurassic Twin Creek formation.[9] Veatch's Nugget consists of a lower, brightly colored, red bed member, 600 feet thick, correlated by Boutwell with his Ankareh[10], and an upper member, 1,300 feet thick, composed of thin-bedded, light colored sandstones, light yellow on fresh fractures but

[9] Veatch, A. C.: Geography and geology of a portion of southwestern Wyoming, U. S. Geol. Survey, Prof. Paper No. 56, pp. 50-56, 1907.

[10] Boutwell, op. cit. p. 59.

weathering dark brown, that form rugged topography with characteristic dark brown slopes.

It now appears that the Thaynes and Woodside of southwestern Wyoming, like the formations of the same names in the Park City district, should be considered Triassic and that the stratigraphic limits of the Triassic system in southwestern Wyoming are essentially the same as in southeastern Idaho.

Earlier work, southeastern Idaho.—The interpretations of Boutwell and Veatch were carried northward into southeastern Idaho by Gale and Richards[11] and later by Richards and Mansfield,[12] with such adaptations as were required by the somewhat changed stratigraphic conditions. The Woodside shale was found to be thicker, more calcareous, locally meriting the designation limestone, not red colored but olive drab or yellow and with abundant fossils. The Thaynes formation also was thicker, and sufficiently calcareous to be called a limestone. In addition to the ''Permo-Carboniferous'' faunas found in Wyoming and in the Park City district, numerous ammonites were found and the Meekoceras zone, or lowest ammonite horizon, was selected to mark the base of the formation. The term Ankareh shale was applied to a series of maroon, chocolate, and reddish shales with some sandy and limy strata lying above the massive limestones of the upper Thaynes and including at its top another massive limestone. The Nugget sandstone was marked by the occurrence in some parts of the area studied of beds of pure white and conglomeratic sandstone near the base. The formation included beds of red sandy shales and in some areas there was an upper division of several hundred feet of white sandstone. The thickness assigned to the Ankareh was 670 feet and to the Nugget 1,900 feet. The effect of this adaptation of Park City terms was the downward extension of Boutwell's term Nugget and the restriction of his term Ankareh.

[11] Gale, H. S.: Geology of the copper deposits near Montpelier, Bear, Lake Co., Idaho, U. S. Geol. Survey, Bull. 430, pp. 112-121, 1910.

Gale, H. S. and Richards, R. W.: Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah, U. S. Geol. Survey, Bull. 430, pp. 457-535, 1910.

[12] Richards, R. W. and Mansfield, G. R.: Preliminary report on a portion of the Idaho phosphate reserve, U. S. Geol. Survey, Bull. 470, pp. 371-439, 1911; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey, Bull. 577, 1914.

Fort Hall Indian Reservation.—In 1913 the writer and G. H. Girty made a joint study of the Triassic formations of the Fort Hall Indian Reservation. The Woodside shale was found to be somewhat thinner than in the Montpelier district, 900 feet, but the Thaynes much thicker, about 3,650 feet. The Thaynes proved to be a group divisible into three formations, each with a distinctive fauna. These formations have been described and named[13] but only the uppermost, the Portneuf limestone, need be mentioned here. Following the previous usage in southeastern Idaho, the beds between the massive Portneuf limestone and the conglomerate supposed to mark the base of the Nugget were assigned to the Ankareh, but these comprised 800 feet of sugary, yellow sandstones, without significant shales. From their stratigraphic position, however, they were called "Ankareh sandstone." The basal conglomerate of the Nugget as then interpreted was found to be about 500 feet thick, succeeded above by well defined limestone and shale members, below the main sandstone. The aggregate thickness was apparently as much as 2,400 feet. These four members were also differentiated and named.

Later work, southeastern Idaho.—1914-16 the interpretations used in the Fort Hall Indian Reservation were carried eastward into the Cranes Flat, Lanes Creek, and Freedom quadrangles and southward into the Montpelier quadrangle. In the Lanes Creek and Freedom quadrangles the Portneuf limestone of the Thaynes was found divisible into two massive limestone members with a well defined red bed member between. The "Ankareh sandstone" of the Fort Hall Indian Reservation and the four members of the Nugget above mentioned were all present and readily recognizable. The limestone member above the basal conglomerate of the Nugget, however, was locally reddish with shaly tendencies in its lower part.

In the Montpelier quadrangle east and northeast of Montpelier the subdivisions of the region to the north are still recognizable. The uppermost member of the Portneuf limestone, however, has dwindled in thickness from about 400 feet in the Freedom quadrangle to about 50 feet in the home Canyon section near Montpelier, but

[13] Mansfield, G. R.: Subdivisions of the Thaynes limestone and Nugget sandstone, Mesozoic, in the Fort Hall Indian Reservation, Idaho, Jour. Washington Acad. Sci., vol. 6, No. 2, pp. 31-42, 1916.

the red bed member has increased in thickness from about 200 feet in the Freedom quadrangle to 1,000 feet or more in Home Canyon. Here the apparent increase is in part due to folding. These red beds and the overlying limestone which belong in the Thaynes as traced southward were included in the Ankareh *shale* as traced northward in the earlier mapping.

The "Ankareh sandstone" of the Fort Hall Indian Reservation as traced southward decreases in thickness and in the Home Canyon section east of Montpelier is only about 100 feet thick, though farther south it appears to be somewhat thicker. This sandstone was perhaps originally included by Gale and Richards with the overlying conglomeratic bed in the Nugget and not considered a part of the Ankareh shale. In their description of the Ankareh shale[14] they state that a massive limestone marks the top of the formation, but in their description of the Nugget they refer to the conglomeratic bed as "near the base." This sandstone was, however, considered a part of the Ankareh in a section measured in 1912 by Mr. Richards and the present writer in a branch of Indian Creek east of Bear Lake.

The four subdivisions of the Nugget as previously described are present in the Home Canyon section but the conglomeratic member is represented by a dense purplish quartzite and the shaly tendency of the lower part of the limestone member above mentioned has there developed so that the limestone appears in the midst of shale rather than below the shale member.

Present classification.—The foregoing account of attempts to carry the Triassic terminology of Boutwell and Veatch into southeastern Idaho shows the necessity for a revision or redefinition of Triassic formation names. The terms Woodside, Thaynes, and Nugget are well established in the literature of the general region and apply to rocks that are characteristically developed and readily recognized, though showing considerable variation from their character at their type localities. These names are, therefore, retained respectively as the Woodside shale, the Thaynes group, and the Nugget sandstone.

The conglomeratic, calcareous, and shaly members in the lower part of the Nugget as described in the Fort Hall Indian Reservation are designated formations with

[14] Gale, H. S., and Richards, R. W., op. cit., p. 420.

the names Higham grit, Deadman limestone, and Wood shale respectively, and the name Nugget sandstone is restricted to the "main sandstone member" of the author's earlier paper. This sandstone has the characteristic lithology and position of the upper division of Veatch's Nugget, the conspicuous sandstone at Nugget station, Wyoming, the type locality of the formation, and corresponds also to the Nugget as mapped by Boutwell.

The term Ankareh shale cannot be retained in southeastern Idaho without confusion and is therefore dropped from the classification of that area. The name Timothy sandstone, which is taken from Timothy Creek in the Freedom and Lanes Creek quadrangles, is introduced for the sandstone that lies between the Portneuf limestone (top of Thaynes) and the Higham grit, and which in the earlier paper was called the "Ankareh sandstone."

Triassic and Permian.—The relations of the Triassic to the Permian in this region are not definitely known. As first described in the Park City district the Woodside, Thaynes, and Ankareh were all assigned to the Permian. Later studies have demonstrated the Triassic age of the Thaynes group and have pointed strongly to the base of the Woodside as the probable base of the Triassic system. The marked lithologic and faunal change at that horizon makes this interpretation easy to express cartographically.

The field relations suggest conformity between the two systems, for the boundary between the Woodside and the underlying Phosphoria is marked by great regularity wherever shown and the attitudes of the two formations correspond quite closely. There is, too, no conglomeratic development at the base of the Woodside or evidence of erosion in the Phosphoria preceding the deposition of the Woodside, unless the somewhat variable thickness of the Phosphoria be so considered. Nevertheless the striking faunal and lithologic differences above noted point to very different conditions of deposition for the two formations and indicate a stratigraphic break (unconformity) of some magnitude.

Age determination.—The Lower Triassic age of the Woodside, Thaynes, and Timothy is based upon ammonite zones which occur 1,000 to 2,250 feet above the top of the Paleozoic formations. The fossils of the overlying 3,000 feet or more of sediments are less distinctive and the faunal relations of some of them, notably certain brachiopods of the Portneuf limestone, have not been fully studied. It is therefore possible, though perhaps not probable, that some of these strata may be of later age than Lower Triassic. The Timothy sandstone in particular may prove to be of later age because of the unconformity described below.

Unconformities.—In Home Canyon, about six miles east of Montpelier, the Timothy sandstone consists of cross-bedded and coarse-textured sandstones with conglomeratic layers, in which the fragments are small pieces of limestone like that of the Thaynes. This phase has not been observed elsewhere. The conglomeratic layers indicate that at least locally there was erosion of Triassic limestone while the deposition of the sandstone was in progress. The noteworthy southward thinning of the limestone above the red bed member of the Portneuf, previously mentioned, suggests that this unconformity may be widespread.

The southeastward thinning of the Timothy sandstone from about 800 feet in the Fort Hall Indian Reservation to less than 200 feet in the Montpelier quadrangle and the pronounced lithologic change with the introduction of the Higham grit, which is more or less conglomeratic and locally strongly ferruginous at the base, indicate a widespread unconformity between the Timothy and the Higham although the boundary between the two formations is apparently regular. The unconformity doubtless marks an oblique transgression of the Lower Triassic formations by the Higham and later beds.

Age of doubtfully Triassic formations.—The great thickness of the formations assigned to the Lower Triassic, 5,350 feet, the unconformity at the base of the Timothy sandstone, and the marked unconformity at the base of the Higham grit all suggest that the latter formation and the overlying Deadman limestone and Wood shale may be of later age than Triassic. No fossils, however, have yet been found in any of these formations so they are provisionally retained in the Triassic.

Jurassic System.

Subdivisions and thickness.—The Jurassic system is well represented in many parts of southeastern Idaho. It includes four formations, namely, the Nugget sandstone, formerly considered Triassic or Jurassic, the Twin Creek limestone, the Preuss sandstone, and the Stump sandstone. The Nugget sandstone in this region is apparently conformable with the Wood shale below. Schultz,[15] however, believes that in southwestern Wyoming, at least, the Nugget sandstone will prove to be unconformable on beds corresponding to the Wood shale. The contact between the Nugget and the overlying Twin Creek, though apparently uniform, is also believed to be an unconformity. The Twin Creek limestone is overlain unconformably by the Preuss sandstone and another unconformity separates the Stump sandstone from the overlying Cretaceous (?) formations. The total thickness of the system is about 6,500 feet.

Changes in nomenclature.—Before 1914 the Twin Creek limestone was the only recognized Jurassic formation in southeastern Idaho although the overlying rocks which had been correlated with the Beckwith formation of southwestern Wyoming were considered in part Jurassic. The Twin Creek is a marine limestone with some highly fossiliferous beds. The upper part has been determined as Upper Jurassic. Possibly the lower part may include Middle Jurassic rocks. In 1914 field work in the rocks that had been classified as Beckwith formation developed the presence of marine Upper Jurassic fossils in beds now assigned to the Stump sandstone, about 1,300 feet stratigraphically above the top of the Twin Creek limestone. The term Beckwith has been discontinued in southeastern Idaho and the rocks there formerly included by it are now distributed among seven formations of which the first two, the Preuss and Stump sandstones, are Jurassic and the remaining five, underlain by a pronounced unconformity, are tentatively assigned to the Cretaceous.[16] With the assignment of the Nugget to the Jurassic the base of the system is lowered at least to the top of the Wood shale. It is possible that further field studies may justify again lowering the base to include the group now tentatively considered Triassic.

[15] Schultz, A. R., personal communication.

[16] Mansfield, G. R., and Roundy, P. V.: Revision of the Beckwith and Bear River formations of southeastern Idaho, U. S. Geol. Survey, Prof. Paper 98, pp. 75-84, 1916.

Art. VII.—*The Anderson Esker;* by John R. Reeves.

The above name of this esker was used by Leverett in a short description in which he states its existence and location. This is the only work known by the author on the esker and is thought to be insufficient in detail, hence the following study.

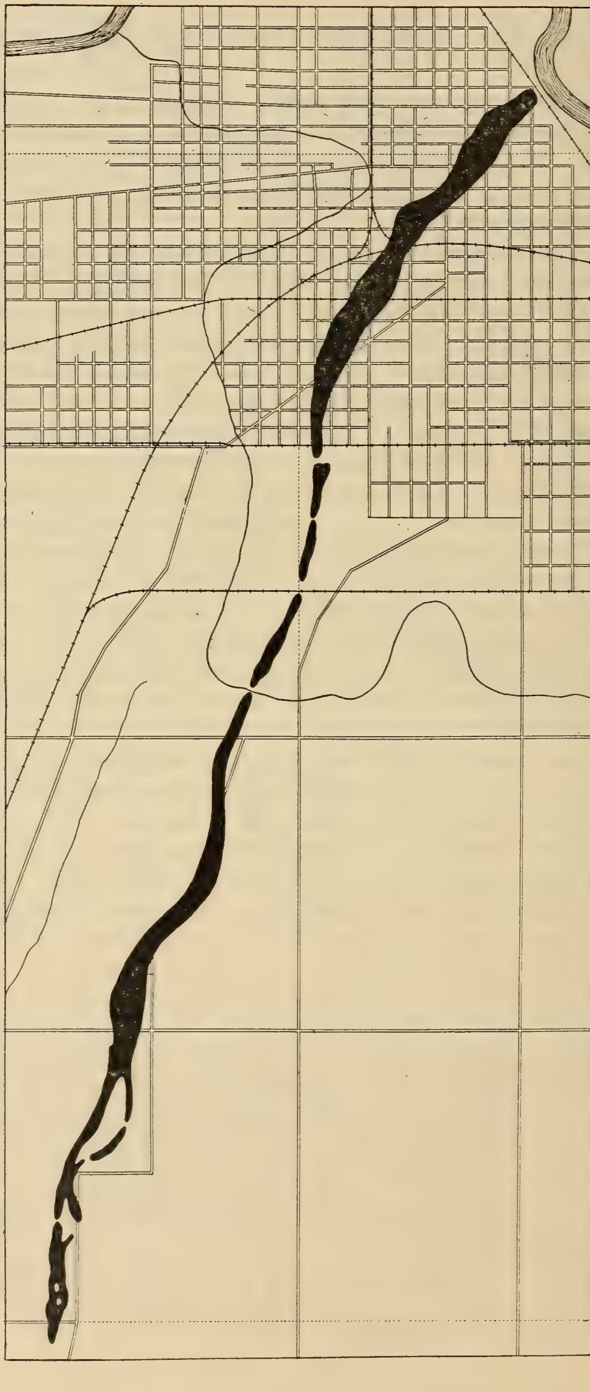
The northernmost end of the esker is found in the northern part of the city of Anderson, Indiana, bordering on White River at Eighth Street and Central Avenue. From this point it runs in a general south by west direction through the main part of the city and into the country beyond for a distance of four and one-half miles.

The esker is a part of a morainic system developed by, according to Leverett, the Huron-Erie lobe of the Labradorian Glacier. In his paper he says, "a remarkable abandoned channel . . . occupied in part by an esker, passes from southern Grant County southward to the East White Gravel plain in northern Shelby County, a distance of about sixty miles. It is, as a rule, but one-eighth to one-fourth mile in width, but in the portion between White River and Fall Creek it is nearly one mile wide. In this portion it contains an esker which follows it from Anderson southward for four miles."

The esker may be divided roughly into four parts, each part about one mile in length and each presenting certain features not common to the other parts. The first or northernmost part is the widest section of the whole esker, averaging some one hundred and fifty yards in width and twenty feet in height. The main business district of Anderson and part of the residence district lies on this part of the ridge.

The next part is broken or interrupted in four places each about one-fourth mile apart. In general the esker is less developed in this section than any other, its average width being but one hundred and fifty feet and its height about five feet. This part of the ridge lies in a rich farming district and has been plowed over many times which may partly account for its small size. At the end of this section a small branch has cut through it at right angles.

In the third section the esker is more distinctly developed than in any other part although a great amount



of it has been dug away, the gravels being valuable for commercial uses. From the break at the branch it gradually becomes larger in width and height until at its southern end it is two hundred fifty yards wide and thirty feet high.

The last section is rather complex in its form. It begins with a division into two branches, the east one being about one-half as large as the west one. They converge again three-eighths of a mile south forming in between them a long narrow basin. The eastern branch is broken in two places, one being one-fourth of a mile south of the division and the other at the point of convergence. Only a few yards south of the union of the two branches the esker again divides, the largest part of the gravel having been heaped up in the eastern branch. There is a long break in this branch but the two branches again unite making the main ridge some one hundred fifty yards wide and twenty feet high. From this point on to its end, the esker loses its symmetrical form, having been deposited in heaps forming irregular basins.

A great many pits have been dug in the esker for the clean water-washed gravel of which it is made up, but many of these pits have been closed, only a few remaining open where it is possible to observe the gravels. From these newest pits observations were made and collections taken.

In all exposures the stratification of the gravels was quite marked, there being a great variety in size of the sand grains and rocks. For instance one stratum would be made up of fine sand with dark streaks or stratification lines, immediately on top of which would be another stratum pitched at a different angle than the lower composed of rocks not less than one-half inch in diameter and generally twice this size, and then above this would be another layer at the same or different angle which would be made of gravels of various sizes. Each of these stratum represents a different velocity and shifting of the current of the stream which deposited them. In places where the strata were parallel it is probable that the stream pursued an orderly course but in places mentioned where the strata lay in steep angles it may be assumed that the stream dashed and pitched along its course. The strata which contained the rocks of larger sizes must have been deposited by a swift current for it would require such a current to move rocks of this size. There being no fine sand in these layers lends evidence to the supposition that the current was swift. Likewise the strata of fine sand was evidently deposited by a gentle current, supporting evidence to this being the absence of large rocks.

An interesting feature found in one exposure was a sand-filled pocket. A study of this showed that the upstream end of the pocket was composed of the largest grains, the sand of the pocket becoming finer toward the downstream end where the smallest grains were found. Evidently, as the current with its load flowed into the pocket, the velocity was checked, thus causing some of the largest particles of the load to drop, and as the flow continued to be checked more of the load was dropped, the sizes varying according to the ability of the current to carry them.

A collection of rocks taken from the southern end of the esker ranging in size from one-fourth inch to one and one-half inches in diameter was sorted, measured, and the kind of rock determined. Below is a table showing the results.

Shape.		Composition.	
Round	11%	Limestone	75%
Sub-angular	25%	Granite	24%
Angular	64%	Vein quartz	1%

It was found that the larger sizes contained a higher per cent of round rocks than the smaller sizes. The table shows the largest part of the material carried by the stream to be limestone, also that the majority of the rocks were angular showing that they were not carried far else they would be more rounded.

Indiana University, Bloomington, Ind.

Art. VIII.—*A New Agelacrinitid from the Chazy of New York;* by Thomas H Clark.

In 1919 I described an Agelacrinitid, *Carneyella raymondi,* from the Trenton limestone at Martinsburg, N. Y. This was of especial importance because, as was stated, "so far as is known, this is the first agelacrinitid to be found in the Ordovician rocks in New York State."[1] While collecting on Valcour Island, N. Y. last summer I was fortunate enough to discover a specimen of the same genus in the Chazy limestone. So far as I know, this is the first Agelacrinitid to be reported from a horizon lower than the Trenton in the United States. The discovery of this specimen, for which the name *Carneyella valcourensis* is proposed, lengthens the range of these fossils considerably.

The specimen is small, incomplete, apparently free, and somewhat deformed by having one side doubled under. It shows all five rays, but parts of some of these have been bent under by the crumpling of the specimen. It is by no means well preserved, but fortunately it does show that the supra-oral plates are both larger and of different form than the lateral covering plates. A very diligent search by Dr. Raymond and myself failed to secure other specimens.

The accompanying table illustrates the comparative ranges of the species of Foerste's recently described genera Carneyella and Isorophus,[2] as well as those of Bather's genus Lebetodiscus,[3] the three genera of the Agelacrinitidæ that are represented in the Ordovician rocks on this continent. Foerste remarked: "In Isorophus the supra-oral plates differ only slightly from the lateral covering plates of the rays, and the genus is regarded as more primitive in type." This last statement should be regarded in the light of the fact that, of the two genera, Carneyella is the older, and reached its fullest development at the time when Isorophus was introduced and apparently did not survive the maximum development of that genus.

[1] Bull. Mus. Comp. Zoöl., vol. 63, No. 1, p. 11.
[2] Bull. Sci. Lab. Denison Univ., Vol. 18, p. 341, 1916.
[3] Geol. Mag. 1908, Dec. V, Vol. 5, p. 550, pl. XXV. Reprinted in "Studies in Edrioasteroidea," 1915.

Description.

Carneyella valcourensis sp. nov.

The type and only known specimen is incomplete, but the original theca was probably slightly less than three-quarters of an inch in diameter. The peripheral ring is for the most part missing, but where it is preserved it is narrow and composed of an inner ring of large plates and an outer circlet of small ones. All five rays can be seen, but only one is complete. Adopting the conventional system of numbering the rays, ray I is seen to be curved in a contra-solar direction, while ray V is solar, the two enclosing the anus. Rays II and IV are both incomplete, the latter being continued to some extent upon the aboral surface by being doubled under. Ray III is missing on the upper surface altogether, but part of it was preserved upon the under side when the individual was deformed. The specimen is not sufficiently well preserved to allow an examination of the flooring plates (*sensu* Foerste), nor can any accessory covering

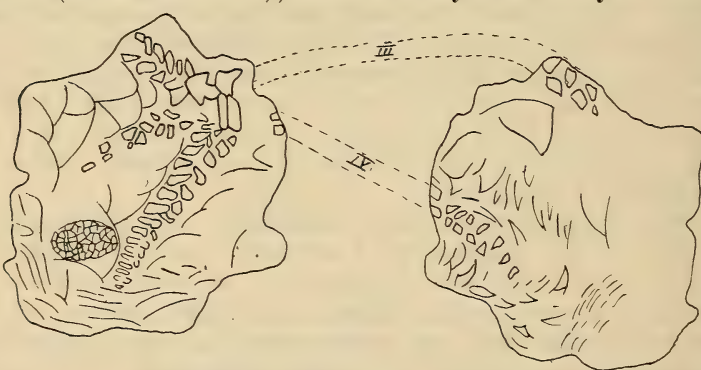


Fig. 1.—Sketches of the two sides of the type specimen, *Carneyella valcourensis* Clark. X 4.

plates be observed. The anal pyramid is composed of numerous small mosaic plates with an eccentric circular anal opening. The supra-oral plates are quite well preserved, three in number, larger than the lateral covering plates, and different in form from them. The interradii are covered, where shown, by large plates.

The specimen is free, but with the posterior part of the oral surface doubled under so as to appear to be on the aboral surface. It was collected from the Middle Chazy limestone, or more exactly, from the top of Raymond's Zone A_{20}.[4]

[4] Ann. Carnegie Mus., Vol. 3, No. 4, 1906, p. 514.

Carneyella multibrachiata has rays I, II and IV all bifurcated; *C. raymondi* has ray II bifurcated. *C. valcourensis* differs from these two species in having no rays bifurcated. Moreover both *C. multibrachiata* and *C. raymondi* are small species, the types being 10mm. and 8mm. in diameter respectively. *C. valcourensis* lacks the heavy border of large thick plates which characterizes *C. billingsi;* the latter species, like *C. youngi,* possesses straight rays. *C. chapmani* has a border of small plates while the border plates in *C. valcourensis* are large; in *C. chapmani* all the rays are contra-solar. The interradii of *C. platys* are covered by small imbricating plates, but in *C. valcourensis* these plates are large. There is a strong curvature to all the rays in *C. pilea,* so much so that the tips of the rays become parallel, or nearly so, to the peripheral ring. Rays I and V in *C. valcourensis* show only slight curvature.

TABLE I.

Range of North American Ordovician Agelacrinitidæ.

					Trenton					Richmond		
	Beekmantown	Chazy	Lowville	Black River	Lower	Middle	Upper	Eden	Maysville	Lower	Middle	Upper
GENUS *Lebetodiscus.*												
L. dicksoni Billings						*						
L. loriformis Raymond						*						
GENUS *Carneyella.*												
C. pilea (Hall)									*			
C. vetusta (Foerste)							*					
C. raymondi Clark						*						
C. youngi (Raymond)						*						
C. chapmani (Raymond)						*						
C. platys (Raymond)						*						
C. billingsi (Chapman)						*						
C. multibrachiata (Raymond)					*							
C. valcourensis sp. nov.		*										
GENUS *Isorophus.*												
I. faberi (Miller)[1]												*
I. austini (Foerste)[2]												*
I. cincinnatiensis (Roemer)									*			
I. holbrooki (James)									*			
I. inconditus (Raymond)						*						

[1] Aug. F. Foerste, 1914, Bull. Sci. Lab. Denison Univ., vol. 17, p. 441.
[2] Aug. F. Foerste, 1914, Bull. Sci. Lab. Denison Univ., vol. 17, p. 444.

Museum of Comparative Zoology,
Cambridge, Mass.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Oxidation of Paraffine by Means of Oxygen Gas.*—Heretofore little success has been attained in the many attempts that have been made to produce directly oxidation products, such as fatty acids and alcohols, from the hydrocarbons of paraffine and similar substances. C. Kelber has recently found, however, that in the presence of certain catalyzers, such as oxides of manganese, oxygen gas brings about such changes with considerable rapidity. His most interesting observation, however, at which he was astonished, was the fact that oxygen gas, in the absence of any catalyzer, when it is passed in a finely divided condition into melted paraffine at a temperature of 140 to 150° C. begins to act after a time, a watery liquid and also a mobile oil distil over into the receiver, while carbon dioxide is another product of the reaction. If the rapidity of the oxidation is not checked either by cooling or by diminishing the stream of oxygen, the temperature rises with increasing violence of the reaction to above 200°, and the oxidation is finished in 4 or 5 hours. At the time of the publication of this announcement the products of this reaction had not been studied, but they appear to be similar to those produced in the presence of a catalyzer, where there is a yield of 40 to 50% of fatty acids insoluble in water but soluble in petroleum ether, 5% of fatty acids insoluble both in water and in petroleum ether, a small percentage of unsaponifiable matter, and also some water-soluble and volatile acids as well as other compounds, some of which are alcohols. The fatty acids insoluble in water give alkali-salts which show a high frothing capacity. It seems quite possible that this oxidation process may be of commercial importance.—*Berichte,* **53**, 60.

H. L. W.

2. *A New Determination of the Value of the Radium-Uranium Ratio.*—The amount of radium in equilibrium with uranium in minerals containing the latter element is of considerable theoretical and practical interest. This ratio was first determined by Rutherford and Boltwood as $7{\cdot}4 \times 10^{-7}$, but a little later this value was changed to $3{\cdot}8 \times 10^{-7}$ on account of the fact that an error had been made in regard to the strength of the radium standard solution on account of a partial precipitation of the radium. Still later Boltwood, having made a re-determination of the uranium in the standard uraninite, gave the value as $3{\cdot}4 \times 10^{-7}$. Afterwards Rutherford, by comparing the previously used radium standard with the International Radium Standard, calculated the ratio to be $3{\cdot}23 \times 10^{-7}$. Other investigators have determined the ratio as follows: Heimann and Marckwald, $3{\cdot}328 \times 10^{-7}$; Becker and Jannasch,

$3 \cdot 383 \times 10^{-7}$ and $3 \cdot 415 \times 10^{-7}$ by different methods. S. C. LIND and L. D. ROBERTS have now made a very careful determination of the ratio, which seems to be particularly reliable on account of the many precautions used and from the fact that their standard radium chloride was the pure salt and gave the same amount of radium by calculation as by comparison by the γ-ray method with the International Standard. The result, the average of 18 determinations, is $3 \cdot 40 \times 10^{-7} \pm 0 \cdot 03$. It agrees with the average of the results of Becker and Jannasch and also with Boltwood's result before it was modified by Rutherford.—*Jour. Amer. Chem. Soc.*, **42**, 1170. H. L. W.

3. *Treatise on General and Industrial Inorganic Chemistry;* by ETTORE MOLINARI. Large 8vo, pp. 876. Philadelphia, 1920 (P. Blakiston's Son & Co.).—This is the second English edition, translated from the fourth revised and amplified Italian issue by Thomas H. Pope of England. The book is a very noteworthy one in being a combination of a good treatise on inorganic chemical facts and theories with a very elaborate presentation of the industrial side of the subject. There is another volume dealing in a similar way with organic chemistry. There has been of late years an increasing tendency to introduce some examples of industrial applications into text-books of general chemistry, and we have here in the volume under consideration a very impressive extension of this idea with the hope of reforming and improving the usual method of teaching chemistry. It is the view of the author that general chemistry can no longer be a simple and arid exposition of fundamental laws and of the properties of innumerable known substances, but should possess a soul which brings it into contact with the vital activities around which it clings. It appears that this ground is well taken, since it is desirable to arouse interest and enthusiasm and to develop practical knowledge and ability in our students.

The book gives excellent descriptions of the important inorganic chemical industries, including those of metallurgy. It gives much interesting historical information in regard to these industries, it is provided with 328 illustrations and two phototype plates, it gives also a great many useful statistics of production and prices, and without doubt it should receive the careful attention of our teachers of general chemistry. Coarser and smaller type are used in printing the book, so that the former may be assigned to the student for particular study without involving an undue amount of text, while the remaining, much larger part would undoubtedly be read to a considerable extent by students for the sake of its interesting and important information.

Morover, the matter relating to industrial processes furnishes a very satisfactory text for more advanced students.

H. L. W.

4. *Laboratory Manual of Elementary Colloid Chemistry;* by EMIL HATSCHEK. 12mo, pp. 135. Philadelphia, 1920 (P.

Blakiston's Son & Co. Price $2 net).—This book, published originally in London, is the first laboratory manual, or collection of practical exercises dealing with this rapidly developing and important branch of chemistry. It gives accurate and very detailed directions for carrying out the fundamental operations, for making a number of representative preparations and for examining them by the standard methods.

There is no doubt that the book presents a very satisfactory course of laboratory work, and at the same time gives excellent explanations of the principles of the subject. Since many of the methods and materials of colloid chemistry are peculiar, and strange even to students who are well trained in other branches of chemistry, the course presented here appears to be a very desirable one in connection with a good modern chemical education. H. L. W.

II. Geology and Natural History.

1. *The Brachiopoda of the Namyau Beds, Northern Shan States, Burma;* by S. S. Buckman. Mem. Geol. Survey India, Palæntologica Indica, new ser., vol. **3**, No. 2, 299 pp., 21 pls. 6 text figs., 1917 [1919].—The next generation of paleontologists will hail this volume as one of the leading paleontologic studies of the early part of the twentieth century; the present generation of workers will as a rule either fail to praise it or silently pass it by. All who have studied Buckman's results know that he is a very detailed worker, applying to fossil forms the biogenetic law plus chronogenesis. In addition, he is familiar with the best work in paleontology. His methods are not only modern and correct, but he is the seer who leads into new though difficult paths of study. His entire tendency is toward discerning the major and minor genetic lines of organisms, seizing upon all characters, however trivial they may appear to others, with the result that he is our chief "splitter" of genera, species, and stratigraphic time divisions. The present work is a morphogenetic study carried out in detail.

The seemingly monotonous and endless array of rhynchonellids and terebratulids forms the basis of the present study. They have long been known to contain a host of parallel developments in external expression. Buckman has for years been a student of brachiopods, fossil and recent, and of the methods adopted by Hall and Clarke in their study of this class of animals, with the result that to the 18 genera heretofore known from the Jurassic and Cretaceous he here adds 66 new ones! A study of the internal characters—other than crura and loops—combined with the external ones, and a detailed analysis of the stages of growth have brought about this great number of new genera. Even so, it is only the beginning of what is to come, for he says (pp. 133-

134): "All the observations made during the investigation point to the conclusion that the division is not carried far enough . . . Little knowledge and less observation are necessary to throw together various homœomorphous series under any one name. It requires long and careful research to find the bases for proper separation, which is not only much more satisfactory in the end, but gives a better idea of affinities and a far truer picture of the methods of evolution."

Of species figured there are 265, and of these 79 occur only in India, the remainder being from Europe, and chiefly England. The new forms from Burma total 64, those from Europe 80. None of these results would have been attained had it not been for the work of the geologists of India in burning the hard sandy limestone lenses that occur in a red sandstone-shale series to get out the fossils. They finally succeeded in getting about 1,000 specimens, hard sandstone casts of the interiors. Accordingly, Buckman had to take to burning off the shell of European species in order to have similar material for comparison, and lo! many a homœomorph was revealed, because of the varying and unsuspected specific and generic internal structures. The method of thus treating shells he has described in this Journal (vol. **32**, 163, 1911, and vol. **33**, 593, 1912). A preliminary list of the new genera, with their genotypes, was published in 1914, in a leaflet entitled "Genera of some Jurassic Brachiopoda," and in the Records of the Geological Survey of India, vol. **45**, part 1, 75-81, 1915.

Not a single species is common to Europe and India. Therefore the attainment of the conclusion that the Namyau beds appear to correlate best with the "Bathian near about the Bradford clay," i. e., from Great Oolite to Cornbrash (Jurassic), involved this detailed morphogenetic study, and it was abundantly worth while. It left Buckman, however, with the belief "that the study of the European species from the point of view of morphogeny is very much in arrear, that the number of species which appear in literature is but a small proportion of a large total, that the knowledge of those which have been illustrated is gravely deficient on account of the lack of internal details, and that little advance can be made until all species have been republished with full information of their internal characters—a long task, but one absolutely essential" (p. 136).

The kindergarten days of brachiopod knowledge are now gone, and all future workers with these organisms, if they are to be leaders, will have to be specialists, as has long been the case with the students of ammonites. Doctor Buckman is to be congratulated on having the courage, and the patience, to take a long step in this direction. C. S.

2. *Systematische Petrographie auf genetischer Grundlage; Band 1: Das System;* by W. Hommel. Pp. 174, with 5 plates and 5 text figures. Berlin, 1919 (Gebrüder Borntraeger).—

This volume is the result of an attempt to represent all rocks by means of formulas. Just as in chemistry two kinds of formulas are necessary to represent adequately a chemical compound, so in petrography two kinds are required in order to characterize a rock completely: a molecular formula, which is based upon the chemical analysis, and a constitutional formula, which gives the texture of the rock and the nature of the constituent minerals. A new method of plotting chemical analyses of rocks is developed and is believed to be superior to Osann's method.

The underlying theoretical concept of the book is that all rocks are derived from a single primary magma by fractional crystallization (the crystallization-differentiation of Bowen). From this genetic concept is developed a natural classification of rocks, including the metamorphic and sedimentary groups, but this classification, however, leaves the impression that it is but lightly tied to the actual facts of the field. In volume two this system is to be more fully elucidated. A. K.

3. *Geological Survey of Western Australia;* A. Gibb Maitland, Government Geologist.—The Annual Progress Report for 1918 is notable for giving a large geological sketch map of Western Australia (33 × 21 inches). This is on a scale of 50 miles to one inch, which is so liberal as to make a large amount of detail possible. The report also contains a series of papers, many of them economic in nature, dealing with deposits of graphite, manganese, asbestos, molybdenite, bauxite, etc. The occurrence of some rare minerals is also noted, as, gearksutite in chalky nodules, jarosite in a fine yellow powder impregnating sandstone, scheelite, gahnite and others.

Bulletin No. 77, by Edward S. Simpson, discusses the sources of industrial potash in Western Australia. An appendix describes the obtaining of potash and iodine from local seaweeds, this is by I. H. Boas. Another describes, by T. Blatchford, alunite deposits of Kanowna.

Bulletin No. 82 is devoted to the magnesite deposits of Bulong in the Northeast Coolgardie Goldfield.

4. *New Zealand Geological Survey;* P. G. Morgan, Director. —Bulletin No. 22 (new series) of the Geological Survey Branch of the Department of Mines, by P. G. Morgan and others, is a quarto publication of 316 pages, with 14 plates, 2 maps and 6 text-figures. The bulletin is devoted to the Limestone and Phosphate Resources of New Zealand especially in relation to agriculture. Part I, now in hand, discusses the limestone and gives a full summary of the many deposits in the Dominion. Occurrences in 72 counties of the North Island and 53 counties in the South Island are noted.

5. *Principles of Animal Biology;* by A. Franklin Shull, with the collaboration of George R. Larue and Alexander G. Ruthven. Pp. xv, 441, with 245 text-figures. New York, 1920 (MacGraw-Hill Book Company).

Laboratory Directions in Principles of Animal Biology; by A. Franklin Shull, with the collaboration of George R. Larue and Alexander G. Ruthven, and Peter O. Okkelberg. Pp. ix, 81. New York, 1919 (McGraw-Hill Book Company).—Although teachers of introductory courses in biology have long since abandoned the old type system of Huxley in their lectures and recitations, many have not deemed this practicable in the laboratory exercises which constitute an important part of the study. Consequently there often arises an unfortunate lack of harmony between the classroom and the laboratory. That it is possible to avoid this, and to conduct classes in biology exactly as is done in chemistry and physics; namely, to make the classroom and laboratory work of each day mutually complementary, many teachers have already discovered. And if any doubt still exists in the minds of some, it should be dispelled by these companion books, the outcome of practical experience in large elementary classes. Only in exceptional cases will it be necessary to dissociate the classroom and laboratory topics and no important branch of biology needs to be omitted.

The course presented begins with a brief historical introduction, and leads through the morphology and physiology of the cell to cellular differentiation, morphology and physiology of organs, reproduction and breeding habits; embryology; genetics; taxonomy; ecology; zoogeography; paleontology; and evolution.

This text-book in the hands of a capable and enthusiastic teacher will lead the student consistently from the elementary principles of living matter to the profound conceptions of his own position in the living world and his relationship with, and dependence upon, his fellow organisms. To the general reader the book will give a comprehensive survey of the field of animal biology as it has been developed in recent years. To such the excellent illustrations will take the place of the laboratory study, and a glossary of unusual merit will supply the meaning of all the technical terms which the book contains. W. R. C.

6. *Cytology; with Special Reference to the Metazoan Nucleus;* by W. E. Agar. Pp. xii, 224; with 91 text-figures. London, 1920 ((Macmillan & Company).—The search for the mechanism of inheritance has been carried on with great zeal in recent years, and although there are still many details not fully understood, the essential features of the hereditary apparatus have apparently been discovered. While the chromatin of the nucleus is looked upon as the direct agent in heredity, all the parts of the cell are so intimately related and mutually dependent that an understanding of the whole is necessary for a clear conception of any part. This book is, therefore, essentially a summary of our present knowledge in regard to the structure of the metazoan cell and the various modifications and manifestations of the cell organs, but the principal emphasis is naturally placed on the chromosomes as the physical basis of heredity.

The structure and development of the germ cells, their union in fertilization; the sex-determining chromosomes and their behavior in the life cycles of organisms with alternate sexual and parthenogenetic stages; the cleavage of the egg and the differentiation of the resulting cells into the tissues of the body; the cytological explanation of variations and evolutionary mutations; and the physical explanation of sterility are the principal subjects treated. The book is concisely written and illustrated with text-figures of the highest excellence. W. R. C.

7. *General Botany for Universities and Colleges;* by HIRAM D. DENSMORE, Professor of Botany at Beloit College. Pp. xii, 459, with 289 figures in text. Boston, 1920 (Ginn & Company).—The author's viewpoint in this excellent addition to the list of text books of botany is biological throughout. In the first part the higher seed plants are considered with respect to their environment, structure and physiology; in the second part the great plant groups are concisely but clearly and accurately treated; in the third part the representative families and species of the spring flora in the northern United States are taken up, and a brief account of plant associations is included. So far as possible the purely scientific portions of the text are logically connected with those aspects of plant biology which are of immediate human interest. Much emphasis is therefore laid upon the phenomena connected with hybridization, breeding and evolution, and the significant processes connected with cell and nuclear divisions are more fully treated than in most elementary works. The thoroughly modern discussion of plant anatomy is likewise a noteworthy feature. As a basis for a year's college course in general botany the new text seems admirably adapted.

A. W. E.

8. *Problems in Botany;* by W. L. EIKENBERRY, Associate Professor of Education, University of Kansas. Pp. xii, 145. Boston, 1919 (Ginn & Company).—The purpose of this laboratory manual is to place before high-school pupils a series of problems dealing with plant activities, their relation to human interests being emphasized throughout. References to Bergen and Caldwell's text-books are given in connection with each of the 118 exercises. Among the subjects treated the following are perhaps the most important: plants and water, nutrition, reproduction and propagation, relation to environment, relation of simple plants to man's life and industries, and plant industries. Each problem is definitely stated, clear directions are given for studying the material recommended, and the pupils are expected to draw their own conclusions from their experiments and observations. A. W. E.

9. *Joseph Dalton Hooker (Pioneers of Progress, Men of Science);* by F. O. BOWER, Regius Professor of Botany in the University of Glasgow. Pp. 59, with frontispiece. London, 1919 (Society for Promoting Christian Knowledge).—The great importance of the work done by Sir Joseph Hooker (1817-1911),

for many years Director of the Royal Gardens at Kew, is clearly and graphically presented in this little volume. Although his principal writings deal with taxonomic botany and the geographical distribution of plants, his scientific outlook was very broad, and he was one of the first naturalists to accept and defend Darwin's theory of evolution. Among his contemporaries he occupied a pre-eminent position, and the author confidently predicts that their estimate of his attainments will be an enduring one.

A. W. E.

III. Miscellaneous Scientific Intelligence.

1. *The National Research Council.*—The National Research Council is a co-operative organization of leading scientific and technical men of the country for the promotion of scientific research and the application and dissemination of scientific knowledge for the benefit of the national welfare. The following officers have been elected for the year beginning July 1, 1920: Chairman, H. A. Bumstead, professor of physics and director of the Sloane physical laboratory, Yale University; first Vice-Chairman, C. D. Walcott, president of the National Academy of Sciences and Secretary of the Smithsonian Institution; second Vice-Chairman, Gano Dunn, president of the J. G. White Engineering Corporation, New York; third Vice-Chairman, R. A. Millikan, professor of physics, University of Chicago; permanent secretary, Vernon Kellogg, professor of biology, Stanford University; treasurer, F. L. Ransome, treasurer of the National Academy of Sciences.

The Council was organized in 1916 under the auspices of the National Academy of Sciences to mobilize the scientific resources of America for work on war problems, and reorganized in 1918 by an executive order of the President on a permanent peacetime basis. Although co-operating with various government scientific bureaus it is not controlled or supported by the government. It has recently received an endowment of $5,000,000 from the Carnegie Corporation, part of which is to be expended for the erection of a suitable building in Washington for the joint use of the Council and the National Academy of Sciences. Other gifts have been made to it for the carrying out of specific scientific researches under its direction.

2. *International Congress of Mathematicians.*—M. E. Picard, President of the French National Committee, announces that the International Congress of Mathematicians will hold a meeting at Strasbourg, beginning on September 22, 1920. The Congress will be divided into four sections, as follows:

I. Arithmetic; algebra; analysis.
II. Geometry.
III. Mechanics; mathematical physics; applied mathematics.
IV. Philosophical, historical and pedagogic questions.

A fee of 60 francs for each person is required for qualification to membership to the Congress; this is to be paid to the treasurer, M. Valiron, 52 Allée de la Robertsau, Strasbourg. A reduction is made (to 30 francs) for those belonging to the family of a member.

Those who have communications to make to the Congress should apply to the general secretary, M. Kœnigs, 96 Bd. Raspail, Paris, or later to M. Kœnig, care of M. Villat, rue de Maréchal-Pétain, Strasbourg.

3. *Pasteur—The History of a Mind;* by EMILE DUCLAUX. Translated and edited by ERWIN F. SMITH and FLORENCE HEDGES. Pp. 363, illustrated. Philadelphia, 1920 (W. B. Saunders Company. Cloth, $5.00 net).—The unique position which Pasteur held in the modern development of the biological sciences, as well as the remarkable and unusual personality of the man himself, lend a particular value to the details referring to this eminent investigator. Anything which helps to throw light upon the evolution of his ideas and the genesis of his researches is welcomed. To the admirable biography by Vallery-Radot there is at last added, in excellent English translation, the story of Pasteur's scientific endeavors presented by Emile Duclaux, long associated with the undertakings of the French savant. Professor Smith and his collaborator deserve thanks for having presented a French classic, "Pasteur: Histoire d'un Esprit" to English readers. The book is an account of Pasteur's experiences in the various intellectual struggles which made him famous—a series of records of sound logic based on experimentation. It is rare to find a translation presented in a form that preserves so much of the vigor and fascination of the original text. L. B. M.

4. *The Relation Between Religion and Science: A Biological Approach;* by ANGUS STEWART WOODBURNE. Pp. vii, 103. Chicago (University of Chicago Press) 1920. An examination of "the age-long problem of the interrelationship of religion and science from a new angle, namely, that of psychology considered as a biological science." The writer shows in an interesting and logical manner that on the basis of multiple, instinctive behavior a sound theory of the origin of religion and science is possible.

W. R. C.

5. *Explorations and Field Work of the Smithsonian Institution in 1919.* (Miscellaneous Publications, Vol. **72,** No. 1.) Pp. 80, profusely illustrated. Washington, 1920.—This pamphlet is as interesting in its varied subject matter as it is in its many remarkable illustrations. It passes from the Canadian Rockies to Australia, the Congo, Santo Domingo; back to the Glacier National Park, the Florida Keys and then to Colorado and Arizona, etc. The frontispiece (from a photograph by Dr. Walcott) is a beautiful panoramic view, thirty inches in length, taken from the east moraine of Southeast Lyell Glacier, about 50 miles northwest of Lake Louise station on the Canadian Pacific railway.

6. *Annual Report of the Board of Scientific Advice for India for 1918-19.*—The report of this Board for 1917-18 is briefly mentioned in the May number (p. 388). The present report gives a similar summary of scientific work accomplished in the year following. The thirty-sixth meeting was held at Simla on May 19, and the thirty-seventh at Delhi on November 24. A subject of special interest under consideration was the discovery of quick-growing trees to be recommended to agriculturists for cultivation as a fuel supply. Five sub-committees are mentioned, each including three officials, to cover the entire field of scientific activities for the country; a sixth, with four members, is responsible for the libraries.

7. *The Technical Review.*—This periodical is planned to be a review and digest of the technical press of all countries and a survey of engineering industry throughout the world. It is published from the *Technical Review* office at 2 Central Buildings, Westminster, S. W., 1, London. The subscription price (abroad) is one pound ten shillings for 26 issues. No. 10 of Volume **6** embraces pages 395-434. The abstracts given are unusually full and useful.

8. *Report of the Commission appointed by the University of Pennsylvania to investigate modern Spiritualism in accordance with the bequest of the late Henry Seybert, with a Foreword* by H. H. Furness, Jr. Pp. 159, Philadelphia, 1920. (J. B. Lippincott Company.)

The Truth of Spiritualism; by "Rita" (Mrs. Desmond Humphreys). Pp. 175, Philadelphia, 1920 (J. B. Lippincott Company.)

The recent visit to America of Sir Oliver Lodge has greatly served to increase the interest in the subject of spiritualism. His dignified bearing at the many addresses recently made, and his evident confidence in his belief in the subject he so clearly presented, cannot have failed to impress all those who had the privilege of hearing the author of "Raymond," even if they did not accept his views.

Of the two books, the titles of which are given above, the first is a re-issue of a volume, first published in 1887, giving the results of the work of the Seybert Commission, which extended over more than a year and which embraced the most thorough investigation of spiritualism yet attempted. The Commission consisted of ten gentlemen, including Dr. William Pepper, Dr. Horace H. Furness, Dr. Weir Mitchell, Dr. Joseph Leidy and others not less well known, only one of whom is now living. It is needless to say that the investigation was thorough in every particular. The results reached cannot be summarized more satisfactorily than by quoting two of the closing paragraphs of the book by Dr. Furness. These are as follows:

"Although I have been thus thwarted at every turn in my investigations of Spiritualism, and found fraud where I had looked for honesty, and emptiness where I had hoped for fulness, I cannot think it right to pass a verdict, universal in its application, where far less than the universe of Spiritualism has been observed. My field of examination has been limited. There is an outlying region claimed by Spiritualists which I have not touched, and into which I would gladly enter, were there any prospect that I should meet with more success. I am too deeply imbued with the belief that we are such stuff as dreams are made on, to be unwilling to accept a few more shadows in my sleep. Unfortunately, in my experience, Dante's motto must be inscribed over an investigation of Spiritualism, and all hope must be abandoned by those who enter on it.

"If the performances which I have witnessed are, after all, in their essence Spiritual, their mode of manifestation certainly places them only on the margin, the very outskirts of that realm of mystery which Spiritualism claims as its own. Spiritualism, pure and undefiled, if it mean anything at all, must be something far better than Slate Writing and Raps. These grosser physical manifestations can be but the mere ooze and scum cast up by the waves on the idle pebble, the waters of a heaven-lit sea, if it exist, must lie far out beyond."

The second work above mentioned, dedicated to Sir Oliver Lodge, is by a lady who has the fullest belief in the "Life Beyond," and her point of view, as of those fully in accord with her, can best be expressed in her own words. As to what Spiritualism in her view has shown, she says in the Introduction: "Life and death are not two enemies but two intelligences. They should agree over the inevitable separation which is a special distinction of each, not war against a perfectly natural and unavoidable contingency. Life imprisons matter in that house of illusion which is the flesh, but death opens the door of spirit to liberty and freedom."

She closes her work, which even the most skeptical must read with interest, with the words: "The heavy curtain of doubt that has so long hung between two worlds, parting the Here from the Beyond, is slowly lifting, and slowly revealing what our own fears have kept from us. Once we realise that we are receiving help, and giving it, that the spirits beyond can and do visit us and remember us, that life is a *continuation*, not a termination, the meaning of death's great mystery will be made clear, and we shall pursue fearlessly and high-mindedly all that pertains to the psychology of existence."

Obituary.

Mr. T. W. Backhouse, of West Hendon House Observatory, long active as an astronomer and meteorologist, died on March 13 in his seventy-eighth year.

Augustin P. DeCandolle, a botanist whose family name has been distinguished since the time of his great-grandfather (1778-1841), died at Vallon near Geneva on May 9 at the age of fifty-one years.

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SCIENTIFIC INTELLIGENCE.

Established by BENJAMIN SILLIMAN in 1818.

THE AMERICAN JOURNAL OF SCIENCE.

FOURTH SERIES

VOL. L—[WHOLE NUMBER, CC]

No. 296—AUGUST, 1920.

WITH PLATE I.

NEW HAVEN, CONNECTICUT.

1920.

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Plate I.—Restoration of *Aletomeryx gracilis*, from a model by R. S. Lull. One-fifth natural size.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. IX.—*New Tertiary Artiodactyls*; by RICHARD SWANN LULL. With Plate I.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

TABLE OF CONTENTS.

INTRODUCTORY.

In 1914 a Yale expedition under the guidance of the writer was working its way westward along the Niobrara River, following, in so far as possible, although in a reverse direction, the route of the very successful Marsh expedition of 1873. While camped near the mouth of Antelope Creek, a tributary of the Niobrara, one of our number, Mr. W. S. Benton, had the good fortune to find on one side of a small tributary canyon, a talus slope literally strewn with bones, many entire, others the more resistant articular ends of limb bones or the centra of vertebræ, jaws and teeth, which, while varying in size, apparently all belonged to the same species of small ruminant, which for want of better identification was called "*Blastomeryx.*" Several days were spent by various members of the party in collecting all of the surface material on the talus slope, and then, the bone-bearing layer being identified, it was excavated for a considerable area, with still more astonishing results, for no fewer than nineteen skulls were obtained in varying degree of perfection.

The locality lies in the northwestern portion of Cherry County, Nebraska, and it is our purpose to reopen the quarry in the near future, as it gives promise of further results. The quarry, "Quarry F" as it is called on our records, lay in a 6-foot bed of hard, light gray sandstone at a level of 106 feet above the surface of the Niobrara River, and 25 feet above the canyon floor. A section prepared by Doctor Malcolm R. Thorpe, another member of the party, is here reproduced.

Talus, fragments of white sandstone................	25′
Fine-grained, grayish, shaly sandstone	15′
Massive white sandstone. Soft, more or less jointed. Turtle and other (mammal) small bones..........	19′ 6″
Hard, light gray sandstone, jointed. *Aletomeryx* bones.	0′ 6″
Talus. *Aletomeryx* bones	25′

Associated Material.

Besides the specimens of the species to be described in this paper, "Quarry F" also yielded the remains of several other forms, some of which pertain to the actual 6-foot layer in which the ruminant was entombed, others were found either in the talus or on the slope above. Yet other material came from the opposite side of the small canyon and from the same approximate levels.

Procamelus sp.—Found among the *Aletomeryx* material are portions of a right tarsus, including the astragalus, cuboid, and navicular, and the distal end of the tibia, all of which articulate perfectly, as well as parts of the cannon-bone and the phalanges. These pertain to a camel of moderate size, and may provisionally be referred to *Procamelus* sp. indet.

Rhinoceros gen. et sp. indet.—There is also a portion of a lower molar of a rhinoceros of indeterminate genus and species. Further rhinocerine skull fragments came from the overlying layers.

Chelonia.—There are also the remains of two or three turtles, including a very perfect skull which lacks only a part of the dorsal surface. This Doctor Wieland has identified as *Trionyx,* while the other material pertains either to two different Emyds or an Emyd with one of the Testudinidæ.

Protohippus placidus.—A conjectural association which, were it not conjectural, would be of real value as a time determinant is a horse molar belonging to *Protohippus placidus* or *niobrarensis,* which Professor Buwalda considers as not earlier than Lower Pliocene time. It is labelled as of Quarry F, but differs in color from any of the teeth from the actual 6-foot level, and we have no positive record of its having been found *in situ.* It might have come from one of the overlying beds. On the opposite side of the canyon, but at a somewhat higher level, Mr. F. W. Darby found a lower jaw with teeth so badly worn as to be undecipherable, together with a metapodial and phalangeal bones. They pertain to a horse about the size of that which bore the tooth mentioned above, and may represent the same genus and species, but more probably belong to a *Merychippus.* If correctly identified, they would fix the age as not later than early Pliocene or late Miocene.[1]

ALETOMERYX GRACILIS, N. GEN. N. SP.

The small ruminant, evidently an antelope new to science, may be called *Aletomeryx*[2] *gracilis,* n. gen. n. sp.

[1] Professor Merriam, after inspecting the material, agrees with this opinion concerning its geological age.

[2] From ἀλήτης, wanderer, and μήρυξ, ruminant. The name is chosen because of the great migratory power indicated by the slenderness of limb, etc.

The material upon which this description is based is practically perfect, although pertaining to many individuals and so intermingled that with the exception of two mandibles of which the teeth show a peculiar and absolutely symmetrical wear, one can not be sure that any two bones belong to the same individual. There is a palate with teeth as well, in which the wear is also identical.

Some idea of the profusion of animals can be gained from certain figures of which the first two represent the minimum numbers possible, not the maximum.

Left astragali	39
Right "	36
Right proximal metapodials	95
Left " "	99

The last, which have not been separated into front and rear, must represent at least 48 and at most 194 individuals. Of skulls, 19 or more are represented, 16 of which, in addition to an endocranial cast, are of diagnostic value.

Out of this profusion of bone, every element of the skeleton has been recognized, including the vestigial second and fifth digits, and the hyoids, the only exceptions being the first cuneiform, certain ribs, sternals, and the caudals. This being the case, it was possible to make a composite mount of the animal embodying every element except the two first cuneiforms, the caudals, and all but two or three sternals and several ribs. This mount, which includes some unusual features, will be discussed in greater detail below.

Much of the material is in excellent preservation, although the skulls have suffered most, both from erosion and from crushing. The limb bones are generally broken. The teeth for the most part are beautifully preserved.

Description of Mount.

The restoration of *Aletomeryx* here shown (pl. I, and text fig. 1) has some unusual features which are, perhaps, worthy of notice. As far back as 1910, I essayed a restoration of the Connecticut Triassic dinosaur *Anchisaurus colurus,* in which the fragility of the bone and obdurate character of the matrix made the removal and mounting of the bones impracticable. I therefore made a model, one third linear dimensions, in which the skeleton

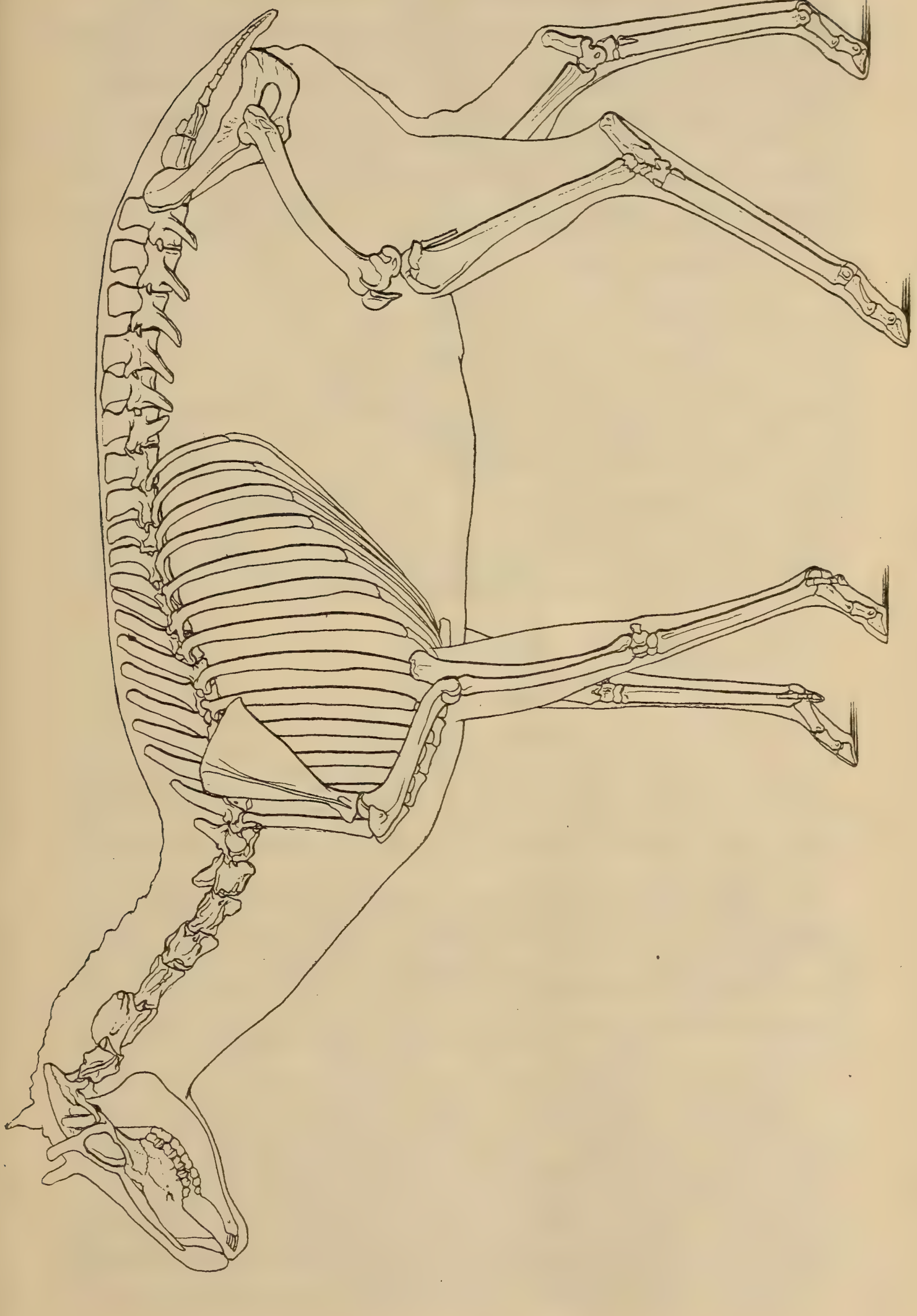


FIG. 1.—Skeleton of *Aletomeryx gracilis*, drawn from the restoration by R. S. Lull. One-fifth natural size.

was modeled in detail on the one side and the flesh on the other. This plan has, I believe, been followed elsewhere (Colorado) in the mounting of the actual bones and modeling the flesh on one side, although I was unaware of it at the time the present restoration was attempted. In both my *Anchisaurus* and the Colorado mount the mistake was made of modeling completely the limbs of the flesh side, leaving the others in their skeletal condition, which made the result incomplete from either aspect. In *Aletomeryx*, therefore, I erected the skeleton, using as few supporting wires as I could, and then modeled the muscles of the right side of the body, head, and all four limbs, so that, viewed from the right, the model is that of a complete animal in the flesh, while the left aspect displays practically the entire skeleton. The bones, with the exception of the skull and pelvis, are nearly all removable and may thus be studied in detail. Sisson's Anatomy of Domestic Animals, and photographs and a mounted head of the prongbuck (*Antilocapra*) were used in the preparation of the model, the musculature of which was studied and rendered with great care.

Morphology.

AXIAL SKELETON.

Skull (Figs. 2-6).

Holotype, Cat. No. 10732, Peabody Museum Collection. Paratypes Nos. 10747, 10744, 10735, 10734, etc. Two males, two females, and one or more of indeterminate sex, probably males.

The skull of *Aletomeryx* is well proportioned, with an ample brain case, the basi-cranial axis forming an angle of an average of $20\,{}^{5}/_{7}$ degrees with the palate, the measurements running 12½, 13½, 16, 23, 23½, 27½, 29 degrees through seven skulls in varying condition of crushing. It therefore somewhat approximates that of *Antilocapra,* in which the average of three skulls is about 23 degrees, with almost no variation among them. *Antilocapra,* however, gives the impression of a greater flexion of the face upon the cranium than does *Aletomeryx.* With the deer the axis of the face is nearly in the same line as that of the cranium. *Aletomeryx,* therefore, in this regard agrees with the hollow-horned ruminants rather than with the deer.

Horns.—The most striking feature of the skull, when preserved, is the horns, differing decidedly in the two sexes as in the prongbuck, *Antilocapra*. These horns arise over the posterior portion of the orbit as in *Antilocapra* and *Dromomeryx*, but differ from those of the former in being triangular in cross-section at their base, the forward angle continuous with the upper, the after one with the hinder rim of the orbit, which is completely surrounded by bone. The outer face of the horn is flush

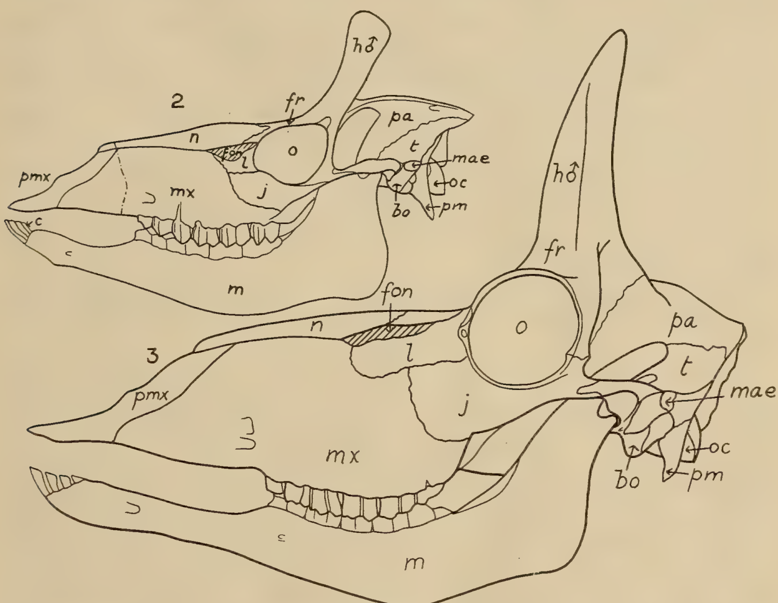


FIG. 2. Skull of *Aletomeryx*, adult male. Left lateral aspect. One-third natural size. *bo*, auditory bulla; *c*, canine tooth; *fon*, fontanelle; *fr*, frontal; *h*, male horn; *j*, jugal; *l*, lachrymal; *m*, mandible; *mae*, external auditory meatus; *mx*, maxillary; *n*, nasal; *o*, orbit; *oc*, occipital condyle; *pa*, parietal; *pm*, paramastoid (paroccipital) process; *pmx*, premaxillary; *t*, temporal.

FIG. 3. Skull of *Antilocapra*, with milk dentition. Left lateral aspect. One-third natural size. Lettering as in fig. 2.

with the rim of the orbit; in *Antilocapra* the rim extends beyond the horn level. The inner angle is prolonged inward as the supratemporal ridge over the top of the cranium, curving backward to meet its fellow and form the parietal crest, which is a thin but low ridge. In *Antilocapra*, on the other hand, there is no crest, as the limitations of the temporal fossæ are wide apart and the rounded hinder edge of the laterally compressed horn passes into the faint ridge which delimits them. Distally the horn becomes somewhat flattened transversely, but dilated fore and aft, ending in a rounded terminus with an elongated oval section. In *Antilocapra*, the horn-core tapers to a point, the section being flattened with a rounded hinder and sharp forward margin in a young animal (RSL, male) and circular in an older male (Peabody Museum Osteological Collection No. 1518).

In *Aletomeryx* there are faint longitudinal blood-vessel depressions discernible in the older individual, No. 10734, but not in the younger. These impressions occupy the same position as in *Antilocapra*, that is, on the outer aspect, and lodged the artery to the corium or skin of the horn, a continuation of the superficial temporal. In each instance, the artery reaches the horn via the posterior side of the orbit. The superior outline of the orbit is continued upward in the form of a shallow tapering groove 5 mm. or so on the outer aspect of the horn in the male *Aletomeryx*.

The horns of *Dromomeryx* have been described by both Douglass and Scott. Scott's description follows:[3]

"The horns are very peculiar and quite unlike those of any other known genus, fossil or recent. At the base the section forms a spherical triangle, the three sides of which present forward, backward and inward; the anterior face is concave, a feature which is more marked in this species [*Dromomeryx* (*Blastomeryx*) *antilopinus*] than in [*Dromomeryx*] *B. borealis;* the other faces are convex. In the specimen before us the horns are broken away about three inches above the base, but Prof. Cope's numerous skulls of the larger species show that in that form, at least, the horns were remarkably long, perfectly simple and non-deciduous, none of them exhibiting any burr or any tendency to branch. The young stages of *Dicroceros* have a very similar unbranched horn, but the many known skulls of *Blastomeryx* show that this simplicity is not a transitory character in this genus. Faintly marked grooves and ridges may be seen on the surface of the horns, but their smoothness indicates, with great probability, that they were permanently covered with skin. The external angle of the base of the horn in [*D.*] *B. borealis* continued into a wing-like process which extends outward behind the orbit. In the type of *B. antilopinus* this process is broken away, but it can hardly have been so prominent as in the larger species. As in *Dicroceros* and *Antilocapra* the horns rise directly above the orbits, but are more erect than in the former genus."

[3] Scott, W. B., Trans. Amer. Philos. Soc., n. ser., vol. **18**, p. 172, 1895.

Douglass thus describes[4] the horns of *Dromomeryx borealis:*

> "The horns are nearly circular in section above, but are triangular just above the basal wing-like processes. The latter are directed postero-externally. The antero-external faces are concave and the outer borders thickened."

Douglass restores the horn as tapering to a point, a feature not evident from either description.

In both species of *Dromomeryx,* therefore, the horns are markedly different from those of *Aletomeryx,* in which there is no trace whatever of the basilar wing-like processes, evidently an utterly unique feature of the former genus. Professor Merriam described to the writer orally a specimen in the University of California collection in which the horns are complete, tapering, and curve inward toward the median line of the skull.

Antilocapra is also unique in being the only living ruminant with a deciduous and also a branched horn. The skull before me (RSL, male), a relic of an early expedition to Montana, is that of a young male whose milk incisors and canines had not yet been shed, nor had the third true molars fully erupted. The animal died during the first week in July and upon maceration of the skull a hairy skin was found beneath the horns. In *Aletomeryx* the distal dilatation of the horn precludes the possibility of a dermal horn, for growth on the part of the osseous horn implies either a shedding of the covering as in *Antilocapra* or a shifting outward of the entire structure, additional horn material being secreted within and forming ring-like outcroppings at the base of the older horn, as in the other Cavicornia. It is difficult to see how with a dilated osseous core either of these could be accomplished other than by a splitting of the tegumentary horn. Then, too, the very faint character of the vascular impressions which are relatively much less distinct than in *Antilocapra,* and, indeed, not discernible at all in the younger male, is additional evidence for the absence of any close fitting inelastic covering. The horns are not antler-like, and hence could hardly have been comparable to those of existing deer, except perhaps at the time the antlers are forming and in velvet, when they may also show somewhat dilated termini, as in the fallow deer, comparable to the horn under discussion.

[4] Douglass, Earl, Ann. Carnegie Mus., vol. 5, p. 466, 1909.

The conclusion reached is that the horns of *Aletomeryx* were covered permanently with hairy skin comparable to those of the giraffe or the developing antlers of the deer. This would be a primitive condition leading to that of the prongbuck on the one hand, where the hair develops into a dermal horn by agglutination, or to the deer on the other, where the velvet is shed, laying bare the osseous antler, which in turn is lost. There is no evidence that the horns of *Aletomeryx* were ever shed, nor that they were derived from separate centers of ossification as in the giraffe; they are merely the processus cornuus of the frontal bone. Their surface is not porous as in *Antilocapra* or *Bos*, except on the summit, but in the males is dense and polished like that of the adjacent frontal bone.

Female horns.—The relative development of male and female horns in *Aletomeryx* corresponds to that in *Antilocapra*, as several skulls show. The female horn is merely a low, rounded protuberance with a subtriangular base. Its position is precisely as in the male, which is also true of the axial direction backward and somewhat outward, decidedly so in the old male. The summit of the female horn is finely porous as in *Antilocapra*.

The dimension of the osseous horns are as follows:

	Aletomeryx				
	male 10732	male 10734	male horn 10748/2	male horn 10748/3	female 10735
	m.	m.	m.	m.	m.
Height above orbit	·0265	·0530	·0365	·0300	·0057
Diam. at base, ant.-post.	·0100	·0135	·0115	·0105	·0082
Diam. at base, transverse	·0100	·0174	·0138	·0137	·0080
Diam. at summit,* ant.-post.	·0083	·0180	·0188	·0140	
Diam. at summit,* transverse	·0060	·0095	·0090	·0100	rounded point.

* Somewhat oblique.

	Aletomeryx		*Antilocapra*		
	female 10747	female skull cap 10748/1	RSL male	male Ost. Col. 1518	RSL female
	m.	m.	m.	m.	m.
Height above orbit	·0100	·0008	·0858†	·0970	·0109
Diam. at base, ant.-post.	·0095	·0095	·0340	·0373	·0167
Diam. at base, transverse	·0097	·0070	·0194	·0225	·0068
Diam. at summit,* ant.-post.		rounded point.			
Diam. at summit,* transverse		rounded point.	·0055	point.	

* Somewhat oblique. † ·1385 with dermal horn.

Facial and cranial bones.—There is no trace of a suborbital or lachrymal fossa as in most of the deer and antelopes, and herein again *Aletomeryx* agrees with *Antilocapra* and with the Bovidæ.

In the present genus, as well as in *Blastomeryx, Dromomeryx,* and *Antilocapra,* there is on either side of the face a fontanelle closed during life by membrane but now opening into the nasal cavity. This is bounded by the frontal, lachrymal, nasal and maxillary bones. Supraorbital foramina through the frontal into the orbits are also present in each genus. These in *Antilocapra* may be single or divided by a bar of bone into two spaces varying in proportions. In the female *Aletomeryx* skull No. 10747, there are three such foramina arranged in an oblique row on either side of the median line of the skull, while in skull No. 10744 (sex indeterminate), there are but two; again in a third female, No. 10735, one only is present, which is also true apparently of male skull 10734. There is, as in *Antilocapra,* a distinct groove (sulcus supraorbitalis) running from this supraorbital foramen to the fontanelle already mentioned. This is least distinct in No. 10748, where there are three foramina instead of one. This groove marks the course of the frontal vein. (See fig. 4 A, B.)

Just without the supraorbital groove, a little behind the anterior limit of the orbit, is a distinct protuberance which has no equivalent in *Antilocapra* nor in *Dromomeryx.* The fronto-lachrymal suture passes through this eminence, which seems almost like an incipient horn. It is present, though varying in development, in both male and female skulls.

Lachrymal foramina are double as in *Antilocapra,* and lie just within the limits of the orbit, although the anterior one is almost on the margin. "In most deer the orifice of the lachrymal canal is double and situated on the margin of the orbit, whereas in most of the hollow-horned ruminants it is single and placed well within the margin. There are, however, exceptions in both cases" (Flower). Both *Aletomeryx* and *Antilocapra* are among the exceptions.

The frontal bones extend backward to a point a little behind the orbits, much as in *Antilocapra,* but instead of crossing the supratemporal ridge delimiting the temporal fossa, as in the prongbuck, the fronto-parietal suture follows for the most part the very apex of the ridge until, toward the middle of the skull, the ridges swing backward to unite and form the parietal crest, while with a graceful curve the suture swings across the skull. Thus there is defined a triangular area, bounded in front by the curved suture and on either side by the supratemporal ridges. The sagittal crest is low and very thin,

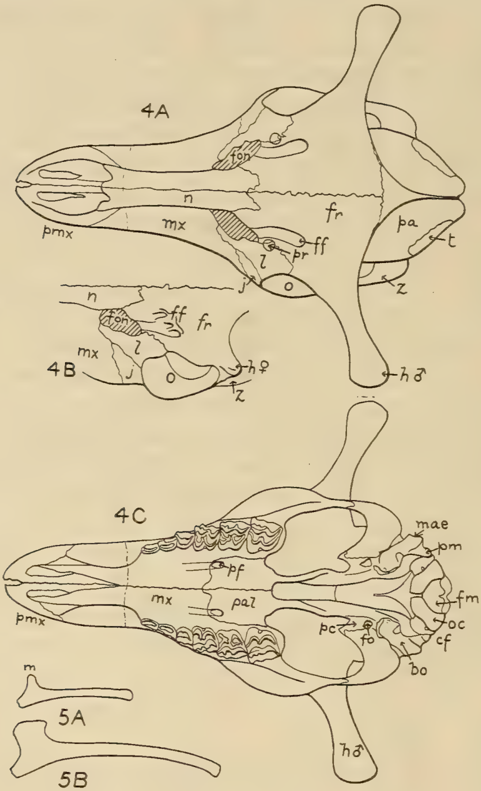


FIG. 4. Skull of *Aletomeryx*. A, male, dorsal aspect; B, frontal region of female, showing horn, *h*, and triple frontal foramen, *ff*; C, male, ventral aspect. *cf*, condyloid fossa; *fo*, foramen ovale; *pal*, palatine; *pc*, pterygoid crest; *pf*, palatine foramen; *z*, zygomatic arch. Other letters as in fig. 2. One-third natural size.

FIG. 5. Hyoid. A, *Aletomeryx*, to be compared with B, *Antilocapra*. *m*, muscular angle. One-third natural size.

almost a knife-like ridge. In *Antilocapra* it does not exist, while in *Dromomeryx* it is low and broad. The temporal ridges are not very well defined, but are roughly parallel with the supratemporal; they fade out entirely on the superior aspect of the skull. A foramen occurs in the left parietal near the sagittal crest in the female skull No. 10735. One can not verify its presence in any of the other crania because of conditions of preservation. A similar foramen is shown by Douglass[5] and Scott[6] in their figures of *Dromomeryx,* although its position is lower on the skull.

The nuchal crest is generally broken away in the skulls before me. In the holotype, No. 10732, however, it is well developed and overhangs the occiput, so that as preserved it extends about 10 mm. beyond the vertical portion of the occipital bone. To what extent this is exaggerated by crushing, it is difficult to say. Herein again *Aletomeryx* differs from *Antilocapra* and agrees with *Dromomeryx.* The profile of the skull shows a well rounded brain-case, somewhat arched nasals, and a distinct concavity between the orbits just behind the fronto-nasal suture. This is in agreement with *Antilocapra* and to a less extent, perhaps, with *Dromomeryx,* in which the profile is more nearly straight except for the concavity between the orbits in *D. borealis.* Scott makes no mention of this cavity in *D. antilopinus,* but speaks of the "straight upper surface of the skull."

In *Aletomeryx,* there lies between the horns a low but distinct median protuberance corresponding to the frontal eminence of the ox. In *Antilocapra* this frontal eminence is broader, and in the old male No. 1518 forms a transverse ridge connecting the bases of the horns. This ridge lies just behind the frontal depression.

The parietal region of the skull, as seen in profile, is somewhat similar in *Aletomeryx* and *Dromomeryx antilopinus,* curving downward somewhat less than in *Antilocapra.* Douglass restores this portion of the skull of *D. borealis* as though it were nearly straight. His evidence for this is not apparent, and it may have been more as in Scott's specimen and therefore in closer agreement with *Aletomeryx.*

The orbit is somewhat irregular in outline, as shown by the figure, while that of *Antilocapra* and of *Dromomeryx,* to judge from Douglass' figure, is more nearly circular. Scott speaks of the orbit in *D. antilopinus* as being much lower down and farther forward in the face than in *Antilocapra,* its upper border not projecting above the superior contour of the cranium. This is not entirely true of *Aletomeryx,* for while the postorbital region of the skull is relatively longer than in *Antilocapra,* the orbit is relatively high and the upper margin does extend above the superior contour of the cranium.

[5] Op. cit., pl. LIX. [6] Op. cit., pl. VI.

The jugal below the orbit is expanded transversely and concave inferiorly, as in *Antilocapra* and *Dromomeryx;* in the former, however, it is the postorbital portion of the frontal over which the widest measurement of the skull is taken, in *Aletomeryx* it is the lower margin of the orbit, in *Dromomeryx* it is over the wing-like processes at the base of the horns.

Basicranial portion of the skull.—As compared with *Antilocapra,* the proportions of this area of the skull differ markedly, as the entire after portion is relatively much longer in proportion to the width in *Aletomeryx.* Aside from this, the differences are largely those of detail. The occipital condyles are relatively somewhat broader in *Aletomeryx,* although their proportions vary slightly in the several available crania, which is also true of *Antilocapra.* The condyloid fossa is deep and the condyloid or hypoglossal foramina are apparently single, not double as in *Antilocapra.* In *Dromomeryx antilopinus,* Scott describes the condyloid fossa as being much larger and more deeply impressed than in *Antilocapra.* This is not true of *Aletomeryx.* In both *Dromomeryx* and *Aletomeryx,* however, the paroccipital process is further in advance of the posterior limit of the condyles than in the prongbuck.

The auditory structure is much as in *Antilocapra,* the wedge-shaped paramastoid process being laterally compressed and pointing somewhat backward as in *D. antilopinus,* not forward as in the prongbuck and in Douglass' figure of *D. borealis.*

The relations of the mastoid agree, apparently, in *Dromomeryx* and *Aletomeryx.* Tympanic bullæ are relatively much the same as in *Antilocapra;* the deep groove for the attachment of the stylohyoids of which Scott speaks and which forms a deep pit in the *Antilocapra* skull before me is hardly in evidence in skull No. 10735, but is better developed in No. 10749 and No. 10750. The shape and degree of inflation of the bullæ differ quite markedly in these three skulls. As in *Dromomeryx,* the external auditory meatus is a long tube which is directed more posteriorly than in *Antilocapra,* forming an angle with the axis of the skull of about 60 degrees in *Aletomeryx* to 70 degrees in *Antilocapra.*

The glenoid cavity is comparable to that of *Antilocapra,* except that the anteroposterior diameter is greater and the pterygoid crest is much more developed. The postglenoid process is much more prominent than in *Antilocapra.* Herein *Aletomeryx* agrees with *D. antilopinus.* The palatine bones show much the same development in *Aletomeryx* and the prongbuck, and the grooves leading forward from the anterior palatine foramina over the surface of the maxillaries are comparable. In none of the crania before me is it possible to recognize the vomers. As preserved, the sphenoid extends clear forward into the posterior nares, forming the only visible axis of the skull (see fig. 4 C), whereas in *Antilocapra* at least one half the basal axis from the hinder margin of the hard palate to the foramen magnum is formed by the vomers. This apparent distinction may be merely accident of preservation. The form of the palate between the cheek teeth varies in the different *Aletomeryx* skulls as it does in two of the prongbuck skulls before me. In the latter, the tooth series form straighter lines in the male than in the female. In *Aletomeryx* I can not see that this variation in the degree of curvature is in any way determined by sex, but on the other hand is a matter of individual variation pure and simple. As in *Antilocapra,* the outline of the palate is generally sharply constricted just in front of the tooth series. In No. 10747 (female), on the other hand, this is not evident. In no skull is the muzzle preserved, so that there is no direct evidence of the presence or absence of upper canine teeth. In all the great profusion of teeth, however, that were recovered from the quarry, some vestige of a canine would surely be present had such been a characteristic of the animal, especially as they were most diligently sought for. It is negative evidence, but to me conclusive in favor of the belief that this genus possessed no such tusk-like canines as did *Blastomeryx* (see fig. 25). The lower canines are present, incisiform, and form part of the incisor series without diastema.

The cranial measurements follow:

	Aletomeryx			
	10732 mt'd. sp'm.	10744 mid-adult	10749 adult	10760 Young unworn dent.
	m.	m.	m.	m.
Length over all (est.)	·1712	·170	?	?
Width of brain case	·043	·048	·0473	?
Maximum width (zygoma)	·078	ca. ·080	?	ca. ·080
Height ant. to orbit	·032	·035	?	·035
Vert. diam. of orbit	·020*	est. ·027	·020	·026
Occipital height	·0335	·035	·028*	?
Occipital width	·044	ca. ·042	·0445	?
Width of palate at M^2	ca. ·028	·029	·0264	ca. ·032*

* Crushed.

	Antilocapra			
	RSL Young male milk dent.	180 female Adult worn dent.	RSL Young female milk dent.	Ratio 10744 and 180
	m.	m.	m.	m.
Length over all	·2840	·2860	·2550	1·68
Width of brain case	·0700	·0720	·0730	1·50
Maximum width (zygoma)	·1300	·1280	·1250	1·60
Height ant. to orbit	·0650	·0700	·0634	2·00
Vert. diam. of orbit	·0400	·0436	·0400	1·61
Occipital height	·0575	·0570	·0565	1·63
Occipital width	·0825	·0790	·0763	1·88
Width of palate at P^2	·0350	·0305	·0310	1·17
Width of palate at M^3	·0485	·0520	·0485	1·45
				Av. 1·61

Brain.—A very excellent natural cast of the interior of the cranium of *Aletomeryx* exists (Cat. No. $\frac{10765}{1}$), lacking only the olfactory bulbs and certain details of the inferior aspect. Another specimen, however (Cat. No. $\frac{10765}{2}$), consisting of a cranial floor containing a residue of matrix, was cleared and a wax impression taken of its interior. This gave additional data, so that we are lacking only the olfactory bulbs and optic nerves, and these have been restored in the drawings (fig. 6). The endocranial cast differs of course from the brain itself in that it is a replica of the dura mater and not of the cortical surface, hence the fissures are neither so numerous nor so well-defined as they would be in the actual brain. Furthermore, the imprint of the inner surface of the petrous bone, which is so striking a feature of the cast, is lacking on the brain itself. Nevertheless, the relative proportions of parts are clearly shown, although in the inferior aspect (fig. 6 C), instead of cranial nerves one sees the impressions of the several foramina which transmitted them.

The brain is of considerable size, as the figures, which are in their natural dimensions, show, but varies somewhat in proportions as compared, for instance, with that of the ox, in that the portion below the rhinal fissure is relatively larger and the cerebral portion above proportionately less, a more primitive condition in the fossil. The hinder portion of the cerebrum is of ample width as compared with the prefrontal area, showing a relatively high development of muscular control as compared with intelligence. The centers of hearing and sight are also

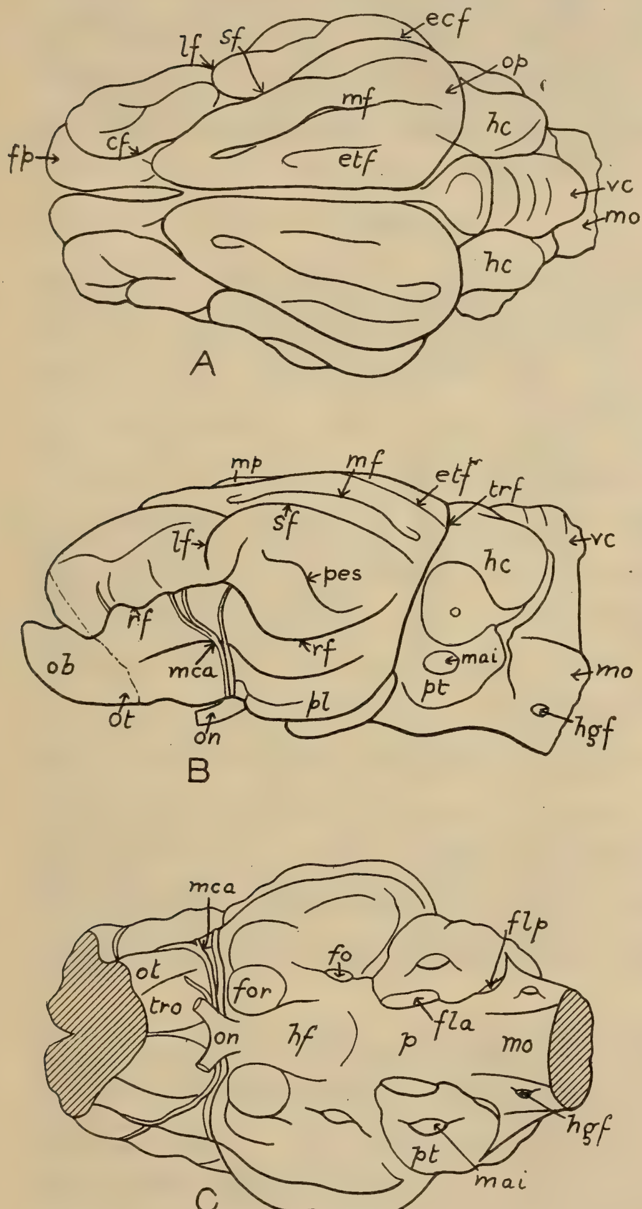


FIG. 6.—Brain-cast of *Aletomeryx*. A, dorsal; B, left lateral; C, ventral aspect. Natural size. *cf*, coronal fissure; *ecf*, ectomarginal; *etf*, entomarginal; *fla*, foramen lacerum anterius; *flp*, foramen lacerum posterius; *fo*, foramen ovale; *for*, foramen orbito-rotundum; *fp*, frontal pole; *hc*, hemisphæria cerebelli; *hf*, hypophysial fossa; *hgf*, hypoglossal foramen; *lf*, lateral fissure; *mai*, meatus acusticus internus; *mca*, middle cerebral artery; *mf*, marginal fissure; *mo*, medulla oblongata; *mp*, marginal pole; *ob*, olfactory bulb; *on*, optic nerve; *op*, occipital pole; *ot*, olfactory tract; *p*, pons varolii; *pes*, posterior ectosylvian fissure; *pl*, piriform lobe; *pt*, petrous temporal impression; *rf*, rhiral fissure; *sf*, suprasylvian fissure; *trf*, transverse fissure; *tro*, trigonum olfactorium; *vc*, vermis cerebelli.

ample in development, as were apparently those of the sense of smell. The cranial cast displaces 45 cc. of water; estimating the specific gravity as approximately 1, it would give a brain weight of ca. 45 grams or 1½ ounces.

Further detailed description is rendered unnecessary by the figures, in which the size, identifiable fissures, and foramina are indicated.

Mandible.

Mandibles representative of more than twenty individuals are present in greater or less degree of perfection. They pertain to individuals of varying age, from very young with milk dentition to aged animals whose teeth were badly worn. The ramus is rather slender, though proportionately less so than in *Antilocapra,* and the shape of the jaw from below the third molar to the angle varies as well, as the figures show, that of *Aletomeryx* lacking the peculiar cut-away appearance of the prongbuck. Thus the whole ascending portion of the ramus is relatively much broader in the fossils, and the coronoid process is more erect. This is in harmony with the longer and more primitive cranial portion of the *Aletomeryx* skull. The anterior part of the mandible changes form somewhat with age as with *Antilocapra,* the rami becoming more slender just behind the symphysis. The symphysis itself also lightens, for in the younger jaws the presence of both milk and permanent incisors, the latter in process of formation, necessitates a greater volume of containing bone. The mental foramen lies just behind the after symphysial limit; the mandibular foramen, which is on the inner face of the ascending process, lies at about the upper level of the teeth in the older specimen, about their mid-height in the younger jaws.

Four alveoli are present at the anterior end of each ramus for the three incisors and the incisiform canine which forms an integral part of the cropping series. In jaw No. 10754 the uncut I_3 and canine are present, in another fragmentary symphysis, $I_{2 \text{ and } 3}$. The unworn tooth crowns as they appear are spatulate with entire rounded margins quite comparable to those of *Antilocapra.* They may have been somewhat more procumbent. Several loose incisors are present in the material, but none that were in use are in position in any of the jaws.

Scott's specimen had no trace of any lower jaws; Douglass, on the other hand, figures several pertaining to *Dromomeryx americanus, borealis,* and *madisonius.* His restoration of the skull of *D. borealis*[7] shows a jaw very different from that of *Aletomeryx* at the anterior end, as it is much more slender and lacks the graceful downward curve of the upper margin. It is possible that the figure may be somewhat in error, especially as the mental foramen is omitted.

The posterior portion of the jaw of *D. borealis* is not preserved. The condyle in *Aletomeryx* shows a saddle-shaped surface comparable to that of *Antilocapra.*

Mandibular dimensions appear below.

	Aletomeryx			
	10754 Unworn	10763 Mt'd. sp'm.	10762	10761 Very old
	m.	m.	m.	m.
Length of ramus	·1330	·1340	·1327	·1250
Depth at P_2	·0130	·0149	·0137	·0128
Depth at M_1	·0165	·0160	·0170	·0144
Depth at M_3, outside	·0218	·0240	·0214	·0180
Length of molar-premolar ser.	·0630	·0640	·0610	·0586
Length of premolars	·0210	·0223	·0200	·0183
Length of molars	·0425	·0426	·0410	·0377

	Antilocapra			
	RSL male milk	180 female	RSL female milk	Ratio 10762 and 180
	m.	m.	m.	
Length of ramus	·2150	·2130	·1960	1·60
Depth at P_2	·0230	·0215	·0200	1·49
Depth at M_1	·0324	·0240	·0324	1·41
Depth at M_3, outside	·0337	·0355	·0345	1·66
Length of molar-premolar ser.	·0775	·0750	·0800	1·23
Length of premolars	·0282	·0240	·0300	1·20
Length of molars	·0490	·0490	·0500	1·20
				Av. 1·39

Teeth (figs. 7, 8).—The dental formula of *Aletomeryx* is $I\frac{0}{3}$, $C\frac{0}{1}$, $P\frac{3}{3}$, $M\frac{3}{3}$, agreeing therein with the Antilocapridæ, Giraffidæ, Bovidæ, and with all Cervidæ in which the upper canine is lacking. The incisiform lower canine is present as in the above families.

The first premolars are of course lacking in each jaw, but the remaining premolars and molars form a compact row in which the teeth show a slight tendency to overlap

[7] Op. cit., pl. LIX.

so that the total length of the series is less than the sum of their individual dimensions.

The premolars in each jaw show no tendency to become molariform. A curious partial exception lies in skull No. 10749, in which the third left upper premolar (P^3) has two inner and but one outer lobe, which, however, is disproportionately long. The equivalent tooth on the right side is normal. This is of course an abnormality, an instance of meristic variation. The cheek teeth show a

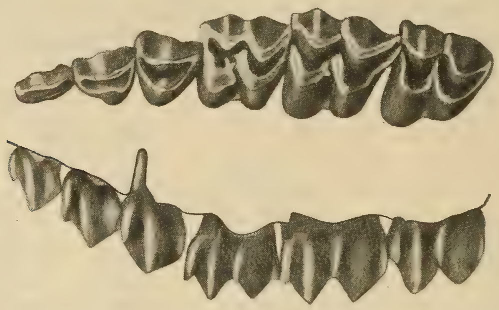


FIG. 7. Upper dentition, crown view and from without, of *Aletomeryx*. Cat. No. 10760. Slightly more than natural size.

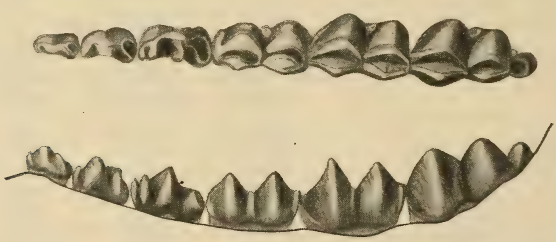


FIG. 8. Lower dentition, crown view and from within, of *Aletomeryx*. Cat. No. 10754. Natural size.

slight tendency to become hypsodont, although not so much so as in the prongbuck. Herein they differ apparently from *D. borealis,* in which "the molars are very brachyodont" (Scott).

P^2 is an elongated oval, somewhat irregular in external outline, and consists largely of a single cusp, the protocone, flanked anteriorly by a pronounced accessory cusp. Internally the deuterocone is the merest rudiment, on a well-developed but narrow cingulum, which is in marked contrast to that of *Dromomeryx,* in which P^2 bears a well-developed inner lobe. Externally the anterior cusp is buttressed by a pronounced style corresponding to the parastyle of the molars. There is, however, a less decided ridge flanking the protocone than in *D. borealis.* Comparison with *D. americanus* and *D. antilopinus* is impossible from lack of preservation of the tooth.

P^3 is broader in proportion to its length and subtriangular in outline. The protocone is well developed, but the anterior cusp is relatively less pronounced, although well buttressed. Here the deuterocone is present and the inner crescent is no longer like a mere cingulum but is better developed, although in a stage transitional between that of P^2 and P^4. There is practically no trace of a cingulum such as that indicated by Douglass[8] in *D. borealis.* In P^4 the transverse diameter exceeds the anteroposterior for the first time, the tooth being again triangular with a well-rounded internal angle. The internal crescent forms about one third the bulk of the tooth, but the deuterocone has practically merged into the crescent, a faint ridge on the inner concave face of the latter being its only indication. The outer crescent is flanked by an anterior, median, and posterior style, the last being the least conspicuous. P^2 is two-rooted, while P^3 and P^4 are borne upon three each, in conformity with their triangular shape.

Upper molar teeth.—The three upper molars are somewhat similar. The first and second have accessory folds on the adjacent ends of their inner crescents, on both in M^1, on the anterior crescent in M^2. No trace of a cingulum is present, but each tooth bears a very small internal cusp lying between the bases of the inner crescents. This varies in development in different individuals. Externally the parastyle and mesostyle are strongly developed, as is also a buttress flanking the paracone. The outer face of the posterior external crescent (metacone) shows no such buttress. In *Dromomeryx antilopinus* (Scott) the third premolar is the largest of the series, exceeding P^4 in both dimensions, which is not true of the present form, wherein P^4 has the greater transverse diameter and area, although it is somewhat less than P^3 antero-posteriorly. The proportions of the molar teeth agree in the two species, as do the para- and mesostyles. The same is true of the median rib on the antero-external crescent and of its obsolescence on the postero-external. Scott

[8] Op. cit., pl. LXIII, figs. 1, 6.

also speaks of the progressive increase in size of the internal pillar of upper molars 1-3 in *D. antilopinus* and of its being very small or absent on M^3 and larger on M^{1-2} in *D. borealis*. These are variations within the species of *Aletomeryx*, and are probably not of diagnostic value in *Dromomeryx*. Scott also speaks of the relative shortness of the hinder horn of the antero-internal crescent and the curious crenulations of the adjacent horns, which is also true of *Aletomeryx*, although in M^1 as a rule the crenulations are most pronounced, while they may be absent in M^3. In *D. borealis* this crenulation is apparently absent. The chief tooth distinctions therefore between *Aletomeryx* and *D. antilopinus* are the much greater size of the entire series, the relatively greater size of P^3, and the decidedly brachyodont character of the teeth of the latter. From *D. borealis*, the size and brachyodont distinction also holds, together with the distinction of P^2 already mentioned, and the simplicity of the adjacent horns of the inner crescents, although in one specimen referred by Douglass[9] to this species this last distinction does not hold. Cingula are mentioned by Douglass on the anterior face of the antero-interior cusps (?crescents). None are discernible in *Aletomeryx*. He also states that the valleys between the inner and outer crescents are not deep. In *Aletomeryx* they are very deep in the unworn tooth.

Lower dentition (fig. 8).—The premolars increase in size and complexity from P_2 to P_4; their chief distinctions from those of *D. borealis* and *D. americanus* lie not only in the lesser actual size of the teeth, but in the greater simplicity of P_3. The molar teeth in *Aletomeryx* all lack the "*Palæomeryx* fold" on the posterior face of the antero-external crescent; otherwise they also are generally similar.

The lower dentition in *D. antilopinus* is apparently unknown. The degree of hypsodonty in the lower teeth of *D. americanus, D. borealis* and *D. madisonius* is in approximate agreement with *Aletomeryx*. The enamel wrinkling of the outer surface of the teeth is much the same. There is here a slight individual variation in *Aletomeryx*, depending in part on the degree of wear.

The tooth measurements are (see also table of mandibular measurements):

[9] Op. cit., pl. LXIII, fig. 1.

	Aletomeryx 10732 M'td. sp'm.	10744	10749	10760
	m.	m.	m.	m.
Molar-premolar ser.	·0498	·0526	·0540	·0567
Premolar ser.	·0250	.0220	·0233	·0250
P^2, length	·0070	·0073	·0076	·0080
P^3, length	·0080	·0080	·0080	·0092
P^4, length	·0087	·0076	·0072	·0085
Molar ser.	·0323	·0334	·0323	·0360
M^1, length	·0085	·0098	·0100	·0118
M^1, width		·0114	·0104	·0118
M^2, length	·0105	·0118	·0115	·0130
M^2, width		·0132	·0124	·0134
M^3, length	·0128	·0121	·0120	·0136
M^3, width		·0129	·0120	·0133

Antilocapra

	RSL male	RSL female a little older than RSL male	180 female adult, worn	Ratio 10749 and 180
	m.	m.	m.	
Molar-premolar ser.	·0732	·0715	·0710	1·31
Premolar ser..	·0320*	·0320*	·0280	1·20
P^2, length	·0097*	·0100*	·0076	1·
P^3, length	·0116*	·0110*	·0095	1·19
P^4, length	·0128*	·0125*	·0090	1·25
Molar ser.	·0428	·0440	·0455	1·40
M^1, length	·0147	·0142	·0130	1·30
M^1, width	·0105	·0105	·0105	1·01
M^2, length	·0157	·0160	·0150	1·30
M^2, width	·0098	·0098	·0114	0·92
M^3, length	·0145+	·0150+	·0178	1·48
M^3, width	·0086+	·0070+	·0110	0·91
				Av 1·19

Milk dentition.—There are three specimens, a right (Cat. No. $\frac{10766}{1}$) and a left (Cat. No. $\frac{10766}{3}$) maxillary and a right mandible (Cat. No. $\frac{10766}{2}$), containing milk teeth. The two maxillaries do not seem to pertain to the same individual, as in one the teeth are somewhat smaller. Each contains three teeth preceded by a single empty alveolus in front of which the bone is broken away. The larger individual contains a portion of another molar, only a tip of which protrudes, while the broken hinder surface of the other specimen shows a very distinct tooth impression. There is nothing distinctive about the two posterior teeth, which are typical molars, except that the external column of the postero-external crescent is more distinct than in the adult teeth. The anterior of the preserved teeth, however, apparently Dp^3, is very distinctive, having two external crescents which are quite molar-like, while the single internal crescent, if such it may be called, is complicated by a median fold which in turn bears crenulations and abuts against the space between the two outer crescents. The horns of the inner crescent are extended fore and aft and the posterior one bears an internal crenulation. Anteriorly a fold extends inward from the antero-external crescent to embrace the forward horn of the inner crescent. It forms the anterior border of the roughly triangular tooth.

Lower milk dentition.—Four teeth are preserved. Here the most peculiar feature lies again in the complexity of a single tooth, this time Dp_4, which is not unlike a molar except that it is three-lobed like M_3 reversed, in that the anterior lobe is the smallest. This lobe consists of an external and internal portion connected together broadly by their anterior ends and diverging posteriorly, otherwise they resemble somewhat a miniature replica of the inner and outer crescents of a normal lobe. An external pillar arises from the cingulum in each reëntrant angle between the lobes, making two instead of the normal one.

The measurements of the milk dentition, all maximum, are as follows:

Upper series.	m.
Total length of the three teeth	·0300
Dp^3, length	·0106
Dp^3, breadth	·0073
Dm^1, length	·0115
Dm^1, breadth	·0093
M^2, length	·0122
M^2, breadth	·0102
M^2, height of crown	·0098

Lower series.	
Total length of the four teeth	·0340
Dp_2, length	·0055
Dp_2, breadth	·0022
Dp_3, length	·0070
Dp_3, breadth	·0034
Dp_4, length	·0115
Dp_4, breadth	·0055
M_1, length	·0113
M_1, breadth	·0063

Hyoid (fig. 5).—A pair of hyoid elements are present, representing the right and left stylohyals or great cornu. Of these, the right is complete for its entire length. Compared with the equivalent bone of *Antilocapra*, the fossil is somewhat more robust in proportion to its length, the distal end is flatter and more expanded, but while the proximal articular portion is more robust, the muscular angle is much more slender. In *Antilocapra*, this has a marked fore and aft expansion. In *Aletomeryx*, the angle corresponds more nearly with that of the ox. It is the place of origin of the stylohyoid muscle, the action of which is to draw the base of the tongue upward and backward. The significance of the relative development of this muscle is, however, not clear.

Vertebral Column (Figs. 9-13).

The vertebral formula is assumed to be that of the prongbuck[10]—cervical 7, thoracic 13, lumbar 6, sacral 4, caudal?—which in turn compares with the ruminants in general except for the reciprocal variation of 13 thoracic to 6 lumbar or 14 thoracic to 5 lumbar. As there is no complete series of vertebræ pertaining to a single individual, there is here a chance for error.

The vertebral column as a whole is about 700 mm. long, and the regional measurements as compared with those of *Antilocapra* (female) No. 180 follow:

	Aletomeryx	*Antilocapra* No. 180	
	m.	m.	Ratio
Cervical	·0203	·0335	1·75
Thoracic	·0245	·0335	1·364
Lumbar	·0193	·0245	1·464
Sacral	·0066	·0086*	1·30+
Total	·0707	·1001	Av. 1·475

* Four sacrals.

Cervical vertebræ. Atlas (fig. 9).—This bone resembles that of *Antilocapra* very closely, differing mainly in that the outer margins of the wings are more nearly

[10] In both *Antilocapra* skeletons before me the sacrum consists of five vertebræ, but four is the number given in Flower's Osteology.

parallel and the median notch on the antero-ventral margin is much less pronounced. The position and development of both dorsal and ventral tubercles correspond, as do the several foramina. There is of course slight individual variation among the several atlases before me, which I have designated Nos. 1-3. The measurements, all maximum, follow:

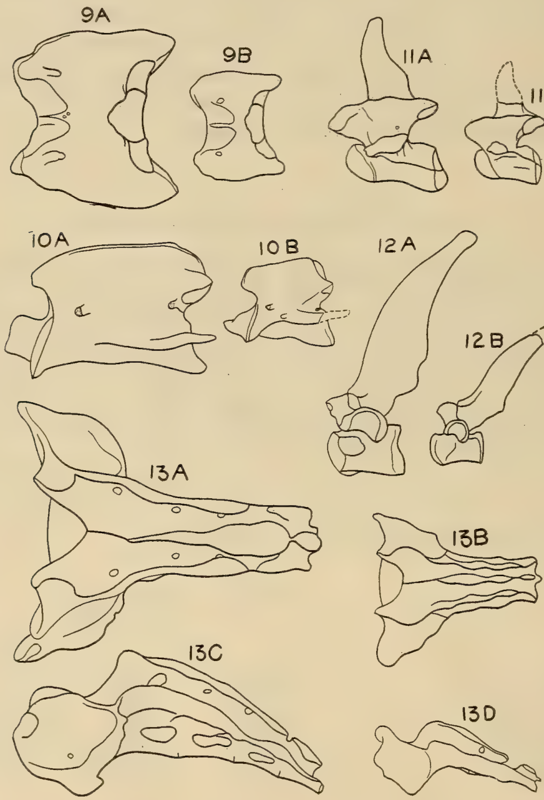


FIG. 9. Atlas, dorsal aspect. A, *Antilocapra;* B, *Aletomeryx.* One-third natural size.

FIG. 10. Axis, left lateral aspect. A, *Antilocapra;* B, *Aletomeryx.* One-third natural size.

FIG. 11. Cervical VI. A, *Antilocapra;* B, *Aletomeryx.* One-third natural size.

FIG. 12. Dorsal I. A, *Antilocapra;* B, *Aletomeryx.* One-third natural size.

FIG. 13. Sacrum. A, dorsal aspect, *Antilocapra;* B, same, *Aletomeryx;* C, left lateral aspect, *Antilocapra;* D, same, *Aletomeryx.* One-third natural size.

	Aletomeryx 1	2	3	Average *Aletomeryx*	*Antilocapra* 180 female	Ratio
	m.	m.	m.	m.	m.	
Length	·0359	·0373	·0360	·0364	·0626	1·72
Width	·0430	·0440*	·0470	·0444	·0693	1.56
Depth over tubercles	·0210	·0243	·0280	·0244	·0458	1·87
Neural canal, width	·0137	·0160	·0145	·0147	·0211	1·44
" " depth post.	.0140*	·0135	·0157	·0144	·0210	1·46
" " " ant.	·0114	·0126	·0110·	0117	·0177	1·51
Indices, length to width, 1·22: 1·10						Av. 1·59

* Estimated.

Axis (fig. 10).—The axis bones of *Antilocapra* and *Aletomeryx* (numbered 1-3) are again very similar, the only noticeable distinctions being the flatter centrum and more pointed odontoid process and the greater obliquity of the anterior face in the fossil. The foramen transversarium is also more conspicuous in the fossil. Other differences will show in the table of measurements.

	Aletomeryx 1 Young	2	3	Average 2 and 3	*Antilocapra*	Ratio
	m.	m.	m.	m.	m.	
Length, centrum	·0410*	·0455	·0469	·0462	·0776	1·68
Width, ant. face	·0255	·0270	·0277	·0273	·0430	1·57
Width, across postzygapophysis	·0190	·0236	·0250	·0243	·0315	1·30—
Depth	·0345	Not preserved.			·0520	
Neural canal, width	·0070	·0097	·0097	·0097	·0145	1.50
Neural canal, height	·0070	·0083	·0085	·0084	·0144	1.76
						Av. 1·56

* Epiphysis lacking.

Cervicals III-V.—Cervical III, as in *Antilocapra*, lacks the spinous process which begins to appear in cervical IV, and is better developed in cervical V but is well at the anterior end of the arch. It reaches its culmination in vertebra VII. The principal distinction between cervical V and the equivalent one of *Antilocapra* lies in the position of the transverse process, which lies relatively further forward in the fossil, and the foramen transversarium is single instead of being paired. The vertebral spine is pronounced as in the other cervicals, and tends to become cleft inferiorly.

The dimensions of cervical V are as follows:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Length of centrum	·0320	·0540	1·69
Width, anterior face	·0127	·0176	1·39
Depth, anterior face	·0110	·0177	1·61
Neural canal, height	·0087	·0123	1·41
Neural canal, width	·0109	·0138	1·26
Width across postzygapophysis	·0220	·0360	1·63
			Av. 1·50

Cervical VII.—This bone again resembles very closely that of the prongbuck, the main distinction being the greater fore and aft extension of the zygapophyses, which is true also of cervical VI (see fig. 11), and, although to a less extent, of cervical V. In this feature there is individual variation, at least one seventh cervical of *Aletomeryx* approximating that of *Antilocapra* in this respect. There are well developed capitular rib facets on the after margin of the centrum, but the ventral spine is lacking in both this and the preceding vertebra.

The measurements of cervical VII are as follows:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Centrum, length	·0245*	·0377	1·54
Centrum, width, posterior face	·0190	·0327	1·72
Centrum, height, posterior face	·0130	·0186	1·43
Neural canal, width	·0123	·0164	1·33
Neural canal, height	·0090	·0140	1·55
Width across postzygapophyses	·0254	·0390	1·54
			Av. 1·52

* Allowance made for lacking epiphysis.

Dorsal vertebræ.—In the fossil the dorsal vertebræ are ill preserved, as the spinous process is rarely present and even the neural arch and transverse processes are generally imperfect.

Dorsal I (fig. 12).—A nearly perfect example of this element, aside from the one in the restoration, lacks only the epiphyses and the tip of the spinous process. Again the resemblance to the equivalent bone in *Antilocapra* is most striking, even to the paired longitudinal ridges on the ventral aspect of the centrum. The chief distinction seems to be a double-ridged low process on the posterior margin of the spinous process just above the postzygapophyses. This is indicated but faintly in *Aletomeryx.* There is a little distinction in the arrangement of the minute foramina which penetrate the lateral aspect of the centrum. In *Aletomeryx* the postzygapophysial facets are separate, in *Antilocapra* they are confluent.

The measurements follow:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Centrum, length	·019*	·0290	1·53
Height over all	·055†	·0900	(1·63)
Width across transverse processes	·038	·0567	1·49
Neural canal, height, anterior end	·011	·0134	1·22
Neural canal, width	·012	·0160	1·33
			Av. 1·37

* Allowance made for epiphyses lacking.
† Estimated.

Dorsal XIII.—The thirteenth dorsal vertebra again compares closely with that of *Antilocapra,* the principal distinctions being the proportionately less height of the centrum and the relatively lighter rib facets. The spinous process is incomplete but it seems to have been less erect in the portion preserved.

The measurements follow:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Centrum, length	·0205	·0300	1·46
Centrum, width, posterior	·0200	·0280	1·40
Centrum, height, posterior	·0112	·0186	1·66
Height over all	·0430*	·0700	1·63
Width over transverse processes	.0280	·0404	1·44
Neural canal, height, anterior	·0060	·0100	1·67
Neural canal, width, anterior	·0090	·0130	1·44
			Av. 1.53

* Estimated.

Lumbar vertebræ. Lumbar III.—This bone differs from that of *Antilocapra* mainly in the less pronounced ventral ridge, the relatively greater fore and aft extent of the summit of the spinous process, and the less proportionate height of the centrum and of the entire bone.

The dimensions are:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Centrum, length	·0250	·0340	1·36
Centrum, height, anterior	·0140	·0218	1·55
Centrum, width, anterior	·0185	·0220	1·19
Height over all	·0373	·0707	1·89
Width over transverse processes	·0800*	·1070	1·34
			Av. 1·46

* Estimated.

Lumbar VII.—The most remarkable feature of this bone is the relative length of the centrum, which is ·028 m. long compared with ·0315 for *Antilocapra,* a ratio of but 1·12 as compared with 1·36 for the third lumbars. This would seem to be a more primitive feature. The condition of the bone renders other over-all measurements of little value.

The dimensions are:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Centrum, length	·0280	·0315	1·12
Centrum, height	·0122	·0184	1·51
Centrum, width	·0195	·0264	1·36
			Av. 1·33

Sacrum (fig. 13).—Several sacra are present, none of which consist of more than four vertebræ. In the two specimens of *Antilocapra* before me, however, there are five. This number may be due to the coalescence of the anterior caudal. Some of the fossil sacra must have pertained to animals of equivalent age, so that the four-vertebræ condition may also be looked upon as more primitive. In the male prongbuck No. 1518, the summits of the sacral spines are all free, while in the large female, No. 180, they are coalesced and the third and fourth are broadened out laterally as well. In all the *Aletomeryx* sacra there is a coalescence of the first two or three spines to form the median sacral crest, with somewhat broadened summits. The posterior centra are relatively broader and flatter than in *Antilocapra* and the intercentral (ventral sacral) foramina have less fore and aft extent. In both genera there is a very rapid narrowing of the sacrum from the wings backward, variable, however, in individuals in the fossil. In general the prongbuck sacrum does not taper so much behind the wings as do those of *Aletomeryx*. This greater tapering in the fossil may again be indicative of greater primitiveness.

The measurements follow:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Length over all	·0645	·1000*	1·55
Height over all	·0285†	·0570	2·00
Breadth across wings	·0605	·1000	1.65
Length of centrum I	·0170	·0250	1·47
Length of centrum II	·0155	·0212	1·36
Length of centrum III	·0130	·0200	1·54
Length of centrum IV	·0138	·0180	1·30
Width, posterior end	·0170	·0258	1·52
			Av. 1·55

* Four sacrals only.
† Somewhat crushed.

Caudal vertebræ.—No trace of *Aletomeryx* caudals has been found. It is fair to assume, however, that the tail approximated the average ratio of the vertebral column, about 1·40. Of the caudal vertebræ of *Antilocapra,* No. 180, but two remain. The male, No. 1518, a smaller animal, has a tail ·125 m. long, while the sacrum measures but ·085 m. The sacrum of the mounted *Aletomeryx* measures ·063 m. If the ratio of tail to sacrum were constant, the rule of proportions would give a length of ·0926 m. for that of *Aletomeryx.* This is probably a minimum estimate, as caudal reduction is to be expected in these forms with evolutionary advance.

Ribs.—A number of ribs are present, none of which, however, is complete throughout its entire length. They have no outstanding differences with those of *Antilocapra* except perhaps a less width. At any rate, there seem to be fewer wide ribs in the fossil, but to what extent this apparent difference is due to imperfection of the material is not so clear.

Sternum.—Three sternal elements are present, of which two may pertain to the manubrium; one certainly does. This seems to lack the anterior extremity, otherwise it differs from that of *Antilocapra* in the greater relative volume at mid-shaft, and if correctly oriented, in possessing a dorsal median groove where the prongbuck possesses a ridge. The mid-shaft in *Aletomeryx* is actually wider than in *Antilocapra.* Another sternal, which may be the fourth, is broad and flat, with dilated extremities and a concave dorsal surface. Ventrally, there is a slight longitudinal ridge which is lacking in the prongbuck.

Relative dimensions are:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Manubrium.			
Length	·0360*	·0550	1·53
Width, posterior end	·0117	·0170	1·53
Depth, posterior end	·0100	·0170	1·70
Least width	·0085	·0080	0·94
Sternal IV.			
Length	·0280	·0410	1·46
Greatest width	·0260	·0334	1·28
Least width	·0140	·0547	3.92
			Av. 1·77

* Incomplete.

APPENDICULAR SKELETON.

Fore Limbs.

Scapula (fig. 14).—Many scapular fragments are present, one pair being in excellent condition. Of these, one, the smaller left, which is on the mounted specimen, is proximally perfect and distally partly restored from the impression in the matrix. The other, right, is left out of the mount, as it would be embedded in the flesh, and is therefore available for description. It resembles that of *Antilocapra,* as the figures show (see fig. 14), differing mainly in being more widely triangular in proportion to the length. The ratio of the last dimension greatly exceeds that of vertebral dimensions, as is apparent from the measurements. The spine is high, with a slightly reflected edge in its upper portion. In *Antilocapra,* the reflected edge extends to the acromion. Muscular impressions are comparable. The posterior margins are slightly different. The same is true of the position of the nutritive foramina. The round ligament is clearly impressed in the glenoid fossa in *Antilocapra.* In *Aletomeryx* there is only a slight marginal notch. The outline of the fossa is somewhat more regular in the fossil.

The measurements are:

	Aletomeryx m.	Antilocapra m.	Ratio
Length	·1058	·1990	1·88
Width, vertebral end	·0710±	·1177	1·65
Width, humeral end	·0230	·0426	1·85
Width, least	·0125	·0234	1.86
Index	1 : 0·67	1 : 0·51	
			Av. 1·83

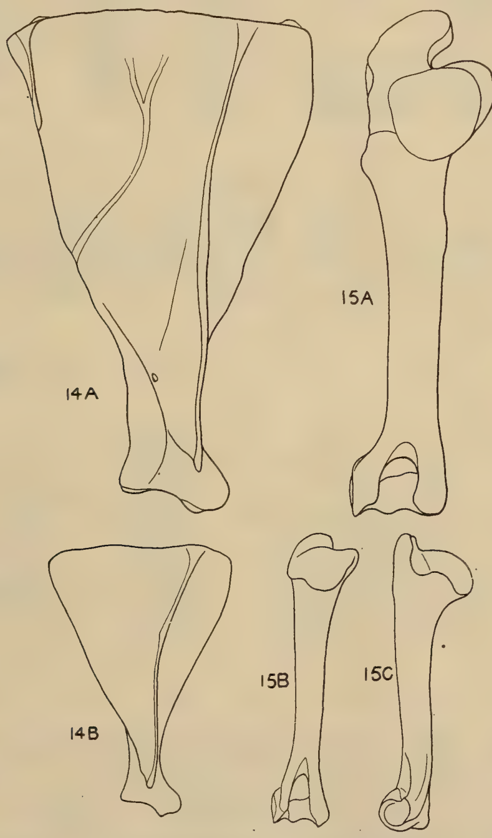


FIG. 14. Scapula. A, *Antilocapra;* B, *Aletomeryx.* One-third natural size.

FIG. 15. Humerus. A, posterior aspect, *Antilocapra;* B, same, *Aletomeryx;* C, external aspect, *Aletomeryx.* One-third natural size.

Humerus (fig. 15).—This bone again resembles that of *Antilocapra* very closely, differing in the relative lightness of the lateral tuberosity in *Aletomeryx* and the greater length of the coronoid and olecranon fossæ which extend higher on the humeral shaft. Other distinctions are very minute, such as the precise position of the various nutritive foramina and the relative proportions as seen in the following table of measurements.

	Aletomeryx 1 (young)	2	*Antilocapra* female 180	Ratios
	m.	m.	m.	1 to 80
Length over all	·1140	·1159	·2000	1·75
Width, lateral, mid-shaft	·0102	·0095	·0192	1·88
Width, prox. end	·0280	·0275	·0505	1·80
Width, dist. end	·0215	·0217	·0370	1·72
Width, ant.-post., mid-shaft	·0130	·0136	·0250	1·92
Width, ant.-post., prox. end	·0307	·0327	·0564	1·83
Width, ant.-post., distal end	·0189	·0192	·0308	1·63
			Av.	1·79

Radius (fig. 16).—The distinctions between this bone and that of *Antilocapra* are so slight as to be incapable of description, as the figures show. The table of measurements follows:

	Aletomeryx	*Antilocapra* female 180	
	m.	m.	Ratio
Length over all	·1245	·2065	1·66
Prox. end, ant.-post. diameter	·0114	·0225	1·97
Prox. end, transverse diameter	·0197	·0370	1·88
Mid-shaft, ant.-post. diameter	·0080	·0120	1·50
Mid-shaft, transverse diameter	·0134	·0210	1·56
Distal end, ant.-post. diameter	·0134	·0244	1·82
Distal end, transverse diameter	·0195	·0340	1·74
		Av.	1·73

Ulna (fig. 16).—No complete ulna of *Aletomeryx* is present. Several proximal ends, however, are available for study, one of which articulates perfectly with the radius which has just been described. Of this, about half the total length is preserved and it differs from that of *Antilocapra* in two respects. The most conspicuous of these is the grooved character of the summit of the olecranon, so that, as in the dog, it bears three prominences, of which the posterior one is large and rounded and the anterior ones, which bound the groove, are thin and elongated, the outermost being the longest. In the prongbuck the groove is lacking, as the inner ridge is obsolete. Neither the ox nor the modern horse exhibit a grooved olecranon, but the ancestral horses *Mesohippus* and *Miohippus* do, as do also the dog and sometimes the cat. This character therefore seems to be a primitive one, and hence its presence in *Aletomeryx* does not exclude the genus from the direct ancestry of *Antilocapra.* The shaft of the fossil ulna is not so thin relatively as in the prongbuck, nor does its outline suggest such a degree of reduction of the distal portion as in the modern animal.

The measurements are:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Length over all	·1490*	·2480	1·66
Prox. (olecranon) ant.-post. diam.	·0187	·0290	1·55
Prox. (olecranon) transverse diam.	·0085	·0134	1·57
Mid-shaft, ant.-post. diameter	·0057	·0060	1·05
Mid-shaft, transverse diameter	·0014	·0028	2·00
Distal end	Not preserved.		
			Av. 1·56

* Estimated.

Carpals (figs. 16, 17).—All of the carpalia are present. They differ only in minor details from those of the prongbuck, as the figures show.

Metacarpals (fig. 17).—Metacarpalia I, II, III, and IV are present, the second and third being united into a cannon-bone which again resembles that of the antelope very closely, differing therefrom in dimensions and in the very distinct impression of metacarpal V on the proximal half. The inner side of the cannon-bone shows no such impression. Below, the bone is rounded, nevertheless both lateral digits were present, as they are preserved in the material. To what extent, therefore, the lateral metapodials were developed it is difficult to say, as not more than an inch of the distal end of the inner one is preserved, and merely the articular extremity of the outer. There are impressions of both lateral metacarpals on either side of the distal extremity. No such impressions are visible in the prongbuck, where the lateral toes are entirely lacking.

The measurements of the left fore cannon-bone are:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Length over all	·1190*	·2100	ca. 1·76
Prox. end, ant.-post. diam.	·0117	·0203	1·73
Prox. end, transverse diam.	·0160	·0286	1·79
Mid-shaft, ant.-post. diam.	·0088	·0145	1·65
Mid-shaft, transverse diam.	·0100	·0156	1.56
Distal end, ant.-post. diam.	·0107*	·0192	1·80
Distal end, transverse diam.	·0178*	·0277	1·56
			Av. 1.69

* The distal end is from another individual than that from which the entire shaft with its proximal end was derived.

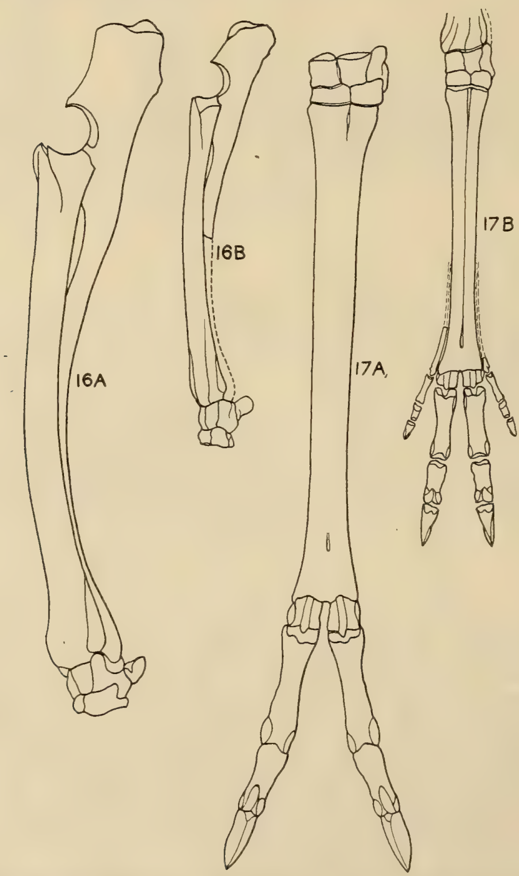


Fig. 16. Left radius, ulna, and carpus. A, *Antilocapra;* B, *Aletomeryx.* One-third natural size.

Fig. 17. Manus, dorsal aspect. A, *Antilocapra;* B, *Aletomeryx.* One-third natural size.

Phalanges (fig. 17 A, B).—It has been extremely difficult to separate the phalanges of the fore feet from those of the hind, the unguals only showing constant differences in a measure comparable to those of the prongbuck. The unguals differ from those of the latter in having an acuminate upper posterior angle, especially in those referred to fore feet, whereas in the prongbuck this angle is always rounded.

Dimensions of the outer phalanges of the left manus follow:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Proximal phalanx.			
Length	·0278	·0500	1·79
Shaft, width	·0064	·0089	1·39
Medial phalanx.			
Length	·0167	·0278	1·66
Shaft, width	·0058	·0086	1·48
Ungual phalanx.			
Length	·0175	·0310	1·78
Height	·0120	·0217	1·80
Width	·0068	·0102	1·50
			Av. 1·63

Lateral digits (fig. 17 B).—Of these there are preserved the distal portion of a metacarpal, together with a proximal, two medial and two ungual phalanges, all from the right side of a foot, but whether they represent the second of the left or the fifth of the right manus I cannot say. There is also the distal epiphysis of the metacarpal and the proximal phalanx from the opposite side of the foot. These seem to be a little larger and more robust than do their opposites, but whether or not this is due to individual variation can not be ascertained. The phalanges are typically flattened on their medial face, and rounded externally. They bear much the same proportions to one another as do those of digits III and IV.

The dimensions are:

	1 m.	2 m.
Length of proximal phalanx	·0105	·01052
Length of second phalanx	·0040	·0040
Length of ungual phalanx	·0082	·0070

Hind Limbs.

Pelvis (fig. 1). Os innominatum.—One fairly well-preserved pelvis and others less perfect are present, the best one being that in the mounted skeleton. It shows few distinctive characters as compared with that of *Antilocapra,* except a greater simplicity of surface, in that the muscle limitations are somewhat less pronounced. Few relative dimensions can be given because of the imperfection of the fossils. Those available are:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Length over all	·1300	·2430	1·87
Right ilium, width, ant. end	·0670	·0988	1·48
Right ilium, least width	·0133	·0223	1·68
Acetabulum, ant.-post. diameter, inside rim	·0160	·0293	1·83
Right ischium, width, mid-length.	·0150	·0237	1·58
			Av. 1·69—

Femur (figs. 18, 19).—Herein again there are very close resemblances between the fossil and the living prongbuck, the differences as usual being of minor importance, such, for instance, as the somewhat greater slenderness of the great trochanter. These distinctions are best seen in the figures, and in the following table of measurements:

	*Aletomeryx** m.	*Antilocapra* m.	Ratio
Length over all	·1460	·2330	1·60
Prox. end, ant.-post. diameter	·0160	·0290	1·81
Prox. end, transverse diameter	·0350	·0575	1·64
Mid-shaft, ant.-post. diameter	·0130	·0193	1·48
Mid-shaft, transverse diameter	·0123	·0200	1.62
Distal end, ant.-post. diameter	·0365	·0580	1·59
Distal end, transverse diameter	·0293	·0455	1·55
			Av. 1·61

* Composite bone.

Patella (fig. 24).—The patella of *Aletomeryx* is a variable bone, but is in each instance prolonged downward into an attenuated point, giving it a more markedly triangular outline.

Relative dimensions of an average *Aletomeryx* patella and that of *Antilocapra* follow:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Length	·0246	·0342	1·35-1·39
Width	·0158	·0237	1·50
Thickness	·0107	·0217	2·02
		Av.	1·62

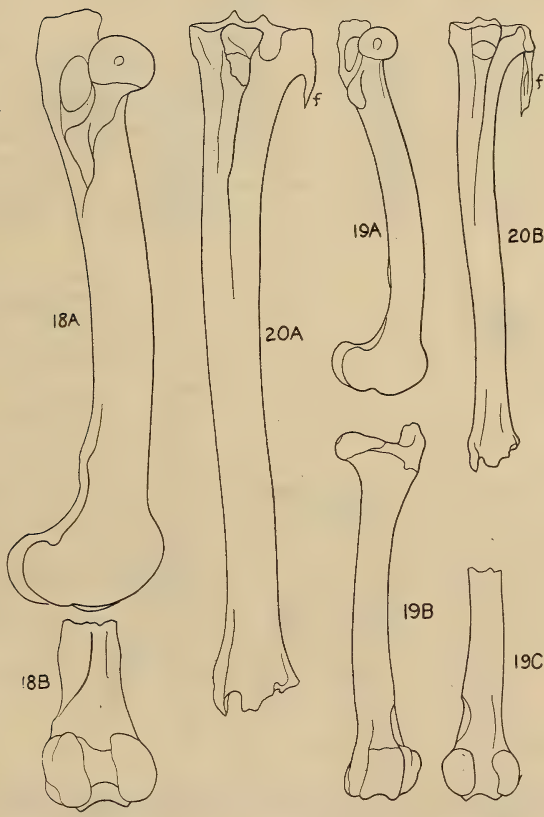


FIG. 18. Left femur of *Antilocapra*. A, inner aspect; B, distal end, posterior aspect. One-third natural size.
FIG. 19. Left femur of *Aletomeryx*. A, inner aspect; B, anterior aspect; C, distal end, posterior aspect. One-third natural size.
FIG. 20. A, left tibia of *Antilocapra;* B, left tibia and proximal end of fibula (*f*) of *Aletomeryx*, anterior aspect. One-third natural size.

Tibia and fibula (figs. 20, 21).—The tibiæ in *Aletomeryx* and *Antilocapra* are quite comparable, as are the distal ends of the fibulæ, which are complete bones in themselves, with the merest vestige of a shaft. Proximally the fibula of *Antilocapra* is reduced to a thoroughly ankylosed bony process depending from the outer posterior corner of the tibial head. In *Aletomeryx*, on the other

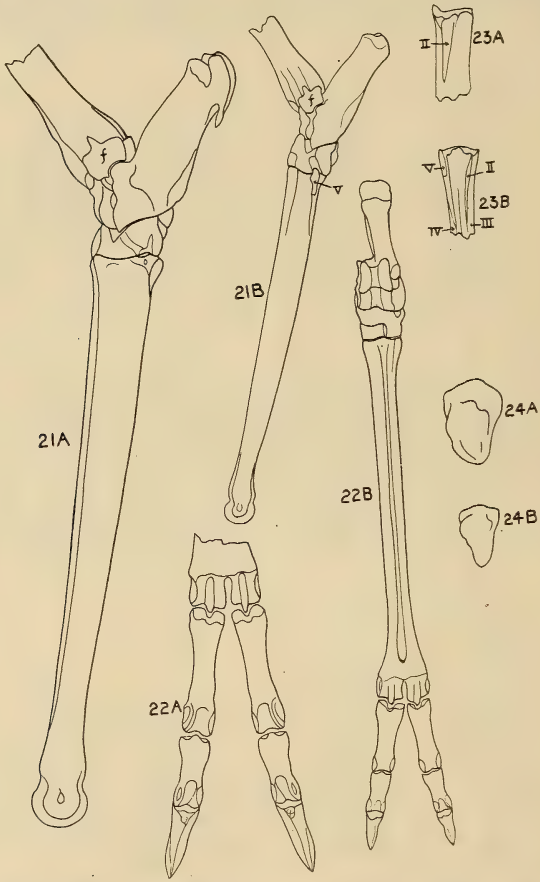


FIG. 21. Left tarsus and metatarsus. A, outer aspect, *Antilocapra: f,* distal end of fibula. B, *Aletomeryx*: *f,* distal end of fibula; *v,* vestige of metatarsal V. One-third natural size.

FIG. 22. A, phalanges of *Aletomeryx,* dorsal aspect; B, left pes of *Aletomeryx,* anterior aspect. One-third natural size.

FIG. 23. A, proximal end of left cannon-bone of *Aletomeryx,* showing vestigial metatarsal II; B, rear aspect of same, showing metatarsals II, III and IV combined, and V, the last being free. One-third natural size.

FIG. 24. Patella. A, *Antilocapra;* B, *Aletomeryx.* One-third natural size.

hand, the proximal end of the fibula was free, articulating by a facet on the equivalent portion of the tibia. About an inch of what is undoubtedly the proximal end of the left fibula is present. The epiphysis is lacking, but the hollow shaft shows within the length no sign of diminution. Its total length, however, one can not conjecture. Several areas for tendinous attachment appear just beneath the expanded summit of the bone.

Measurements of the tibia and fibula follow:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Tibia.			
Length over all	·1750	·2720	1·54
Prox. end, ant.-post. diameter	·0333	·0546	1·64
Prox. end, transverse diameter	·0322	·0470	1·46
Mid-shaft, ant.-post. diameter	·0122	·0180	1·46
Mid-shaft, transverse diameter	·0130	·0195	1·50
Distal end, ant.-post. diameter	·0160	·0250	1·56
Distal end, transverse diameter	·0209	·0328	1·58
			Av. 1·53
Fibula, distal end.			
Height	·0090	·0160	1·76
Ant.-post. diameter	·0118	·0177	1·50
			Av. 1·63

Tarsus (figs. 21, 22 B).—This region of the foot again resembles that of the antelope very closely, as does the metatarsus. In *Aletomeryx,* the first cuneiform can not be identified in the fossil material and seems to be about the only element lacking, aside from those mentioned above. That it was present, however, is evident.

Dimensions of the assembled tarsus follow:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Length, tuber calcis to cuneiform III	·0610	·0930	1·51
Width across calcaneum and astragalus	·0180	·0295	1·63
Ant.-post. diameter, calcaneum and astragalus	·0225	·0370	1·66
			Av. 1·60

Metatarsus.—The cannon-bone (figs. 21-23) differs mainly in the somewhat greater relative width of the distal end and in the very distinct triangular groove for metatarsal V. Two examples of the latter are present, both from the left side and differing considerably in size. Metatarsal II (fig. 23) is present, but coalesced with the cannon-bone. It tapers to a point distally and varies materially in its length and other dimensions.

Dimensions of the cannon-bone are:

	Aletomeryx m.	*Antilocapra* m.	Ratio
Length over all	·1400	·2200	1·57
Proximal end, ant.-post. diameter	·0160	·0253	1·58
Proximal end, transverse diameter	·0157	·0256	1·63
Mid-shaft, ant.-post. diameter	·0107	·0165	1·54
Mid-shaft, transverse diameter	·0096	·0150	1·56
Distal end, ant.-post. diameter	·0128	·0195	1·52
Distal end, transverse diameter	·0195	·0280	1·43
			Av. 1·54

Phalanges (fig. 22).—Whether or not lateral digits were present I am unable to say. Certainly the manus bore them, but there is no discernible evidence of their presence either on the cannon-bone or in the material itself, as these elements are extremely rare, due no doubt to their minuteness. The little distinction discernible between the phalanges of manus and pes is discussed above (see under manus). The length of the entire hind limb extended is:

Aletomeryx	*Antilocapra*	Ratio
·537 m.	·850 m.	1·58

Of the extended fore limb:

Aletomeryx	*Antilocapra*	Ratio
·420 m.	·720 m.	1·71

The hind limbs are therefore proportionately longer in *Aletomeryx*, which is in keeping with their relatively more advanced condition as compared with the more conservative four-toed fore limb.

BLASTOMERYX MARSHI, N. SP.

(Fig. 25).

In searching in the Marsh Collection for material for comparison, I discovered a specimen bearing the initials O. C. M. and the date June 27, 1873. This material was collected by the Yale College expedition of 1873, which worked eastward along the Niobrara River from the mouth of Antelope Creek to Fort Niobrara, a distance of 85 to 100 miles, between the dates of June 24 and July 7. We have no record of the number of camps nor of the rate of progress during these two weeks. One would judge that they made about four hauls, certainly not fewer, in covering the distance. The presumption is, therefore, that this specimen collected on the 27th must have been found within 25 miles of the locality of *Aletomeryx* and from an approximately equivalent geologic level.

The specimen, Cat. No. 10756, holotype, consists of a skull and jaws, three dorsal and three lumbar vertebræ, a femoral head, the humeral end of the right scapula, and two rib fragments.

The skull, while in fragments, was nevertheless susceptible of repair, such portions as were absent on the one side being present on the other, so that little that is essential is lacking. The dentition, while rather badly worn, is perfect except for the two median incisors and the second and third, together with the inferior canine of the left side. The upper canines are missing, but their alveoli are present and give indication of their size and curvature. Coupled with the well developed laniary tusks were rudimentary horns comparable to those of the female of *Aletomeryx,* though somewhat larger, or to those of the female prongbuck, from which they differ in their position, overhanging as they do the rim of the orbit, and again in being relatively larger. This creature is evidently a *Blastomeryx* and proves beyond question that *Aletomeryx* belongs to a separate phylum, though probably a local contemporary. The two forms differ very markedly in skull profile, *Blastomeryx* being decidedly convex, while *Aletomeryx* is more nearly straight, correlated with the presence or absence of the canine tusk. The *Blastomeryx* skull, while only slightly larger than that of *Aletomeryx,* has nevertheless a more ex-

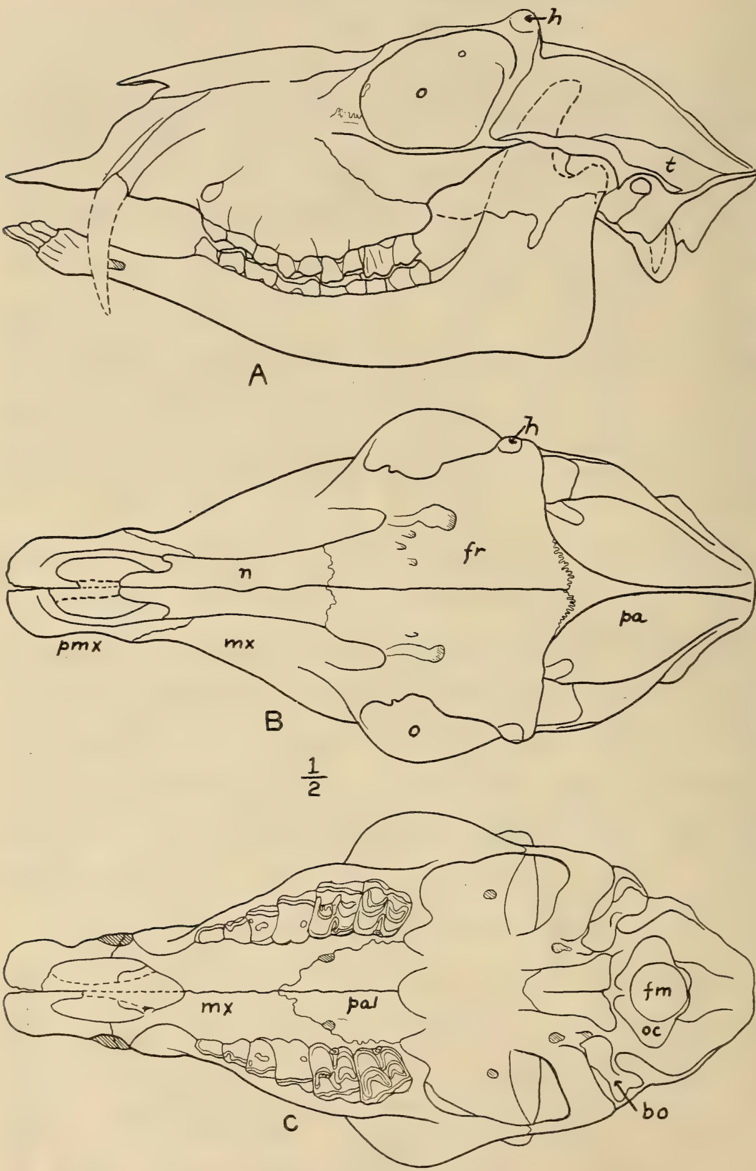


Fig. 25. Skull of *Blastomeryx marshi*. A, left lateral; B, dorsal, and C, ventral aspect. *bo,* auditory bulla; *fm,* foramen magnum; *fr,* frontal; *h,* horn; *mx,* maxillary; *n,* nasal; *o,* orbit; *oc,* occipital condyle; *pa,* parietal; *pal,* palatine; *pmx,* premaxillary; *t,* temporal. One-half natural size.

tended cranial region, and this shows in the brain as well, for not only is the entire organ relatively longer in *Blastomeryx,* but the same proportions are borne out in the individual lobes and convolutions, which are otherwise quite comparable in the two forms, differing only in very minor details. The teeth also are very similar, differing mainly in the relatively larger posterior molar in *Blastomeryx.* They are comparable in length of crown, in the presence of the style between the two inner crescents of the molars, and in the rugosity of the enamel. They also compare in the character of the parietal crest, and in the position of the horns above the posterior limitation of the orbit. This *Blastomeryx* differs from *Dromomeryx* as defined by Douglass in its much smaller size, the character and much smaller size of the horns, the presence of the superior canine, and the fact that the cheek teeth show no tendency toward hypsodonty. The posterior lower molar in the *Blastomeryx* shows a style ("median outer pillar") as in *Dromomeryx.* The others are too much worn to show either this character or the presence of the "*Palæomeryx* fold" if such existed.

Summary.

The genus *Blastomeryx* was proposed by Cope in 1877[11] to include the species formerly described by him as *Dicrocerus gemmifer* from the middle Miocene and which he differentiated from *Dicrocerus* by the fact that in the latter the "true molars [were] without or with one rudimental accessory basal column," whereas in *Blastomeryx the* "true molars [were] with more or less developed basal columns." Matthew in 1908[12] gives a clear description of the generic characters of *Blastomeryx* and summarizes the known species, giving the list as follows:

Lower Miocene: *B. advena* Matthew, *B. primus* Matthew, and *B. olcotti* Matthew. Of *B. gemmifer* he says:

"The type specimen of *B. gemmifer* is a third lower molar and is a little larger and more robust [than in *B. advena*], agreeing more nearly with *B. primus* and *olcotti,* and not clearly separable from them; but probably if it were better known its stage of

[11] Cope, E. D., U. S. Geog. Surv. West 100th Merid., vol. 4, Palæontology, p. 350.

[12] Matthew, W. D., Bull. Amer. Mus. Nat. Hist., vol. 27, pp. 535-562.

evolution would be demonstrably more advanced, as it is in the referred specimen from the same level and locality, the middle Miocene, Pawnee Creek beds of Colorado."

B. wellsi Matthew[13], considerably larger than *B. gemmifer,* occurs in the upper Miocene of the Republican and Little White River valleys, the type being a lower jaw from the Loup Fork beds near the Rosebud Agency, South Dakota. *B. wellsi* differs from *B. gemmifer* in that the premolars are relatively smaller and simpler in the former; the molars are very similar, and the jaw shorter and heavier in general outline. The molars are larger and somewhat longer-crowned than in either *B. primus* or *B. olcotti.*

In 1890 Professor Scott[14] described a species which he refers to *Blastomeryx* but without specific designation. The horizon he calls Loup Fork, and it is at least upper Miocene and probably lower Pliocene. The main distinctions as given by Matthew in the later paper are the more advanced skull and skeletal structure than in *B. primus,* and the much larger size, with a small or rudimentary antler; the orbits are far more prominent, and the ulnar shaft is reduced to "a mere thread of bone"; the lateral digits are much more reduced and the shafts of the lateral metacarpals incomplete. Matthew goes on to say:

"This can not well be congeneric with the lower Miocene species, whether or not it be regarded as derived from them. If we do so regard it, *B. gemmifer* would probably represent an intermediate stage, as is indicated, in fact, by the little we know of it. In view of the near agreement in size and other characters between *B. gemmifer* and the lower Miocene species, it seems preferable to place the latter in *Blastomeryx,* and regard the species described by Scott as referable to a more advanced genus, with rudimentary antlers and with the lateral digits of the fore foot incomplete. It seems inadvisable to name the upper Miocene [Scott] genus until we know something more definite of its dentition and skull characters and its distinctions, if any, from *Mazama.*"

Four other species have been described: *Blastomeryx antilopinus* Scott, *B. borealis* Cope, *Palæomeryx americanus* and *P. madisonius* Douglass. These, as Matthew

[13] Bull. Amer. Mus. Nat. Hist., vol. 20, p. 124, fig. 17, 1904.
[14] Bull. Mus. Comp. Zool., vol. 20, p. 76.

says, belong to a larger and more brachyodont phylum of Cervidæ, with supraorbital horns of peculiar type. They are distinct from *Blastomeryx,* probably also from the true *Palæomeryx,* but at present of uncertain relationship. These four species Douglass (1909)[15] has referred to a new genus *Dromomeryx,* the characters of which he describes in detail:

Size greater than that of an ordinary specimen of *Odocoileus americana* or *Antilocapra americana,* at least the bones are heavier. Skull long, crest of the occiput produced backward, face quite long, orbit large, malar below the orbit projects outwardly. Horn cores large and simple, and they expand outward below into heavy lateral wings behind the upper portions of the orbits. They stood nearly perpendicular to the upper plane of the skull. There are no lachrymal pits. Oblong vacuity in upper portion of face anterior to orbit. Parieto-temporal suture below the middle of the brain-case. Basi-cranial and basi-facial axis form a considerable angle. Palate quite broad between cheek teeth, narrow anterior to them (probably indicative of absence of canines). Mandible long, not deep, and curves downward beneath molars and premolars. Teeth brachyodont, with a tendency to become hypsodont, and with quite prominent pillars on anterior portions of all the outer crescents of the upper cheek. Lower molars have median outer pillars on teeth and "*Palæomeryx* folds" on the anterior outer crescents. Neck and limbs long but heavier than those of *Odocoileus* and *Antilocapra.* At least vestiges of lower portions of lateral metapodials. Humerus proportionately larger than in *Antilocapra.* Radius and ulna separate, trapezoid and magnum, navicular and cuboid united. Distal keels of metapodials high, unguals high and narrow.

The species of "*Blastomeryx*" described by Scott in 1890 can not be distinguished from *Aletomeryx* from either his description or his figures, except that the ulna of *Aletomeryx,* which is preserved for at least half its length, can not be described as being "hardly more than a thread of bone," as it is well developed, more like a ribbon than a thread (see figs. 1, 16 B). Scott does not describe the character of the horn other than to say that

[15] Ann. Carnegie Mus., vol. 5, pp. 457-479.

it is small or rudimentary, which applies very well to the female horn of *Aletomeryx.*

Matthew's opinion, expressed verbally (December, 1919), is that *Aletomeryx* has for its nearest known relative *Merycodus,* despite the fact that the latter bore a branched antler. The similarities are based upon skeletal characters, and the dentition. He agrees with the author that *Aletomeryx* is related to the true Antilocapridæ, although he does not commit himself as to its direct ancestry with the existing prongbuck. There is, however, no known detail of structure which would debar the fossil from the ancestral line.

ART. X.—*The Binary System Åkermanite-Gehlenite;* by J. B. FERGUSON and A. F. BUDDINGTON.

The assignment of formulæ to minerals of variable composition is a problem which often confronts and perplexes the mineralogist. In general he must rely upon analyses, frequently made on impure material. The divers explanations of the complex mineral groups, which have resulted, bear evidence to the difficulties that hamper anyone who endeavors to glean the truth from such results. Unfortunately, to date, the laboratory studies on mineral systems have not afforded the aid that many may have expected of them. This has been due, more to the tedious character of the researches required and the necessity of building from firm foundations, rather than to any inherent defects in the laboratory methods themselves. In view of this situation it is with a feeling of distinct pleasure that we present the results of a research which owes its directional character to the statistical studies of a mineralogist and its successful completion to the earlier laboratory studies without which it could not have been carried out.

The compound $2CaO . Al_2O_3 . SiO_2$, which will be referred to throughout this paper as gehlenite, was thoroughly investigated by Rankin and Wright[1] in the study of the ternary system $CaO\text{-}Al_2O_3\text{-}SiO_2$. The optical properties given by them are:

Tetragonal
(001) distinct
negative
ω 1.669
ϵ 1.658
$\omega\text{-}\epsilon$ 0.011

The density is 3.038 and the melting point 1590°C. The refractive index of the glass of this composition as later determined by us is 1.638 ± 0.002.

The compound $2CaO . MgO . 2SiO_2$ was discovered by Ferguson and Merwin[2] in their study of the ternary system $CaO\text{-}MgO\text{-}SiO_2$ and the mineral åkermanite was thought by them to consist essentially of this compound.

[1] G. A. Rankin and F. E. Wright, this Journal, 39, 26, 1915.
[2] J. B. Ferguson and H. E. Merwin, this Journal, 48, pp. 118 and 122, 1919.

The optical properties given by them for the artificial material are:

Tetragonal
positive
ω 1.631
ϵ 1.638

The melting point is 1458° C. The density was not determined by them. Schaller[3] gives 3.12 for the mineral. We have determined it on the artificial material and find the density to be 2.944 at 25° C. The refractive index of the glass of this composition as determined by us is 1.641 ± 0.002.

Although the X-rays have not yet led to a clear definition of the crystalline character of solid solutions, still there is a well-grounded belief that substances of similar optical properties and like molecular volumes[4] are more likely to form solid solutions than others. If this hypothesis is any criterion of such possible behavior, one would surely predict that åkermanite and gehlenite would form a continuous series of solid solutions, for in addition to the similar optical properties which they possess, their molecular volumes are nearly equal, being $273.06/2.944 = 92.8$ and $274.64/3.038 = 90.4$ respectively if we assume the formulæ previously given to correctly interpret their molecular condition. In his study of the melilite group of minerals, partly on these grounds and partly for other reasons, Schaller[5] arrived at a similar conclusion although he gave to åkermanite a slightly different composition from that assumed by us. A consideration of his deductions led us to undertake the study of this binary system since it appeared to be the most effective way in which to start a comprehensive laboratory study of the minerals of the melilite group.

Method.—The quenching method was employed throughout the entire research. Details of this method may be found in many of the previous publications from the laboratory. The thermal apparatus was the identical apparatus used by Ferguson and Merwin in their study of the ternary system CaO-MgO-SiO_2 and perhaps refer-

[3] W. T. Schaller, U. S. Geol. Survey, Bull. 610, page 117, 1916. When later in the paper we refer to Schaller, the reference is that given here.

[4] A. E. H. Tutton; Crystalline Structure and Chemical Constitution, page 128, London, 1910.

[5] Schaller has given to the compound which we call gehlenite the name velardinite. We will refer to this later in the paper.

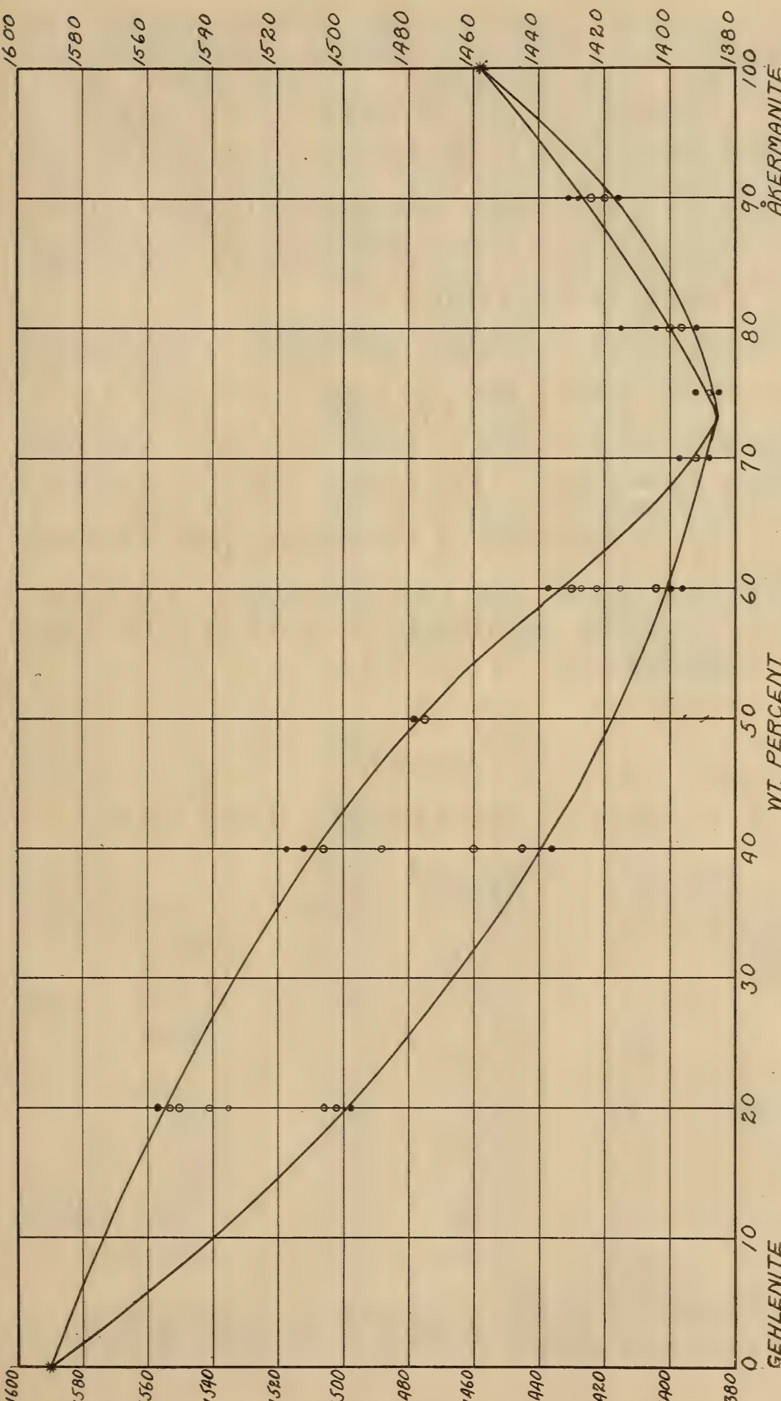


FIG. 1.—The temperature-composition diagram. The compositions are given in weight percent but may with slight error be regarded as mols percent.

ence should be made, therefore, to their paper.[6] The melting points used in the calibration of the thermoelement were: gehlenite 1590°C.; anorthite 1550°C.; åkermanite 1458° C., and diopside 1391.5° C. The presence of considerable iridium in the platinum foil, used to hold the charges, gave rise to an extremely annoying contamination of the thermoelement, necessitating repeated calibrations and rendering almost impossible the obtaining of thermal results which could be considered to have a relative accuracy of better than 4°C.[7]

For the study of the optical properties of the crystals of intermediate composition, the method of crystallizing undercooled glasses gave the best results. Zoned crystals usually were obtained from charges which had been heated at temperatures at which both liquid and solid phases could co-exist. For the first method, a treatment overnight at a temperature just below the temperature at which the beginning of the melting took place was sufficient.

Thermal Results and Their Discussion.—The results of the quenching experiments are given in Table I and interpreted graphically in figure 1.

TABLE I.

The quenches which yielded significant thermal results. *

Composition wt. percent. Gehlenite.	Åkermanite.	Temperature in degrees Centigrade.	Time in minutes.	Phases present.
100	0	1592	15	Glass
		1588	15	Crystals
		1590	15	Crystals + trace glass
0	100	1459	15	Glass
		1457	15	Crystals
10	90	1431	15	Glass
		1429	15	Glass
		1427	15	Glass
		1424	15	Glass + crystals
		1420	15	Glass + crystals
		1416	15	All crystals

[6] This Journal, 48, 88, 1919.

[7] Under the best conditions results which have a relative accuracy of 1°C may easily be obtained.

Composition wt. present. Gehlenite.	Akermanite.	Temperature in degrees Centigrade.	Time in minutes.	Phases present.
20	80	1415	15	Glass
		1404	15	Glass
		1400	15	Glass + crystals
		1397	15	Glass + crystals
		1394	15	All crystals
25	75	1390	15	Glass + trace crystals**
		1388	15	Glass + crystals**
		1386	20	Trace glass + crystals
		1385	45	Crystals
30	70	1397	15	Glass
		1394	15	Glass + crystals
		1392	15	Glass + crystals
		1390	15	Crystals
40	60	1437	15	Glass
		1432	15	Glass
		1430	15	Glass + crystals
		1406	15	Trace glass + crystals
		1404	15	Trace glass + crystals
		1400	15	Crystals
		1396	15	Crystals
50	50	1475	15	Trace crystals
		1478	15	Glass
60	40	1517	15	Glass
		1512	15	Glass
		1506	15	Glass + crystals
		1488	15	Glass + crystals
		1460	15	Glass + crystals
		1445	15	Glass + crystals
		1441	15	Crystals
80	20	1560	15	Glass
		1557	15	Glass
		1553	15	Glass + crystals
		1550	15	Glass + crystals
		1541	15	Glass + crystals
		1535	15	Glass + crystals
		1524	15	Glass + crystals
		1510	15	Glass + crystals
		1502	15	Glass + crystals
		1498	15	Crystals

* The initial material was crystallized by long heating previous to use because of the tendency of the glasses to undercool.

** Simultaneous experiment with diopside gave all crystals.

The system affords an excellent example of a series of solid solutions with a minimum melting point. This point lies at 1388°C., a little below the melting point of diopside and corresponds to the composition of about 74 per cent åkermanite, 26 per cent gehlenite. Thus the minimum is 70 degrees below the melting point of åkermanite, the component with the lower melting point. On the åkermanite side of the minimum, the hiatus has a maximum value of 8 degrees and on the gehlenite side the hiatus has a maximum value of 70 degrees.

The liquidus and solidus curves are typical in shape and, were the proper thermal data available, a check upon their location might be made by means of thermodynam-

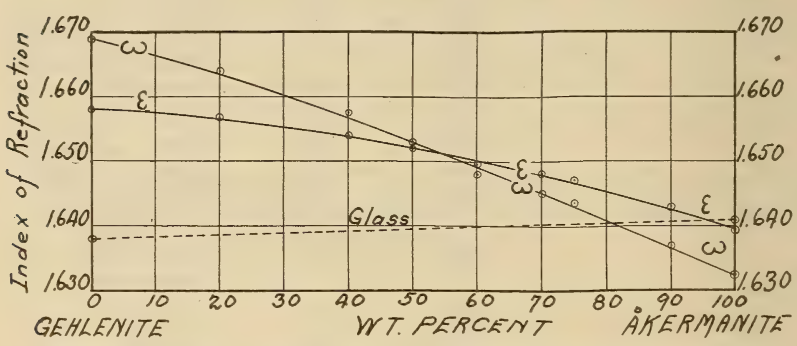


FIG. 2.—Refractive indices plotted against composition in weight percent, for crystals and glasses.

ical calculations. Such calculations would also give some idea as to the molecular complexity of the components but in view of the lack of such data there is little use entering into any discussion of this character. Those interested are referred to the various papers by J. J. Van Laar[8] upon solid solutions in systems of two components.

Optical Characters.—Åkermanite and gehlenite have similar crystal habits. Both are tabular parallel to the base and in sections appear as laths and octagonal and rectangular plates. The optical characters of crystals with the composition of åkermanite and gehlenite and of intermediate mixtures are given in Table II. In fig. 2, curves for the indices of refraction for sodium light of both crystals and glasses plotted against composition in weight percent are given. The indices of refraction are correct to ± 0.002.

[8] Zs. phys. Chem., 63, 225, 1908; 64, 265, 1908.

TABLE II

Optical characters of artificial crystals of the Akermanite-Gehlenite series.

Composition wt. percent. Gehlenite.	Åkermanite.	ω_{Na}	ϵ_{Na}	Birefringence.	Optical character.	Elongation.
100	0	1.669	1.658	0.011	—	γ
80	20	1.664	1.657	.007	—	γ
60	40	1.657+	1.654	.004	—	γ
50	50	1.653	1.652	.001	—	γ
40	60	1.648—	1.649+	.001+	+	a
30	70	1.645	1.648	.003	+	a
25	75	1.643	1.647	.004	+	a
10	90	1.637	1.643	.006	+	a
0	100	1.632+	1.639+	.007	+	a

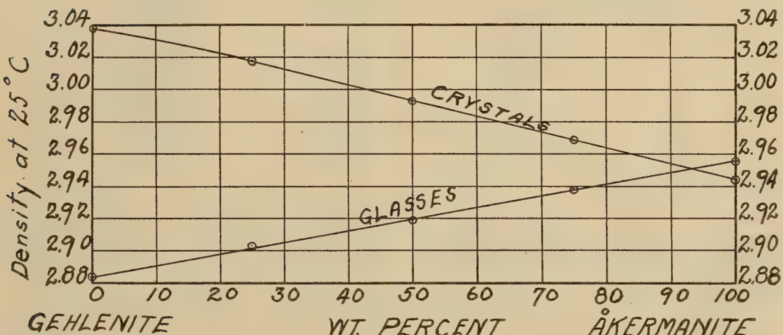


FIG. 3.—Densities plotted against composition in weight percent, for crystals and glasses.

The optical character of åkermanite is positive and that of gehlenite is negative. In intermediate mixtures the birefringence for sodium light decreases from 0.011 for gehlenite at one extreme and 0.007 for åkermanite at the other, to zero at a composition lying between 50 per cent gehlenite–50 per cent åkermanite, and 40 per cent gehlenite–60 per cent åkermanite. Crystals of a certain definite composition between these limits are isotropic for sodium light. Owing to fluctuations of temperature, zoned crystals were repeatedly obtained from solutions of each of these compositions which exhibited a core of higher index of refraction, negative optical character, and very low birefringence with blue-gray interference colors surrounded by a zonal growth of material of lower index of refraction, positive optical character, and higher birefringence with yellow interference colors. Similar features have been observed and described by Smyth[9] in natural melilite crystals occurring in alnoite at Manheim, New York.

Densities.—The densities at 25°C. of both crystals and glasses with the composition of åkermanite, of gehlenite, and of intermediate mixtures are given in Table III. In fig. 3 they are plotted against composition in weight percent. The densities were determined by the method

TABLE III

Densities of artificial crystals and glasses of the Akermanite-Gehlenite series, at 25° C.

Composition wt. percent. Åkermanite	Gehlenite.	Density crystals.	Density glasses.
0	100	3.038	2.884
25	75	3.018	2.903
50	50	2.993	2.919
75	25	2.969	2.938
100	0	2.944	2.955

of Day and Allen,[10] using the modified type of pycnometer bottle suggested by Johnston and Adams.[11] The crystals were prepared by heating a charge of appropriate composition over night a little below the temperature of beginning of melting. The values are correct to ± 0.003.

It will be noted that in the case of åkermanite the glass has a higher density than the crystals at a temperature of 25°C. This unusual relation is confirmed by the relative values of the indices of refraction for glass and crystal, the index for the former being a trifle higher than the maximum index of refraction for the latter. This does not necessarily mean that crystalline åkermanite contracts and becomes denser on melting, because the coefficients of expansion of the glass and the crystal are probably different and the difference between their densities at 25° C. is so small that their relative densities may be reversed at the temperature of melting.

Specific volumes.—In Table IV are given the computed

[9] C. H. Smyth, this Journal, 46, 104, 1893.

[10] Day and Allen, Carnegie Institution of Washington, Publication 31, 1908.

[11] Johnston and Adams, Jour. Am. Chem. Soc., 34, 563-584, 1912.

values of the specific volumes for glasses and crystals of the composition of åkermanite, gehlenite, and several intermediate mixtures. In fig. 4 curves for the specific volumes plotted against the composition in weight percent are shown.

TABLE IV

Specific volumes of artificial crystals and glasses of the Akermanite-Gehlenite series.

Composition wt. percent Åkermanite.	Gehlenite.	Sp. vol. crystals.	Sp. vol. glasses.
0	100	90.4	95.2
25	75	90.8	94.5
50	50	91.5	93.8
75	25	92.1	93.1
100	0	92.8	92.4

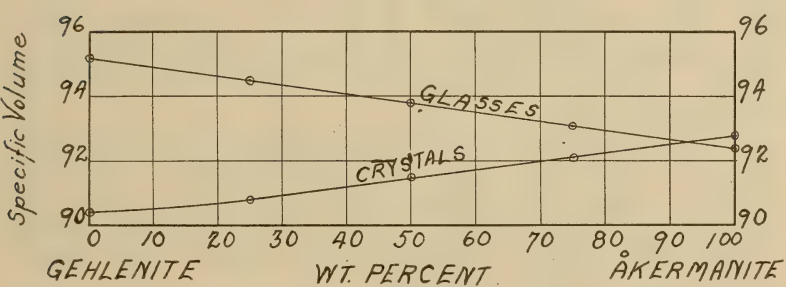


FIG. 4.—Specific volumes plotted against composition in weight percent, for crystals and glasses.

Vogt[12] has discussed the relations of åkermanite and gehlenite as interpreted from a study of slags. He concludes that they mix to form an isomorphous series, and finds that the birefringence of certain intermediate mixtures decreases to zero at a certain intermediate composition. The formulæ assumed by Vogt for gehlenite and åkermanite, however, differ from those used by us, and many of the materials studied by Vogt contain iron, manganese, soda, and other impurities, so that the data he obtained are from more complex mixtures than the system discussed by us.

A further investigation of the minerals of the melilite group is contemplated, and a more thorough discussion awaits its completion.

[12] J. H. L. Vogt, Mineralbildung in Schmelzmassen, 96-176.

We are under obligations to Dr. H. E. Merwin of this Laboratory for his generous counsel in the microscopical examinations.

Conclusion.

1. The binary system $2CaO . MgO . 2SiO_2$ (Åkermanite) - $2CaO . Al_2O_3 . SiO_2$ (Gehlenite) was studied by the quenching method, the solidus and liquidus curves drawn, and the system found to form a complete series of solid solutions with a minimum melting point.

2. The optical characters for crystals of several intermediate compositions were determined and found to be a continuous function of the composition. Crystals of a certain intermediate mixture are isotropic for sodium light, and constitute a transition phase from crystals of positive optical character to those of negative optical character. Zoned crystals showing material of both positive and negative optical character in the same crystal were found. These are analogous, in this character, to certain natural melilite crystals which have previously been described.

3. The densities of crystals and glasses of åkermanite, gehlenite, and several intermediate mixtures were determined and found to confirm the isomorphous character of the system. Åkermanite was found to show the unusual feature of its glass having a greater density than the corresponding crystals at 25°C.

Geophysical Laboratory, Carnegie Institution of Washington,
Washington, D. C., May 25, 1920.

ART. XI.—*Some Chemical Observations on the Volcanic Emanations and Incrustations in the Valley of 10,000 Smokes, Katmai, Alaska;* by J. W. SHIPLEY.[1]

Contribution from the Chemical Laboratory, University of Manitoba, Winnipeg.

The great volcanic explosion of June, 1912, in Southwestern Alaska which blew out the Katmai crater to a depth of over 3,700 feet, distributing more than two cubic miles of ash and pumice over the surrounding country, left on the Behring Sea slope of the Aleutian Peninsula in the Valley of 10,000 Smokes an excellent opportunity for studying the chemical nature of the gaseous emanations characteristic of the eruption. The volcanic gases have been pouring out continuously from vents distributed over an area of fifty square miles ever since the eruption and in the course of that time have built up large masses of incrustants around the vents. Extremely disintegrating in character, these gases have profoundly altered the chemical composition of the surface rock adjacent to the channels through which they find an exit. Igneous rock material has been decomposed and built up into altogether different chemical compounds by the action of the gaseous emanations in the presence of water.[2]

The floor of the valley through which the volcanic gases force their way is composed of volcanic detrital matter, pumice and ash, ejected by Novarupta volcano on the Behring Sea slope of the Aleutian peninsula. Novarupta, ten miles due west of Katmai, exploded before the latter and threw out much material locally. Falling hot on the snow-covered northern slopes and assisted by the heavy rainfall accompanying the eruption, much of this ejecta slid into the valleys and formed a vast mud flow.[3] The flow continued down the main valley for over fifteen miles and, as it drained away, left a considerable residue adhering to the valley floor. The highest level attained by the flow of mud is marked on the valley walls frequently 300 feet above the present level. After coming to rest the mud was subjected to heat from below, dried, and caked and over a large part of the area was

[1] The author was attached to the 1917 Katmai Expedition of the National Geographic Society in the capacity of chemist.

[2] Shipley, Science, vol. 49, p. 589, June 20, 1919.

[3] Described by Griggs, Ohio Jour. of Science, vol. 19, p. 117, 1918.

eventually baked. An examination of the baked mud showed it to be made up of angular pumice, tuff and volcanic ash having a specific gravity almost identical with that of building brick. The contracting, hardening mass split and cracked according to the strains and stresses set up by the irregularities of the valley floor beneath. The volcanic gases force their way upward through this superincumbent detrital material, using the existing cracks and fissures and dissolving out new channels where these were not available. The area covered by the mud flow is about fifty square miles and, by a strange coincidence, the limits of the mud flow are approximately the limits of the volcanic activity.

The distribution and superficial characteristics of the volcanic vents over this area have been excellently described by Griggs.[4] The great volume of gases pour out from large well-defined vents, but in addition to these, the volcanic emanations exude from the surface of the mud flow over large areas not possessing any visible orifices whatsoever. The gases issue under considerable pressure at temperatures varying from atmospheric to well above 400°C. Unfortunately, the boiling point of mercury was the limit of our thermometry, but in 1918 Sayre and Hagelbarger with a thermo-electric pyrometer observed temperatures of 450°C. Our own observations indicated much higher temperatures than our thermometers would register.

The nature of the incrustations in the neighborhood of a vent was largely determined by the temperature of the issuing gases. Where the temperature was high the incrustations were anhydrous and baked and contained none of the more volatile sublimates or hydrated salts. Deposits of sulphur or orpiment were not found adjacent to a very hot vent and the deposition of ammonium chloride was in the throats of orifices little hotter than 100°C.

The Nature of the Gases.—The major part of the issuing gases consisted of water vapor. Many fumaroles emitted little else, but on the other hand, a few were almost anhydrous, scarcely any moisture condensing from samples drawn off. The latter were invariably strongly acid and in one particular contained large quantities of SO_3. Hydrochloric and hydrofluoric acids were common constituents of the vapors, the former being most mark-

[4] Nature, vol. 101, p. 497, Aug. 22, 1918.
[5] National Geog. Magazine, vol. 33, Feb. 1918.

edly present in the lower part of the valley ten miles below Novarupta. The surface of the mud flow was impregnated with HCl condensing from the vapors passing over it. The presence of HF was not suspected until large deposits of amorphous SiO_2 were observed around vents from which issued strongly acid vapors. Later its presence was indicated by the etching of the gas-washing bottle into which the vapors were pumped and condensed and in the laboratory where fluorine was found in the majority of the incrustants examined.

Hydrogen sulphide and sulphur dioxide were common constituents of the evolved gases. In one instance, from a vent depositing flowers of sulphur SO_2 was strongly in evidence, while the lead acetate paper indicated the presence of sulphide. Possibly the gaseous reaction between the two gases was not complete or else a volatile sulphide other than H_2S was being emitted.

Volatile ammonium compounds were detected in almost all of the vapors examined. Some were very strongly impregnated and as already mentioned NH_4Cl was crystallizing in the throat of vents on the western rim of Novarupta. These were relatively cool, acid fumaroles from which the gases were issuing under low pressure. The salt collected in an annular mass on the walls of the vents a couple of feet within the orifices. Below the accumulation, the salt was no doubt dissociated into its gaseous constituents NH_3 and HCl. A 4-oz. bottle filled from one of these vents analyzed 98% NH_4Cl.

A rather interesting relationship between the growth of blue-green algæ and the presence of ammonium compounds in the emanations was established. Algæ were found growing up to the edge of vents where the thermometer indicated 100°C. No algæ grew where the vapors showed an absence of ammonium. This relationship held over the large areas where the gases were slowly exuding through the porous mud flow. Apparently, the evolution of ammonia compounds was quite general, for the afternoon sun disclosed the slopes surrounding Novarupta clothed in a coat of green provided by the growth of algæ.

Sulphur.—Sulphur deposits were not met with so frequently as might have been expected from the chemical conditions obtaining in the vapors. From the hotter vents the sulphur would escape into the atmosphere, but the most of the sulphur was fixed as sulphide, sulphates or the free acids of sulphur. A series of vents on the rim of Novarupta had considerable quantities of flowers of sulphur depositing on the walls bathed by the escaping gases. It was here that SO_2 and H_2S apparently co-existed. These deposits were 99% pure containing iron as an impurity. Selenium or tellurium was not detected in any of the samples collected in the valley. Crystalline rhombic sulphur was frequently found associated in varying proportions with masses of amorphous SiO_2. The two minerals had been deposited together with a little Fe_2O_3 as an impurity.

The most peculiar deposition of sulphur observed was in the form of rosettes around miniature orifices adjacent to the larger vents. The rosettes were composed of needle-like crystals of sulphur half an inch or more in length and apparently was sulphur in the monoclinic system. On attempting to collect the needles, however, they crumbled to pieces which on examination proved to be rhombic crystals of sulphur. The sulphur originally deposited as monoclinic had been transformed into rhombic crystals retaining the outward form of the monoclinic mass.

Arsenic.—Associated with sulphur as an incrustant over several of the fumarole cracks small deposits of sulphides of arsenic were discovered. The mass consisted of yellow crystals of orpiment containing some reddish crystals that may have been realgar or the β variety of orpiment which, according to Borodowsky,[6] is red. On analysis the proportion of arsenic to fixed sulphur gave a ratio corresponding to the formula As_2S_5 but it may have been that the CS_2 extraction failed to remove all of the free sulphur.

Arsenic deposits.

Free S (soluble in CS_2)	52·0%
Fixed S	21·0%
As	19·6%
Residue (insol. in Na_2CO_3)	4·4%
Volatile at 80°	1·6%
not determined	1·4%
	100%

Fluorides.—The presence of fluorine was indicated by the etching of the glass gas-washing bottle through which

[6] Chem. Abst., vol. 1, p. 1106, 1907.

samples of the volcanic gases had been pumped. The incrustants tested in the laboratory almost all reacted for fluorine. The amount present as fluoride varied from a fraction of a percent up to 7% and was most abundant in incrustants around the more acid fumaroles. No specific compound of fluorine was identified but calcium was usually present in more than sufficient amount to combine with it.

Apart from the importance of HF in the gases as a disintegrating agent the presence of fluorine was very significant as to the origin of the gases. Clarke[7] states that fluorine compounds "are especially characteristic of the deep-seated or plutonic rocks where the gaseous exhalations have been retained under pressure, and are commonly regarded as of pneumatolytic origin."

Corundum.—Several of the incrustants after decomposition with sodium carbonate left a residue of small crystals which on examination proved to be corundum. The presence of these crystals is rather interesting in view of Hautefeuille's[8] synthesis of corundum by the action of HF on alumina and by Bruhns[9] in the wet way on heating NH_4F with alumina to a temperature above 300°. The conditions under which Bruhns synthesized corundum obtain naturally in the Valley of 10,000 Smokes.

Silica.—The most characteristic deposit of the fumarole activity consists of amorphous silica. Many fumaroles have built up deposits of almost pure SiO_2 several feet high choking up the vents and causing the gases to force their way out through secondary orifices in the accumulated, baked, mass. Sulphur was frequently associated with these deposits and all samples tested in the laboratory showed the presence of fluorine. These deposits of SiO_2 although most marked around the hotter, acid, vents nevertheless were common over the whole valley. Three of the purest samples analyzed as follows:

Analysis of Silica deposits.

Sample No.	SiO_2	Free S	Fe_2O_3	Undetermined.
	%	%	%	%
I	93·5	3·4	3·0	0·1
II	95·8	3·9	0·2	0·1
III	96·7	3·1	....	0·2

[7] Data of Geochemistry, page 336.
[8] Ann. Chim. phys., vol. 4, p. 153, 1865.
[9] Neues Jahrb., vol. 2, p. 62, 1884.

The deposition of SiO_2 probably results from the decomposition of SiF_4 in the volcanic gases by the action of the water contained in the gases. Many of the fumaroles have temperatures, a few feet within the orifice, above the critical temperature of water, 375°C. Decomposition of the SiF_4 would only take place after the issuing gases had cooled off sufficiently to permit the formation of water. The decomposition of the silicates constituting the mud flow is quite marked over practically all areas of activity and, immediately surrounding the more active vents, the ash and pumice have been completely disintegrated. According to Moissan[10] SiO_2 begins to volatilize at about 1200°C while Day and Shepherd[11] found it to sublime readily at 1755°C. There is no indication of temperatures approaching these in the fumaroles of the valley.

Boron.—Qualitative tests gave no indication of the presence of borates in the incrustants of the valley.

Gypsum and Apatite.—Nodular concretionary depositions of mixed crystals with well-developed pure crystals of selenite, halite and alum attached to the main mass were frequently found covering the orifices of active areas. Next to the deposits of SiO_2 these nodular masses were the most common type of incrustation. The nodular mass on analysis proved to contain calcium, fluorine, chlorine, phosphate (PO_4) and sulphate—the latter two acid radicals predominating. Over the hotter vents the principal constituent of the nodular mass was anhydrite. Apatite was not definitely identified but was presumably the form of phosphate present because of the association with chlorine and fluorine. Thin layers of Fe_2O_3 were observed buried in these nodular masses.

Alum.—Potassium alum in lichen-like incrustations was forming in all active areas in the valley. After a few hours without rain the accumulations became very apparent only to disappear, wherever exposed, as soon as the rain began again. The less soluble sulphates and phosphates of calcium preserved a lichen-like structure on which the crystals of alum reformed when weather conditions permitted. A small pond fed by surface drainage over the mud flow was so impregnated with alum as to be altogether unfit for drinking.

Iron.—Compounds of iron were omnipresent, the beau-

[10] Compt. Rend., vol. 138, p. 243, 1904.
[11] Science, N. S., vol. 23, p. 670, 1906.

tiful coloring of the incrustants being largely due to the salts, oxides and hydroxides of iron. Chlorides of iron were recognized but due to the deliquescence of the crystals were not identified. Ferrous and ferric sulphates were collected, but the compounds were not identified.

Magnetite and amorphous Fe_2O_3 were met with everywhere. Considerable deposits of "Venetian Red," Fe_2O_3, were forming around cracks in the side of a gully from which the volcanic gases were slowly seeping.

Vivianite ($Fe_3P_2O_8 . 8H_2O$).—Several acres of the mud flow are covered with a hot blue mud, six inches deep, resting upon the surface of volcanic ash. The blue mud is saturated with water and on cool days vapors could be seen rising from the surface. A brown crust of oxide of iron covers the surface and a chemical examination of the mud showed it to be impregnated with magnetite and vivianite ($Fe_3P_2O_8 . 8H_2O$). This is one of the most interesting volcanic formations in the district.

Pyrite.—Well-developed isometric crystals of FeS_2 imbedded in a gangue composed of the phosphate and sulphate of calcium together with silica were found in the wall of an inactive vent. The deposit had been exposed by the water erosion of a surface stream flowing across a line of activity in the upper valley. The deposit had formed about ten feet beneath the surface of the ash and was the only one of pyrite observed in the valley.

Manganese.—Na_2CO_3 fusions indicated the presence of manganese in many of the incrustants, at times in considerable quantities. None of its compounds, however, were identified. A small deposit of a brilliant, orange-yellow, highly hygroscopic, incrustant was collected along the cooler marge of a small orifice. It was almost entirely water soluble and on analysis, yielded the following percentages: Mn 17·3, Al 17·5, Fe 6·9, Ca 1·1, Cl 15·5 and F 7·0. I should not care to venture even a guess as to what this incrustant might be.

Tar.—A most interesting organic deposit resembling coal tar in odor and appearance was observed saturating the ash around fumaroles on the western slope of Novarupta volcano and in the immediate neighborhood of the NH_4Cl fumaroles. One fumarole in this same area was emitting nitrous acid. The gases from fumaroles in this area possessed a similar tarry odor and emitted much H_2S. On analysis of the impregnated ash the deposit proved to be of a very complex character. A 20-gram sample was extracted successively with the following solvents until no further extract from each was obtained. The solvents in the order used were: ether, petroleum ether, carbon disulphide, benzene, carbon tetra-chloride, ethyl alcohol and glacial acetic acid. Each of the solvents extracted organic matter varying in amount from half a gram to a centigram, CS_2 and $(C_2H_5)_2O$ being the most effective. Several of the solvents extracted considerable quantities of free sulphur. On evaporation, a brownish-black resinous mass was left by each solvent. None of the extracts belonged to the aliphatic series, none contained nitrogen and none were unsaturated.

Steam distillation carried over the organic matter together with the free sulphur, and the first portion of the distillate gave an unmistakable odor of *naphthalene.*

The occurrence of this deposit of aromatic hydrocarbons may have some significance in the theory of volcanic origin for such compounds. The deposit lies close to the most active area of the district and is associated with NH_4Cl and sulphur, while H_2S is unusually concentrated in the escaping gases. On the other hand they might equally well be attributed to steam distillation from the sedimentary rocks with subsequent condensation in the ash on the surface. The Jurassic sandstones meet the igneous intrusion in the immediate neighborhood.

Surface Temperatures.—The normal temperature for the volcanic ash in the month of July was between 10° and 12°C at a depth of four inches. Owing to there being considerable areas over which the activity seemed to be general rather than confined to a narrow vent or fissure, the temperature of the mud flow was taken at numerous places. Temperatures above 10°-12° were abnormal and indicated hot gases permeating the mass of the flow. The temperatures recorded varied from 10° to 100°C., higher temperatures than 100° only being found in the open vents or cracks but hot vents and fissures were frequently surrounded by areas covered with blue mud the temperature of which approximated 100°. This blue mud was a mixed layer of ash and the phosphate of iron already described, saturated with water to a depth of four to eight inches. Such an area of hot vents and viscous blue mud covering at least five acres occurs about five miles down the valley from Novarupta volcano. This area is quite fluid beneath the brown crust covering the mud.

A series of surface temperatures was taken at ten-yard intervals at a depth of four inches across a relatively inactive area in the upper valley. The series extends from the base of Mount Cerberus to a point 1160 yards to the northward approximately half way across the mud flow.

The accompanying curve contains the temperatures plotted against the distance. There are only two intervals where the temperatures approximate normal, namely the 170 to 300 yard interval and the 590 to 730 yard interval. Both these areas are covered with water-deposited ash freshly lain after every heavy rainfall. Sub-surface temperatures at a depth of twelve inches ran from 7 degrees to 10 degrees higher. It follows, therefore, that the whole surface of the mud flow over which this series extends has an abnormally high temperature and is being supplied with heat from below.

As the active vents are approached, the surface temperature rises and remains relatively high until the activity diminishes. It is over these areas that the hot volcanic emanations are percolating through the porous mass of the mud flow. The mud flow is either in intimate contact with a heated mass of the earth's crust or the outlets for the gaseous emanations from the magma are well distributed beneath the flow.

Common origin of Novarupta Lava Plug and the Mud Flow.—In order to establish any relationship of common origin in the ejecta of the district, the silica, iron and alumina in representative samples of the lava plug of Novarupta, the Great Mud Flow, the Katmai Red Mud Flow and the pre-eruptive (1912) volcanics as represented in the rocks of Falling Mountain were determined. The results follow:

Rock	SiO_2 %	Al_2O_3 %	Fe_2O_3 %
Lava plug	75·2	14·2	3·2
Great Mud Flow	73·7	13·8	3·8
Red Mud Flow	63·6	18·4	7·8
Pre-eruptive volcanics	69·2	17·9	6·3

It is rather interesting to note that the Katmai ejecta and the old volcanics are of similar composition while the lava plug of Novarupta and the Great Mud Flow are much alike. The two latter apparently are of common magmatic origin and differ markedly from the Katmai

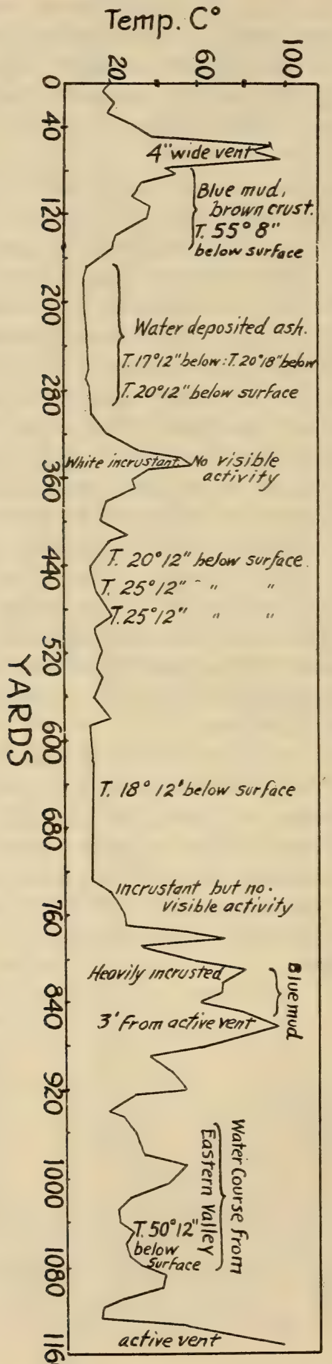


Fig. 1.—Surface temperature of mud flow at a depth of four inches.

ash which because of its location on the peninsula axis was largely composed of pre-eruptive material blown to powder.

Metamorphic action of the Volcanic Gases.—The country rock (volcanic ash and pumice) in the neighborhood of an active vent was subjected to the chemical action of permeating gases and solutions. The porous character of the rock permitted easy, intimate, contact and also offered the maximum of surface so that chemical action was speedy and effective. Adjacent to the hot acid vents the ash was completely disintegrated. As the distance from the vents increased the metamorphism diminished until the unaffected ash was reached. The decomposition resulted in the formation of more or less soluble salts of the bases present in the ash combined with the acids free in the volcanic vapors or dissolved in the percolating waters. These salts were deposited at or near the surface on the evaporation of the water or within the vent itself if the temperature was above the boiling point of water. In the latter case the salts were anhydrous.

Two partially metamorphosed samples of the volcanic ash, after extraction with water, were analyzed. The results show a loss of silica, sodium and potassium with a relative concentration of the iron and alumina. These samples were from areas where hydrofluoric acid was present in the vapors and consequently the loss of the SiO_2 would be expected, in fact, deposits of amorphous SiO_2 occurred around the vents at the surface.

Analysis of partially metamorphosed volcanic ash (percentages).

Sample	SiO_2,	Al_2O_3,	Fe_2O_3,	MnO,	CaO,	MgO,	Na_2O,	K_2O,	F
I.—	50·6	21·1	14·8	0·3	5·0	4·8	3·4	0·8	1·0
II.—	60·6	21·6	5·7	—	5·5	5·9	—	—	1·1

Sample No. II was more decomposed than No. I having lost much of its iron.

Pneumatohydatogenesis.—The above term was applied by Bunsen to the combined action of gases and water solutions in the formation of salts. The salts and compounds found in the Valley of 10,000 Smokes have their origin in such combined action. Hydatogenesis in the valley is confined largely to the surface layers for, as already mentioned, the temperature of many fumaroles is above that of the critical temperature of water and consequently, water as such does not occur. That the disintegration of the ash in the mud flow was modified at considerable depth was evidenced by a cave-in exposing a subterranean, horizontal tunnel, twelve feet in diameter and seventy-five feet below the surface. The walls were composed of the characteristic mud flow material baked a deep brick red, apparently unattacked and containing no incrustants. Tunnels closer to the surface were heavily incrusted due to the cooling down of the vapors and sublimates and the possibility of salt formation and transportation in the presence of water.

Stream erosion across several active areas exposed cross sections of some of these tunnels, giving an excellent opportunity for studying the disintegration and deposition of material in the surface layers of the mud flow. Directly above the tunnel the ash was almost completely disintegrated and replaced by a deposit of SiO_2 while laterally the decomposition fell off and the ash was impregnated with deposits of oxides, sulphates, phosphates and chlorides together with amorphous SiO_2. The affected area extended from the tunnel fan-wise to the surface with the greatest accumulation of salts near the surface.

Conclusion.—It is quite impossible to differentiate the primary and secondary volcanic compounds in this region. The majority of the incrustants examined were secondary products arising from the decomposition of the ash by the volcanic gases, but, on the other hand, the great volume of escaping vapors has a magmatic origin. Gautier[12] and other investigators have shown that most of the gaseous products and sublimates observed in volcanic emanations can arise from the interaction of water, carbon dioxide, and the solid constituents of the lava. In the Valley of 10,000 Smokes, water vapor is the major constituent of the emanations. Its origin is debatable, but according to Gautier, one cubic kilometer of granite can provide 30,700,000 metric tons of water from its water of combination and oxidizible hydrogen. Consequently, should a portion of the earth's crystallized crust come in contact with the heated magma, sufficient water could be freed to give rise to the phenomena observed in the Valley of 10,000 Smokes.

Much of the surface drainage enters the porous mud flow and adds its quota to the saturation of the ash. Sur-

[12] Compt. Rend., vol. 142, p. 1465, 1906.

face drainage in flood time has poured into open vents, the evidence of the ensuing struggle between inflowing water and issuing gases being found in the form of mounds of ash and pumice six to eight feet high, spewed out around the vents. To what extent surface infiltration provides water for the mud flow will remain problematical but the source of the heat necessary to account for the high temperatures prevailing must be considered magmatic.

The temperature a short distance within the hotted vents was several degrees lower than that at the orifice, and vacuum tubes filled with the hot gases on being sealed after cooling, sometimes blew out the glass capillary. Evidently the issuing gases were not in equilibrium and chemical action continued after their collection, resulting in an increase in the volume. The higher temperature at the orifice would indicate an oxidation of the volcanic gases on contact with the air.

A thorough study of the mineralization going on in this valley would provide valuable data concerning the formation of a number of economically important chemical compounds. A study of the physico-chemical relations existing within the vents where salts are being deposited would be equally interesting. The Valley of 10,000 Smokes is but one of Nature's huge chemical laboratories thrown open for inspection by the eruption of 1912.

"The author wishes to express his appreciation of the encouragement and help extended by Dr. R. F. Griggs and his associates in the field, and to Mr. D. Binnington for assistance in the laboratory examination of the tarry deposits."

ART. XII.—*The Ordovician of Madison, Indiana;*[1] by EULA D. McEWAN.

The present report is the result of the study in the laboratory of a great amount of material collected by the writer from the Ordovician section at Madison, Indiana, in the summer of 1914. The collection was made along the creek at the foot of the ravine, in the ravine which heads at the culvert about 200 feet north of the north end of the south cut, and in the south cut on the P. C. C. and St. L. Railroad.

The fossils were collected zonally, great care being taken to locate their horizons exactly. The laboratory work required the preparation of about three hundred microscopic slides with sections of the bryozoa.

The following classification applies to the section:

$$\text{Richmond}\begin{cases}\text{Waynesville}\\\text{Arnheim}\end{cases}$$

$$\text{Maysville}\begin{cases}\text{Mount Auburn}\\\text{Corryville}\\\text{Bellevue}\end{cases}$$

The lowest exposure of the section is several hundred feet downstream from where the creek is joined by the ravine. The lowest 20 feet consist of blue limestone and shales,[2] the former varying from a few inches to nearly a foot in thickness. The succeeding 7 feet consist of thin layers of limestone and argillaceous limestone separated by soft yellow shale layers usually an inch or only a few inches in thickness.

At an elevation of between 27 and 77 feet above the base of the section the limestone layers become more massive. In the lower position of these beds the limestone has rust-like spots. At an elevation of about 53 to 60 feet the limestone is lumpy.

[1] The writer is under obligation to Professor E. R. Cumings of Indiana University, under whose supervision all the laboratory and field work was done. He offered many valuable suggestions and also furnished many specimens for comparisons.

[2] For a complete discussion of these rocks consult Cumings, "The Stratigraphy and Paleontology of the Ordovician Rocks of Indiana," 32d Annual Report of the Department of Geology and Natural Resources of Indiana, 1907, pp. 634-637.

Between the elevations of 77 and 83 feet shale and shaly limestone predominate. *Rafinesquina* and other broad flat fossils are found here in an edgewise position at an elevation of about 75 to 80 feet.

The rocks which occur between 89 and 135 feet are found in the upper part of the ravine and the lower part of the railroad cut. They consist of heavy limestone and argillaceous limestone varying from an inch to 10 feet in thickness and separated by shale layers.

Between 135 and 172 feet above the base of the section are brown weathered layers of limestone and shale. These occur in the uppermost part of the ravine and in the railroad cut. The upper 30 feet of the section consist of heavy limestone layers separated by shale.

Bellevue.

The lowest exposure of this division is in the creek at the foot of the gully at a point several hundred feet down stream. The Bellevue is also beautifully exposed in a quarry in the eastern part of Madison. It is very fossiliferous, containing great numbers of individuals representing each species. The common forms are *Platystrophia ponderosa* (Foerste), *P. unicostata* (Cumings), *P. unicostata crassaformis* (McEwan), *Hebertella sinuata* (Hall), *Rafinesquina alternata* (Emmons), *Monticulipora molesta* (Nicholson), *Bythopora gracilis* (Nicholson), *Hallopora ramosa* (D'Orbigny,) and *Homotrypella dubia* (Cumings and Galloway).

The faunal evidence in the exposure 20 to 27 feet above the lowest outcrop seems to suggest a gradual change from Bellevue to Corryville time. A few new species, such as *Dekayia appressa* Ulrich and *Cyclonema simulans* Ulrich, suggest an invasion of the area possibly by the lowering of some barrier. The fauna is on the whole very similar to that of the underlying Bellevue. This part of the section is located along the creek at the foot of the hill below the south cut.

Corryville.

In the next 50 feet Corryville species become more prominent. *Chiloporella flabellata* (Ulrich), *Dekayia appressa* (Ulrich), *Platystrophia laticosta* (Meek), and *Eridotrypa simulatrix* (Ulrich), are common. The lower part of the division is located along the creek and the upper part is in the gully heading just north of the south cut.

Corryville-Mount Auburn.

Corryville species continue until the end of Maysville time. The introduction of *Platystrophia ponderosa auburnensis* (Foerste), and *Cœloclema oweni* (James) in the beds 77 to 83 feet above the lowest exposure indicates the advent of Mount Auburn time. The lumpy layers of limestone in which some of the Corryville-Mount Auburn faunal list occurs suggest that the close of Maysville time was marked by shallow water. No definite evidence of a disconformity was observed. It may be that the sea never entirely retreated from the area. The presence of several Maysville species associated with Arnheim species supports this. However, the faunal aspect as a whole underwent great change, and it is likely that over most of the interior the end of the Maysville and the advent of Richmond time is marked by a general retreat and advance of the sea.

Arnheim

The Arnheim is marked by the disappearance of most of the Maysville species and the invasion of large numbers of Richmond species, such as *Homotrypa pulchra* (Bassler), *Batostoma varians* (James), *Mesotrypa orbiculata* (Cumings and Galloway), *Peronopora decipiens* (Rominger), *Platystrophia foerstei* (McEwan), and *P. wallowayi* (Foerste). The division is found in the upper part of the gully and the lower part of the cut along the railroad.

Waynesville.

The upper 83 feet of this section show a definite invasion of great numbers of Waynesville species, such as *Amplexopora pustulosa* (Ulrich and Bassler), *Heterotrypa subramosa* (Ulrich), *Homotrypa flabellaris* (Ulrich), *H. wortheni* (James), *Homotrypella hospitalis* (Nicholson), *Stigmatella crenulata* (Ulrich and Bassler), *Bythopora meeki* (James), *Dalmanella meeki* (Miller), *Atactoporella schucherti* (Ulrich), *Eridotrypa simulatrix, Platystrophia annieana* (Foerste), *P. cypha* var. *Catazyga headi schuchertana* (Ulrich), and *Strophomena planumbona* (Hall).

Faunal Lists.

Bellevue, (1–20)

The figures heading each faunal list refer to the height in feet above the base of the section of the uppermost and lowermost strata in which the given faunal is found.

Amplexopora filiasa, Atactoporella multigranosa, Atactoporella ortoni, Bythopora gracilis, Ceramoporella distincta, Ceramoporella granulosa, Ceramoporella ohioensis, Corynotrypa inflata, Hallopora andrewsi, Hallopora ramosa, Hallopora subnodosa, Heterotrypa paupera, Heterotrypa frondosa, Homotrypella dubia, Monticulipora molesta, Petigopora asperula, Petigopora petechialis, Proboscina frondosa, Crania scabiosa, Hebertella sinuata, Platystrophia ponderosa, Platystrophia unicostata, Platystrophia unicostata crassiformis, Rafinesquina alternata, Rafinesquina alternata fracta, Zygospira modesta, Cyclora minuta, Cornulites flexuosus.

Bellevue-Corryville.

20–27

Atactoporella multigranosa, Bythopora gracilis, Ceramoporella ohioensis, Ceramoporella whitei, Cœloclema cf. *alternatum, Corynotrypa inflata, Dekayia appressa, Hallopora* cf. *onealli, Hallopora ramosa, Hallopora ramosa rugosa, Heterotrypa frondosa, Homotrypella dubia, Monticulipora molesta, Stigmatella* cf. *clavis, Crania scabiosa, Hebertella sinuata, Platystrophia ponderosa, Platystrophia unicostata, Rafinesquina alternata, Rafinesquina nasuta, Trematis multipunctata, Zygospira modesta, Cyclonema simulans, Cyclora minuta, Byssonychia* sp. undet., *Calymene meeki.*

Corryville.

27–77

Atactoporella multigranosa, Bythopora gracilis, Ceramoporella distincta, Ceramoporella ohioensis, Cœloclema cf. *alternatum, Chiloporella flabellata, Dekayia appressa, Eridotrypa simulatrix, Hallopora* cf. *onealli, Hallopora ramosa, Hallopora subnodosa, Heterotrypa frondosa, Peronopora pavonia, Petegopora petechialis, Crania scabiosa, Platystrophia laticosta, Rafinesquina alternata, Cyclora minuta, Byssonychia radiata, Orthoceras dyeri, Calymene meeki.*

Corryville-Mount Auburn.

77–83

Amplexopora septosa, Atactoporella cf. *mundula, Atactoporella ortoni, Bythopora gracilis, Ceramoporella ohioensis, Chiloporella flabellata, Cœloclema* cf. *alternata, Cœloclema oweni, Dekayia appressa, Dekayia multispinosa, Eridotrypa simulatrix, Hallopora* cf. *onealli, Hallopora ramosa, Hallopora ramosa rugosa, Hallopora subnodosa, Heterotrypa frondosa, Platystrophia ponderosa auburnensis, Rafinesquina alternata fracta, Zygospira modesta, Calymene meeki, Isotelus* sp. undet.

Arnheim.

83–158

Amplexopora ampla, Amplexopora pustulosa, Batostoma varians, Berenicea primitiva, Bythopora delicatula, Bythopora gracilis, Bythopora meeki, Bythopora striata, Ceramoporella whitei, Dicranopora emacerata, Eridotrypa simulatrix, Hallopora ramosa, Hallopora ramosa rugosa, Hallopora subnodosa, Heterotrypa frondosa, Homotrypa pulchra, Homotrypa spinea, Mesotrypa orbiculata, Peronopora decipiens, Petigopora petechialis, Stigmatella sp. undet., *Crania scabiosa, Dalmanella meeki, Hebertella sinuata, Platystrophia cypha, Platystrophia foerstei, Rafinesquina alternata, Bellerophon* sp. undet., *Cyclonema bilix, Cyclora minuta, Byssonychia radiata, Byssonychia grandis, Pterinea demissa, Calymene meeki.*

Waynesville.

158–188

Amplexopora pustulosa, Arthropora schafferi, Atactoporella schucherti, Atactoporella sp. undet., *Batostoma varians, Bythopora meeki, Ceramoporella distincta, Ceramoporella ohioensis, Ceramoporella whitei, Dicranopora emacerata, Eridotrypa simulatrix, Hallopora* cf. *onealli, Hallopora subnodosa, Heterotrypa prolifica, Heterotrypa subramosa, Homotrypa flabellaris, Homotrypa wortheni, Homotrypella hospitalis, Monticulipora parasitica, Peronopora pavonia, Rhombotrypa quadrata, Stigmatella crenulata, Catazyga headi schuchertana, Crania* sp. undet., *Dalmanella meeki, Hebertella sinuata, Leptæna richmondensis, Platystrophia annieana, Platystrophia cypha* var., *Plectambonites sericeus, Rafinesquina alternata, Strophomena planumbona, Zygospira modesta, Anomalodonta gigantea, Byssonychia grandis, Opisthoptera alternata.*

ART. XIII.—*Studies in the Cyperaceæ;* by THEO. HOLM. XXX. *Carices æorastachyæ: Cryptocarpæ* nob. (with 14 figures in the text).

Members of the *Cryptocarpæ* are: *C. cryptocarpa* C. A. Mey., *C. Lyngbyei* Hornem., *C. capillipes* Drej., *C. prionocarpa* Franch., *C. hæmatolepis* Drej., and *C. cryptochlæna* nob.

Typical *C. cryptocarpa* is the plant described and figured by C. A. Meyer from the northeastern corner of Asia, south to Japan, and from Alaska south to Washington. Less typical is Drejer's *C. filipendula* from Iceland and the west coast of Greenland, even if some of those from Iceland cannot be distinguished from the typical Alaskan. While only the typical plant is mentioned by Meyer,[1] three varieties are described by Drejer[2]: α *variegata* elegantior et gracilior, spicis femineis ovato-oblongis, squamis atrosanguineis perigyniis flavo-viridibus ovato-obovatis, from Iceland; β *littoralis* humilior, spicis magis elongatis cylindraceis concloribus (squamis perigyniisque fuscis), from Iceland, and finally γ *concolor* major et robustior, spicis cylindricis concoloribus, perigyniis ovatis v. obovatis, from Greenland.

Of these α *variegata* corresponds well with the type described by Meyer, although the latter is a rather robust plant, as are, however, so many other species from Alaska and vicinity, when compared with their eastern representatives; not only in the *Carices,* but also in numerous other phænogamous genera. But neither β *littoralis* nor γ *concolor* have, so far, been recorded from Alaska and vicinity.

As a perfectly valid, and indeed as an excellent species *C. cryptocarpa* has been accepted unanimously by all the leading writers on Caricography, with *C. filipendula* Drej. as a synonym, nevertheless another name has been substituted merging the species with the local, and quite distinct *C. Lyngbyei* Hornem.[3 and 4]. However, as will be shown in the subsequent pages, this proposition is unfortunate, and in order to demonstrate the validity of both

[1] Mém. Acad. St. Petersbourg, I, p. 226, t. 14, 1831.

[2] Revisio critica, 1841, p. 46.

[3] G. Kükenthal: Cyperaceæ-Caricoideæ, Leipzig, 1909, p. 363.

[4] C. H. Ostenfeld: Flora Arctica. Copenhagen, 1902, p. 75. See also this Journal (vol. 17, p. 313, April, 1904), where the synonymy of some arctic species has been briefly discussed.

C. cryptocarpa and *C. Lyngbyei* as independent species, we insert the original diagnosis, written by C. A. Meyer as follows:

Carex cryptocarpa C. A. Mey.

"*C.* spicis masculis subternis, femineis subternis* distantibus pedunculatis nutantibus, stigmatibus binis, perigyniis glabris tenuissime granulatis ellipticis compressis brevissime rostellatis ore integris, gluma oblonga mutica duplo brevioribus. Bracteæ in spicis femineis, foliaceæ, basi auriculato-amplectentes (nec vaginatæ), summitatem culmi æquantes vel superantes; summæ, ad spicarum mascularum basin, setaceæ. Spicæ omnes exserte pedunculatæ (pedunculis triquetro-filiformibus, sublævibus pollicem ad tres pollices longis); masculæ duæ vel tres; rarius solitaria in speciminibus humilioribus; subdistantes, subclavatæ, multifloræ, ½ poll. longæ vel longiores; summa suberecta; inferiores cernuæ. Spicæ femineæ duæ vel tres, distantes, oblongæ; florentes cernuæ, fructiferæ nutantes; multifloræ; non raro omnes apice flosculis aliquot masculis instructæ, sæpius tamen infima ex toto feminea. Glumæ arcte imbricatæ, oblongæ vel oblongo-lanceolatæ, acutæ, muticæ, glabræ, læves, piceæ, carina viridi pictæ, margine, nudo oculo, concolores, oculo armato vero masculæ ex toto, femineæ apice tantum margine hyalino angustissimo cinctæ.

Perigynium ellipticum, subcompressum, hinc planum, illinc convexum, rostro brevissimo integro apiculatum, flavescens, subnervosum, sub lente tenuissime granulatum, gluma omnino tectum et illa plerumque duplo brevius. Caryopsis ovato-elliptica, compressiuscula, hinc subplana, illinc convexa et obsolete carinata, cæterum obscure fusca, tenuissime granulata.

Habitat in Unalaschka et Kamtschatka. *C. glauca* Scop., habitu proxima, satis distincta, foliis glaucis, glumis brevioribus et stigmatibus tribus. *C. crinita* Lam., *C. maritima* Muell., et *C. salina* Wahlenb. præter alias notas distinguuntur glumis mucronatis."

While in the typical plant the pistillate spikes are mostly situated near the apex of the culm, we have observed in several specimens from Alaska, that the spikes may be more remote, the basal being situated at about the middle of the culm, or even below the middle. In

* With respect to the number of staminate and pistillate spikes we found in 71 specimens from Alaska, Vancouver Island, Queen Charlotte Island and Washington: 30 specimens with 1 staminate spike; 27 specimens with 2 staminate spikes; 14 specimens with 3 staminate spikes; 31 specimens with 3 pistillate spikes; 25 specimens with 2 pistillate spikes; 12 specimens with 4 pistillate spikes; 3 specimens with 1 pistillate spike.

In 53 specimens there were from 1-4 androgynous (lateral) spikes, 1 and 2 being the most frequent.

such specimens the pistillate spikes are more slender and longer than in the type: forma *remota* nob. Spiculæ ♀ magis distantes, cylindricæ, longiores.

Alaska: Growing in wet places near beach at Wrangell and Howkan, and abundant near villages, Sitka (Walter H. Evans); Seldovia (C. V. Piper); Popof Island, Shumagin Islands (A. Saunders). Furthermore some specimens from Vancouver Island may be described as: Var. δ *sphærochlæna* nob.

Humilior; spiculæ ♀ duæ, fere sessiles, contiguæ, cylindricæ; utriculi fusci, turgidi, divaricati. Vancouver Island: Vicinity of Victoria (John Macoun). But otherwise we have not observed any deviation from the description of the typical plant. And it is especially to be pointed out that the scales of the pistillate flowers were never mucronate or aristate; they varied only from being oblong to oblong-lanceolate (figs. 4 and 6). The perigynium is of a yellowish green color, faintly nerved, or with no veins visible, broader, but much shorter than the dark, purplish colored squama. This marked difference in color of squama and perigynium, and especially the greater width of the latter, is what Drejer refers to, when he states (l. c. p. 48): "nomen quoque *C. cryptocarpæ* a facie plantæ maturatæ nimis abhorret, quia perigynia tum minime teguntur, sed contra squamas reflectunt, ita ut tota spica omnino squarrosa reddatur."

Now concerning *C. filipendula* Drej. α *variegata* from Iceland, this cannot be considered distinct from the typical *C. cryptocarpa* C. A. Mey., since the habit, and the structure of squama and perigynium is the same; the only difference depends on the Alaskan plant being more robust. But with regard to the Greenland plant, γ *concolor* (Flora Danica vol. 40, Tab. 2372, 1843) this shows a different habit, the culm being phyllopodic, the spikes cylindric and quite remote, beside that the pistillate scales are distinctly mucronate ("mucrone serrulato brevi apicatæ"); the plant resembles in several respects *C. salina,* of which certain varieties have been collected in Finmark, which by Blytt and Boott were considered intermediate between *C. filipendula* and *salina.*

The geographical distribution of *C. cryptocarpa* is thus: the shores of Bering Sea, of the northern Pacific ocean, where it is quite abundant, and Iceland: "species in paludibus et pratis vulgatissima (Japetus Steenstrup)."

A near ally of *C. cryptocarpa* is the very local *C. Lyng-*

byei Hornem., known only from the Faroe Islands. By Drejer (l. c. p. 49) a diagnosis in Latin has been presented, which may be inserted here, together with some remarks by Drejer showing the principal characters by which it may be readily distinguished from *C. filipendula, maritima, salina, crinita* and *macrochæta.* The diagnosis reads as follows:

Carex Lyngbyei Hornem.

"Spicis masculis sub 2, femineis 3 in pedunculo longissimo gracili pendulis flaccidis, squamis ♀ lanceolatis arista longissima serrulata cuspidatis perigynia (immatura) obovata valide costata multo superantibus stigmatibus 2. *C. Lyngbyei* Hornem. Fl. Dan. t. 1888. Ejusd. Plantel. Ed. 3. II. p. 276.

Færoe! Lyngbye.

Non nisi dua specimina incompleta et male conservata in herbario Hornemanni exstant, quarum alterum spicas ♀ 3 habet ♀ 2, alterum femineas 6, terminali basi flore masculo unico (v. 2 ?) instructa. Rad. deest (in Hornem. Plantel. l. c. fibrosa dicitur, vix recte! sine dubio affinium more stolonifera vaginata). Pedunculi gracillini flaccidi infimus supra basin et extra vaginulam ocrea atro-sanguinea instructus. Spicæ lineares elongatæ. Squamæ atroviolaceæ. Bractea infima vaginulata culmum superans, superiores longitudine decrescunt. Perigynia immatura obovato-cuneata griseo-fusca.

A *C. filipendula* facile distinguitur aristis longissimis serrulatis. *C. maritima* Muell. jam colore lutescente dignoscitur. *C. salina* flaccidis rarifloris; squamis ovatis acutis mucronatis perigynia obsolete nervosis. *C. crinita* Lam. distincta est colore viridi, perigyniis enerviis vel (ex Kunth) binervibus. *C. macrochæta* C. A. Mey. (Cyp. nov. t. 13) affinior videtur, sed bene differt perigyniis obsolete nervosis superne hispidis, aristis etiam longioribus, pedunculis brevioribus, spicis non nisi ternis. Nostra species a Cl. Kunth (Cyperogr. p. 523) satis infauste ponitur inter species quoad stylorum numerum incognitas, citatis tamen figura fl. D. quæ stigmata bina clare ostendit, et diagnosi Hornemanni "stigmatibus binis!" addita insuper interrogatione: "an forma distyla *C. frigidæ?*"

The species has since been collected by Chr. Jensen and E. Rostrup, and is said to be rather rare on meadows by the sea, often associated with *C. salina*;[5] and the *C. salina* Wahlenb. of the Faroe Islands is the robust var. *Kattengatensis* Fr.

As shown in the accompanying fig. 1, *C. Lyngbyei* is

[5] Botany of the Færœs, Copenhagen, 1901, p. 81.

a very graceful plant of which the habit seems quite distinct from that of *C. cryptocarpa;* moreover as pointed out by Drejer the pistillate scales are aristate (fig. 2), and the perigynium prominently nerved (fig. 3). Among the specimens kindly presented to the writer by Chr. Jensen and E. Rostrup we failed to find any which might be referable to *C. cryptocarpa,* although the arista was sometimes absent, being very brittle and easily broken off by drying the specimens.

Carex Lyngbyei appears thus to be a species characteristic of the Faroe Islands, having never, so far, been reported from any of the stations where *C. cryptocarpa vera* occurs, neither from Iceland nor from the shores of the Pacific and Bering Sea.

To the diagnosis may be added that the terminal spike is sometimes androgynous with a few (2) pistillate flowers at the base (fig. 1.)

Carex capillipes Drej.

Known only from Iceland, and having been collected only at a few stations, this plant was by Drejer considered to represent a distinct species; the several specimens figured in Flora Danica (Tab. 2844) show us a plant of quite a characteristic aspect, and very different from any of the other *Carices* known from Iceland, although leaving no doubt of its proximate affinity being with *C. cryptocarpa.* Nevertheless it is one of the numerous species, which by Kükenthal (l. c. p. 364) has been reduced to varieties or forms, in this case to a variety of *C. Lyngbyei.*

Let us consult the original diagnosis written by Drejer (l. c. p. 50):

Carex capillipes Drej.

"Spica mascula 1, femineis 2-3 in pedunculo longissimo scabro flaccidis rarifloris; squamis ovatis acutis mucronatis perigynia subovata superne margine scabrida superantibus, stigmatibus 2. Island! Steenstrup.

Rad. deest. Culmus triqueter superne scaber. Fol. margine scaberrima. Spicæ remotæ, terminalis erecta, mascula v. simul basi feminea, oblongo-lanceolata. Squamæ fem. elongatæ. Bracteæ elongatæ foliaceæ culmum æquantes v. superantes scaberrimæ, evaginatæ v. infima longe vaginata, vagina antice membranacea. Pedunculus basi ocrea colorata instructus. Squamæ atro-fuscæ nervo augustissimo dilutione scabrato excurrente. Perigynium lutescens obsolete nervosum rostratum, rostro subintegro. Stylus cum stigmatibus intra perigynium inclusus.

Proxima *C. filipendula* facile dignoscitur pedunculis lævibus spicis densifloris, perigyniis lævibus cet. *C. rariflora* Sm. haud ita absimilis est, quam e diagnosi crederes; luculenter autem differt stigmatibus 3, spicis (approximatis) bracteis pedunculisque (lavibus) multo brevioribus, squamis lato-ovatis, obvolventibus, ligula elongata cet. Præter has nullam scio, cum qua nostram comparare necesse esset.''

According to Grœnlund[6] the species has been collected near Olafsdalr by Japetus Steenstrup, and near Grimsnes by himself; unfortunately we have no information about the other species with which it may have been associated, but the two stations mentioned are not among those from where Grœnlund has recorded *C. cryptocarpa.* In this connection may be stated that only typical *C. salina* has been found in Iceland, where it is very rare, however.

The lax-flowered pistillate spikes born on scabrous peduncles (fig. 7), and the perigynium being scabrous along the superior margin, (fig. 10) are characters which have not been observed in *C. cryptocarpa;* moreover the species has never, so far, been found in the regions where *C. cryptocarpa* abounds: on the shores of the Pacific Ocean and Bering Sea; it also deserves mention that dwarfed and very slender specimens of the latter (from Alaska) deviate in no respect from the type except by their diminutive size and very small spikes.

By comparing the diagnoses and figures of *C. cryptocarpa* and *C. capillipes* it certainly appears as if both are species distinct, and until more material has been collected and further observations have been made, we prefer to consider them as such.

Carex prionocarpa Franch.

This species, described by Franchet,[7] shows the same habit as *C. cryptocarpa;* it is stoloniferous, the bracts are foliaceous, and the spikes number from 5 to 7, 3 staminate, and 3 to 4 pistillate; the scales of the pistillate flowers are fuscous, obtuse, generally shorter and narrower than the perigynium (fig. 11); the perigynium is glaucous, ovate-oblong, spinulose along the margins and the nerves, and the beak is very short, with the orifice entire; the style is bifid. The species is a native of Japan: the island of Yeso.

[6] Grœnlund, Chr.: Islands Flora, Kjœbenhavn, 1881.
[7] Franchet, A.: Les Carex de l'Asie orientale, Nouv. Archives du Mus. Série III. Tome 9, p. 128, Paris, 1897.

Carex hæmatolepis Drej.

This interesting species has, so far, only been found in South Greenland, and since several authors have identified a variety of *C. salina* as representing *C. hæmatolepis,* it may be well to reprint the original diagnosis as presented by Drejer (Revisio critica, p. 44).

"Spica mascula 1, femin. 3-5 elongatis cylindraceis laxifloris in pedunculo lævi valido erectiusculis v. demum nutantibus, squamis ovatis acutis serrulato-mucronulatis perigynia ovali-ovata substipitata subsuperantibus, stigmatibus 2-3. Grœnland! Vahl.

Radix ut affinium. Culm. erectus strictus, acutangulus scaberrimus v. scabriusculus. Fol. erecta latissima scaberrima. Spica ♂ interdum altera rudimentaria basi augetur, sæpe quoque basi feminea est (in uno specimine sp. terminalis mere feminea), oblongo-clavæformis. Squamæ ♂ obovato-oblongæ acutiusculæ muticæ raro mucronatæ, atrofuscæ nervo pallido. Spicæ ♂ inferiores pedunculatæ, summa subsessilis. Bract. inferiores foliaceæ scaberrimæ basi biauriculatæ auriculis atrosanguineis confluentibus amplectentibus, infima culmum subæquans, sequens spicam ♂ subattingens, tertia setacea spica sua sublongior. Pedunculi plerumque validi spica sua breviores, in nonnullis tamen tenuiores et longiores, ocrea atrosanguinea instructi. Squamæ ♂ atro-sanguineæ tenuissime punctulatæ nervo tenuissimo discolore, ovatæ, acutæ serrulato-aristatæ v. muticæ, perigynia fere tegentes et superantes. Perig. obsolete nervata decolora stramineo-viridia, rostro brevissimo integro. Stylus brevissimus vix exsertus, stigmata 2, rarius 3, longissima. Variat foliis angustioribus, squamis ♂ et ♀ magis rotundatis, spicis ♀ omnibus pedunculatis, superioribus apice masculis.

Species pulcherrima, ab altera parte *C. saxatili* et *C. hyperborea,* ab altera *C. filipendula* cet. affinis. A *C. saxatili* differt spicis longius pedunculatis, magis elongatis, squamis sæpe mucronulatis, perigyniis subnervatis cet. A *C. filipendula* spicis suberectis, rarifloris, elongatis, pedunculis semper brevioribus et validioribus, squamis brevioribus, culmo scabro v. scaberrimo. *C. Lyngbyei, macrochæta, maritima* facile dignoscuntur squamis longissime aristatis. *C. recta* Boott (l. c. p. 220. t. 222) differt spica ♂ brevi cum femineis superioribus æquialta, culmo modo superne scabro. *C. aperta* Boott (l. c. p. 218. t. 219) similior videtur, sed differt rostro bidentato, perigynio orbiculato cet.; hæc quoque a cl. autore cum *C. cæspitosa* comparatur, cui nostra nimis dissimilis est."

According to Drejer (l. c.) the affinity is with *C. cryptocarpa,* and the Scandinavian plant, named *C. hæmatolepis* by certain authors, is a member of the *Salinæ* viz. *C. salina* var. *Kattegatensis* Fr.—

From *C. cryptocarpa* our species may be readily distinguished by the characters mentioned by Drejer, and as may be seen from our figures (figs. 12-14) the squamæ and the perigynium, especially the former, exhibit a structure distinct from that of *C. cryptocarpa* (figs. 4-6).

Carex cryptochlæna nob.[8]

The most robust species of the *Cryptocarpæ,* and very characteristic by its heavy, cylindrical, pistillate spikes, which are sessile or short-peduncled, erect or spreading. So far as concerns the habit it resembles *C. magnifica* Dew., but the structure of the scales and perigynia are more like that of *C. cryptocarpa;* the large, pale green perigynium is sparingly denticulate along the upper margins, a structure which has not been observed in *C. cryptocarpa,* but in *C. prionocarpa,* as stated above.

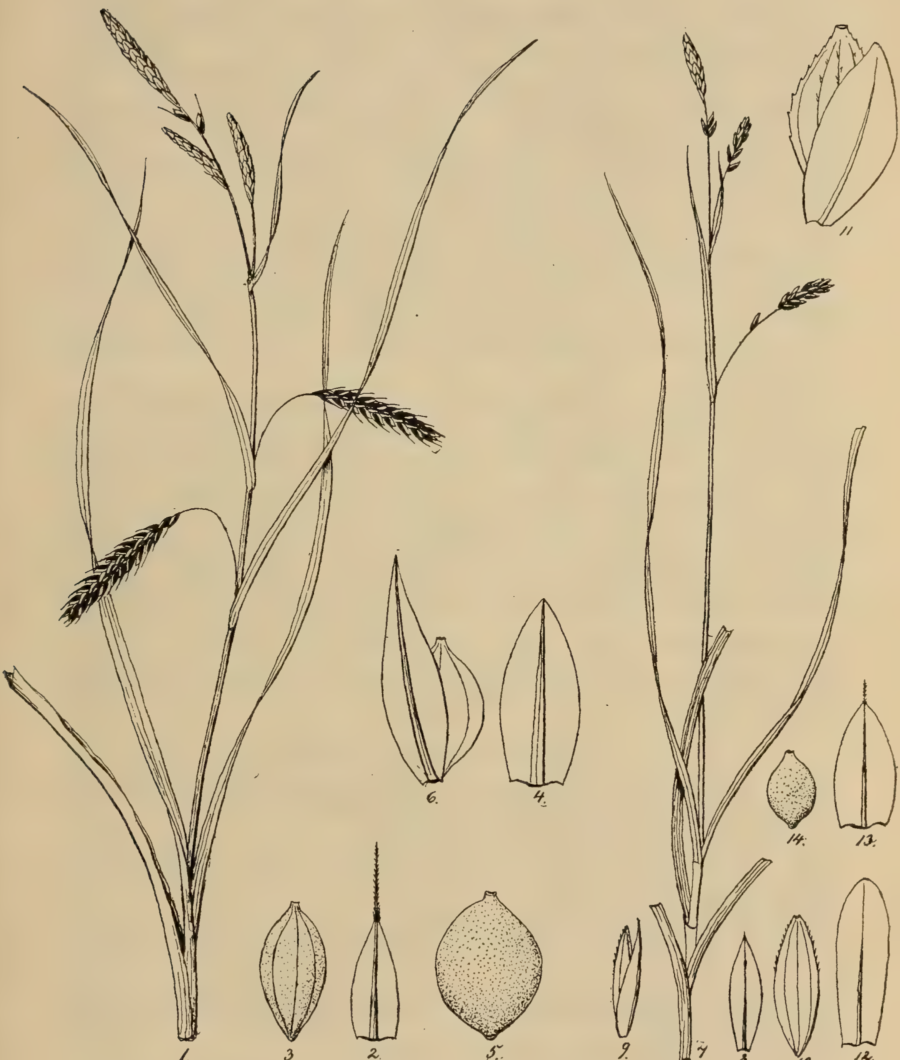
With regard to the habitat Dr. Walter H. Evans collected the species in Alaska: Kussiloff, on sands with *Elymus,* while *C. cryptocarpa* inhabits wet marshes, borders of ponds, and meadows near the coast.

As may be seen from the preceding pages the geographical distribution of the *Cryptocarpæ* is very limited: *C. cryptocarpa* inhabiting the shores of the northern Pacific and Bering Sea, beside Iceland; *C. Lyngbyei* known only from Faroe Islands; *C. capillipes* only from Iceland; *C. prionocarpa* from Japan (Yeso); *C. hæmatolepis* only from South Greenland, and finally *C. cryptochlæna from Alaska.*

And while these species differ in the extreme forms, they do unite in some characters, as if their descent might be traced through modification from some common type. We have seen the very important distinctions derived from the structure of the perigynium, the squamæ, the inflorescence to some extent, and to these may be added that *C. cryptocarpa, C. prionocarpa* and *C. cryptochlæna* are *aphyllopodæ, C. Lyngbyei, C. hæmatolepis* and the Greenland *C. cryptocarpa,* on the other hand, are *phyllopodæ:* with respect to *C. capillipes,* the rhizome being not represented, we cannot decide whether it be aphyllopodic or phyllopodic.

The nearest allies of these species may be sought among the *Salinæ,* and quite especially in the var. *Kattegatensis* of *C. salina,* even though all the *Salinæ* are *phyllopodæ.* The present geographical distribution in connection with the association with certain types of the

[8] Holm, Theo.: New or little known *Carices* from Northwest America, this Journal, vol. 20, p. 305, October, 1905.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Salinæ may indicate, that the *Cryptocarpæ* represent a modified branch of these. We remember that typical *C. salina* as well as the vars. *Kattegatensis*, and *Thulensis* and even *C. subspathacea* occur in Alaska, where *C. cryptocarpa* abounds; furthermore that *C. Lyngbyei* is associated with *C. salina* var. *Kattegatensis* on the Faroe Islands, while, on the other hand, *C. salina*, and only the typical plant, is very rare on Iceland. With respect to Greenland, *C. subspathacea* and *C. reducta* occur there, beside the so-called variety *concolor* of *C. filipendula*, which we are most inclined to refer to the *Salinæ*. At present Alaska with adjacent islands, and the northeastern corner of Asia may be looked upon as the most important center of geographical distribution of the *Cryptocarpæ*, extending as far south as Vancouver Island and Japan.

Carex salina Wahlenb. is a very variable species, and reaches the arctic region in Norway, Sweden and Lapland; *C. subspathacea* is circumpolar. But concerning *C. cryptocarpa*, this has, so far, only developed a very few, and indeed rather inconspicuous forms, and the geographical distribution is farther south than that of the *Salinæ* in general; the same may be stated with regard to the other *Cryptocarpæ*. We might thus be entitled to the conclusion that the *Cryptocarpæ* represent a modified, southern branch of the *Salinæ*, and especially of the polymorphic *C. salina* Wahlenb.

EXPLANATION OF FIGURES.

FIG. 1. *Carex Lyngbyei* Hornem.; specimen collected by E. Rostrup on Suderœ, Faroe Islands; two-thirds of the natural size.
FIG. 2. Pistillate scale of same; enlarged.
FIG. 3. Utriculus of same; enlarged.
FIG. 4. Pistillate scale of *C. cryptocarpa* C. A. Mey., from St. Paul Island, Bering Sea; enlarged.
FIG. 5. Perigynium of same; enlarged.
FIG. 6. Scale and perigynium of *C. cryptocarpa* from Alaska: Seldovia; enlarged.
FIG. 7. *Carex capillipes* Drej.; specimen collected on Iceland, Grimsnæs, by Chr. Grœnlund; two-thirds of the natural size; copied from Flora Danica Tab. 2844.
FIG. 8. Pistillate scale of same; enlarged.
FIG. 9. Pistillate scale and perigynium of same; enlarged.
FIG. 10. Perigynium of same; enlarged.
FIG. 11. *C. prionocarpa* Franch.; scale and perigynium; enlarged; copied from Franchet (l. c.)
FIG. 12. *C. hæmatolepis* Drej. from South Greenland collected by J. Vahl; staminate scale; enlarged.
FIG. 13. Pistillate scale of same; enlarged.
FIG. 14. Perigynium of same; enlarged.

Clinton, Md., March, 1920.

SCIENTIFIC INTELLIGENCE.

I. Geology and Natural History.

1. *Report of the Second Norwegian Arctic Expedition in the "Fram," 1898-1902;* 4 volumes, 1907-1919. Pp. 2071 with 9 maps, 111 plates. Published by the Videnskabs-Selskabet i Kristiania, at the expense of the Fridtjof Nansen Fund for the Advancement of Science.—The thirty-six parts of these four splendid volumes, by thirty-one authors, treat of the results in geography, terrestrial magnetism, meteorology, botany, zoology, and geology, gathered by Captain Otto Sverdrup and his band of fifteen loyal workers. Two of the latter died while in the far north, and the geologist, Per Schei, passed away in 1905 before he had time to work out his splendid collection of fossils.

The most striking results of the expedition were attained in geography, in mapping the southern and western shores of Ellesmere Land, along with the new territories, Axel Heiberg Land, Amund Ringnes Land, and Ellef Ringnes Land,—in all about 100,000 square miles. Probably the next best results were attained in geology, and more especially along the lines of Paleozoic stratigraphy, though the results in botany and zoology are also very good. Of plants, Simmons, the botanist, collected about 50,000 specimens, with the greatest number of new things among the lichens and mosses.

We now know that the Paleozoic strata of Ellsmere Land have a thickness of at least 14,000 feet, beginning with the Upper Cambrian and closing with the highest Pennsylvanian. The Devonian succession is best known, with a thickness of about 6,000 feet, yielding varied marine faunas of Lower and Middle times, while the Upper Devonian, of coarse detrital and of fresh-water origin, contains interesting fishes and land plants. The Mesozoic is represented only by marine Upper Triassic, and then there is no record until the lignitiferous fresh-water strata of the Miocene were laid down. Sea terraces are described at many levels all the way up to 570 feet above the present strand. Ellesmere Land is a dissected table land, of recent elevation, rising rather rapidly toward Greenland.

These striking results should be in every reference library, both because of their great value, and in order to show our Norwegian colleagues that we appreciate their labor of love. The volumes are golden monuments to Captain Sverdrup and his courageous band. C. S.

2. *Eocene insects from the Rocky Mountains;* by T. D. A. Cockerell. Proc. U. S. Nat. Mus., **57**, 233-260, pls. 32-36, 1920.—From the Green River series, Scudder and others have described 239 kinds of insects, to which are here added 35 new

forms, "an extensive series, but it is but a beginning." Of new genera there are 14. All of the species are small, seemingly indicating that the climate was not tropical. It is also evident that through a wider study of new material, more or less easily obtained, the insects will permit paleontologists to divide the Green River series into a number of zones. C. S.

3. *Annotated list of the Recent Brachiopoda in the collection of the United States National Museum, with descriptions of thirty-three new forms;* by W. H. Dall. Proc. U. S. Nat. Mus., **57**, 261-377, 1920.—Probably the largest and most valuable collection of Recent brachiopods anywhere is in the United States National Museum, where over 6,000 specimens are deposited, representing 181 different forms in 54 groups. In the present memoir, 33 new forms are described, along with the new group terms *Cnismatocentrum, Pantellaria, Pereudesia,* and *Jolonica.* The total number of living species is now about 215.

We all know that Doctor Dall is a law-abiding biologist, and we should, therefore, accept his decision when he shows that according to the rules of nomenclature *Gryphus* of Megerle von Mühlfeldt is not preoccupied by Brisson's earlier but erroneous name; hence *Liothyris* and *Liothyrina* are synonyms of *Gryphus* 1811. Again, the correct name for the well known brachiopod *Lingula anatina* is *L. unguis* Linné, and for *Terebratulina caput-serpentis, T. retusa* Linné. There is no good reason for biologists to grumble of these changes, since they are in full accord with the rules adopted by the International Zoological Congresses.

C. S.

4. *Palæontology: Invertebrate;* by Henry Woods. Fifth edition, pp. 411, 173 figs., Cambridge, 1920.—This well-known introduction to invertebrate paleontology, appearing first in 1893, is now in its fifth edition. Emphasis is placed on the forms found commonly as fossils, although something is said of all groups, even of those not found fossil. The book is to be regarded as the background for a laboratory course in which a few hundred genera are studied mainly from their mature characters; very little is said of their ontogeny, phylogeny, or classification. The illustrations are usually diagrams, designed to bring out the essential characters of stocks—probably enough for a laboratory manual. All in all, the work is probably the best elementary text-book of invertebrate paleontology, and is easily adaptable to American colleges. C. S.

5. *The life of the Pleistocene or Glacial Period;* by Frank C. Baker. Univ. of Illinois Bull., vol. **17**, No. 41, 476 pp., 57 pls., 1920.—This comprehensive and detailed monograph of the life of the American Pleistocene is the foundation upon which all succeeding students of glacial floras and faunas will build. None of the species is described or illustrated, but a great number of local assemblages are listed, and the specific identifications have the backing of ten specialists. Of plants, there are 145, and of these

but 7 are extinct, or about 5 per cent. Of animals, there are 540, of which 203 are extinct. The amount of extinction is not, however, general to all the kinds of animals, for among the 298 forms of molluscs it is but 2 per cent, while in the insects (108) it rises to about 96 per cent, and among the vertebrates (130) to more than 71 per cent.

In the first interglacial time, the Aftonian, there are now known 89 species. None of the invertebrates and plants is extinct, while of the 25 vertebrates not less than 23, or 92 per cent, are no longer living. The greatest abundance of known life is in the third interglacial time, the Sangamon, having 314 species.

"It is singular that the bones of *Homo* have not been found in America in connection with interglacial deposits," that is, in "no undisputed" interglacial one "in the territory once covered by the great ice sheets." The author, however, appears to agree with Hay that the human remains of Vero, Florida, may be of early or middle Pleistocene time (pp. 373-374).

"The interglacial intervals, especially the Yarmouth and Sangamon intervals, were of wide extent and long duration. . . It is probable that conditions during these intervals were not largely different from those of to-day, at least during the temperate period of the intervals. Factors of stratigraphic differentiation must be found in the insects and mammals, the plants and mollusks being of little value for this purpose on account of their uniformity through the interglacial intervals. Plants, however, are good indicators of climatic changes and have had, and will continue to have, an especial value in placing the climate of the fauna which may be found associated with them. Mollusks are excellent indicators of ecological conditions, which they usually rather accurately attest." (372-374.) C. S.

II. Miscellaneous Scientific Intelligence.

1. *The Professionl Preparation of Teachers for American Public Schools.*—Carnegie Foundation for the Advancement of Teaching. Pp. xix, 475 with 85 tables and a map of the State of Missouri. New York, 1920.—This report is based upon an examination of tax-supported schools in Missouri by W. S. Learned, W. C. Bagley and others. It originated in an investigation requested by the Governor in 1914, but the study of the local situation has been found to involve a thorough-going examination of the whole teacher-training problem in the United States, hence there results a wide application. Among the conclusions arrived at are the following. The teacher-training function of the state should be exercised by a single directing body, the "normal schools" and colleges being treated together as a part of the whole system of higher education. Further the

aim of each state should be to work toward a situation where the teacher in the elementary and secondary schools shall possess a training that is adequate and a professional recognition that will attract and satisfy the aspirations and the economic needs of able men and women. This is not simply a question of cost, but the recruiting of an adequate number of sincere, able, and thoughtful teachers requires that the people as a whole shall discriminate between that which is sincere and that which is superficial and insincere.

Married teachers are regarded as most desirable, because of their broader outlook and experience and since they may be assumed to have a vital interest in society and hence unusual opportunities for leadership and influence. The distinction between high school and elementary, or ''grade,'' teachers is regarded as one of the most serious difficulties in the way of professional advancement for teachers. It is believed that the public can be made to realize the value of good teaching. Helpful social relations between home and school should develop a discrimination between the teaching now provided and the better teaching that is to be desired.

2. *The Microbiology and Microanalysis of Foods;* by Albert Schneider, M.D., Ph.D. Pp. x, 262, with 131 illustrations. Philadelphia, 1920. (P. Blakiston's Son & Co.).—This book, which deals with changes in foods as the result of decomposition and with the technique of the examination of food products suspected to have undergone spoilage, is liberally illustrated. One hundred and thirty-one drawings, or photomicrographs, serve as guide to the beginner who desires to learn the microscopy or, to use the author's expression, ''microanalysis'' of food materials. The variety of topics considered is so large, ranging from sauerkraut to chewing tobacco, and the types of deterioration so numerous, that they cannot be referred to in detail here. The author attempts a microanalytical rating of food products which can, of course, by no means replace the other standards of purity in vogue in the laboratories of the food chemists. Inasmuch as the volume is specifically addressed to dietitians it is regrettable that a diet table, (page 254, following), devised in the year 1920, should attempt to evaluate foods in terms of ''Carbonates (Heat, Fat, or Weight), Nitrates (Muscle or Strength), Phosphates (Brain and Nerve)''. The viewpoints thus represented have been abandoned by students of nutrition more than a generation ago. L. B. M.

Obituary.

Dr. Gustav Seligmann, the German mineralogist, died on June 28 at his home in Coblenz, aged seventy-two years.

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VOL. L SEPTEMBER, 1920

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FOURTH SERIES

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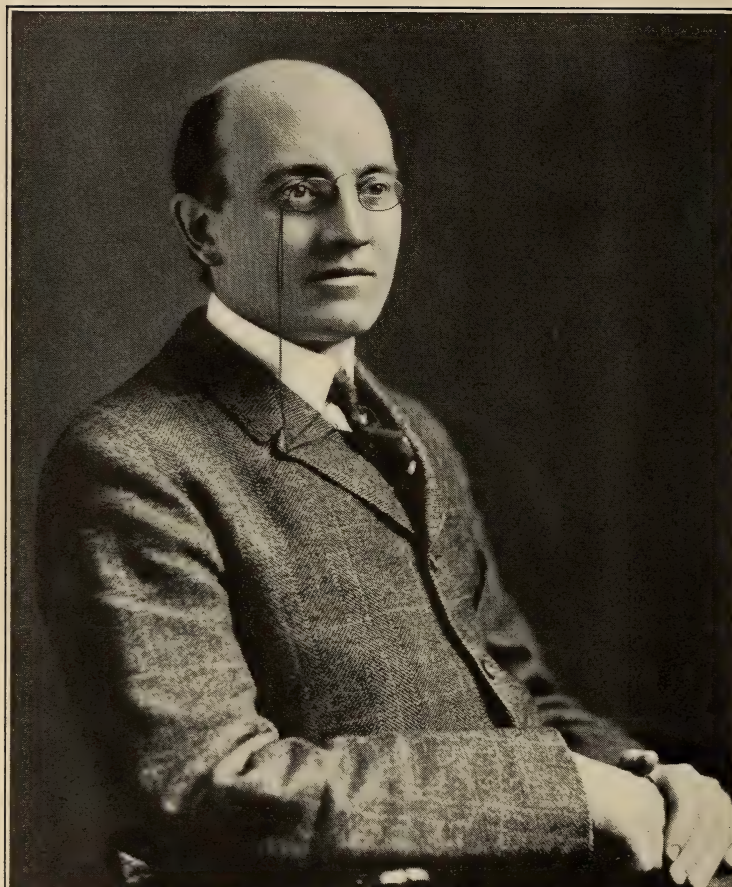


Louis Valentine Pirsson
1860–1919

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

LOUIS VALENTINE PIRSSON.

In the death of Louis Valentine Pirsson, professor of physical geology in Sheffield Scientific School, which occurred on December 8, 1919, there passed from this life a notable investigator, writer and teacher in the field of geology, a markedly able executive in University work and a man of many lovable and admirable personal traits. He was taken at the time when his power of utilizing wide knowledge and mature judgment was at its maximum, and American geology has, in his untimely death, suffered severe loss.

It is proposed in this notice to dwell particularly on the personality of the man as exhibited in divers directions during his career, rather than to furnish that fuller statement of his life and appraisal of his work which will be given in other more extended memoirs. Pirsson's accomplishments were due not so much to an inborn unquestionable and controlling impulse to a special field of scientific work as to an inherent fine quality of mind which, combined with a great love of nature, made it inevitable that some field of natural science should appeal strongly to him.

Looking first to the influence of ancestry as a source for certain characteristics, it is to be regretted that the data are meager. Pirsson's great-grand parents on his father's side came from Chelmsford, Essex, England, to the vicinity of New York, where the great-grandfather, William Pirsson, Jr., taught school for a time. A son of this William Pirsson, who married Emily Morris of New York City, became a manufacturer of pianos and lived in the suburbs of Fordham. It was in the comfortable home of this grandfather that Louis was born, on November 3, 1860, the son of Francis Morris and Louisa M.

(Butt) Pirsson. His parents were very young, the father not yet established in life, and Louis lived at his grandfather's home until after the death of his mother, which took place when he was but 4 years old. There is but slight record of the mother beyond the impression that she was a woman of refinement and possessed of much personal charm. On the father's side there is some evidence of an artistic temperament. Pirsson himself records, without reference to individuals, that members of his family were as a rule interested in some form of natural science.

When Louis was nearly 9 years old he became the ward of Thomas Lord of New York City, whose wife was a cousin of his father. The Lords were fond of travel and spent several years abroad soon after assuming this guardianship, so Louis was placed in the family of Rev. William J. Blain, living on a small farm near Amsterdam, New York. Mr. Blain was the pastor of a small Presbyterian church and was obliged to augment his slender salary by the return for such services and the produce of a few acres of land. Louis was treated as a member of the family, whose head was a strict disciplinarian of almost puritanical ideas, but he was also a good teacher and from him Louis received the greater part of his primary education. He was also given a thorough training in the strict and regular performance of many small duties which were a part of the regimen necessary for this family. But it was not all work, for Mr. Blain had an excellent library and here the boy early acquired a strong taste for reading of good literature.

After a few years Mr. Blain took another boy into his family to care for and educate and in the newcomer Louis found the companion needed to assist in developing his latent love for natural history. The following passage from an outline of his early life is significant: "Practically with the advent of this boy my scientific career began. I had been fond of reading books on natural history, some of which I found in Mr. Blain's library and others which had been sent me by relatives. As soon as I had an active companion we immediately began to go afield. We collected bird's eggs, minerals, and snakes, had a museum in the woodshed, and called ourselves naturalists. The neighboring brooks furnished material for an aquarium which we built. Interest in some form of natural history had existed in most of my family. Up to the time I entered college, and even later, birds were my chief interest. Only circumstances prevented me from becoming a zoologist."

Louis remained in Mr. Blain's family until the autumn of 1876 when he was nearly 16 years old. At that time his guardian placed him in Amenia Academy, Dutchess county, New York. Two years later this school was transferred to New Marlboro, Berkshire county, Massachusetts. This school was clearly not of high grade, but when it was decided that Louis was to go to college it was the influence of the principal, a Yale man, that sent him to New Haven and the boy's own desires that made him enter the Sheffield Scientific School, which he did, under the handicap of several conditions, in 1879.

Reviewing these early years it is clear that the boy who was denied the surroundings and affectionate care of a home was, after all, fortunate in some important respects. Under Mr. Blain he had learned to do appointed tasks with regularity and thoroughness and gained a sense of responsibility for the discharge of a duty. This he gratefully acknowledged in after years. The life in the country or in small villages was that suited to the physical development of a child who was not strong and gave opportunity for the independent development of an inborn tendency toward natural science.

From 1872 until near the middle of his college course Louis spent much of his summer vacations at the seashore with his guardian, who was at that time enjoying a large income and was very fond of yachting, fishing, and other costly sports. The boy had ample opportunity to become fully acquainted with the luxurious pastimes and other diversions of social circles of much wealth. While he enjoyed much of this life to the full, his notes of these years show that he always turned with still greater satisfaction to visits with friends of school days, especially at New Marlboro, where he renewed his rambles as a naturalist and fisherman.

Of Pirsson's college years there is, in his own phrase, "but little to say." He quickly overcame his entrance handicap and graduated with honors, in 1882. In the midst of his college course his guardian suffered severe financial reverses, involving, to some extent, the slender capital of his ward. Partly from this condition and partly from interest Pirsson gave special attention to chemistry, particularly to analytical work, as likely to lead to a future financial return.

The period of seven years following Pirsson's graduation was one of a hard struggle to earn a living while pursuing his own studies in chemistry looking toward a career as teacher and investigator. He paid his debts and became self-supporting. He also succeeded in establishing himself as a teacher of analytical chemistry, he made many valuable friendships continuing through life, but he did not really "find himself" by discovering the field of scientific work in which he was best adapted to engage with enthusiasm.

For two years he supported himself by odd jobs, assisting in the chemical laboratories of Professors Allen and Mixter and in the physical lectures by Professor Lyman. He also worked in the Sheffield library at this time, and, as in several succeeding years, he earned a large part of his scanty income by tutoring. Professor Allen's health was poor and during the academic year 1884-5 he was absent, the laboratory being placed in charge of H. L. Wells, with Pirsson and T. B. Osborne as assistants. Later, on Allen's retirement, Wells became his successor with Pirsson as first assistant. This relation continued until the summer of 1888.

During these years Pirsson became an expert analyst and attempted to begin a career as an investigator but he felt the lack of fundamental training in research methods and it was not until later years that he found the proper field for the successful application of his skill as an analytical chemist.

The school year 1888-9 Pirsson spent at the Brooklyn Polytechnic Institute, nominally as professor of analytical chemistry, but actually called on for elementary instruction in several sciences. Such a position was naturally not suitable for a man desiring a career as an investigator.

In the summer of 1889 the opportunity appeared through which Pirsson was to recognize beyond any question the line of scientific work which appealed most strongly to him. Through his kindly and constant friend Professor Brush he was offered the position as field assistant in the party of the U. S. Geological Survey under Arnold Hague, engaged in the study of the Yellowstone National Park. He was actually occupied as immediate assistant to Joseph P. Iddings and Walter H. Weed, with both of whom he was to maintain intimate relations for many years. While Pirsson had very little training to qualify him as a useful assistant in geological field work and he records that it seemed to him that he did not learn much, still, the man and his job had been brought together. He returned to New Haven after the field season determined to become a geologist.

The first step was to take up crystallography, advanced mineralogy and petrography under Professor Penfield. From this inspiring teacher, able investigator, and close friend Pirsson got the thorough training in research methods which he needed. His instructor's enthusiasm was contagious and the year passed very happily. A second season on the Geological Survey, in 1890, with Iddings and Weed, in the survey of the Livingston Quadrangle, Montana, confirmed the decision to go into geology. A few months more of work in Penfield's laboratory, and Pirsson was ready for the next step, a year and a half abroad, traveling and studying petrography and allied geological branches with Rosenbusch in Heidelberg and with Fouqué, Mallard, and Lacroix in Paris.

Pirsson was exceptionally prepared to profit by this experience under German and French masters of petrology and he made full use of his opportunities. He was sufficiently matured, in his general scientific point of view, to preserve his independence in thought and hence never came thoroughly under the spell of the great German master, who was accustomed to demand implicit confidence from his pupils. It is noteworthy that his constant aim was to secure the maximum benefit from his studies. Neither at this time nor later did it seem worth while to work for a doctor's degree, which he never obtained. Heidelberg was at this time the Mecca for students of petrography, who flocked there from all parts of the world, and Pirsson was thus fortunately thrown into close association with several men destined to become leaders in petrographic work in their respective countries. With some of these men he long maintained a more or less intimate friendship.

While abroad Pirsson received an offer to become State Mineralogist of Missouri and another, from Professor Brush, to return to New Haven as instructor in mineralogy and lithology in the Sheffield Scientific School, under Professor Penfield, at the munificent salary of $1,000 per annum. He accepted the latter offer, of course, and entered on his duties in the fall of 1892.

In 1893 Pirsson was relieved of his work in mineralogy and took over the course in geology which had been given by Professor Verrill. In 1894 he was invited to consider a transfer to Johns Hopkins University as successor to the brilliant teacher of petrology, George H. Williams, but his work had been recognized at the Scientific School and he preferred to accept a promotion to the position of assistant professor of inorganic geology. In 1897 he was promoted to the full professorship in physical geology, a position he held until his death.

From the time of his permanent connection with the Sheffield Scientific School, the development of Pirsson's career was rapid in three directions; first as an investigator and author of notable contributions to the advancement of geology; second as a teacher and author of text books; and third in University administration. It seems advisable to consider separately these three phases of his busy and effective life.

In the field of research Pirsson possessed in fine development the natural qualifications of a true scientific investigator. He had a keen, logical and philosophical mind, coupled with a lively imagination which he knew how to regulate. His powers of patient accurate observation and of concentrated attention were naturally associated with a highly retentive memory. He was very methodical in his plan of work, from the beginning to the end of every important task. Thus when he came to take up his real life work he was exceptionally equipped. He had a thorough training in physics, chemistry, crystallography and general mineralogy, and in his skill as an analytical chemist he possessed a tool which was to be of great service. Added to all this was a wonderful store of general knowledge, which was often turned to good account.

Pirsson's researches fall naturally into a few groups. First come a series of mineralogical papers, some ten in number, representing the results of his two years' work in Penfield's laboratory. These studies were made on specimens collected by himself or placed at his disposal by Professor Brush. They are important as showing how completely he was equipped for such work whether involving the measurement and figuring of complex crystals or determining by analysis the chemical composition and discussing the same. After these first two or three years Pirsson did little detailed mineralogical investigation except on constituents of igneous rocks.

Following his purely mineralogical studies Pirsson plunged at once into a series of broad petrologic investigations in Montana. Those researches were a direct outgrowth of his experience in the Geological Survey, especially in 1890, when a glimpse of the Crazy Mountains on the northern border of the Livingston Quadrangle indicated the rich field for study lying farther north in similar laccolithic mountain groups, east of the Rocky Mountains proper. The investigations in the field were carried out in 1893, 1894 and 1896, in association with W. H. Weed of the Geological Survey, when the Castle, Little Belt, Highwood and Judith Mountain groups were examined. Mr. Weed examined the Bearpaw and Little Rocky Mountains alone, in 1895, and collected specimens of the igneous rocks to be studied by Pirsson. The description of these mountain groups, especially as to their igneous geology and petrography, issued by the Geological Survey in a number of joint papers, and in periodicals, together with several articles by Pirsson alone, forms one of the most important contributions to American petrology. Pirsson's share in this work was a large one, extending beyond the purely petrologic discussion.

The various publications giving the results of this work are among the most widely known and highly valued of all petrological contributions of the past twenty-five years. Their importance lies in several directions. They gave a great deal of evidence concerning the nature of laccolithic type of igneous intrusion as the primary cause of isolated mountain groups in a plain country and confirmed the general ideas of Gilbert on this subject. Pirsson's powers as an observer combined with his skill in graphic illustration and in clear description render the petrologic portions of these reports of special value.

The chemical analyses, mostly made by Pirsson, and the microscopical study of the rocks, revealed many interesting rock types, some of them quite new to science. The character and relations of these rocks were accurately established and clearly described, furnishing an important contribution to systematic petrography. But Pirsson was keenly alive to the questions of genesis and secured from this material many valuable hints as to the difficult subject of magmatic differentiation and genetic relations.

Finally he presented a survey of the established facts which went far to substantiate and illustrate the idea of regional characteristics of igneous rocks which lead to the current designation of certain areas as "Petrographic provinces." That of central Montana as established by Pirsson is one of unusual general interest.

Pirsson's increasing University duties prevented his entering further on field work of considerable magnitude. But he turned to the study of promising areas in New Hampshire near Squam Lake, where he spent many summer vacations. In association with H. S. Washington he undertook the study of the Belknap Mountains, south of Lake Winnepesauke and of Red Hill on the eastern side of Squam Lake. A similar study of Tripyramid Mountain, on the south side of the White Mountains, was undertaken in collaboration with William North Rice.

In addition to the districts with which his published articles dealt he gained a first-hand knowledge of, and examined with considerable care, many other important localities and entertained for a time a project of extended research in New Hampshire. But the increasing demands of college duties interfered with this plan.

In these researches modern methods of petrographic study brought out the existence of many important rock types with interesting genetic relationships which earlier work had not disclosed. In all this work Pirsson was always mainly interested in making a contribution to our knowledge of the origin of the chemical and mineral differences in igneous rocks—petrogenesis. He had little interest in petrographic description *per se.*

Pirsson's field researches were mainly confined to Montana and New Hampshire but he was quick to see the importance of chance observations in many directions and interested others to follow up the more promising leads where he could not do so. Thus, through a visit to Bermuda he learned of the geological results of a deep boring for water, and by coöperation with Drs. Vaughan and Cushing of the U. S. Geological Survey and Dr. Thomas of the British Survey an important contribution was made to our knowledge of this mid-Atlantic island.

The philosophical side of the investigator was always prominent in Pirsson's publications. The Montana work led to special discussions of "Complementary rocks and radial dikes," a review of significant relations of the "Phenocrysts of igneous rocks," and the paper above mentioned on the "Petrographic Province of Montana."

His main work was done in a period when thoughtful petrographers of various countries were endeavoring to select from the mass of detailed knowledge accumulated in a few decades the criteria upon which might be based a much needed contribution to the systematic classification of igneous rocks. Pirsson's accurate and extensive knowledge of the rocks, his originality and good judgment naturally made him one of a group of American petrographers who jointly undertook in 1898 the task of formulating an entirely new system, on a new basis, and supplying the necessary terminology.

The group of men who accomplished this task—consisting of Pirsson, Iddings, Washington, and the writer—embraced men of different temperaments and mental characteristics, with views originally conflicting on many points. Success in reaching an agreement was rendered possible only through the influence of qualities such as Pirsson possessed in most notable degree. These qualities were recognized by his colleagues in making him the "Moderator" of numerous conferences where he was charged to bring about the necessary moderation of extreme views occasionally expressed as well as to guide the discussions. His judicial temperament and constructive ability made him a very effective member of the group.

The ideal College or University teacher is unquestionably one who possesses enthusiasm as an instructor, an extensive accurate knowledge of his subject, the power of clear presentation and explanation, and, in addition, that close touch with the problems of the science which can only come with experience as an investigator. In Pirsson this ideal was realized in high degree. His experience with undergraduates in chemistry, mineralogy and geology extended over thirty-seven years, and with graduates to about twenty-five years, largely in petrology.

Pirsson was greatly interested in both classes of students though it is probably true that the training of the graduate men afforded him the greater pleasure. He gave a great deal of earnest conscientious attention to the effective presentation of a difficult subject to the underclass men. He had his own ideas as to how this should be done and his scheme is preserved in the text book soon to be referred to.

It was Pirsson's aim in presenting geology to beginners to arouse their interest, not so much by a general statement in attractive form, appealing specially to their imagination, as by giving them a clear connected outline of the more essential facts of earth history arranged in the logical order of the science. Or, as Professor Schuchert has expressed it,—"To undergraduates Pirsson was a good teacher, holding them not by picturesque or fascinating language, but by his knowledge of his subject and his clear and fluent presentation of it."

Nearly twenty years ago Pirsson and his colleague, Charles E. Beecher, planned a text book in geology for undergraduates, but the death of the latter in 1904 prevented the execution of the plan. Some years later, in collaboration with Professor Schuchert, the plan for a "Text-book of Geology" was revived and the work was published in 1915. The success of the book has been notable. Some 15,000 copies of the "Physical Geology" part of this text book have been sold and a thoroughly revised edition, which the author completed but a few months before his death, is about to appear. It may be of interest to record the origin of one feature of the "Physical Geology" which illustrates the logical methods of the author, while the success of the book seems to indicate the soundness of his judgment on an important point in text books.

When planning the book Pirsson examined a considerable number of corresponding text books by well-known authors, with the object of ascertaining the relative weights which different men had given to different branches of the subject, as represented by space. He found that every author gave a disproportionate amount of space to his own specialty. Disregarding this special branch of each work he secured an average weight assigned by the authors in question to the principal topics, aside from the one in which prejudice had been displayed. Pirsson thought that the proper balance of treatment would be more nearly secured by accepting such an average than by using his own judgment. And this average was adopted for his Physical Geology.

The Text-book was planned for the undergraduate and Schuchert tells of Pirsson's repeated injunction that the geologist's desires or needs must not be allowed to influence the presentation.

Pirsson's aim to adapt his presentation to the needs of a particular group was further illustrated by the text book "Rocks and Rock Minerals," intended to meet the need of the mining engineer and geologist alike, for a simple classification and nomenclature for rocks applicable in the field on megascopic examination. This book has been widely used.

Pirsson had long projected in his mind a text book of petrology for advanced students. He gave a great deal of thought to the plan of this work which had many original features. It was to cover the broad field of the origin, composition, texture and classification of igneous rocks, and express the author's judgment, after thirty years of experience, as to the best method of teaching this difficult subject. Perhaps a third of the book had been prepared in its first draft. It is greatly to be regretted that it can never be finished, though certain chapters may be found adapted to publication.

A very considerable number of well-known geologists, teachers, and mining engineers have received a large part of their training in physical geology and petrology from Professor Pirsson. Among these is a notable group of members of the United States and Canadian Geological Surveys. Pirsson's students were always impressed with his extensive, accurate knowledge of his subject and found him a master of clear, concise statement, yet patient in the explanation of difficult points. He was keen to perceive the individual student's weaknesses and quick with help to remedy them. Remembering a lack in his own early training he paid special attention to instruction in the best habits and methods of research and to instilling into advanced students the high ideals of the seeker after truth which were so prominent in his own character. He was himself "uncompromising with the facts of a problem in hand" and laid wholesome stress upon this principle.

A trait of much influence which was highly appreciated was the sincere, kindly and truly friendly interest Pirsson always exhibited in the progress of a student's work.

Professor Pirsson was not only an investigator of high rank and a successful teacher, but his interest in and understanding of the broad problems of University administration were such as to make him a most valuable officer of the Sheffield Scientific School. This phase of his career has been so happily described by his long time friend and colleague, Professor Chittenden, that it is a pleasure to quote this tribute, kindly prepared at the writer's request, by the one best qualified to speak of these activities.

"Professor Pirsson possessed many traits of character rarely combined in one individual. The charm of his personality, his high ideals, his kindly manner, all helped to endear him to his associates; while his good judgment and forceful convictions were always respected by those with whom he worked. Endowed not only with clearness and keenness of mind which rightfully belong to one trained in the methods of science, he had benefited from the special opportunities he had enjoyed as a student of geology to cultivate habits of careful and discriminating observation. Thus, he had learned early in life the wisdom of forming judgment only after careful consideration of all the facts obtainable and with due regard to relative values. As a result, he was a highly valued member of the Governing Board of the Sheffield Scientific School, to which he was elected in 1897, at the time of his appointment as professor of geology. Further, his keen sense of duty and personal responsibility in any work upon which he entered, all combined to make him an especially useful member of the Governing Board, and he soon became closely identified with the life of the institution.

"In 1898, he was made Secretary of the Governing Board, which position he held for many years. Later, he assumed the duties of Class Officer of the Senior Class and Chairman of the Discipline Committee. In this way he was brought closely in touch with matters pertaining to the student body, and here particularly he manifested that kindly and sympathetic interest which showed in all his dealings, both with colleagues and students. The undergraduates recognized in him a friend, as well as adviser. They appreciated, in full measure, his fairness as a disciplinarian and his sympathy as a friend. In matters of large importance, educationally and otherwise, such as a university faculty naturally has to deal with, his opinions and views were always listened to with interest, even by those who might differ from him, and his judgment was invariably respected. Few men, professors in a university, are called upon to serve in so many and varied capacities as Professor Pirsson was during the period of his active work in the Sheffield Scientific School.

"In 1912, Professor Pirsson was elected a member of the Board of Trustees of the Sheffield Scientific School. This brought him in contact with problems of a different kind—largely financial; and here, too, his good judgment and breadth of vision made him a valued member of the Board.

"During a period of more than two decades of active work, Professor Pirsson assumed, in full measure, all the responsibilities which his position carried with it. As a teacher he was forceful and painstaking, as an investigator in his chosen field of work he was an enthusiast, and yet he was always ready to give freely his time and thought to the many questions constantly arising in an educational institution. Whatever he did, he did well. This simple statement may perhaps be taken as best illustrating the character of the man. Careful, thoughtful, painstaking effort was given to everything Professor Pirsson undertook. Hence, he could be relied upon, and for this very reason he was frequently overtaxed by burdens of many kinds which a less coöperative man would have refused to carry. He was the embodiment of the true university professor, whether viewed from the standpoint of the teacher or investigator in his chosen field of science, as adviser of inquiring students, or as worker in faculty or committee. Above all, he was the embodiment of unselfish devotion to duty."

Pirsson served as an associate editor of this Journal from 1899 to the time of his death. He was painstaking and conscientious in furnishing, with characteristic generosity of time and labor, brief but pointed notices of many geological publications. About forty of his original papers also appeared in this Journal.[1]

The recognition of Pirsson's contributions to geology brought him membership in the National Academy of Sciences, the Geological Society of Stockholm, Sweden, the Washington Academy of Sciences, the American Academy of Arts and Sciences, and the Connecticut Academy of Arts and Sciences. He was a fellow of the Geological Society of America, of which he served as Vice-President in 1915.

Many of the qualities and accomplishments which were necessary to Pirsson's professional success were also notable in social life, where he was a charming companion.

[1] For a full Bibliography of Pirsson's publications, see the forthcoming biographical memoir to be prepared for the National Academy of Sciences by Joseph P. Iddings.

The power of accurate observation guided by a broad and most intelligent interest permitted him to make the best use of the opportunities afforded by extensive travel in many countries and by wide acquaintance with professional people. He had a wonderful fund of experience and information while a keen sense of humor ensured a delightful flavor to many of his tales of experience. He was fond of a good story and was himself a skilled raconteur.

Many of Pirsson's friends will recall with great pleasure evenings spent during the decade 1885 to 1895 with a group mainly of young instructors and associate professors, in quarters they occupied in the attic of the old Sheffield Hall. Among these "Attic philosophers," as they came to be known in New Haven, were S. L. Penfield, H. L. Wells, C. E. Beecher and Pirsson. After the day's work was ended it was the custom of these men to gather in the central hall under the roof with their chance guests and talk on whatever the work or the events of the day suggested, in serious or in lighter vein as the case might be. It was good talk, too, of the kind that helped or entertained. In these seances Pirsson's talents and resources showed to great advantage. His fund of information and store of anecdote made him a leader in the group of notable men named.

Pirsson was a hard persistent worker. Many forms of relaxation did not appeal to him. But there was one sport which he enjoyed most heartily. He was a true disciple of Isaac Walton. From boyhood through life he rarely failed to devote several weeks of each year to trout fishing. His keenest pleasure was in fly fishing for the game trout of the Yellowstone, of Maine or of the brooks and ponds of the Berkshires. Season after season he returned to New Marlboro, where as a boy he had become familiar with the pools and rapids in which the best sport was to be found. With an accuracy and care which were characteristic of the man, for many years Pirsson kept a special record of his fishing trips, giving exact dates, localities, companions, the spots where luck was best, the number and weight of the fish caught. The details of specially exciting contests were given in full and a tabular résumé of the season's catch ended the journal for each season.

Stories of the rambling naturalist and fisherman always aroused his enthusiasm and he wrote a number of tales of his own experiences which appeared under a nom de plume in Forest and Stream.

As the story of Pirsson's early life has shown, he was denied as a boy the joys and blessings of the intimate home circle. In New Haven, which became his home from the time of his entrance into the Scientific School, he gradually formed a circle of highly valued warm friends. In 1902 he was married to Miss Eliza Trumbull Brush, a daughter of his early teacher and close friend, Prof. George J. Brush.

Conscientious and unsparing devotion to manifold duties gradually had its effect on a constitution never rugged. A number of years ago Pirsson began to suffer from rheumatism, but he could not, at first, bring himself to give up his work and devote the necessary time to recuperation. Gradually his trouble developed into chronic arthritis, and the best of advice and the care of his devoted wife could only bring temporary relief. During periods of apparent improvement he continued his work, at great cost. After a few months of intense suffering he passed away in December of 1919, in his sixtieth year.

In the course of this trying illness the beauty and dignity of his patient fortitude bore the heroic stamp and his solicitude for others and courteous appreciation of every attention never failed.

WHITMAN CROSS.

Art. XIV.—*Origin of Rock Tanks and Charcos;* by Kirk Bryan.[1]

Table of Contents.

Introduction.

In arid regions small water supplies are very important. That a few gallons of water can be obtained at a certain place for a period as short as two or three days may make possible a journey which otherwise could not be undertaken. In the Papago Country, a great area in southwestern Arizona lying along the Mexican border between Nozales and Yuma, west of Santa Cruz River and south of Gila, such small water supplies are, in many localities, the only dependence of travelers. In a reconnaissance made in 1917 for the purpose of preparing a guide to desert watering places[2] considerable attention was given to rock tanks or "tinajas," and to charcos, or "mud holes." Both types of watering places are pools of water which remain in small depressions or basins after rains. The origin of these basins presents interesting problems in minor geology. The distribution, also, of both charcos and rock tanks is controlled by the physiography of the region. For these reasons it seems advisable to give an account of the origin of these watering places in advance of the publication of the final report.[3]

Summary.

Rock tanks are located both in and away from stream channels. The latter variety are basins formed by the

[1] Published by permission of the Director of the U. S. Geological Survey.
[2] Bryan, Kirk: Guide to desert watering places in the Papago Country, Ariz., U. S. Geol. Survey, Water-Supply Paper 490-D, in preparation.
[3] Bryan, Kirk: The Papago Country, Ariz., U. S. Geol. Survey Water Supply Paper in preparation.

irregular erosion of rocks, and are usually small. They are mere pockets in the rocks which hold water for a few hours or days after a rain. The rock tanks formed in stream channels are mostly plunge pools and potholes associated with falls. In the Papago Country they seldom exceed 10 feet in diameter and 5 feet deep. Sand tanks are similar basins which are filled with coarse sand by the tail end of floods. Water is held in the interstices of the sand. Since rock tanks are generally associated with falls, the distribution of these is of prime importance. In the Papago Country falls occur in streams mainly because of: (1) renewed uplift along faults parallel to the mountain ranges, but at right angles to most of the mountain canyons; (2) dissection of rock plains or pediments at the foot of mountains by headward cutting of small rock gorges. Falls produced by either cause, and therefore most rock tanks, occur at or near the borders of the mountains.

Charcos are depressions in adobe flats over which floods spread widely. The important charcos are formed by the swiftest thread of the current, which excavates a channel deeper in some places than in others. After floods, pools of water remain, the larger of which are from 15 to 30 feet across, and from 20 to more than 1,000 feet long. The largest adobe flats, and therefore most of the charcos, lie at the centers of the intermontane valleys.

Rock Tanks.

Definition.

A rock tank is a cavity or depression in rock which is filled periodically with rain or flood water. The Mexicans commonly, and many Americans, use the Spanish word "tinaja," a bowl or jar, in speaking of rock tanks. These cavities may occur either: (1) away from stream channels, or (2) in stream channels.

Rock tanks away from stream channels.

In mountains or hills small rock pockets are found which are due to the unequal weathering of rock surfaces. They vary in size from a few inches across and a half-inch deep to pans which are from 5 to 20 feet across and 6 to 8 inches deep. Such pockets hold water for longer or shorter periods following a rain and are of little value as water supplies. Experienced hunters and travelers, however, know well how to take advantage of these tanks for the few hours or days after a rain when they hold water.

Rock tanks in stream channels.

The most important rock tanks are irregularities in the rocky beds of streams which hold pools of water after floods. These irregularities are due to the eddies of the current which tend to erode the stream bed un-

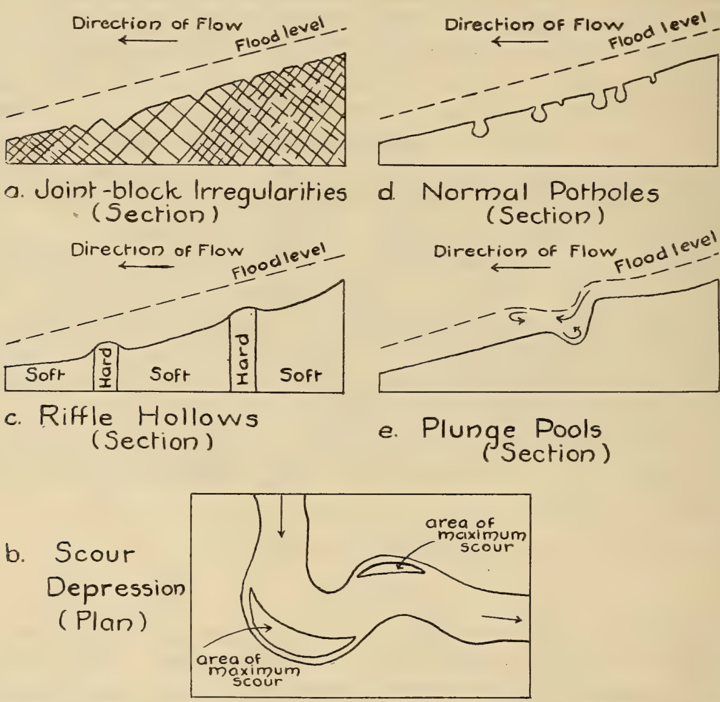


FIG. 1. Diagram showing five types of depressions in channels: a, joint-block irregularities; b, scour depressions; c, riffle hollows; d, normal potholes; e, plunge pools.

equally. The inequalities are probably no more common in ephemeral streams than in the permanent streams of humid countries. The beds of ephemeral streams are, however, exposed throughout their length during the greater part of the year, and undrained hollows or depressions are on this account easily found.

The common depressions are of five types: (1) joint-block irregularities; (2) scour depressions; (3) riffle hollows; (4) potholes; (5) plunge pools, fig. 1.

Most rocks are divided into blocks by sets of intersecting fractures or joints. The impact of the current and of sediment which it carries tends to break out blocks of rock in the stream channel. This process of plucking results in irregularities of the stream channel, as shown in fig. 1, a. When the joints are widely spaced the blocks are large, and the depressions are correspondingly large. Closely-spaced joints, however, produce a rough but comparatively even-floored channel. It is obvious that very wide spacing of joints will produce joint fragments too large to be easily removed and that there is for any stream an optimum spacing of the joints which will produce the maximum roughness of channel floor. In these rugosities water remains after a flood, but these pools are seldom of great importance as watering places. Commonly the process of joint-block plucking is combined with the processes detailed in the following paragraphs. A favorable spacing of joints is essential for the production of the larger rock tanks. The fractures must also be water-tight or nearly so in the bottom and downstream wall of the tank, else the water will drain rapidly. In some tanks it is evident that joints on the upper side of the cavity are open, and through them small amounts of water seep into the tank for short periods after floods.

Where the channel of a stream is curved the swiftest thread of the current is near the outside of the bend. The maximum erosive force of the current is exerted over a crescentric area in the bend, as is shown in fig. 1, b. These areas are likely to be scoured below the grade of the stream, producing the hollows here called scour depressions. In combination with joint-block plucking and the formation of potholes scour depressions are likely to form important tanks in hard rock. A scour depression in relatively soft hardpan appears to be the cause of one of the waterholes in the Vekol Valley, Maricopa County, fig. 2. This consists of a hollow at the point of an elbow in the sandy channel of the stream. A cavity in the underlying hardpan holds water after a flood. The pool of water is 6 feet by 4 feet, and 2 feet deep, located under the bank. Seepage from the sand of the stream channel and from the sandy clay of the banks maintains the water for a considerable time after adjacent charcos have dried up. The water does not last very long, for the level fell 1½ feet between September 20 and September 22, 1917.

Riffle hollows occur when the bed of a stream is composed of alternate layers of hard and soft rock, as illustrated in figure 1, c. Erosion of the softer rock is carried below the grade established by the harder rocks which project in the stream bed and constitute obstacles to the stream flow. Such hollows are commonly from 3 to 12 inches deep, and vary in size according to the spacing of the harder portions of the rock in the stream bed. Riffle hollows make very shallow pools unless deepened by pothole action, or unless they grade into plunge pools.

A pothole is formed by the grinding or drilling of an original hollow in a stream bed by sand, pebbles, or bowlders rotated by the current. The top of a pothole is nearly circular, and the diameter generally increases below, as shown in figure 1, c. The diameters of potholes

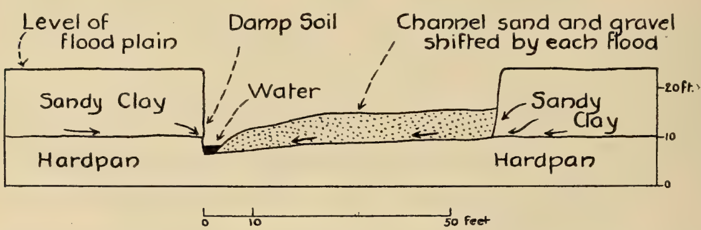


Fig. 2. Cross-section of the stream channel and waterhole in the Vekol Valley, Maricopa Co.

range from 3 inches to 10 feet or more, and the depths from 6 inches to 8 feet or more.[4] Potholes develop in all streams actively eroding their channels in consolidated rock. They are, however, more likely to be found in gorges and below waterfalls. They are thus associated with and grade into plunge pools.

Plunge pools are formed by the impact of water and the sand and gravel which it carries, at the foot of waterfalls, fig. 1, d. A fall differs from the changes in grade of stream beds described in connection with riffle hollows in that it is usually sufficient to cause a flexure in the flood surface of the stream. Consequently, a very great velocity, accompanied by eddies and back currents, is present at the foot of the falls. The erosive effect at the foot of the falls increases with the discharge of the stream in flood, and the quantity and character of the

[4] Elston, E. D.: Potholes, their variety, origin and significance, Sci. Monthly, vol. 5, pp. 554-567, 1917, and vol. 6, pp. 37-51, 1918.

sediment carried. Streams of the size common in southwest Arizona are competent to erode pools about 10 to 20 feet in diameter and 3 to 10 feet deep. The shape of the pool depends on the character of the rock and the amount of modification due to joint-block plucking and pothole formation. Plunge pools are the largest type of channel irregularity, and consequently hold the largest pools of water. Most important rock tanks are of this class.

Physiographic relations of rock tanks.

From the foregoing discussion it is seen that the largest rock tanks are plunge pools at the foot of falls, and that even the other channel depressions are likely to be larger and more important in the parts of a stream near falls and rapids. The factors governing the occurrence of falls are thus of importance. Falls are found in southwest Arizona under at least three different circumstances: (1) where there are marked differences in the ability of adjacent parts of the rock to resist erosion; (2) where dissection of the mountain pediments on a new grade produces headwater falls; (3) where renewed uplift of fault-block mountains produces falls on a stream crossing the fault line.

Falls due to differing resistance of rocks to erosion.

Falls wholly due to an unusually resistant rock were found in only one locality in the Papago Country, and on a minor scale; but the locus of the falls due to other causes is often determined by a resistant bed, as in the case of the lower falls at Baker Tanks, southeast of Wellton, Yuma County. The variety of circumstances and the association of different types of tanks is well illustrated by this watering place. The tanks are in a streamway which leads in a northwesterly direction on the southwest flank of the Baker Peaks. Below the tanks the stream channel lies in a small canyon 150 feet wide, and about 25 to 30 feet deep. Above the tanks the channel is but 2 to 3 feet below the adjacent plains. Between these two parts of the stream is a stretch of falls and rapids about 1,000 feet long, which is shown in fig. 3. The rock in which these falls occurs is a coarse, arkosic conglomerate, which strikes N. 77° west, and dips 65° southwest. The bulk of the material is a granitic debris with pebbles one-eighth to one-half inch in diameter. The rock is banded and cross-bedded, and contains many large bowlders, singly or in groups and lenses. The bowlders are from 3 inches to 3 feet in diameter, and are more or less rounded joint fragments of granite and gneiss. The bedding is massive, but there are numerous joints, some of which are slickensided.

Since deposition the conglomerate has been tilted and eroded so that its cut edges now form part of the pediment of the adjacent Baker Peaks. As in other parts of

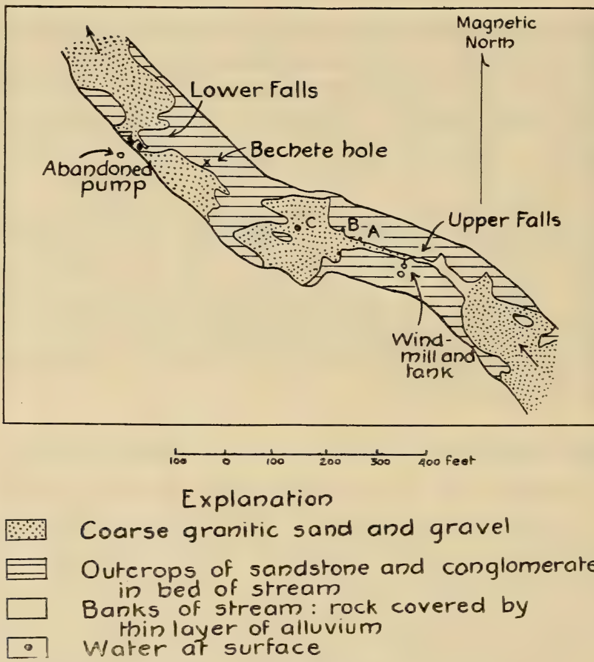


Fig. 3. Sketch map of Baker Tanks, Pina County.

southwestern Arizona, the pediment is dissected. Headwater cutting of a new canyon by the stream is the cause of the falls. As shown in fig. 3 there is a narrow gorge in the conglomerate beginning 150 feet southeast of the windmill. In this gorge are falls and rapids. From the windmill west for 150 feet is a narrow gorge from 10 to 20 feet wide with walls 10 feet high, the bed of which is a plunge pool. This is filled with coarse sand to a depth said to be more than 20 feet. The windmill pumps water from a pipe imbedded in the sand. At the lower end of the little gorge at the points marked A and B are potholes about 3 feet in diameter developed along joint plains. Below the gorge is a flat about 500 feet long, which ends in a second fall. The flat has an irregular rock floor, the hollows in which are covered with sand. These hollows are due to irregular erosion. At the point marked C, there is a hollow somewhat deeper than the others, in which water may usually be found by digging away the sand.

The second or lower falls are about 6 feet high, and are caused by two beds of very coarse conglomerate which resist erosion somewhat better than the rest of the rock. The downstream bed of coarse conglomerate has been largely cut through; the upstream bed has been cut at only one point, near the abandoned pump. At

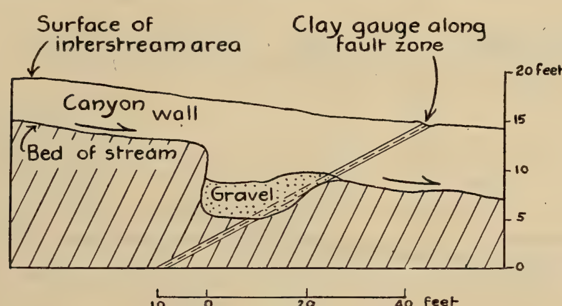


Fig. 4. Section along stream channel at Tabaseca Tank, Riverside County, Calif.

this place two very perfect potholes about 10 feet in diameter have been formed at one side of a narrow gully in the rock. Both of these hold about 4 feet of water, though the total depth of each is about 10 feet. Below the falls is a plunge pool covered with sand, in which water can be found by digging.

The influence of a notably soft rock in the production of falls is shown at Tabaseca Tank.[5] This tank lies in an arroyo which drains the northern flank of the Chocolate Mountains in sec. 31, T. 7 S., R. 14 E., M. D. B. and M., Riverside County, California. The arroyo lies in a narrow gully about 10 feet below the level of the surrounding plain which is part of a slope cut on rock and

[5] Brown, John S.: The Salton Sink Region, a geographic, geologic, and hydrologic reconnaissance, U. S. Geol. Survey Water-Supply Paper, in preparation.

extending along the front of the mountains. The plain is underlain by rhyolite which, in the vicinity of the tank, is broken along a fault plane that crosses the stream and dips upstream about 25 degrees (fig. 4). Shearing and decomposition by water percolating along the fault plane have changed the originally hard rhyolite to soft, claylike gouge about one foot thick. The gouge of the fault in its resistance to stream action is similar to any other soft rock layer. As the stream cuts down its bed the triangular block on the upstream side is constantly undermined by the ease with which the clay gouge is eroded. With the waterfall once initiated, the formation of a plunge pool is made easy by the presence of the soft layer, and the channel is excavated below grade. The pool is about 20 feet in diameter and filled with gravel

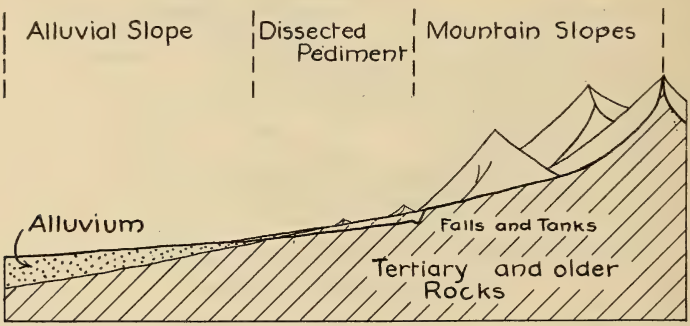


Fig. 5. Diagram showing the production of falls and tanks by erosion of mountain pediment on a new grade.

and bowlders. Water is found in the gravel throughout the year unless campers have drawn too heavily on it.

Falls due to changes in stream grade.

Many of the mountains of southwest Arizona are surrounded by plains, sloping to the intermontane valleys. These plains or pediments[6] are underlain by hard rocks similar to those of the mountains. The streams which once wandered more or less at will are in most of the pediments now entrenched in steep-walled gullies or little canyons which are deeper toward the mountains. The change in grade does not appear to be due to uplift

[6] Bryan, Kirk: Mountain pediments; a discussion of the erosion of desert ranges. Paper delivered Dec. 31, 1919, before the Geological Society of America, Boston, Mass., to be published under the title: Geology and Physiography of the Papago Country, Ariz., by the U. S. Geol. Survey.

and seems to be due to a change in the supply of sediment and the volume of the streams. This change is perhaps climatic, and has certainly been general over large parts of southern Arizona and northern Mexico. The little canyons of the pediment increase in length by headward erosion. At the head of each little canyon is a falls or rapids which marks the separation between the old grade and the new. These relations are brought out in the diagram, fig. 5.

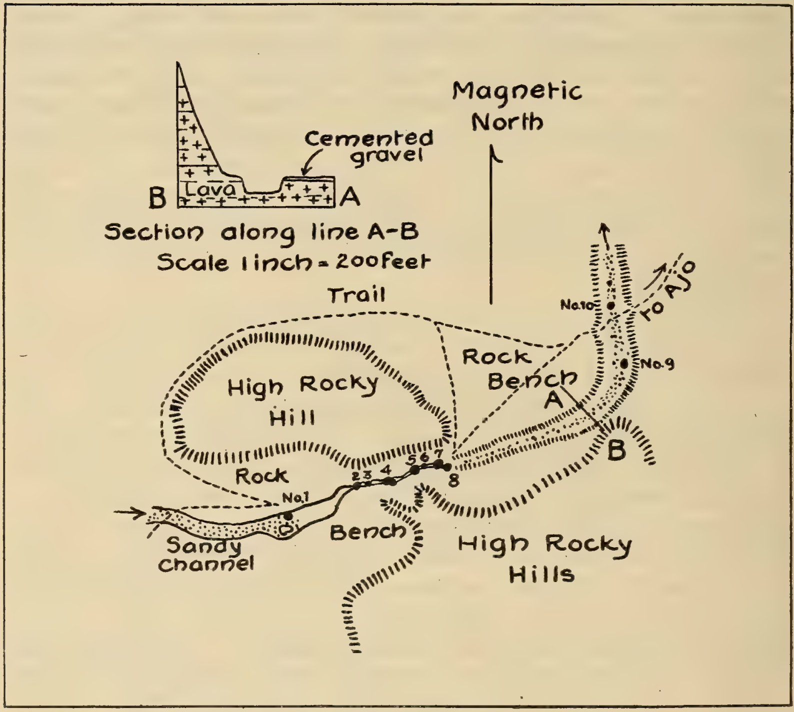
Since each stream which heads in the mountains suffers such a change in grade there are many falls. Though not every falls produces a plunge pool of sufficient size to make an effective watering place, the prevalence of falls due to the dissection of the mountain pediment is the principal reason for the large number of rock tanks in the desert region. The local conditions at each falls determine the size and effectiveness, as watering places, of the plunge pool and associated potholes. The variety of these circumstances can best be illustrated by an example.

Black Tanks is a well-known watering place in the Crater Mountains, Pima County. The tanks consist of a series of plunge pools numbered from 1 to 8, in fig. 6, with two very temporary waterholes marked 9 and 10. The stream has a sandy bed about 2 feet below its flood plain in the open valley above and west of the tanks. Below the falls section with its 8 tanks, the stream flows in a steep-walled gully with banks from 10 to 20 feet high. The falls and rapids extend about 500 feet, with a total drop of about 50 feet between the upper and lower channels of the stream. Throughout this stretch the stream runs in a rocky gorge of variable width. The individual falls are determined by the resistance of the horizontal layers of lava which form the bedrock. The larger plunge pools are from 4 to 5 feet deep and 10 to 15 feet wide.

On either side of the channel is a rock bench which varies in width from 50 feet to several hundred feet. This bench slopes gently upward to the foot of the steep slopes of the hills, fig. 6, inset cross-section. On the north side of the stream below the tanks the bench is covered with from 2 to 3 feet of cemented gravel. The rock benches extend around the hills and are continuous with similar rock benches which connect with the mountain pediment. It is evident that Black Tanks are the headwater falls of the new canyon working headward in an old valley with gentle slopes, which was formed at the same time as, and forms part of, the neighboring sloping plains or mountain pediment. Baker Tanks (p. 3) and many others belong to this type.

Falls due to renewed uplift.

Most of the mountains of southwest Arizona are narrow, uplifted strips of the earth's crust bounded by faults



SCALE OF MAP IS 1 INCH TO 622 FEET.

FIG. 6. Sketch map of Black Tanks.

on one or both sides. After uplift streams cut canyons and established smooth grades from the crest of the mountains to the adjacent valleys. In certain ranges renewed uplift took place on one side of the mountains only, probably along the same fault-plane on which the original uplift occurred. This uplift resulted in flattening the old stream grades in the higher part of the mountain and producing a cliff or fault scarp across the stream channels on that side of the range. Streams immediately began to cut headward through this fault scarp, and it has generally been removed. However, in certain ranges, the Estrellas and Tinajas Altas in particular, the new grade has not yet reached the crest of the range, and is separated from the old by falls, as illustrated in fig. 7.

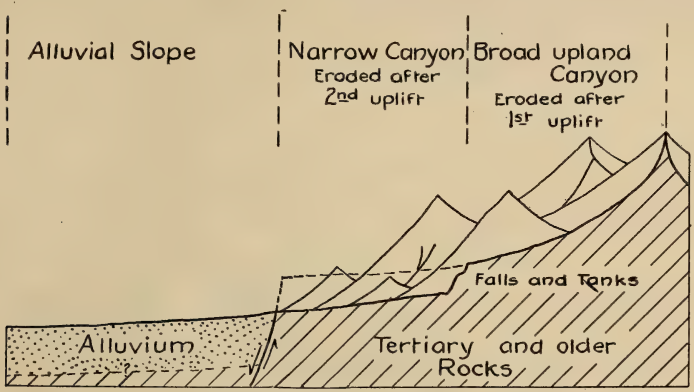


Fig. 7. Diagram showing production of falls and tanks by renewed uplift of eroded fault-block mountains.

The famous Tinajas Altas is the only watering place which can be definitely ascribed to this cause, but it is thought that a number of other tanks, including Tule Tank and Heart Tank, were probably formed in the same way.

Schrader has noted a number of rock tanks on the east flank of Estrella Mountains, Maricopa County, at the elevations of 2,000 to 3,000 feet.[7] The Maricopa topographic sheet shows that in a number of these canyons the stream grades between the elevations of 1,500 feet and 3,000 feet are so steep as to be almost continuous falls. Above 3,000 feet the grade is flat and the canyon is wide with gentle slopes. There is thus good evidence that the Estrella Mountains have been rejuvenated by block faulting, and that the tanks are plunge pools and potholes associated with falls due to the dissection of the fault scarp.

[7] Schrader, Frank C.: Report on the Gila River Indian Reservation, Arizona, as to the mineral or non-mineral character of its lands, 1918. Unpublished manuscript in the files of the Land Classification Board, U. S. Geol. Survey.

The Tinajas Altas are situated in Yuma County on the east side of the Tinajas Altas Mountains, part of the Gila Range, 27 miles south of Wellton, and about 4 miles north of the International Boundary. This locality has been a camping place on the route from Sonora to the junction of Gila and Colorado rivers since prehistoric times. More than 300 persons are said to have died here of thirst and exhaustion during the gold rush beginning

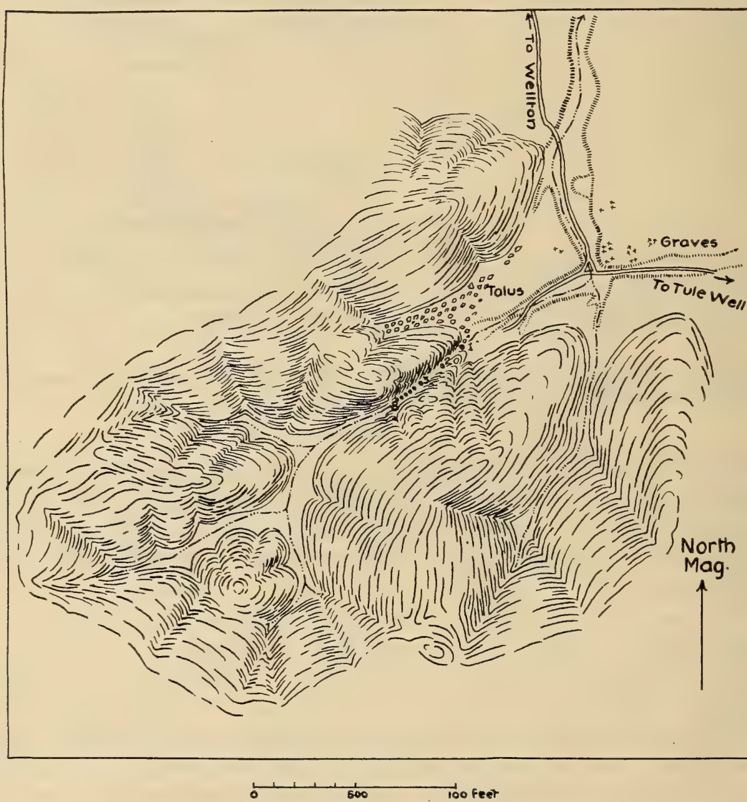


FIG. 8. Sketch map of Tinajas Altas from plane-table sheet by Kirk Bryan, and sketch by C. G. Puffer.

in 1848. About 60 graves were counted of which a few are located on the map, fig. 8. The Tinajas Altas consist of 8 tanks, distributed for 500 feet along a stream course so steep that it may be considered an almost continuous falls.

The map in figure 8 shows that the falls occur in an indentation of the mountain front, and that a considerable drainage area lies above the falls. This upland valley has relatively gentle slopes, and the grade of the stream through it is in marked contrast to the grade in the falls section, which is approximately 1 to 1.

The rock of this part of the mountains is a coarse, pegmatitic granite. Most of the surfaces are strained brown from the deposition of limonite, especially in the cove of Tinajas Altas. In such places there are many caves, reentrants, and pinnacles which add much to the picturesqueness of the mountain slopes.

The details of the falls, and the form and location of the plunge pools, are largely affected by the joints of the granite. The master joints strike N 2° E, and dip 65° NE, and divide the granite into great slabs, varying in thickness from 2 to 10 feet. A less perfect system has a strike N 80° E, and an almost vertical dip.

The profile shown in fig. 9 is made from the plane table location of the tanks, and an aneroid determination of the top of the falls by C. G. Puffer. It shows that in general the falls are parallel to the dip of the joints, and the plunge pools are located at places where the joints are closely spaced. In plan, also, the course of the stream is controlled by the joints, as shown in fig. 10. The steepest grades are parallel to the minor joint system, and the flattest grades to the master joint system. The plunge pools are located on the steps developed at the intersections of the joints.

The lower tank (No. 1 in fig. 8) fills with sand after a flood, and therefore the water lasts longer than in the others. The second tank is accessible by climbing along a cable fastened to the rock about 75 feet south of the channel. From the second tank the third is easily reached. The fourth and higher tanks are very inaccessible, and but little used except by mountain sheep. Animals, however, frequently meet disaster by falling into the water and drowning. Two dead sheep were seen in the upper tanks on October 22, 1917.

Sand Tanks.

Sand tanks are a variety of rock tanks formed in stream channels in the various ways previously outlined, and differing from other rock tanks only in being filled with sand. The tail end of the flood carries sufficient sand to fill the cavity, whereas with ordinary rock tanks the latter part of the flood is relatively clear. The sand thus deposited is saturated with water. The upper por-

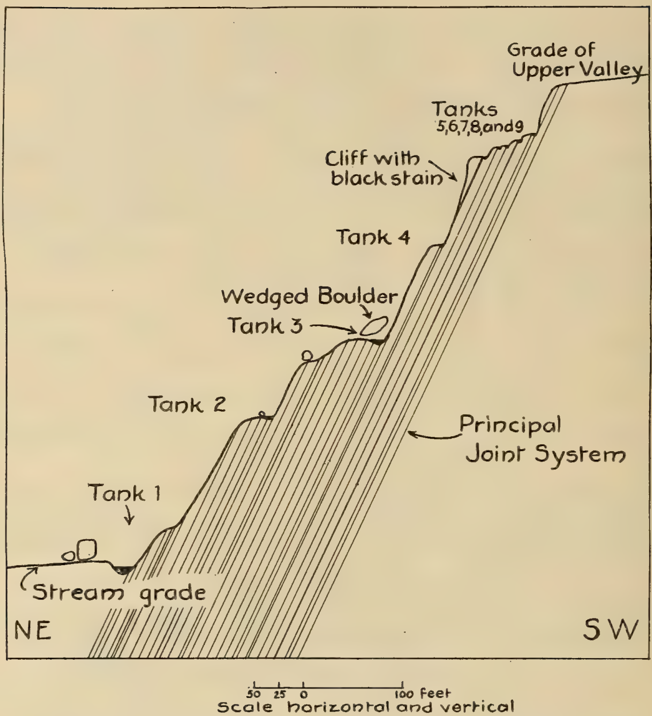


FIG. 9. Diagrammatic profile of falls of Tinajas Altas.

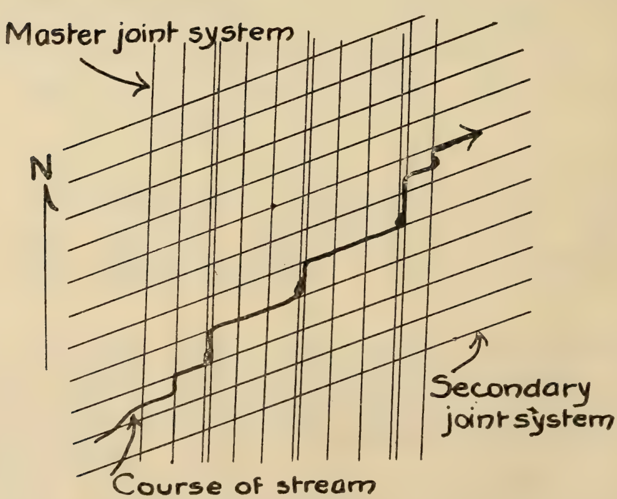


FIG. 10. Idealized diagram to show effect of joint system on course of stream and position of tanks at Tinajas Altas.

tion quickly dries, but because the pore spaces between grains are relatively large, and capillary action is unable to bring the water to the surface, further evaporation can not take place. Though for the same size of cavity the volume of water in sand tanks is less than a fourth that of rock tanks, the water commonly remains for a longer period after a flood than in rock tanks. The use of the water by animals is restricted because it is necessary for them to dig holes down to the water level and throw the sand out of the tank. Coyotes are able to do this with great ease, but horses, burros, and cattle have great difficulty in digging in the sand. Many rock tanks, on the other hand, are so accessible to wild animals and stock that within a few days after they are full all of the water has been used.

For instance, at Black Tanks, tanks 7 and 8 (fig. 6) are commonly filled with sand, and water is obtained by digging. The basins are relatively shallow, and though No. 8 is considered the best, in neither does water last all the year. Tank 4, however, is usually swept clean and makes a large pool. But as Nos. 1, 4, and 5 are accessible to stock the water is rapidly used up under ordinary circumstances. When, however, as sometimes happens, a flood leaves No. 4 tank full of sand, the water in the sand will last throughout the year. Nos. 2, 3, and 6 are too small to be of moment. Nos. 9 and 10 are very shallow. Thus, in dry seasons water is more likely to be found in the sand tanks Nos. 7 and 8 than in the clean rock tanks.

Charcos.

Charco is the name applied to natural water holes in adobe flats and washes in the Papago Country, but in other parts of the southwest, the same type of water hole is called a mudhole, or mud tank, or is not distinguished from other types of tanks and "tanques." Charco is a Spanish word signifying a pool of standing or stagnant water, and has the advantage of being a distinctive name. The word "tank" may then be reserved for natural reservoirs in rock.

Charcos are found as single pools or a series of pools along streams which deposit fine-grained material, usually sandy clay or adobe. They vary from shallow pans 18 inches wide by 6 feet long, to depressions 5 to 6 feet deep, 15 to 30 feet wide, and more than 1,000 feet long; see fig. 12.

The adobe flats in which charcos occur are the result of sedimentation from flood water streams which spread as a thin sheet of water over large tracts of country and deposit mud as sediment. This process produces smooth plains having a gentle slope in the direction of drainage, and generally unmarked by channels, or at most having very insignificant channels 2 to 5 feet wide and a few inches deep. However, in places where the current is exceptionally swift, part of the mud laid down by past floods is removed and a relatively large channel is formed. It is characteristic of these channels that they begin with a series of little cliffs, 6 inches to 18 inches high, which

Fig. 11. Miniature canyons near head of a charco, La Guituni Valley, Pima Co., Arizona.

lead down to numerous small channels and rill marks which collect together into a single channel which pursues a somewhat sinuous course in the direction of the drainage, and finally ends more or less abruptly. In many instances the channel ends in a vertical wall 3 to 5 feet high. It is evident that concentration of the current of a flood normally spread in broad sheets over the flat, digs the original channel, and movement of water into this channel toward the end of the flood or during minor floods causes erosion of the fanlike set of miniature canyons at the upper end, fig. 11. The lower end of the channel is fixed at a place where the current again becomes less swift, due to the spreading of the flood to occupy a larger cross-section. The channels thus formed are depressions below the general level of the adobe flats and in them water may remain after the passage of the flood, fig. 12. Whether water does so remain depends upon the porosity of the bottom of the channel. If erosion has carried the bottom of the channel below the adobe to some bed of sand or fine gravel, water will easily drain away underground. If, however, the channel is entirely in the usual fine-grained, claylike adobe, water will seep away more slowly. The principal losses will then be from evaporation or, dependent on circumstances, from use by stock and wild animals.

Fig. 12. Charco near Pozo Redondo, Pima Co., Arizona.

In this fashion the larger charcos are formed. The smaller ones, however, usually occur along some relatively small stream which spreads out over part of its course in a small, often grassy, flat. These flats are often only a few feet wide and a few yards long. Channel cutting of the kind previously described sometimes takes place in these flats, and many of the smaller charcos seem to be due to a breaking of the grass cover which allows erosion to take place over a very small area. Other holes seem to be due almost wholly to the activities of animals, both wild and domestic, which come to feed in the flat immediately after the rain. Very shallow pools of water attract them; they drink the muddy water, roll in the mud, and trample and compact the bottom. Thus a somewhat deeper hole is formed which, when the next rain comes, will hold water for a longer time, and thereby undergo the same processes for a longer period. The maximum depth below the surface attained by this process seems to be about two feet.

In South Africa Passarge has found large basins which seem to be wholly due to the activities of animals. He has called the process zoögenous erosion. The animals involved are rhinoceri, elephants, buffalo, and wild hogs, whose size and weight being greater than that of Arizona animals, probably make possible the greater depth and size of the African basins.[8]

The larger charcos are, however, the only ones of great importance to travelers, because only these hold sufficient water to last for more than a few days after a rain, or are relatively permanent in position from year to year. Generally, even the larger charco is never quite full, holding not more than 3 or 4 feet of water. When one of these large charcos has once been formed it tends to be relatively long-lived, for the trampling of animals protects its bottom from seepage, in the same fashion that the bottom of reservoirs is puddled, and this trampling also increases the resistance to erosion of the bed of the charco. The trails which animals make in going to and from water are often from 3 inches to a foot deep, and tend to turn water toward the charco. In this connection note the trails between the bushes in fig. 12. However, a change in the main current of the flood waters may leave the charco on the edge of the floods, in which case it is very likely to become gradually filled up and obliterated. There are certain localities where a charco will be recurrent because floods are normally constricted in this part of their course. Such places are commonly along the foot of some isolated hill in an alluvial plain near the mainflood channel. A somewhat similar rocky projection of the wall of a valley will produce the same result. If for any reason the charco is temporarily filled up, a new one will form within a short distance.

Still other charcos are formed by the natural damming of the channel in an adobe flat. The mudhole near the Brush Corral in the Vekol Valley is due to the damming of the narrow channel of the main drain of the valley, at the lower end of a grassy flat by coarse gravel and sand brought in by a tributary stream. The lower end of this narrow channel remains full of muddy water after a flood and forms a charco.

[8] Passarge, Siegfried: Die Kalahari, Berlin, 1904, p. 660.

Art. XV.—*New Species of Oligocene (White River) Felidæ*; by Malcolm Rutherford Thorpe.

(Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.)

Introduction.

The White River (Oligocene) Felidæ material in the Marsh Collection of the Peabody Museum of Yale University consists chiefly of specimens of the genus *Hoplophoneus,* with four examples of *Dinictis* and one of *Pogonodon,* whereas the John Day Felidæ in the same collection show no specimens of *Hoplophoneus,* but several of *Nimravus,* one of *Pogonodon,* and examples of new species which will soon be described by my colleague, G. F. Eaton. This distribution is significant. The White River material, in many instances, represents a fauna whose individuals were of smaller size than the John Day representatives of allied genera. The Elotheres show the same relative size, as do also the various genera of the Merycoidodontidæ. For example, the Eporeodons of the John Day include larger individuals than the White River Merycoidodonts; the same is true of the genus *Promerycochœrus.*

As a result of studies of the Oligocene Felidæ, several factors have been brought out which are of interest. The genus *Pogonodon* Cope is considered by the writer to be worthy of a distinct place in the Felidæ and it should not lose its identity by having its species distributed under the various other Oligocene genera as some writers have favored doing. There are now several species referred to this genus, as follows: *P. platycopis* Cope,[1] the type of the genus; *P. brachyops* Cope;[2] *P. davisi* Merriam;[3] a new species referred to this genus by G. F. Eaton;[4] and *P. cismontanus* n. sp., herein described.

Some of the terms used in this paper in connection with the measurements are new to paleontology and require a word of definition. In practically all cases, the measurements are based on parts which have proved to be most resistant to destructive processes and which

[1] E. D. Cope, Am. Nat., 14, 143, 1880.
[2] E. D. Cope, Ibid., 14, 849, fig. 11, 1880.
[3] J. C. Merriam, Univ. Calif., Bull. Dept. Geology, 5, No. 1, 53-58, 1906.
[4] G. F. Eaton, John Day Felidæ in the Marsh Collection (in preparation).

can, therefore, be taken in the majority of specimens. These terms, some of which are foreign to paleontology, may be made clearer, as follows:

Prosthion: The most prominent part on the alveolar border between the two upper median incisors.

Basion: The mid-point on the anterior margin of the foramen magnum.

Nasion: The highest point on the internasal suture.

Bregma: The point at which the sagittal and coronal sutures meet.

Palatal length: Prosthion to posterior surfaces of the maxillary parapets, in axial projection, including the pterygoid processes of the maxillæ, if present.

Anterior palatal breadth: Between the roots of the canines (minimum).

Posterior palatal breadth: Between the innermost roots of the carnassials.

Length of the temporal fossa: Maximum measurement in an antero-posterior plane between the maxilla and the anterior margin of the glenoid fossa.

Anterior zygomatic pedicle: Situated between the inferior orbital margin and the alveolar margin beneath, and between the infra-orbital foramen and the posterior margin of the zygomatic process of the maxilla.

The measurements of the anterior zygomatic pedicle have proved of considerable value, both as absolute measurements and as ratios, in specific determinations.

The writer wishes to express his thanks to Professors Schuchert and Lull and Doctor Eaton for their kindly interest in, and friendly criticism of, this work throughout its course. The drawings of the various specimens have been made by Mr. Rudolf Weber.

Description of Species.

The Genus Hoplophoneus Cope.

In 1851, Leidy[5] described a Machærodont from the White River badlands, under the name of *Machærodus primævus*. The description is very brief and is based on a mutilated cranium, very much fractured and fissured. Of this skull, the summit of the inion, the zygomata, the anterior extremities of the ossa nasi, the superior incisors, the greater portion of the corresponding canines,

[5] J. Leidy, Proc. Acad. Nat. Sci. Phila., 5, 329.

and the symphysis of the lower jaw with the incisors and canines are broken away. The skull is not figured. The length of the skull from the occipital condyles to the incisive alveoli is 6½ inches.

In 1852, Leidy[6] more fully described *M. primævus.* The skull is figured in his Table XII, A, figure 5, showing the left lateral view, two-fifths natural size. This is the same specimen noted in the preceding year. Leidy changed his previous figures, however, for the basal skull length, to 6¼ inches.

Again, in 1853, Leidy[7] redescribed the original *M. primævus,* giving a very complete and detailed description. Plate XVIII of his paper shows natural size drawings of the specimen, with a lateral view of the right side of the skull with lower jaw; superior view of the right half of the same; view of the left side of lower jaw; external view of the right inferior canine; and lastly, an anterior view of the same tooth. The drawings are of the same skull figured in the previous year and referred to in 1851.

In 1869, in the "Extinct Mammalian Fauna of Dakota and Nebraska," Leidy[8] changed the name *Machærodus* to *Drepanodon,* and stated that "The Dakota *Drepanodon* belongs to the second group [*Machærodus,* with the acute edges of the canines serrulate and the first lower premolar with a trilobate crown and double fang], or that of *Machairodus.*" He examined four nearly complete skulls. Of these, one was described and figured in the 1853 paper (the type specimen), two are represented in plate IV, figures 1 and 5, as well as parts of a fourth in figures 2-4 of the same plate in the 1869 reference. The original specimen (or holotype) of *M. primævus,* and the skulls represented by figures 1 and 5 of plate IV, Leidy named *Drepanodon primævus,* while the parts of a mandible shown in figures 2-4 he referred to a new species, *D. occidentalis.*

G. I. Adams,[9] in 1896, made a new species based upon the skull in Leidy's figure 1, terming it *Hoplophoneus robustus.* Professor Marsh had several casts made of the figure 5 skull in the 1869 reference. One of these

[6] J. Leidy, In Owen's "Report of a geological survey of Wisconsin, Iowa, and Minnesota," etc., p. 564.

[7] J. Leidy, Smithson. Contrib. Knowl., 6, art. 7, p. 95.

[8] J. Leidy, Journ. Acad. Nat. Sci. Phila., 2d ser., 7, 54.

[9] G. I. Adams,, Am. Nat., 30, 49.

casts is in the U. S. National Museum and another in the American Museum of Natural History. They have been erroneously considered as casts of the holotype of *Machærodus primævus,* whereas they are casts of the heautotype,[10] which was first described eighteen years after the holotype. The basal length of the heautotype is 6 inches.

Cope,[11] in 1873, described *Machærodus oreodontis,* from "an incomplete mandibular ramus of the right side, containing two incisors, and the second molar, with portions of other teeth." This specimen belonged to "a saber-toothed cat of rather smaller size than the *M. primævus.*" In the following year, the genus *Hoplophoneus* was established by the same author,[12] with *H. oreodontis* as the type of the genus and species. He stated that the general characters were "Dental formula of mandible: I3, C1, Pm2, M2. Superior canine greatly developed; end of mandible expanded and thickened to protect it. This is simply *Machærodus* with a tubercular molar, as in *Dinictis.*"

Eleven years later (1885), Cope[13] changed the dental formula to $I\frac{3}{3}, C\frac{1}{1}, Pm\frac{3-2}{2}, M\frac{1}{1}$. He also stated that there was no inferior tubercular molar and that his first diagnosis was incorrect, owing to insufficient data. He said further that "The longest known species is the *Hoplophoneus primævus,* Leidy, from the White River badlands of Dakota and Nebraska."

Dinictis Cope.

Four specimens, representing three species and possibly a fourth, were found in the White River formation.

No. 10944 Y. P. M., *D. bombifrons* Adams, was found near Terry's ranch, Nebraska, by A. S. Shelley in 1874. It consists of parts of both mandibles with nearly all the teeth except incisors. This species is synonymous with *D. fortis* Adams.

A right superior molar, No. 10951 Y. P. M., is most

[10] See C. Schuchert and S. S. Buckman: The nomenclature of types in natural history, Science, new ser., 21, 899-900, 1905.

[11] E. D. Cope: Synopsis of new Vertebrata from the Tertiary of Colorado, p. 9.

[12] E. D. Cope, Ann. Rept., U. S. Geol. and Geog. Surv. Terr., for 1873, p. 509.

[13] E. D. Cope: Rept. U. S. Geol. Surv. Terr., 3, Tertiary Vertebrata, Book 1, p. 992.

closely allied to *D. paucidens* Riggs, and corresponds to the measurements and form of the same molar in the type specimen of this species. It was found near Pine Bluffs, Colorado, by E. Devendorf in 1874.

A skull and right mandible, No. 10048 Y. P. M., are identified with *D. squalidens* (Cope) and were found at White River, Nebraska. Another specimen, No. 12116 Y. P. M., is provisionally identified with this species. It consists of a very poorly preserved skull and both mandibles, with teeth well preserved. Its nearest ally is *D. squalidens,* although, while a young individual, it is much smaller and may represent a new species. In view of the obliteration of nearly all skull characters except length, however, it is referred to *D. squalidens,* pending the finding of additional material.

Hoplophoneus primævus (Leidy).

Cat. No. 10051, Y. P. M., White River (Oligocene), Casey, South Dakota.

This specimen, collected by H. C. Clifford in 1891, is slightly smaller in nearly all dimensions than the type, and as the bones are thin and the mandibles long and slim, it is reasonable to suppose that it may represent a female, but from the material at hand it is impossible to make any positive statements in regard to sex differences.

An interesting feature in the specimen is the lack of a coronoid process on the right ramus. The base of the ascending ramus, above the masseteric fossa, is about 2 mm. thicker than on the left ramus, and, instead of a coronoid, there is a lateral osseous growth of over 4 mm., to which was probably attached a part of the masseter muscle. The right condyle is also a little smaller than the left. The animal undoubtedly lived a considerable length of time without the coronoid, the lack of which apparently had no special influence on its life habits, even though it seems to indicate either a pathologic or a traumatic condition.

Hoplophoneus marshi, sp. nov.

(Figs. 1 A and B.)

Holotype, Cat. No. 10049, Y. P. M., White River (Oligocene), Nebraska.

The type of this species, collected by H. C. Clifford and A. S. Shelley, consists of a skull only. It is that of a submature animal, and while some fracturing has occurred, yet very little distortion has taken place. The incisors and both molars are missing, but their alveoli are distinctly visible. The right P^3 is lacking. The

Fig. 1; A, B.

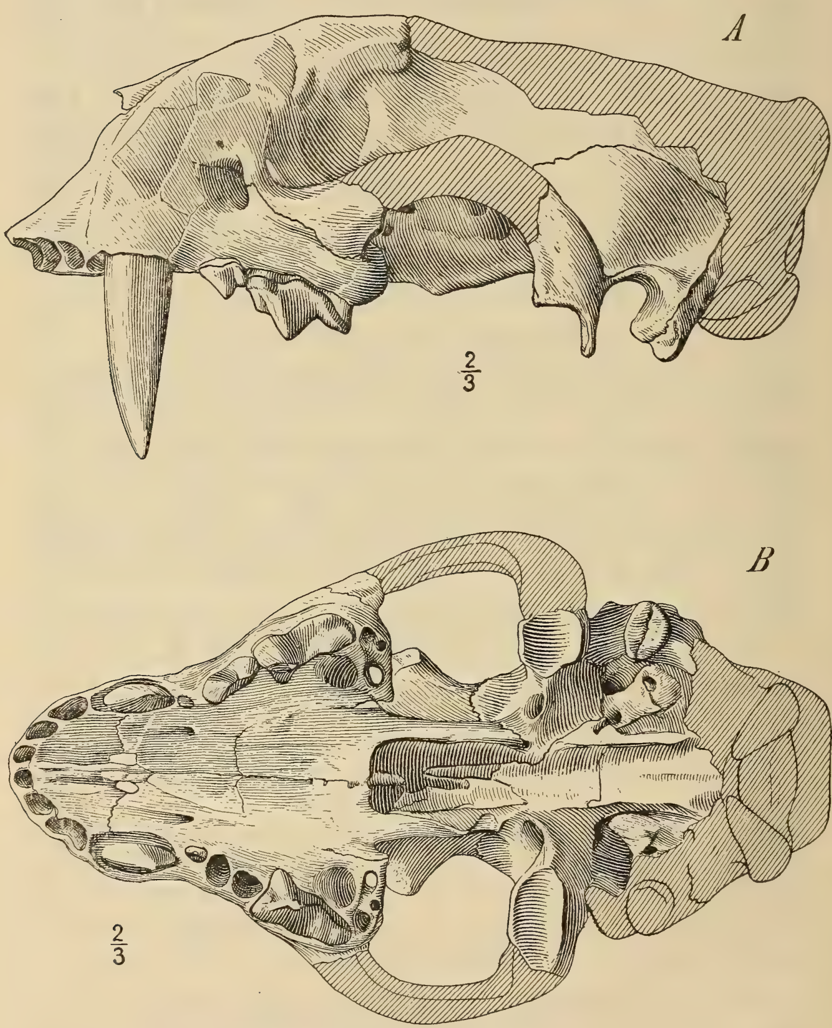


Fig. 1.—Hoplophoneus marshi, n. sp. (A) Left lateral view and (B) inferior view of skull. Two-thirds natural size.

condyles have been restored, as well as portions of the zygomata, occiput, and parietal bones. All of the teeth now present belong to the permanent dentition.

The skull resembles that of *H. primævus* Leidy in some characters and that of *H. oreodontis* Cope in others, but it has several distinctive features of specific value, the most prominent of which are the very large incisor alveoli, the long sharp-pointed palate, the peculiar shape of the canines, and the very large molar alveoli.

The basal length of the skull is 147 mm., which is next to that of the smallest species of the genus, but the incisors, measured at the alveoli, are proportionately much larger, their dimensions being as follows:

	antero-posterior	transverse
I^1..........	7 mm.	4.5 mm.
I^2..........	7 mm.	4.75 mm.
I^3..........	8 mm.	5.5 mm.

Anterior to the orbits, the face is flat, but in front of the infraorbital foramen the maxillary is strongly convex, due to the alveolus of the canine. The infraorbital foramina are large and subangular. The diastema between I^3 and the canine is proportionally a little longer than in *H. primævus* Leidy. The palate is nearly 20 per cent longer than in *H. oreodontis* Cope. The premaxillary border is very convex anterior to the line of the canines. It is, in fact, so pointed that it is unlike any other species of *Hoplophoneus.* The canines are decidedly laterally compressed. The maximum diameter at the alveolus is 14.5 mm., and the transverse diameter is 5.4 mm.; or the maximum diameter is nearly three times the transverse, whereas the other species generally show a relation of about twice the maximum over the transverse. The posterior cutting edge or axis of the canine is at right angles to the plane of the palate.

Cope, in describing *H. oreodontis,* stated that there was no indication of the existence of a second premolar, but one is present on the left side of this specimen, although there is none on the right. This P^2 had insufficient space to develop between the canine and P^3 and hence its position is inward from the true line of the teeth. The diastema between the canine and P^3 on the left side is nearly equal to that between the canine and the I^3. The posterior edge of the paracone of P^3 is denticulate. The total length of the tooth row is 54 mm., which makes it appear near to *H. oreodontis* in size, but this is due to the very small diastema between the canine and P.[3] Both molars are missing, but their alveoli are each 14.5 mm. in length and 6 mm. wide. These molars had two stout roots in a transverse line, and a third, very small, centrally located posterior to the transverse. *H. oreodontis* Cope is from the Upper Oligocene (John Day), while *H. marshi* is of White River age, probably from the *Oreodon* zone of Middle Oligocene.

Measurements.

	mm.
Prosthion to basion	137
Prosthion to nasion	66
Prosthion to bregma*	109
Basion to bregma*	65
Bizygomatic diameter*	94
Postorbital constriction	31
Bimastoid diameter	64
Palatal length	72.5
Posterior palatal breadth	33
Inferior orbital margin to alveolar margin	16
Infraorbital foramen to posterior margin of zygomatic process	24
Length of tooth row, P^3 to M^1, inc.	36
Diastema, C to P^3	4
Diastema, I^3 to C	3
Crown of P^3, length of base	12
Crown of P^3, maximum width	5.5
Crown of P^4, length of base	20
Crown of P^4, maximum width	11

* Approximate.

Hoplophoneus latidens, sp. nov.

(Figs. 2 A-C; 3).

Holotype, Cat. No. 10050, Y. P. M., White River (Oligocene), near Pine Bluffs, Colorado.

The type of this species, found in 1874 by E. Defendorf, consists of a nearly complete skull, atlas and axis. Both second premolars are missing and the canines have been restored. The left molar has been somewhat laterally compressed.

In some characteristics this specimen is closer to *H. robustus* than to the other species of *Hoplophoneus*, although there are close resemblances to *H. primævus* Leidy, and in several distinct features it differs from

Fig. 2; A.

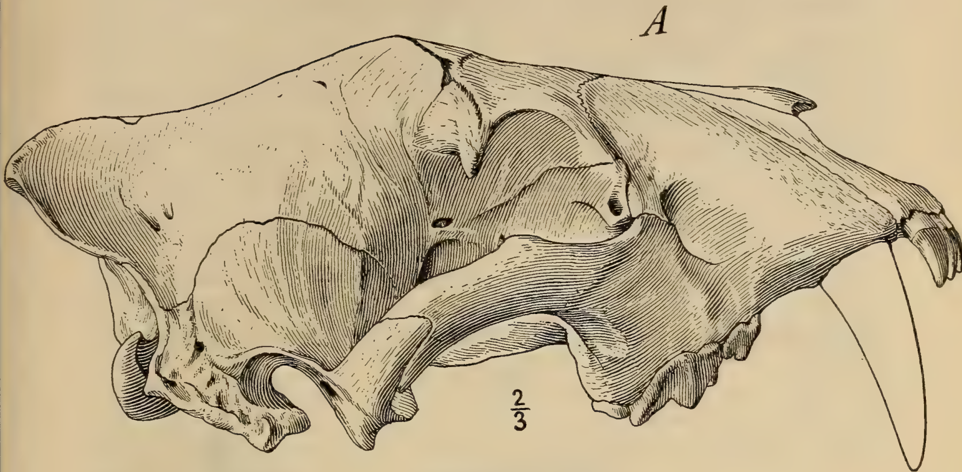


Fig. 2; B, C.

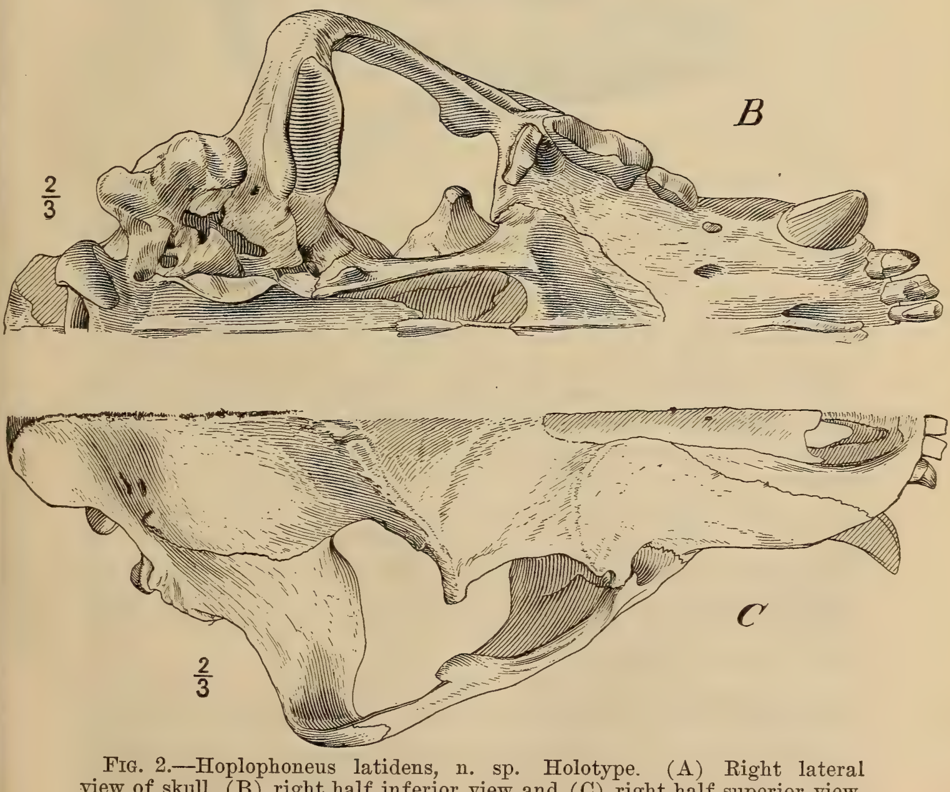


Fig. 2.—Hoplophoneus latidens, n. sp. Holotype. (A) Right lateral view of skull, (B) right half inferior view and (C) right half superior view. All two-thirds natural size.

both. Its basal length is about intermediate between the two species above mentioned, while the prosthion-nasion dimension is but 3.5 mm. above that of *H. primævus.* The prosthion-bregma dimension is only 2.5 mm. below that of *H. robustus.* The cranial region is lower than in *H. robustus* by 13 mm., and lower than in *H. primævus* by 6 mm., which gives the skull a markedly different configuration. The bizygomatic diameter is greater than that of *H. robustus* by 6 mm., although the breadth of the anterior nares is less. Again, the diameter of the postorbital processes of the frontals is greater than in *H. robustus* by 6 mm., but the bimastoid diameter is less by 1.5 mm. The palatal length is

FIG. 3.

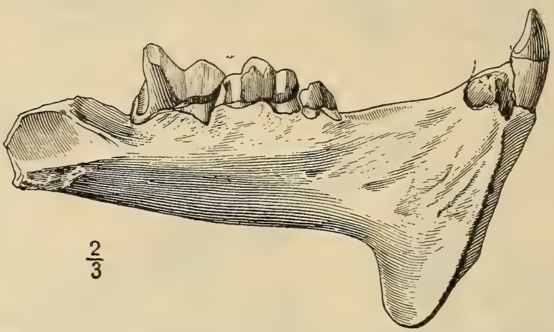


FIG. 3.—Hoplophoneus latidens, n. sp. Paratype. Right ramus, two-thirds natural size.

12.5 mm. less than that of *H. robustus.* One important feature is the difference in shape of the anterior zygomatic pedicle. The measurement from the inferior orbital margin to the alveolar margin is 24 mm., in *H. robustus* it is 18 mm., while the distance from the infra-orbital foramen to the posterior margin of the zygomatic process of the maxilla is 28 mm. and in *H. robustus,* 32.5 mm. The conventional index of these measurements for this specimen is 117, for *H. robustus,* 162.5, and for *H. primævus,* 143. The superior canine is slightly greater in its maximum diameter at the parapet. The postorbital constriction is less than that of *H. primævus* by 3 mm.

Summing up the broad differences of the skull, it is found that this specimen, in comparison with *H. robustus,* is shorter and broader, has a much lower parietal region, and the diameter of the postorbital constriction is less than that of even *H. primævus,* while that of the bimastoid is about equal to that of *H. primævus* and much less than in *H. robustus.* Considerable importance should be attached to the proportions of the anterior zygomatic pedicle.

The atlas and axis of this specimen are worthy of description. The maximum diameter between the external margins of the transverse processes of the atlas is 78.5 mm.; the measurement from the margin of the anterior articular surfaces to the posterior tip of the transverse process is 47 mm. and the maximum diameter across the anterior articular surfaces is 44 mm. The maximum height is 25 mm. and the thickness of the dorsal arch is 8 mm. The ventral tubercle is not as sharp as in the Canidæ, but is gently rounded. The dorsal arch is massive and domed so that no distinct spine is noticeable, thus differing from the modern Felidæ. The alar notches are very shallow, and the transverse processes are stout and massive on their inner posterior margin.

The axis has a very long spine, its length being 66.5 mm., whereas the length of the centrum proper is 33 mm. The odontoid process is stout and heavy. It is 12 mm. long and its transverse diameter is the same at its junction with the centrum while its vertical diameter is 7.25 mm. The width across the posterior articular surfaces is 24 mm., and across the anterior articular surfaces 34 mm. The vertebrarterial foramen is nearly vertically oval, its maximum diameter being 5.5 mm. and its horizontal diameter 2 mm. The transverse processes are long and slender.

No mandibular rami were found with specimen No. 10050, but a right ramus, together with parts of both superior molar series and contiguous portions of the palate, are here referred to this species. These remains bear the number 10949. The ramus possesses the third and fourth premolars and the first molar in good condition. The third incisor is nearly perfect, but the canine is broken off. The left superior second, third, and fourth premolars and the base of M^1, together with a small contiguous portion of the palatine and maxillary bones, are present. The right P^4, the posterior half of P^3, and the base of M^1 are present, also with a small portion of the palatine and maxillary bones. The P^2 is single-rooted in No. 10949, whereas in No. 10050 it is very difficult to determine, as both second premolars are missing and their alveoli are quite indistinct. It is unwise, however, in specific determinations, to place too much stress upon the presence or absence of a second root in the second premolar. In both of these specimens, the superior second premolar is on the point of disappearance. The superior molars of both are three-rooted. The superior carnassial in specimen No. 10949 has a distinct, though small, anterior cusp, developed from the cingulum, in which it is prophetic of *Machærodus*.

Measurements.

	Holotype (10050) mm.	Paratype (10949) mm.
Prosthion to basion	154	
Prosthion to nasion	78.5	
Basion to nasion	99	
Prosthion to bregma	126.5	
Basion to bregma	71	
Bizygomatic diameter	116	
Diameter of postorbital constriction	31	
Bimastoid diameter, max.	70.5	
Palatal length	79	
Posterior palatal breadth	47	
Inferior orbital margin to alveolar margin (min.)	24	
Infraorbital foramen to posterior margin of zygomatic process of maxilla	28	28
Depth of mandibular symphysis (est.)		40
Depth of mandible posterior to P_4.		21.5
Depth of mandibular flange		49
Length of tooth row, C to M^1, inclusive	67.5	
Length of tooth row, P^3 to M^1, inclusive	36	37
Diastema, C to P^3	16	
Diastema, I^3 to C	3	
Superior canine, maximum diameter at alveolus	17.5	
Superior canine, transverse diameter at alveolus	10	
Crown of P^3, length of base	11	11
Crown of P^3, maximum width	5	5
Crown of P^4, length of base	21	21.5
Crown of P^4, maximum width	10	11
Length of tooth row, P_2 to M_1, inc.		39
Diastema, inferior canine to P^3		25.5
Crown of P_4, length of base		14
Crown of P_4, maximum width		6.5
Crown of M_1, length of base		17
Crown of M_1, maximum width		8.5
Inferior canine, maximum diameter at alveolus		7
Inferior canine, transverse diameter at alveolus		5

Fig. 4; A.

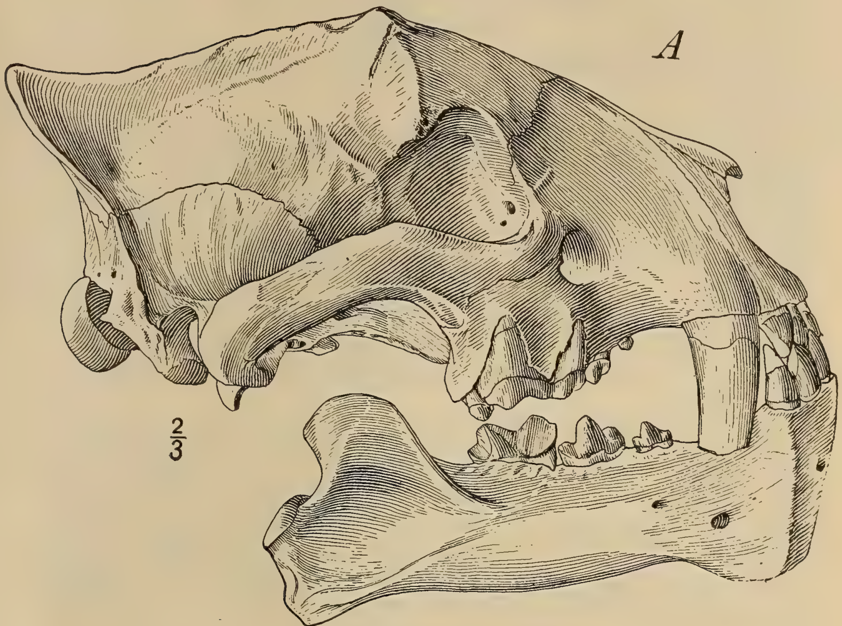


Fig. 4; B, C.

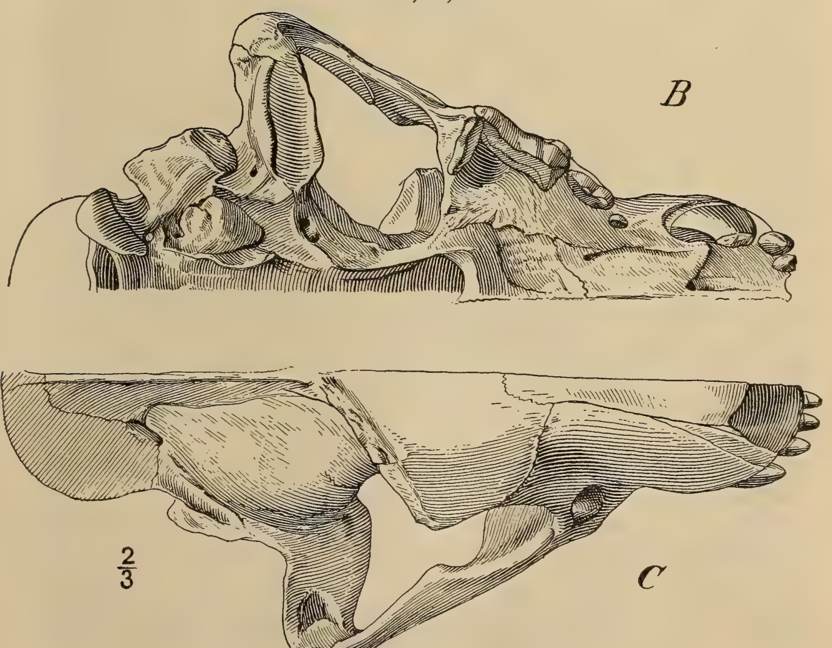


Fig. 4.—Hoplophoneus molossus, n. sp. (A) Right lateral view of skull and jaw; (B) right half, inferior view and (C) right half, superior view. All two-thirds natural size.

Hoplophoneus molossus, sp. nov.

(Figs. 4 A-C).

Holotype, Cat. No. 10052, Y. P. M. White River (Oligocene), White River, Nebraska.

This species is based on an almost complete skull, both mandibular rami, atlas, axis, third cervical, eleventh, twelfth, and thirteenth dorsals, and the first lumbar. Fragments, probably of the sixth, twelfth, and thirteenth ribs, were found with the specimen, which was collected in 1875 by H. C. Clifford. The specimen is an adult and has suffered a small amount of distortion, but not enough to interfere with the general outline and characters of the skull. Both canines are broken off about midway of their length.

This species is most closely allied to *H. primævus*. The basal length is approximately 10 mm. shorter, while the prosthion-nasion dimension is also less by 10 mm. than in *H. primævus*, but the breadth of the anterior nares is greater by 4.5 mm. and the interorbital breadth is less by 5 mm., thus showing a different facial aspect. The postorbital constriction differs by 8 mm., *H. primævus* having the greater diameter. The bimastoid diameter is 10 mm. less in this specimen. The ratio of the anterior zygomatic pedicle in *H. primævus* is 143, but in this species it is 109. The depth of the ramus of this species, posterior to P_4, is greater by nearly 3 mm. The maximum diameter of the superior canine at the alveolus is 3.5 mm. greater, while the length of the base of the crown of P^4 is 1.5 greater, and the distance between P_3 and M_1, inclusive, is 3 mm. greater than in *H. primævus*.

One very obvious difference between this species and the nearest to which it bears resemblance is the heavy, massive bones which make up all parts of the specimen. The cranial capacity is small and the very small diameter of the postorbital constriction is very noticeable, as well as the important relations existing between the pedicle dimensions. The face is broad, and the cranium narrow, while the reverse is true of *H. primævus*.

The atlas and axis will be briefly described. The atlas resembles that of *Felis* and yet is primitive in some characters. There are no alar notches and the dorsal arch has a distinct spine, which is massive and rounded, rather than oblong-shaped. The maximum diameter between the external margins of the transverse processes is 71 mm.; the measurement from the margin of the anterior articular surfaces to the posterior tip of the transverse process is 45 mm., and the maximum diameter across the anterior articular surfaces is 43 mm. The maximum vertical diameter is 33 mm. and the thickness of the dorsal arch is 9 mm., including the small spine. This skull is much smaller than that of No. 10050 and yet the atlas exhibits some dimensions even greater. The massive character is maintained throughout the skeleton in so far as it is present.

The axis is nearly complete except for the posterior tip of the spine, which has been restored. The maximum length is 50 mm. and the length of the centrum is 28 mm., exclusive of the odontoid process. The odontoid is 9.5 mm. long and 9 mm. wide in transverse diameter at its junction with the centrum, while its vertical diameter is 6.5 mm. The width across the posterior articular surfaces is 22.5 mm. and across the anterior articular surfaces, 31 mm. The vertebrarterial canal is triangular, with the right angle nearest the centrum.

Measurements.

	mm.
Prosthion to basion	132
Prosthion to nasion	75
Basion to nasion	93
Prosthion to bregma	107
Basion to bregma	77
Bizygomatic diameter (est.)	104
Diameter of postorbital constriction	26
Bimastoid diameter, max.	60
Palatal length	67
Posterior palatal breadth	41
Inferior orbital margin to alveolar margin	24
Infraorbital foramen to posterior margin of zygomatic process of maxilla	26
Length of mandibular ramus	109.5
Length of mandibular symphysis	39
Depth of mandible posterior to P_4	23
Depth of flange (estimated)	41
Length of tooth row, C to M^1, inc.	59
Length of tooth row, P^3 to M^1, inc.	32
Diastema, C to P^3	13
Diastema, C to I^3	1
Superior canine, maximum diameter at alveolus	15.5
Superior canine, transverse diameter at alveolus	7.5

Crown of P^3, length of base	11
Crown of P^3, maximum width	5
Crown of P^4, length of base	21.5
Crown of P^4, maximum width	10
Length of tooth row, P_3 to M_1, inc.	37
Diastema, C to P_3	20
Inferior canine, maximum diameter at alveolus	7
Inferior canine, transverse diameter at alveolus	4.5
Crown of P_4, length of base	12.5
Crown of P_4, maximum width	6
Crown of M_1, length of base	17
Crown of M_1, maximum width	7.5

FIG. 5.

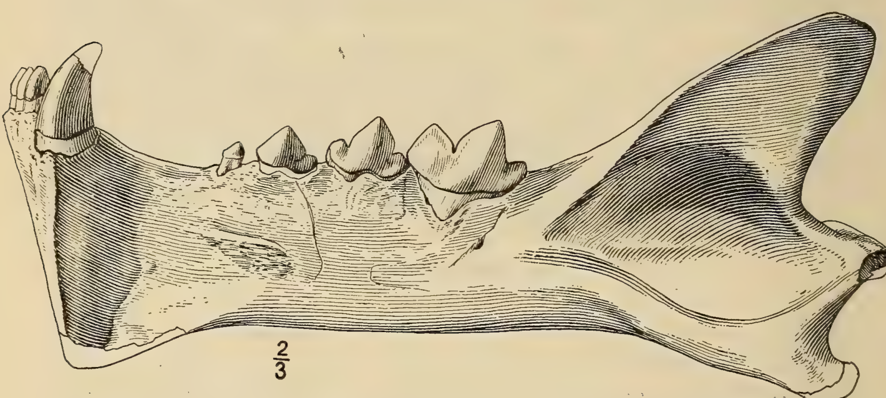


FIG. 5.—Pogonodon cismontanus, n. sp. Left ramus, two-thirds natural size.

Pogonodon cismontamus, sp. nov.

(FIG. 5.)

Holotype, Cat. No. 10053 Y. P. M. White River (Oligocene), Hermosa, South Dakota.

This specimen, collected by H. F. Wells in 1893, consists of a complete left mandibular ramus and the anterior portion of the right. The left M_1 and P_4 are complete. The anterior portion of P_3 is broken away, but the corresponding tooth on the right ramus is complete. The left P_2 is missing, but its alveolus is very distinct, while the right P_2 is complete. Hence, considering both rami, there is one complete tooth row from P_2 to M_1, inclusive. The tip of the left canine is broken off and, with the exception of I_3, the incisors are either missing or damaged.

This is the first reference of *Pogonodon* to the Oligocene of the Big Badlands. The size is close to that of the type of the genus, *P. platycopis* Cope, although in nearly every dimension this specimen is slightly smaller. This size difference is, however, to be expected, since *Hoplophoneus* is largely restricted to the Great Plains region and is generally smaller than *Dinictis* and *Nimravus,* characteristic of the John Day fauna, to which *P. platycopis* belongs. When Cope established the genus *Pogonodon,* he recognized that it had characters referable to both *Hoplophoneus* and *Dinictis,* both of which genera he also founded.

In most respects, *Pogonodon* resembles *Dinictis* more closely than it does *Nimravus,* e. g., in the number of teeth, configuration of horizontal rami, and position of the mastoid. The coronoid process curves backward as in *Dinictis,* and the masseteric fossa is triangular rather than horizontally oval-shaped, and the carnassial notch is deep. On the other hand, it resembles *Hoplophoneus* in that it lacks M_2, which *Dinictis* has, and yet it possesses P_2, a factor which removes it from *Hoplophoneus* toward *Dinictis.* It differs from either *Dinictis* or *Hoplophoneus* in that the sectorial is primitive, having no metaconid but possessing a robust posterior heel with a grinding surface, which is an unique character. The dental formula is I_3, C_1, P_3, M_1. The lateral angular process below the anterior portion of the ramus is not so deep as in *Hoplophoneus,* but corresponds more closely to *Dinictis.* The chin is quite vertical and oblong-square as in *Hoplophoneus.* The canines are considerably larger than the third incisors and are noticeably recurved. The incisors have conic crowns. The inferior border of the mandibular ramus, which underlies the cheek teeth, projects outward and downward as in *Hoplophoneus.* The rami in general are not so deep and are more robust than in *Nimravus.*

The writer's opinion is that the genus *Pogonodon* should be restored to its former position as an independent genus, or at least be considered as a subgenus, but with its affinities clearly recognized. In 1910, Matthew,[14] in a footnote, writes that he regards *Pogonodon* as a distinct subgenus, although in the same reference he includes the then known species of this genus under *Nimravus.*

[14] W. D. Matthew, Bull. Am. Mus. Nat. Hist., vol. 28, 290.

As stated in the first part of this paper, there are now five species of this genus. It also seems evident that the position of the genus in the phylogeny of the Felidæ should be somewhere between *Dinictis* and *Hoplophoneus*, probably a little closer to the former than to the latter.

Measurements.

	mm.
Length of mandibular ramus	175
Depth of mandibular symphysis	48
Depth of mandible posterior to P^4	30
Depth of flange (estimated)	47
Length of tooth row, P_3 to M_1, inc.	55
Diastema, C to P_2	24
Diastema, C to P_3	31
Crown of P_4, length of base	17
Crown of P_4, maximum width	9
Crown of M_1, length of base	24
Crown of M, maximum width	10
Canine, maximum diameter at alveolus	12
Canine, transverse diameter at alveolus	9

ART. XVI.—*Some Minerals of the Melanterite and Chalcanthite Groups with optical data on the hydrous sulphates of manganese and cobalt;*[1] by ESPER S. LARSEN and M. L. GLENN.

Zinc-copper Melanterite and other members of the Melanterite Group.

Introduction.—During the summer of 1916 one of the authors (E. S. L.) found a secondary mineral in considerable amount in the dumps of the Good Hope and Vulcan mines at Vulcan, Gunnison county, Colorado. The mines are on a great body of sulphides made up chiefly of pyrite with some chalcopyrite and sphalerite. The proportion of the constituents, especially the sphalerite, varies greatly in different bands of the ore. Thin seams of quartz carrying gold and tellurium are present on the walls of the sulphide body. The dumps carry thousands of tons of this sulphide, in part massive, in part friable and sandy in texture. Many of the interstices between the fragments on the dumps are filled with a green, columnar mineral which on study in the laboratory proved to be a new member of the melanterite group, which carries about equal amounts of copper and zinc and a little iron; the name zinc-copper melanterite is proposed for the mineral.

In adopting a name for this mineral as well as in adopting the names for the chalcanthite-like dehydration products of the members of the melanterite group, the authors at first planned to follow the suggestion of Washington[2] and to designate the various members of the groups by prefixes to the group names, melanterate and chalcanthate. However, as there were so many objections from all the mineralogists who were consulted and as it seemed probable the names would not be accepted and confusion would result, the plan was adopted of using the usual group name with the principal metals present prefixed to it. Accordingly, the melanterites are minerals with the general composition $RO.SO_3 . 7H_2O$; they are monoclinic and their properties are related to those of the common mineral melanterite. Zinc-copper melanterite is a melanterite in which R is chiefly Zn and Cu with Zn predomi-

[1] Published with permission of the Director of the U. S. Geol. Survey.
[2] Washington, Henry, S.; A suggestion for mineral nomenclature, this Journal, vol. 33, pp. 137-151, 1912.

nating molecularly. Copper-zinc melanterite would have Cu predominating molecularly. To be precise, for zinc melanterite the molecular ratio ZnO to CuO should be greater than 3 to 1, for zinc-copper melanterite that ratio should be between 3 to 1 and 1 to 1, for copper-zinc melanterite between 1 to 1 and 1 to 3, and for copper melanterite the ratio should be less than 1 to 3. Similarly the chalcanthites are minerals with the general composition $RO.SO_3.5H_2O$, they are triclinic and their properties are related to those of the common mineral chalcanthite. In both groups the various members are similar in all their physical properties, notably in their optical properties.

If the unsystematic procedure of giving each species a distinct name without regard to its relations to other minerals had been followed out in the present paper six new mineral names would be required for six relatively unimportant minerals and it is probable that in both groups there are many more members. If independent names are given to all the members of both groups very few mineralogists would find it worth the effort to remember the significance of the various names, but if Washington's suggestion, or some modification of it, is carried out for the groups every mineralogist should know the composition and group relations of any member from its name. It is sincerely to be hoped that mineralogists will soon adopt a systematic nomenclature.

Physical properties.—Zinc-copper melanterite is pale greenish-blue (calamine blue 43d of Ridgways[3] color standards). It has a vitreous luster, a hardness of about 2, and a specific gravity as determined by matching in a heavy solution of 2.02. It fuses readily with intumescence at about 1 to a white froth which on high heating turns black; on rapid heating it decrepitates violently. It colors the flame green. It loses water in a dry room as will be shown in a succeeding paragraph. It is readily soluble in water.

Under the microscope it is seen to consist of very pale blue-green rods not sensibly pleochroic and nearly a millimeter across and several millimeters long. The indices of refraction were measured by matching in oils and immediately measuring the indices of refraction of the oils, and the following values should not be in error more than 0.001; $\alpha = 1.479$, $\beta = 1.483$, $\gamma = 1.488$. The mineral

[3] Ridgeway, Robert. Color Standards and Nomenclature, 1912.

is optically positive, 2 V is near 90°, and the dispersion of the optic axis is slight. The fibers are imperfect and measurements of extinction angles gave inconsistent results. Several sections nearly normal to X and perhaps lying on a cleavage face gave extinction angles, Y to the elongation, of about 34°. The mineral is probably monoclinic and Y to the elongation is large.

The principal optical properties of zinc-copper melanterite, goslarite, pisanite, and bieberite are given in Table I for comparison. In optical properties zinc-copper melanterite is very similar to pisanite, but it has a somewhat lower birefringence; it has a different color and a somewhat lower birefringence than melanterite and bieberite. Goslarite is distinctly different from the others and obviously belongs to a different group. The monoclinic form corresponding in composition to goslarite has not been described.

TABLE I. *Optical properties of members of the melanterite group and of goslarite.*

	Zinc-copper melanterite	Pisanite[a]	Melanterite	Bieberite[a]	Goslarite
Crystal System	Mon.?	Mon.	Mon.	Mon.	Orth.
Color	pale greenish blue	pale blue	pale green	Carmine	colorless
Opt. character	+	+	+	—	—
2V	near 90°	very large	86	near 90°	46
Dispersion	$\rho > v$ perc ?	$\rho > v$ perc?	$\rho > v$ perc.	slight	$\rho < v$ slight
α	1·479	1·472	1·471	1.477	1 457
β	1·483	1·479	1·478	1·483	1·480
γ	1·488	1·487	1.486	1·489	1·484
γ-α	·009	·015	·015	·012	·020

[a] Unpublished data on artificial mineral by E. S. Larsen.

Chemical analysis.—The zinc-copper melanterite selected for analysis showed under the microscope a little admixed chlorite and sulphides and about 1 or 2 per cent of zinc-copper chalcanthite. The result of an analysis of the water soluble portion of this sample by M. L. Glenn is shown in Table II. The formula derived from this analysis is $(Zn,Cu,Fe)O.SO_3 . 7H_2O$ in which Zn : Cu : Fe : : 100 : 98 : 19. The analysis fits the formula very well except for the water and it is probable, as will be shown later, that the mineral had partly dehydrated to zinc-copper chalcanthite between the time it was examined microscopically and the time it was analyzed.

TABLE II. *Analysis and molecular ratios of zinc-copper melanterite from the dump of the Good Hope Mine, Vulcan, near Gunnison, Colo., by M. L. Glenn.*

CuO	12.37	156	
ZnO	12.89	158	$1 \times .98$
FeO	2.14	30	
SO_3	28.78	360	1×1.02
H_2O	42.61	2365	$7 \times .96$
Insol.	1.11		
	99.90		

The Chalcanthite Group.

Zinc-copper melanterite loses water rapidly in dry air and alters to a fine, homogeneous aggregate of a mineral that has optical properties very near those of chalcanthite, and it must be the zinc-copper equivalent of chalcanthite. A small amount of the fine powder left from the analysis of the zinc-copper melanterite and kept in a room two months during the winter was completely altered. The sample contained 35.0 per cent H_2O while the compound with $5H_2O$ should theoretically contain 36.1 per cent H_2O. The resulting product is a pale blue, finely crystalline aggregate which is apparently homogeneous and which has the optical properties given in column 1 of Table III. In column 2 the properties of chalcanthite are given for comparison; in column 3 the properties of an iron-copper chalcanthite derived from the dehydration of artificial pisanite; in column 4 the properties of the siderotil derived from the dehydration of melanterite; in column 5 those of artificial cobalt chalcanthite; and in column 6 those of artificial manganese chalcanthite.

TABLE III. *Optical properties of members of the chalcanthite group.*

	Zinc-copper chalcanthite	Chalcanthite	Iron-copper chalcanthite[a]	Siderotil[a]	Cobalt chalcanthite[a]	Manganese chalcanthite[a]
Color	pale blue	Berlin blue	pale green	white	rose pink	pale pink
Opt. character	—	—	—	—	—	—
2V	mod.	56°	mod.	rather large	med.	med. large
Dispersion		slight	$\rho > \upsilon$ slight	$\rho > \upsilon$ weak	not stg.	
α	1·513	1·516	1·517	1·526	1·530	1·495
β	1·533	1·539	1·536	1·536	1·548	1·508
γ	1·540	1·546	1·543	1·542	1·550	1·514
γ-α	·027	·030	·026	·016	·020	·019

[a] Unpublished manuscript by E. S. Larsen.

The probable error of the indices of refraction should be less than $\pm$ 0.003; zinc-copper chalcanthite, iron-copper chalcanthite, and chalcanthite are very similar optically, but differ slightly in color; the other members of the chalcanthite group can be readily distinguished by their color and optical properties.

Boothite dehydrates to chalcanthite as a specimen so labeled, kindly furnished the author by Colonel Roebling, had the optical properties of chalcanthite. Pisanite dehydrates readily as four specimens so labeled proved on microscopic examination to have changed to iron-copper chalcanthite; artificial pisanite alters rather rapidly to pentahydrate. Melanterite, either natural or artificial, is commonly coated with a white powder of siderotil and the fine powder will dehydrate after standing for some months to the pentahydrate; siderotil is nearly as common a mineral under surface conditions as melanterite and has been found in a number of specimens sent in to the author (E.S.L) from the field. Two museum specimens labelled bieberite proved on optical study to have changed to cobalt chalcanthite. A specimen labelled mallardite had apparently altered to an uncertain lower hydrate.

On standing for a few days at about 45° zinc-copper chalcanthite loses water and alters to a white powder made up of an aggregate of minute fibers with the following indices of refraction:

$\alpha = 1.60 \pm 0.01$, parallel to the fibers. $\gamma = 1.656 \pm 0.01$

The hydrous Sulphates of Cobalt.

Artificial "cobalt sulphate" from the stock bottle in the chemical laboratory of the U. S. Geological Survey is made up of blue, vitreous crystals that are uniaxal—, and very faintly pleochroic in pale pink with $\omega = 1.495 \pm 0.003$, $\epsilon = 1.460 \pm 0.003$. This form also crystallized from a solution of $CoSO_4$ at 45°. A water determination on material from the stock bottle gave 40.7 per cent. and the material is no doubt $CoSO_4.6H_2O$, which should have 41.1 per cent water and is said to crystallize from a water solution at from 40 to 50° C.

It dehydrates rather rapidly on exposure to air to a finely crystalline, pale rose pink (Ridgways 71 f) powder which has the following optical properties and is the pentahydrate: Opt.—, 2V medium, dispersion not strong, faintly pleochroic.

$\alpha = 1.531 \pm 0.003.$ Eosine-pink (1 d)
$\beta = 1.549 \pm 0.003.$
$\gamma = 1.552 \pm 0.003.$ Pale rose-pink (71 f)

A mineral specimen labelled bieberite (cobalt melanterite) Bieber, Hesse, kindly furnished the authors by Col. Roebling of Trenton, New Jersey, is a very finely crystalline, rose red coating; and has the following optical properties: pale rose in section, opt. —, 2V medium,

$\alpha = 1.523 \pm 0.003.$ $\beta = 1.542 \pm 0.005.$ $\gamma = 1.547 \pm 0.005.$

It is probably the pentahydrate, cobalt chalcanthite, and was derived from the dehydration of bieberite.

In a desiccator over H_2SO_4 the $CoSO_4 . 6H_2O$ alters in a few days to a mixture made up of about 80 per cent of a pale rose-pink, porous pentahydrate and 20 per cent of small red crystal aggregates of the monohydrate. The monohydrate is in drusy crystals on the surface and in the pores of the pentahydrate. The optical properties of the pentahydrate are: Opt.—, 2V medium, dispersion not strong, faintly pleochroic.

$\alpha = 1.529 \pm 0.003$, eosine-pink (1 d)
$\beta = 1.546 \pm 0.003.$
$\gamma = 1.548 \pm 0.003$, pale rose-pink (71 f)

A gram of the pale rose-pink material was hand picked for water determination and gave 33.3 H_2O. The microscope showed that the analyzed powder contained approximately 10 per cent of the monohydrate. This would give 35.9 per cent H_2O for the pure material. The pentahydrate should contain 36.7 per cent H_2O and the rose pink material is probably the pentahydrate.

The monohydrate crystals formed with the pentahydrate have the following optical properties: Opt.—, 2V near 90. Inclined extinction.

$\alpha = 1.603.$ $\beta = 1.639.$ $\gamma = 1.683.$

A water determination gave 11.0 per cent H_2O and shows that the crystals are the monohydrate, which should contain 10.4 per cent H_2O.

A solution of $CoSO_4$ either slightly acidified with H_2SO_4) or not and evaporated to dryness on a steam bath gave an amaranth pink (Ridgways 69 d) powder made up of very minute crystalline spherulites and fibers with the following optical properties: $\alpha = 1.600 \pm 0.005$, $\gamma = 1.645 \pm 0.1$, elongation negative. The monohydrate is said to form under these conditions and a water determination on the material gave 12.2 per cent and indicates the monohydrate which theoretically contains 10.4 per cent H_2O. Material precipitated by slowly pouring a concentrated solution of $CoSO_4$ into concentrated H_2SO_4 was no doubt the same though it was not entirely homogeneous and γ appeared to be a little lower. This is probably also the monohydrate although the tetrahydrate is said to form when the solution is poured into H_2SO_4.

The optical properties of the monohydrate formed with the pentahydrate in a desiccator are sufficiently different from the properties of the monohydrate crystallized on a water bath, although the latter is too finely crystalline for accurate measurements to justify the conclusion that there are two forms of that hydrate.

$CoSO_4$ crystallized from a solution at 23°C in a desiccator under reduced pressure was in aggregates of carmine colored (Ridgway 1-i), tabular crystals with the following optical properties: Opt.—, 2V near 90°, dispersion slight.

$$\alpha = 1.477 \pm 0.003. \quad \beta = 1.483 \pm 0.003. \quad \gamma = 1.489 \pm 0.003.$$

The heptahydrate is said to be formed under these conditions; a water determination on this material gave 44.8 per cent and the theoretical water content of the heptahydrate is also 44.8 per cent. The optical properties are similar to those of the members of the melanterite group and the material is artificial bieberite.

The hydrous Sulphates of Manganese.

Artificial "manganese sulphate" from the stock bottle of the U. S. Geological Survey is made up of two forms: pale pink, glassy crystals which are largely altered to nearly white aggregates of minute crystals. The glassy crystals have the following optical properties: Opt.—, 2V moderately large.

$$\alpha = 1.511 \pm 0.003. \quad \beta = 1.519 \pm 0.003. \quad \gamma = 1.521 \pm 0.003.$$

A determination of the water in this material gave 31.5 and indicates the tetrahydrate which theoretically contains 32.3 per cent H_2O. This form was crystallized from solution at 45° and was formed from the alteration of the pentahydrate.

The nearly white alteration product in the stock bottle is optically +, 2V is near 90°.

$$\alpha = 1.562 \pm 0.003. \quad \beta = 1.595 \pm 0.003. \quad \gamma = 1.632 \pm 0.003.$$

A water determination on this material gave 10.85 per cent and indicates the monohydrates which theoretically contains 10.66 per cent H_2O.

$MnSO_4$ crystallized from solution in a desiccator under reduced pressure at 23° C was in well formed tabular crystals that gave inclined extinction when on the flat face or on edge and are no doubt triclinic. Y is nearly normal to the laths and crystals lying on the flat face give an extinction of Z′, length 15° ± 1°. They are optically—, 2V is rather large, and the dispersion is slight.

$\alpha = 1.495 \pm 0.003. \quad \beta = 1.508 \pm 0.003. \quad \gamma = 1.514 \pm 0.003.$

Carefully selected crystals wiped dry on filter paper were analyzed and gave 38.1 per cent H_2O, while the theoretical value for $MnSO_4 . 5H_2O$ is 37.4.

It alters slowly on standing to a form that is opt. —, 2V moderate.

$\alpha = 1.513 \pm 0.003. \quad \beta = 1.520 \pm 0.003. \quad \gamma = 1.522 \pm 0.003.$

This is probably the same as the glassy form of the original sample.

Crystals formed at 45° C and drained from the solution are imperfect laths. Lying on the flat face they appear to give parallel extinction with X nearly normal to the flat face and Z parallel to the length; turned on edge they give extinction Z elongation 5°. They are probably monoclinic, tabular parallel to (100), and elongated along c. Y = b and Z $\wedge$ c = 5°. They are optically —, 2V is rather large.

$\alpha = 1.509 \pm 0.003. \quad \beta = 1.518 \pm 0.003. \quad \gamma = 1.522 \pm 0.003.$

This is probably the tetrahydrate and is like the form of the original sample.

A solution evaporated on a water bath gave a very pale pink powder made up of aggregates of minute fibers with the following optical properties: Opt. — (?), 2V large, probably monoclinic with Z = b, Y to elongation varies with color of light and gives abnormal interference colors.

$\alpha = 1.560 \pm 0.003. \quad \beta = 1.592 - 0.005. \quad \gamma = 1.627 \pm 0.005$

A water determination of this gave 11.2 per cent and shows that it is the monohydrate which should contain theoretically 10.75 per cent. This is the same as the alteration product in the original sample.

Natural szmikite ($MnSO_4 . H_2O$) from Felsöbanya, Hungary[1] is a nearly white chalky aggregate of very minute fibers or plates, probably monoclinic with Z = b.

$$\alpha = 1.57 \pm 0.01. \quad \gamma = 1.62 \pm 0.01.$$

The optical properties of the hydrous sulphates of cobalt and manganese are tabulated in Table IV.

TABLE IV. *Optical properties of the hydrous sulphates of cobalt and manganese.*

	$MnSO_4$ $1H_2O$	[1]$CoSO_4$ $1H_2O$	[2]$CoSO_4$ $1H_2O$	$MnSO_4$ $4H_2O$	$MnSO_4$ $5H_2O$	$CoSO_4$ $5H_2O$	$CoSO_4$ $6H_2O$	$CoSO_4$ $7H_2O$
System	Monocl (?)			Monocl (?)	Tricl.	Tricl.	Uniax.	Monocl.
Habit		Fibers Crusts	Crystals	Tab.				Tab.
Opt. char.	+	?	+	—	—	—	—	—
2V	near 90	?	near 90	mod. lge.	rather lge.	med.	0	near 90
α	1·562	1·600	1·603	1·508	1·495	1·530	1·460	1·477
β	1·595		1·639	1·518	1·508	1·548	1·495	1·483
γ	1·632	1·645	1·683	1·522	1·514	1·550		1·489

[1] Formed when $CoSO_4$ solution is evaporated to dryness on a water bath.
[2] Formed in small amount when $CoSO_4.6H_2O$ is allowed to dehydrate in a desiccator at room temperature.
[4] Unpublished manuscript by E. S. Larsen.

Art. XVII.—*An Upper Carboniferous Footprint from Attleboro, Massachusetts;* by Richard Swann Lull.

[Contributions from the Paleontological Laboratory, Peabody Museum, Yale University, New Haven, Conn.]

In a quarry about 1½ miles southwest of the railroad station at Attleboro, Massachusetts, there was found a slab of dark micaceous shale bearing certain footprints and invertebrate trails apparently new to science. The specimen was loose in the quarry, but there is no question as to its being *in situ,* as it was discovered in the presence of Professor J. B. Woodworth of Harvard University by one of his students, Mr. Fred. Garnjost.

Stratigraphically, the specimen comes from strata immediately below the "Dighton" conglomerate[1] and is, therefore, as Professor Woodworth writes:[2]

"very high Alleghanian if not higher, but below the coarse conglomerates which cap the Rhode Island Coal Measures in all the synclinal axes of the Narragansett area. The beds are higher than those which at Plainville near Wrentham carry very small footprints, one of which I have described."

The surface of the slab is somewhat undulatory and bears rain-drop impressions, which add to the difficulty of interpretation. There is, however, the unquestionable imprint of the hind foot of a quadrupedal form of considerable size and at least two much smaller handprints, neither of which bears a normal position relative to that of the pes. They do, nevertheless, doubtless pertain to the same individual, and as such they will be described. There is a possibility, which was recognized by Professor Woodworth, that the hind foot track may have been in part obscured by another impression, which would account for the apparent abnormality of digit 1. If this be true, I am unable to differentiate the occulting track.

Dromopus? woodworthi, n. sp.

Manus (Fig. 1, m).—Tetradactyl, plantigrade, with rounded palm and diverging digits, terminating in rounded claw impressions. Divarication of digits 1

[1] See Monograph XXXIII, U. S. Geol. Survey.
[2] J. B. Woodworth, Bull. Geol. Soc. America, 11, 449-454, figs. 1, 2, pl. 40, 1900.

and 4, about 85°. Length over all, 36 mm. Distance between lateral toes, 35 mm. Breadth of palm, 18.5 mm.

Pes (Fig. 1, p).—Pentadactyl, plantigrade, claws somewhat more acuminate than in manus, phalangeal pads more or less distinct, phalangeal formula, omitting metatarsals, apparently 2, 3, 4, ?4, 2 +, the outer digit seemingly imperfectly impressed. Sole broadly rounded. Divarication of lateral digits, about 93°. Distance between lateral digits, 80 mm. Length over all, 90 mm. Breadth of sole, 45 mm.

The disparity of size between manus and pes is very marked, showing that the greater proportion of the weight

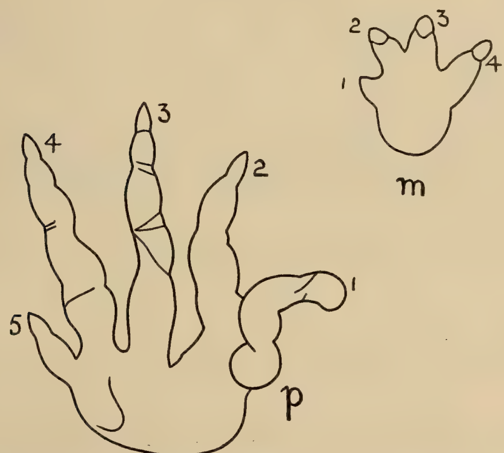


Fig. 1.—Impression of the right manus (m) and left pes (p) of *Dromopus? woodworthi*, n. sp. One half nat. size.

was borne by the latter. There is no indication of a dragging tail.

This footprint is most suggestive of *Dromopus agilis* Marsh[3] from the Kansas Coal Measures, the chief distinctions being the greater size of pes and the non-correspondence of phalangeal formula, which in Marsh's species is the normal 2, 3, 4, 5, 2 of the diapsid reptile. The apparent discrepancy may be due, however, to the obscurity of the present track. The outer digit in the present species is not so widely offset, but this again may be more apparent than real. The foot of the new species is somewhat more clumsy, and the digits are apparently more deeply cleft into the sole.

[3] O. C. Marsh, this Journal (3), 48, 82, pl. 2, fig. 3; pl. 3, fig. 3, 1894.

The manus, on the other hand, differs markedly, that of the present form being proportionately much smaller, especially in the length of the abbreviated digits, the formula of which can not be ascertained.

In some respects the new form suggests *Dromopus velox* Matthew[4] but is much larger and differs again in the relative size of hand and foot. The assignment to the genus *Dromopus,* therefore, may be taken as provisional.

Williston expressed the opinion that in *Dromopus agilis* we had the veritable footprint of a reptile, and it is quite probable that this new species was also of reptilian rather than amphibian lineage. Williston's *Isodectes copei* from the Coal Measures of Ohio, which he regards as the oldest known reptile, and the foot of which would make an impression not unlike that of *D. agilis,* is evidence for the possibility of reptilian existence at this remote period.

I am deeply indebted to Professor Woodworth for the privilege of describing this most interesting form. The type is preserved in the Geological Museum of Harvard University.

[4] G. F. Matthew, Trans. Roy. Soc. Canada (2), 10, sect. 4, 86, pl. 2, figs. 1a, b, 1904.

SCIENTIFIC INTELLIGENCE.

I. Geology

1. *Topographic Maps and Sketch Mapping;* by J. K. Finch. Pp. xi+175, 77 text figs., 1 map; New York (John Wiley & Sons), 1920.—During the great war there was a decided demand for a text-book on map reading and sketch mapping, and this stimulus has brought the book under notice. Moreover, the general public has discovered the fine topographic maps issued by the U. S. Geological Survey, and this book will help to a better understanding of them. It is a small volume, abundantly illustrated, and recommended to instructors in geology and geography, and to civil engineers. There is also an appendix presenting a descriptive list of the principal topographic maps of the world, by F. K. Morris.

2. *The Porto Rico Earthquake of 1918. Report of the Earthquake Investigation Commission;* by H. F. Reid and Stephen Taber. House of Representatives, Document No. 269,

66th Congress, 74 pp., 6 figs., 1919.—This interesting report describes in detail the earthquake of 1918, the distribution of the apparent intensity, the secondary phenomena, effects on structures, after shocks, etc. The earthquakes in the Virgin Islands in 1867-1868 are also described, and there is a catalogue of 275 shocks in Porto Rico and the Virgin Islands from 1772 to 1918.

C. S.

3. *Scientific Survey of Porto Rico and the Virgin Islands.* Vol. I, Part 1. Published by the New York Academy of Sciences, 110 pp., 4 pls., 26 text figs., 1 map, 1919.—This is the first of the final reports of a scientific survey of Porto Rico made through the coöperation of the New York Academy of Sciences, Mr. Emerson McMillin, and the Porto Rico government. The report opens with a history of the survey by N. L. BRITTON (10 pages), followed by a "Geological Introduction" by C. P. BERKEY (pp. 11-29), a "New Base Map of Porto Rico," by C. A. REEDS (pp. 30-31), and a detailed account of the geology of the San Juan region, by D. R. SEMMES (pp. 33-110).

It is a most interesting report, describing the "Older Series," the core of a mountain chain of Cretaceous (probably also some Comanchian) and early Eocene sediments, with much igneous interbedded material of explosive volcanoes. Then followed deformation and peneplanation, and later, submergence ,with the deposition of the "Younger Series" of Cenozoic (chiefly Oligocene) marine sediments, devoid of volcanics and laid down on the flanks of the central Older Series. C. S.

4. *La Fauna Jurásica de Vinales;* by MARIO S. ROIG. Cuba, Secretaria de Agricultura, etc., Boletin Especial, 61 pp., 26 pls., 1920.—In this memoir are described and illustrated forty-three forms of ammonites from the higher Jurassic of western Cuba. Many are common to Cuba and southern Europe. C. S.

5. *Maryland Geological Survey. Cambrian and Ordovician;* by R. S. BASSLER. Pp. 424, 58 pls., 277 text figs., 1919.—This Cambrian-Ordovician memoir of the Maryland State Survey, like all the other reports issued by that splendid organization, is a work of great importance in American stratigraphy. As is well known, the western extension of Maryland is very narrow but long geographically, and if a thorough grasp of its Paleozoic sequence is to be attained, its formations must be studied in the light of their continuance in West Virginia and Pennsylvania. This has been done, and the present report is therefore an account of the Cambrian and Ordovician of those states as well as of Maryland. In addition, stratigraphic correlations are made with many other areas of the United States.

The Cambrian, Ozarkian, and Ordovician systems of Maryland are here divided into 13 formations (7, 1, and 5 respectively), with a total thickness of about 15,200 feet, of which more than 10,000 feet are limestones. The accompanying geologic map is small (1 inch = 5 miles), so that the formations described had to be combined into nine. The volume also brings out clearly the great development of lime secreted by algæ, and the very significant intraformational conglomerates.

Another very valuable feature of the memoir is the 22 paleogeographic maps by E. O. Ulrich (3 Cambrian, 3 Ozarkian, and 16 Ordovician). It is a great question, however, if the Appalachian trough had the three different openings into the Atlantic south of New York here shown. Those who do not accept Ulrich's views will therefore be obliged to draw very different sea-ways.

The final half of the volume describes and illustrates 219 species of fossils, mostly invertebrates, of which but 14 are new (7 Cambrian, 5 Ozarkian, and 207 Ordovician). C. S.

6. *Handbuch der Palæogeographie;* by THEODOR ARLDT. Vol. I, Palæaktologie, Pt. 1, 1917; Pt. 2, 1918; Pt. 3, 1919. Pp. 679, with 76 small maps. Gebrüder Borntraeger, Leipzig.—This is the most comprehensive book treating of the ancient geographies, developed on the basis of the geologic and biologic evidence. Nothing appears to be omitted, and all of the more comprehensive maps are reproduced. The book places paleogeography on a scientific basis, and is a work of reference that will be of great service to all paleontologists and geobiologists. The second volume with the index and the necessary pages for binding has not appeared. C. S.

7. *The Geology of East Texas;* by E. T. DUMBLE. Univ. of Texas Bull. No. **1869**, 388 pp., 12 pls., 1918 (1920).—This comprehensive and detailed report brings together all that is known to the author, after many years of geologic work, regarding the formations in eastern Texas that make up the Mesozoic and Cenozoic series of rocks. The geologic history begins with the Comanchian and ends with the Pleistocene. There are chapters on lignite, hydrocarbons, salt and gypsum, iron, clays, and building stone. Dumble has also recently published a very interesting pamphlet treating of the geology of Texas, the result of three lectures given at the Rice Institute in Houston under the following titles: (1) The Geology of Texas, its part in the Building of a Continent; (2) The Individaulity of Texas Geology; and (3) The Economic Features of the Geology of Texas. C. S.

8. *Pleistocene Marine Submergence of the Hudson, Champlain and St. Lawrence Valleys;* by H. L. FAIRCHILD. N. Y. State Mus., Bulls. **209**, and **210**, 76 pp., 33 pls. and maps, 1919.—This interesting report is doubly instructive because of the many maps that accompany it. It brings together all the knowledge that is of value concerning the invasions of the Atlantic Ocean—widely down the St. Lawrence, narrowly along the Atlantic border, and the Hudson and Connecticut valleys. C. S.

9. *Report of the State Geologist on the Mineral Industries and Geology of Vermont, 1917-1918;* by G. H. PERKINS *et al.* Pp. 247, 18 pls., 10 text figs., 1919.—This volume consists of fifteen different papers treating of the physiography, structure, stratigraphy, Champlain sea-levels, and economic products of

Vermont. Of great interest are the papers by C. H. Richardson recording the finding of Lower and Middle Ordovician graptolites in highly metamorphosed slates and marbles in central Vermont throughout an area 40 miles wide and 100 long. No one ever thought of finding fossils in these greatly altered strata, and the new discoveries will not only enable the geologists to determine the age of the formations but also help much to a fuller realization of the rock structures and their times of deformation.
C. S.

10. *Geology and Natural Resources of Rutherford County, Tennessee;* by J. J. GALLOWAY. Tennessee State Geol. Survey, Bull. **22,** 31 pp., 3 pls., 1 map, 1919.—A good modernization of the geology of one of the most interesting counties of central Tennessee. The stratigraphy relates in the main to the Ordovician, and the Chattanooga is referred to the early Mississippian. The geologic map is on the scale of one inch to the mile. C. S

11. *Geologic Map of Ohio;* by J. A. BOWNOCKER and associates, 32 × 39 inches, 1920.—This is one of the best state geological maps of the many that have been published in recent years. The scale is about 8 miles to the inch, or 1 : 500,000. The color scheme brings out clearly the various formations mapped (14) and the printing is excellent. There are no contour lines, but the original map was made on a contour base. The formation boundaries are shown in great detail. Besides the geology, there is given the detailed geography, drainage, culture, oil- and gas-producing areas, shipping coal mines, and other economic locations. C. S.

12. *Seasonal Deposition in Aqueo-glacial Sediments;* by ROBERT W. SAYLES. Mem. Mus. Comp. Zoology, vol. **47,** No. 1, 67 pp., 16 pls., 2 text figs., 1919.—The author here first describes and illustrates by heliotype plates the nature of the Pleistocene annual-layered clay beds, and then applies this knowledge to the Permian slates at Squantum, Massachusetts, with the result that there can be no doubt that their banding is glacial and seasonal. He adds a survey of the banding described by geologists of many lands and observed also in museum specimens, coming to the conclusion that some of the slates accompanying most tillites since the Huronian are certainly seasonally banded. As tillites are not so readily preserved in the geologic record as are the marine clays of glacial times, we are asked to be more on the lookout for them and thus to further assist in determining the rigorous climates of the past. It was Edward Hitchcock who in 1841 first called attention to the banding in Pleistocene clays as probably due to annual changes in deposition. Since his time, several other American geologists have come independently to the same conclusion regarding the Pleistocene clays, but it was DeGeer of Sweden who in 1912 placed this theory on a firm basis. Now Sayles applies it successfully to almost all of the older glacial accumulations. C. S.

13. *Middle Cambrian Algæ* and *Middle Cambrian Spongiæ;*

by CHARLES D. WALCOTT. Cambrian Geology and Paleontology, **4,** Nos. 5 and 6. Smithson. Misc. Coll., **67,** Nos. 5 and 6, pp. 217-260, pls. 43.59, 1919; and pp. 261-364, pls. 60-90, 10 text figs., 1920.—In the first paper are described 7 new genera and 21 new species of algæ which are definitely referred to the blue-green, green, red, and calcareous types. They are all from the Burgess shale of the Middle Cambrian of British Columbia, probably the most wonderful locality for Paleozoic fossils known. The second, and more interesting, article treats of siliceous sponges, most of which are from the same locality as the algæ. Of monactinellid forms there are 22 species (21 new), and of hexactinellid, 17 (14 new). These are referred to 16 genera, 13 of them being new. The author thinks that practically all of the algæ and sponges were carried by currents into the ancient Wapta Bay. C. S.

14. *On the Structure of Eusthenopteron;* by W. L. BRYANT. Bull. Buffalo Soc. Nat. Sci., **13,** No. 1, 29 pp., 18 pls., 8 text figs., 1919.—An elaborate description and illustration of the highly interesting Upper Devonian fresh-water fish, *E. foordi,* from Scaumenac Bay, Quebec. The study was made in great detail because the crossopterygian fishes are thought to be more nearly related to the amphibians than are the lung-fishes. Finally, there is presented a pen and ink illustration of the fish restored as in life. C. S.

15. *Upper Cretaceous Floras of the eastern Gulf Region in Tennessee, Mississippi, Alabama, and Georgia;* by E. W. BERRY. U. S. Geol. Survey, Prof. Paper **112,** 177 pp., 33 pls., 12 text figs., 1919.—In this interesting memoir are described 187 species of plants, of which 47 are new; 148 of them are dicotyledons. The basal sandstones, the Tuscaloosa formation, essentially fresh-water delta strata, have a flora of 151 forms, while the higher marine Eutaw has but 43 and the Ripley 21. The flora of the Tuscaloosa is very much like that of the Raritan (63 species in common) and Magothy of the Atlantic piedmont, and it may be said that it ranges through 38° of latitude, i. e., from middle western Greenland to southern Alabama. It is postulated that the Tuscaloosa flora "occupied a low coastal land of rather uniform topography—a land favored with an abundant and well distributed rainfall, with equable temperatures within the limits embraced between warm temperate and subtropical, and with slight seasonal changes" (p. 30). There is a large map giving in considerable detail the geographic distribution of the various formations with all the plant localities indicated.

C. S.

16. *Some American Jurassic Ammonites of the Genera Quenstedticeras, Cardioceras, and Amœboceras, Family Cardioceratidæ;* by JOHN B. REESIDE, JR. U. S. Geol. Survey, Prof. Paper **118,** 64 pp., 24 pls., 1 text fig. (map), 1919.—This very important paper for the correlation of the Sundance formation (early

Upper Jurassic) describes 35 species, 30 being new. One form is from the Ellis formation of Montana, and may indicate an horizon somewhat older than the Sundance; another is from British Columbia; three are from the basal beds of the Naknek formation of Alaska; and thirty from the Sundance of Wyoming and South Dakota. In these places are found only the genera *Cardioceras* and *Quenstedticeras, Amœboceras* being restricted to the Mariposa slates of California, apparently the youngest Jurassic horizon in the United States. C. S.

17. *Paleontological Correlation of the Fredericksburg and Washita Formations in North Texas;* by W. S. Adkins and W. M. Minton. Univ. of Texas Bull. No. **1945,** 128 pp., 21 pls. 6 text figs., 1919 (1920).—After six years of work on the Comanchian strata of northern Texas the authors have learned the stratigraphic range of the various invertebrate fossils. The formations, on the basis of lithology, change very rapidly from place to place, either from south to north or from west to east. Accordingly, fossils are the only safe means of correlation, and on this basis the Fredericksburg and Washita series are here divided into 41 faunal "horizons," each typified by guide fossils. The authors have more than 100 new species, but in this memoir only 11 of them are described. To make clear their understanding of the guide species, they here describe and illustrate 74 forms, but 12 of them are not specifically named. Of cephalopods there are 20, bivalves 30, gastropods 2, brachiopods 1, echinids 17, corals 3, and foraminifers 1. The authors are to be congratulated on the good beginning they have made toward a final zoning of the Comanchian of Texas. C. S.

18. *Fossils from the Miura Peninsula and its immediate north;* by Matajiro Yokoyama. Jour. College of Science, Imperial Univ. of Tokyo, **39,** Art. 6, 193 pp., 19 pls., 1 map, 1920.—In this memoir are described 229 species of Mollusca, and 6 of Brachiopods, from the lower Musashino formation occurring to the south of Yokohama. Of these, 93 are new. The fauna has boreal relations and is of colder waters than at present exist in the same latitude. The horizon is thought to be Pliocene, and the number of forms still living is about 95, or 40 per cent of the fossil fauna. The heliotype illustrations are very fine.

C. S.

19. *North American Early Tertiary Bryozoa;* by Ferdinand Canu and Ray S. Bassler. U. S. Nat. Mus., Bull. **106,** text and plates, 877 pp., 162 pls., 279 text figs., 1920.—Previous to the appearance of this great monograph, there had been identified of American Eocene and Oligocene bryozoans but 81 forms, arranged in about 40 genera. We are told, however, that Tertiary bryozoans "often occur literally by the millions in a stratum." Canu and Bassler now describe from the Atlantic and Gulf border (Maryland to Mississippi) Eocene and Oligocene (52 stations) about 742 forms in 266 genera, of Cheilostomata

and Cyclostomata. Of new genera there are 37, but since 1917 these authors have described elsewhere 64 additional ones. This certainly is a tremendous stride forward in our knowledege of these organisms.

In the oldest Eocene Aquia formation, there are 22 and all are restricted forms; in the Midwayian series 66, and only 3 of these go higher; in the Claibornian there are 30, of which 20 go upward; but in the Jacksonian there are 431, with 48 passing upward, 17 coming in from the Claibornian below, and 2 from the Midwayian; in the Vicksburgian there are 193, and of these 48 are from the Jacksonian, 6 from the Claibornian, and 1 from the Midwayian. These figures show that bryozoans in general are chronologically not long ranging, and that only about 16 per cent pass through more than one series. On the other hand, the work also shows forcibly that these animals have a wide range geographically, many of them being common to Europe and America, and even to Asia, Australia, and South America. For these reasons, bryozoans, when present, are fine index fossils, and at many localities they are the only reliable time markers for the strata.

The junior author has been the stimulator of this great undertaking, and he has been instrumental in getting together the material through his own efforts and those of others, separating the species, making the thousands of photographs, and seeing the memoir through the press. The senior author, with his wide knowledge of living Bryozoa, was thus enabled to bring to life, as it were, these fossil forms, and to classify the great mass of material unearthed in America. We see here a fine combination of matured knowledge with the activity of a collector who knew that great results lay ahead. And truly great results are here attained, not only in classification and phylogeny, but even far more in the morphology of calcareous bryozoan structures. The work teems with morphologic drawings, and the plates illustrate the species as one sees them under the microscope by means of photographs that are but slightly retouched. C. S.

20. *A Monograph of the Naiades of Pennsylvania. Part III, Systematic Account of the Genera and Species;* by Arnold E. Ortmann. Mem. Carnegie Mus., vol. 8, No. 1, 384 pp., 21 pls., 34 text figs., 1919.—In this large and handsome monograph are described in great detail 80 forms of fresh-water pearl shells found living in the rivers of Pennsylvania. They are arranged under 32 group terms, and all are illustrated on plates. The distribution is given in detail. It is a monumental work.

C. S.

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[FOURTH SERIES.]

ART. XVIII.—*Entelodonts in the Marsh Collection;* by EDWARD LEFFINGWELL TROXELL. With Plate III.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Connecticut.]

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GENERAL SUMMARY.

The purpose of such a paper is to put at the disposal of science the fine collection of entelodonts in the Peabody Museum. The known species are listed and the standing and a brief description of each are given, as well as a list of the new species proposed at this time. In the discussion of the teeth and bony processes on the skull and mandibles, it is reasoned that the latter were for muscle attachment, and facilitated the movements of the jaws in eating and may also have supported cheek pouches. The anterior mental processes may well have guarded the points of the canines, as in the sabre-toothed cats, or in *Dinoceras*.

The great diversity of the material did not permit the reference of every specimen to a known species, nor did the fragmentary material warrant making a new species for each strange specimen. It was found most practicable, therefore, to group allied specimens, even though at times widely different, in order to emphasize their relationship and to arrange the whole in a systematic way.

Summary of Measurements

	A. clavus clavus holotype mm.	*A. clavus darbyi* holotype mm.	*A.* sp. No. 10286 mm.	*A. crassum* paratype mm.
Skull length, condyles to incisor border	392	430	....	....
Width across muzzle at alveolus of P^2	58.0	62.0	....	....
Width of rami back of anterior tubercles	45.4	....	....	49.0
Depth of ramus at P_2	46.6	....	56.0	60.0
Depth of ramus at M_2	51.6	61.7	68.0	72.3
Diameter of P^4, transverse	21.0	21.8	24.6	....
Diameter of P^4, ant.-post.	21.0	18.2	24.3	....
Diameter of M^2, transverse	24.7	25.3	28.4	....
Diameter of M^2, ant.-post.	24.3	24.0	27.0	....
Upper premolar length	103.0	114.0	....	....
Upper molar length	67.6	67.0	81.0	....
Diameter of P_4, transverse	12.8	14.8	16.2	....
Diameter of P_4, ant.-post.	28.8	25.0	30.5	29.0
Diameter of M_2, transverse	17.9	18.4	20.5	22.0
Diameter of M_2, ant.-post.	24.9	23.6	26.0	26.0
Lower premolar length	112.0	....	141.5	135.0
Lower molar length	71.7	70.5	75.9	76.0

	A. marshi holotype mm.	*P. potens* holotype mm.	*M. zygomaticus* genoholotype mm.	*M. latidens* holotype mm.	*Chærodon caninus* genoholotype mm.
Skull length, condyles to incisor border	540	....	760	....	610
Width across muzzle at alveolus of P^2	80.6	....	96.0	80.0	85.5
Width of rami back of anterior tubercles	64.6	78.0	....	75.0	62.0
Depth of ramus at P_2	62.0	92.0	....	74.0	83.0
Depth of ramus at M_2	75.0	109.0	....	76.0	83.0
Diameter of P^4, transverse..	27.8	....	34.0	39.0	34.6
Diameter of P^4, ant.-post...	28.6	....	31.0	35.0	30.0
Diameter of M^2, transverse.	32.3	....	42.5	45.0	43.0
Diameter of M^2, ant.-post..	29.3	....	40.0	42.2	36.0
Upper premolar length	130.0	....	186.0	....	155.0
Upper molar length	82.8	....	112.0	117.0	105.0
Diameter of P_4, transverse..	18.4	?23.0	*33.5	29.0	27.0
Diameter of P_4, ant.-post...	34.0	41.4	*53.0	44.0	35.0
Diameter of M_2, transverse.	23.8	28.6	*39.5	34.7	31.0
Diameter of M_2, ant.-post..	30.4	35.4	*54.0	43.0	35.5
Lower premolar length	149.0	200.0	....	189.0	166.0
Lower molar length	88.4	108.5	....	126.5	107.0

* *Ammodon leidyanus,* holotype and paratype.

Two new genera, four new species, and one new subspecies have been made in order to establish certain new features not heretofore known in the Entelodontidæ. The concluding sections of the paper are concerned with the detailed description of the types and the more important specimens in the collection.

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Elotherium in *Oreodon* and *Protoceras* beds.

PART I. MORPHOLOGY AND TAXONOMY.

Introduction.

Purpose of the present paper.—The development of our knowledge of the group of giant pigs called entelodonts has been so well given, especially by Scott (1898) and by Peterson (1909), that it is not worth while for us to repeat its general history, but in the great amount of material in the Yale Museum there are several specimens of unusual importance, some of which are entirely unknown to the scientific public, and some are but imperfectly known or have even been misrepresented in the literature, and so it seems necessary to go over this phase of the work again. There is a double purpose in presenting a paper on this material, namely, that of increasing the value of the specimens themselves, forming as they do a part of the interesting collection which Professor Marsh brought together in the early days of his paleontological work; but more especially, by detailed descriptions and drawings, to lay more broadly the foundation on which to study these animals in the future. The fine drawings are due to the artistic skill of Mr. R. Weber.

It is especially fitting, at the beginning of my work here as a member of the Peabody Museum staff, to express my gratitude to the two men, Professor Schuchert and Professor Lull, my former instructors, who have been most generous in their sympathy and assistance, and who now offer me every advantage in carrying on the work of my choice. To my congenial associates and myself the whole Marsh collection is thrown open for study and description under circumstances most propitious.

With reference to the group of entelodonts in particular, some of the Marsh specimens are entirely new, some of them had never been carefully studied before, and most of the material had never been completely prepared. In several instances, well known specimens have been further developed so that now new features are observed, giving evidence which contradicts some of the conclusions of former studies. The present paper treats almost exclusively the fossils in the Marsh Collection of the Peabody Museum at Yale.

In earlier paleontological writings, types were made on single molars or on a fragment of bone without teeth. In attempting to use these fragmentary types as guides, it becomes very evident that we cannot depend upon the characters shown by a single tooth or other small part of the fossil; we must know a large part of the skull; we should know the whole skeleton.

Status of species.—There were some twelve or fourteen species referred from time to time to *Entelodon* (*Elotherium,* see Peterson 1909, p. 43) and finally to the true American forms *Archæotherium, Pelonax, Ammodon, Dinohyus,* etc.; of these, recent authors recognize but few. Following is a list of the Oligocene forms commonly seen in the literature:

Entelodon magnus Aymard 1846. *E. coarctatus* Cope 1889. *E. calkinsi* (Sinclair) 1905. *Archæotherium mortoni* Leidy 1850. *A. robustum* Leidy 1852. *A. ingens* (Leidy) 1856. *A. superbum* (Leidy) 1868. *A. imperator* (Leidy) 1873. *A. crassum* (Marsh) 1873. *A. clavus* (Marsh) 1884. *Pelonax ramosus* Cope 1874. *P. potens*

(Marsh) 1893. *P. bathrodon* (Marsh) 1893. *Dœodon shoshonensis* Cope 1878. *Ammodon leidyanus* (Marsh) 1893 (Miocene). *Dinohyus hollandi* Peterson 1905 (Miocene).

Let us note the status of each of these.

Entelodon magnus Aymard is an interesting specimen of which the skull and lower jaws and other skeletal material constitute the first fossil of the sort found; for many years no distinctions between it and the American forms were noted.

Entelodon coarctatus Cope is undoubtedly quite distinct from any other American species, and from the observations which follow[1] it is apparent that if any of our entelodonts are closely related to *E. magnus* of France, it is this specimen described so long ago by Professor Cope.

Entelodon calkinsi (Sinclair), referred by Peterson (1909, pp. 64-65) to the strange genus *Dœodon,* in this paper is put under the new genus *Chœrodon.* The specimen was found in the John Day beds of Oregon; it is discussed more fully in connection with *Chœrodon caninus,* genoholotype, on a later page.

Archœotherium mortoni Leidy was the first species found in America. The type specimen consisted of a

[1] These two species are shown to be similar from the subjoined table of ratios: P_2 of *E. coarctatus* is relatively rather small as indicated by the ratio 66.9 per cent, while both P_3 and P_4 are comparatively large, with the ratios 80 and 80.6 per cent. The relation of P_3 and P_4 in each case is identical.

Other resemblances between the two are: the very small diastemata or their absence between the premolars, the first premolar small and single-rooted, crowns of premolars wrinkled and compressed, with cutting edges fore and aft. The main known differences between the two species are: the relatively larger size in general and of P_2 in particular, and the seemingly rougher teeth and well developed cingula of *E. magnus.* These differences certainly can not mark a greater variation than that of species, and so we would replace the American form under the old name of *Entelodon.*

Ratios from measurements taken from the drawings of Cope and Peterson.

	E. coarctatus mm.	Ratio %	*E. magnus* mm.
Length of molar premolar series......	167.1	74.0	226.0
Length of three lower molars..........	71.5	75.8	94.4
Height of enamel on crown of P_1	15.8	73.1	21.6
Height of enamel on crown of P_2	18.2	66.9	27.2
Height of enamel on crown of P_3	25.4	80.0	32.0
Height of enamel on crown of P_4	20.0	80.6	24.8

fragment of the skull with two premolars. Although the first description was almost as fragmentary as the fossil, we do find some accurate measurements, and later there were published some drawings. Peterson has discovered at the Carnegie Museum some excellent skulls which he identifies as *A. mortoni,* and has thus put the specific name on a more solid foundation.

Archæotherium robustum Leidy. This species was made on rather an important specimen in the collection of Doctor Owen, from the John Day region, and the name may some day be revived by a careful study of the original material, the location of which is not known at present. Peterson in his memoir makes no mention of this species, which Leidy himself tells us is no doubt the male individual of *A. mortoni.*

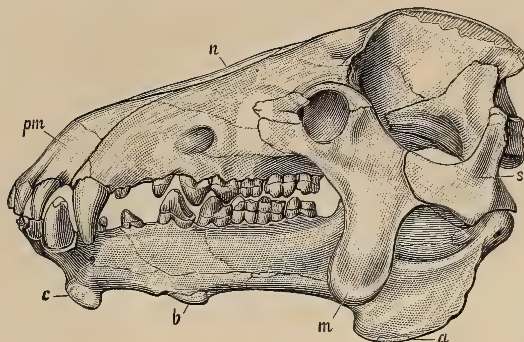
Archæotherium ingens (Leidy). The drawing published by Leidy in 1869 is by him "referred" to the species made in 1856; whether that may be interpreted to mean the same actual specimen we can not be sure. Peterson says that the type is not now known, and Leidy himself stated that he was "prepared to admit that these larger fossil remains may have pertained to robust males of *Elotherium mortoni.*" The type specimen represents "a huge species, indicated by several mutilated canines, the anterior extremity of a lower jaw without teeth, and the crown of an inferior molar tooth."

Archæotherium superbum (Leidy) is like the last species; of it Peterson says the "type is altogether inadequate"; furthermore the geological age and present location also are unknown, and in his estimation the name becomes a thing simply of historical interest.

Archæotherium imperator (Leidy) is represented by fragments which are unsuitable as types and Peterson states that they "should therefore be regarded only as an historical record of the first report of the existence of entelodonts in the John Day formation."

Archæotherium crassum (Marsh) was founded on two skeletons in the Yale Museum concerning which there is considerable misunderstanding; it is certain that the complete zygomatic arch, fig. 9, with associated skeletal parts (Cat. No. 12020)[2] is one of the specimens, of the features of which Professor Marsh says: "The most striking of

[2] Catalogue numbers cited refer to specimens in the Yale Fossil Vertebrate Collection in the Peabody Museum.



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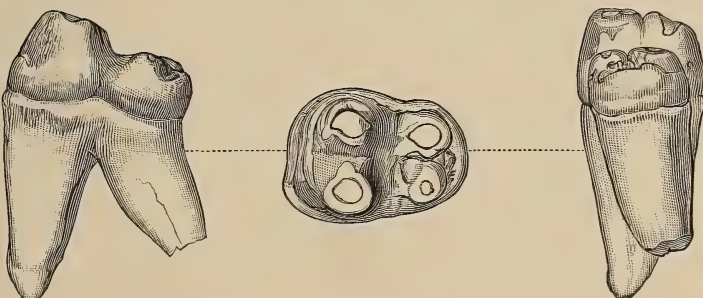

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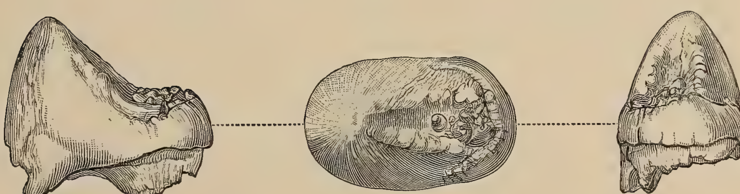

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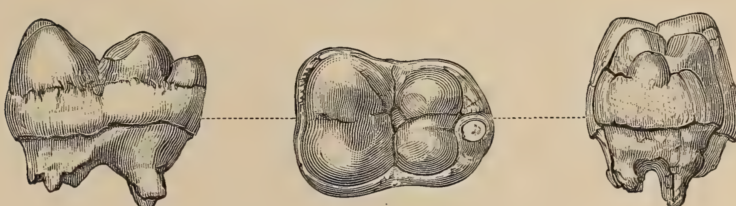

D

Plate III.—Well known types reproduced from Marsh (1893, Pls. VIII, IX).

A, *Archæotherium marshi*, sp. nov., holotype, commonly known as the apotype of *A. crassum* Marsh. Cat. No. 12025. One eighth nat. size.

B, *Pelonax bathrodon* (Marsh). Holotype. Cat. No. 12030. Three views of third lower molar. One half nat. size.

C, *Ammodon leidyanus* (Marsh). Views of genoholotype, P_4, Cat. No. 12040; and D, paratype, M_3, Cat. No. 12041. Both one-half nat. size.

these is a very long process descending from the malar bone and giving attachment to the masseter muscle." This was the first report of this very odd character in one of the entelodonts. On a later page in this paper the type is figured and the description amplified in the hope that we may find material comparable to it. It should be carefully noted that most of the description of this species by Marsh, Peterson, and others has been made from an apotype,[3] specimen No. 12025 (see Pl. III, A), which is found in many respects to be different from the original and is here made the type of a new species, *A. marshi.*

Archæotherium clavus (Marsh) was considered by Peterson to be a subspecies of *A. mortoni,* but due to the fact that the skull has now been completely freed from the matrix, showing the teeth and other parts (figs. 1-3), heretofore unknown features will be pointed out which it is believed will reinstate the name as that of a full and separate species. The holotype is Cat. No. 12035 of the Yale collection.

Pelonax ramosus Cope is a genus and species made on the great size of the tubercles on the lower jaw and on the single-rooted premolars, I and II. It is based on the ramus of a mandible of a very large animal of which the skull, according to Cope, would have measured nearly 2½ feet in length.

Pelonax potens (Marsh) Peterson (figs. 13, 14) is a peculiar species, with very heavy mental tubercles, single-rooted first premolar, and, unlike the type of the genus, with a double-rooted, though small, second premolar. The type specimen consists of the lower jaws with the fourth premolar and the three molars of one side. It is No. 12042 of the Yale Museum collection.

Pelonax bathrodon (Marsh) Peterson (Pl. III, B), has for its type a single lower third molar which, roughly estimated from the dimensions given by Cope in his original description, is about 3 mm. less in length than the corresponding tooth of *P. ramosus.* The specimen is indistinguishable from Cope's description of *P. ramosus* and is inadequate as a type. It is Cat. No. 12030 of the Yale collection.

Dæodon shoshonensis Cope is known by the body of the ramus of a very large animal. The extreme width and

[3] See Schuchert, C., and Buckman, S. S., Science, n. s., 21, 899, 1905.

the absence of the mental tubercles are characters found elsewhere only in specimens of *Dinohyus.*

Ammodon leidyanus (Marsh) (Pl. III, C) was a species made by Professor Marsh on two teeth from the Miocene of New Jersey, and probably represents the largest of the entelodonts known. It is only mentioned here with the Oligocene forms because of its connection with the larger species. The holotype is Cat. No. 12040, and the paratype Cat. No. 12041, of the Yale collection.

Dinohyus hollandi Peterson is a very large Miocene species of which the whole skeleton is known. It is so fully and completely described by the author in his interesting memoir that any further mention here would be superfluous.

To the species already listed, the following new designations will be added in later pages, based on characters summarized under their respective groupings:

Archæotherium marshi, sp. nov., figs. 10-12.
A. clavus darbyi, subsp. nov., figs. 4-8.
Megachœrus zygomaticus, gen. et sp. nov., figs. 15, 16.
M. latidens, sp. nov., figs. 17, 18.
Chœrodon caninus, gen. et sp. nov., figs. 19, 20.

The Bony Processes in Relation to the Teeth and Muscles.

The teeth are so constructed that they interlock throughout; the long separation of the incisors from each other and from the canines, to make way for the opposing teeth, is noteworthy, but the premolars also interlock: P_4 fits into the inner side of $P^{3.4}$ in a triangular pocket; the posterior shelf of P_4 comes in contact with the top of the fourth upper premolar. This strong cutting machine, represented by the formula $P\frac{3.4}{3.4}$, was well adapted to nipping off a particularly tough root, done by a backward, inward shearing of the lower jaw; and to fortify the teeth for this backward pressure, the lower premolars face in that direction, while the upper teeth are set at an angle facing forward.

The molars are constructed to mash the food, which probably consisted of bulbs and roots torn up by the canines and cut off and into short lengths by the premolars. The high cusps of M_2 and M_3 fit in between the cones respectively of $M^{1.2}$ and $M^{2.3}$; there is just room enough for the cones of the uppers, between each set of the high anterior cusps on the lower molars.

The actual movement of the teeth, beginning in front, was a shearing inward of the lower premolars, graduated into the shearing, grinding, crushing of the anterior molars, each one in turn from before backward; and finally the movement was ended when M_3, facing slightly inward, came fairly against the face of M^3 turned at an angle outward. This movement of the jaws may be judged from the wear between adjacent teeth, showing the slight movement of a tooth in the jaw with respect to the others, and also from the wear on the inner sides of the upper molars and on the outer side of the lower; in the latter case it amounts sometimes to the shearing off of a large portion of the side of the tooth.

The incisors are not only worn on the ends but are notched posteriorly, probably by lateral motion of the opposing teeth. The canines are generally worn off at the tips at right angles. Always the upper canine is worn flat anteriorly and it in turn wears a diagonal groove on the posterior side of the lower canine. On the anterior face of C^1, specimen No. 10286, there is a horizontal notch probably resulting from transverse movement against the tip of the lower canine.

In none of the specimens at hand is there evidence of wear by roots drawn across the base of the tooth such as is reported by Scott.

These apparent movements of the teeth and the lower jaw may offer a clue as to the purpose of the mental tubercles. Writers have hesitated to speculate, even, about the use of the many processes found on the skulls of the entelodonts. Peterson (1909, p. 144) "believed . . . that these processes, at least in the genus Dinohyus, existed for the attachment of muscles in order to give required strength to this portion of the head." Cope (1874A, p. 504), in speaking of the great tubercle on the lower jaw of *Pelonax ramosus,* says: "The posterior edge is acute and the extremity very rugose as though for the attachment of a horny or cartilaginous cap or apex." Later (1888, p. 1089) he compared the "osseous projections" to the "wattles in old males of the recent hog. In the *E. ramosum* these tuberosities become processes, and the anterior ones especially are so long that when the chin was stretched, hog-like, on the mud, it was raised well above the surface, allowing the passage underneath of water or of small animals.''

Without commenting on this idea of Professor Cope, let us examine other hypotheses, perhaps equally fantastic. When we compare the skulls with those of *Hippopotamus,* we wonder whether they might have had large thick lips, somewhat prehensile, which the tubercles by their wide extent aided in movement: to pull the lips away from the long teeth before biting and to draw the corners of the mouth forward in order to fold long reeds and grasses into the teeth.

There is a striking similarity between the anterior mental tubercle in *A. clavus clavus* and the protecting flange for the canine in some of the ancient sabre-tooth cats and in the Dinocerata, in that it forms a recess with a bony projection beneath. In some of the species of *Archæotherium,* and more especially in *Pelonax,* these guards are very extensive. In *Pelonax* we do not know the canines, but I imagine they were not so developed as to require such a very long sheath for their protection. The correlation between the wide-reaching tubercles and the widespread points of the upper canines, especially where the body of the ramus becomes smaller and the symphysis shorter, is well illustrated in *A. marshi* (fig. 12), where we find the points of the canines separated a distance about equal to the width of the tubercles.

The posterior mental processes were undoubtedly for muscle attachment, and because they are generally curved backward, we assume that the pull of the tendon was from that direction or from above. Two possibilities present themselves: first, from comparison with the dog (these entelodonts resemble the carnivores in many respects), we presume there was a muscle, homologous to the occipito-mandibularis, having its origin on the paroccipitals, or, in these animals, on the outer extremity of the temporal, and its insertion on the ventral border of the ramus, whose purpose it was to open the mouth or drop the jaws. Secondly, there may have been a muscle corresponding to the buccinator which in the dog is inserted low on the ventral border of the ramus and has its origin on the maxilla. In the Entelodontidæ a muscle of similar nature may have had its origin on the dependent process of the jugal, its insertion on one or both of the mental processes, and may have served the purpose, first, of a cheek muscle to press the food between the teeth, or again to give the mandible the strong backward motion, referred to on a previous page, in the process of mastication.

There is the additional possibility that these lateral extensions from the face and jaws supported cheek pouches or "muscular walls" comparable to those ascribed to the Ceratopsia by Professor Lull,[4] for retaining large quantities of food within the mouth before it was ready to be swallowed.

The dependent process from the jugal arch, in all probability, gave origin to the masseter muscle which generally arises from the jugal and is inserted broadly on the wide angle of the ramus. From the tip of the process the fibres of the muscle might have given the forward, the backward, and even a sideward movement to the mandible, for, judging from the wear on the teeth and the form of the molars, there was a definite transverse motion.

The condyles of the ramus permitted an unusual freedom of movement to the jaws in nearly every direction, including the opening to a wide angle, but the various hypothetical muscles would have fortified against pulling the condyles out of the shallow glenoid cavity. In the enormously developed jugal of *M. zygomaticus* (fig. 15), it is important to notice that the process extends backward so that its outer, posterior edge almost parallels the border of the angle of the ramus. Whatever may have been the original purpose of this dependent process, it is evident that these animals profited by its use until it reached the enormous size shown in this species, probably the last of its race.

[4] Lull, R. S., U. S. Geol. Survey, Mon. 49, p. 194, 1907.

TO BE CONTINUED.

Art. XIX.—*Notes on Hawaiian Petrology*; by Sidney Powers.

Contents.

Introduction.

The Hawaiian Islands are composed principally of olivine basalt with subordinate amount of olivine-free basalt and minor occurrences of trachyte, nephelite basalt, gabbro, trachyandesite, and a few other types as decribed by Dr. Whitman Cross.[1] The distribution of the rarer types and their relation to phases of vulcanism has not been emphasized and forms the subject of a portion of the present paper. There is also given a description of new occurrences of trachyte on Molokai and on the north, northeast, and south sides of West Maui, of very large olivine nodules in a picritic basalt on Kauai, and of extensive deposits of volcanic breccia on West Maui. Attention is also called to the arrangement of subsidiary cones on the younger volcanoes.

All the islands of the group were visited by the writer in 1915, with the aid of a Sheldon Travelling Fellowship from Harvard University, and a few notes concerning the rocks found on them are given below. The islands Niihau and Kahoolawe were never before examined geologically. It is shown that Haleakala, the recently extinct volcano forming East Maui, was last active about 1750. Hualalai, on Hawaii, was probably active as late as 1840-41.

[1] U. S. Geological Survey, Professional Paper 88, 1915.

This paper presents the conclusions of the writer on a variety of subjects. It is presented as his contribution to the knowledge of the geology of the Hawaiian Islands. It is by no means complete on any one of the subjects treated. Petrographic descriptions are given only to substantiate conclusions. Dr. Whitman Cross has the collections of rocks and has very kindly offered to study them petrographically. However, the writer prefers to publish at this time the scattered notes which follow rather than to postpone the publication for complete corroboration. Sincere thanks are due to Professors R. A. Daly and J. E. Wolff of Harvard University, for making this investigation possible, and to Professor Daly, to Dr. T. A. Jaggar, and to Dr. Whitman Cross for kindly criticizing the manuscript.

General Observations.

Necker.—Necker Island is one of the western Hawaiian group, 250 miles northwest of Kauai. The island is described as the "remains of a soil-capped volcanic crater" 300 feet high, ¾ mile long, and 500 feet wide at the widest part.[2] A specimen of basalt collected on this island for Professor W. A. Bryan, of the College of Hawaii, Honolulu, is a fine-grained rock composed of phenocrysts of feldspar and smaller phenocrysts of olivine in a fine-grained groundmass. The groundmass shows under the microscope part ophitic, part poikilitic texture and is composed of labradorite feldspar, slightly titaniferous augite, olivine, magnetite, and apatite.

Nihoa.—Nihoa Island rises abruptly from the sea 120 miles northwest of Kauai. Professor Bryan collected a specimen of altered basalt from the island. The rock is an olivine basalt, and consists of large olivine crystals between feebly poikilitic feldspar laths in an aphanitic, partly glassy groundmass in which magnetite and thin feldspar laths are visible.

Niihau.—Niihau (fig. 1) is a desert island consisting of a fragment of an original island[3] bounded on three sides by a low plain. The surface of the plain is an ele-

[2] W. A. Bryan: Natural History of Hawaii, Honolulu, 1915, p. 98; also described by Carl Elschner, The Leeward Islands of the Hawaiian Group, reprinted from the *Sunday Advertiser*, Honolulu, 1915, 68p.

[3] S. Powers: Tectonic lines in the Hawaiian Islands, Bull. Geol. Soc. Amer., vol. 28, p. 513-514, 1917.

vated coral reef partly covered by flows that have come from about 10 small cones and 3 small pit-craters. Kawaihoa Crater on the extreme southern end of the

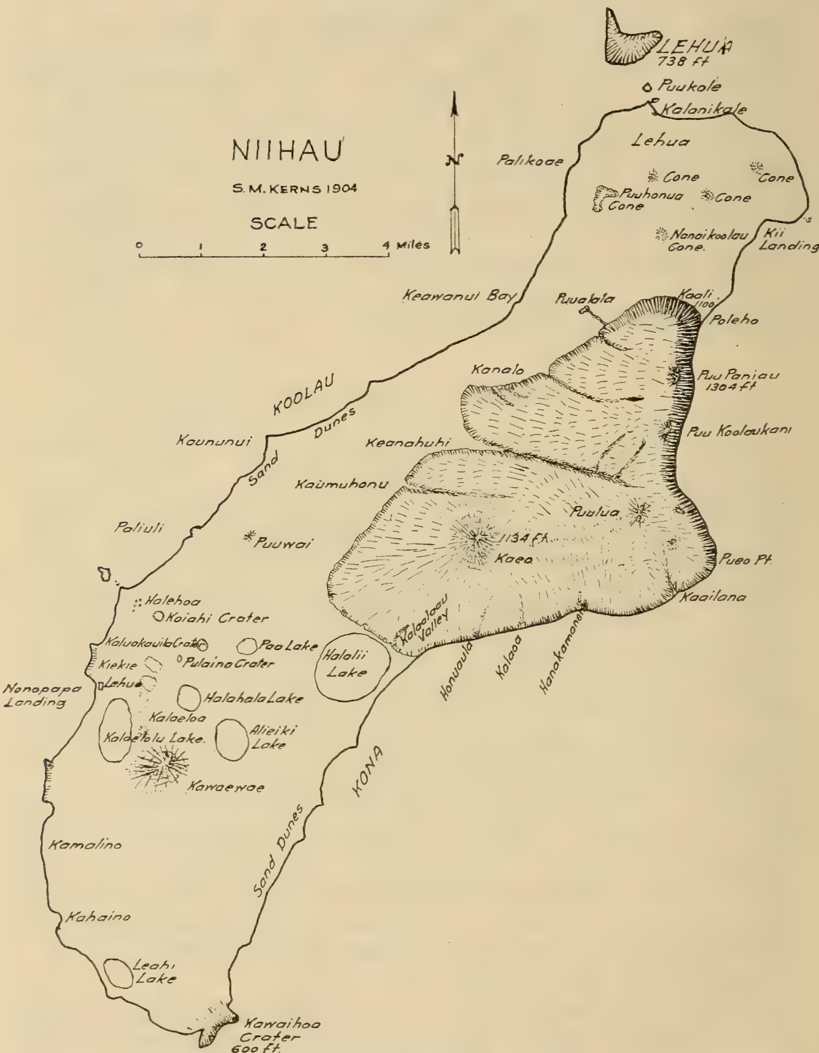

FIG. 1. Map of Niihau, Hawaiian Islands, consisting of a fragment of the original island surrounded by an elevated coral reef on which there are young cones and craters.

island and the islands Lehua and Kaula are composed of tuff of unknown composition. The flows comprising the original island, as seen from the west side, range in thickness from 5 to 30 feet and are composed of aphanitic basalt, occasionally showing small olivine phenocrysts. The flows dip westward at an angle of only 1 to 2 degrees. Four cones are situated on the plateau-like summit of the old Island. The young cones near the Nonopapa landing are composed of olivine basalt. Several pieces of white pumice have been found on the island—evidently material drifted from some far-away volcano.

Kauai.—Kauai is composed principally of olivine basalt. Of the 110 specimens collected on all sides of the island, 82% are found to contain olivine visible with a hand lens. About 30 young cones and craters are found on the east and south sides of the island and these, with the exception of Kilauea Crater, appear to consist of normal basalt and basaltic ash. The cones are notably arranged in lines more or less radial to the center of the original volcano.

Oahu.—Oahu is composed of the older Waianæ (Kaala) Range, in which feldspar basalt is the conspicuous rock-type, and the younger Koolau Range, concerning the petrography of which little is known on account of its topographic features. Of the older volcano only 5 young cones remain, the Laeloa craters of Hitchcock,[4] composed of nephelite basalt and arranged along a line tangential to the range. On the flank of the younger range about 39 distinct cones are found, of which eleven consist of tuff or basalt containing nephelite with or without melilite, the remainder of normal basalt or of basaltic ash.

Molokai.—Molokai consists of the low Mauna Loa on the west and a fragment of Wailau volcano[5] on the east. The major portion of the latter volcano has subsided, leaving a fault-scarp on the north side of the island.

Specimens of rock from Mauna Loa, Molokai, are difficult to collect on account of the absence of deep valleys. Basalt filled with olivine is found on the south and southwest sides while feldspar basalt with conspicuous tablets of plagioclase in a bluish rock occurs with olivine basalt and aphanitic olivine-free basalt near the center of the old volcano on the east and northeast sides of the mountain. The basalt weathers rapidly in this hot, arid region and when the wind sweeps away the red residual soil hard

[4] Geology of Oahu, Bull. Geol. Soc. Amer., vol. 11, p. 36, 1900.

[5] S. Powers: Tectonic lines on the Hawaiian Islands, Bull. Geol. Soc. Amer., vol. 28, p. 513, 1917.

nodules and masses of white or grey clay remain. Fragments of some of the nodules on the application of water swell to many times their original size. A bed of white clay 10 feet in thickness is reported on the northwest side of the island.

Wailau volcano is judged to have consisted largely of feldspar basalt with rare alkali trachyte. In composition and appearance the lavas of Kohala, on Hawaii, most nearly resembles this volcano. A greyish blue feldspar basalt with feldspar crystals sometimes one or two inches long and ¼ inch thick compose a number of flows along the south shore and in the gulches on the north. Olivine basalt dikes occur in Halawa and in Wailau gulches, and gabbro, as described below, is found in Wailau gulch. Kalaupapa, the peninsula north of the fault-scarp, now used as a leper colony, is composed of young olivine basalt which has poured out of three small vents arranged in a line perpendicular to the main fault.

Lanai.—Lanai appears to be composed of olivine and feldspar basalt in about equal amounts. The original center of eruption has been degraded, but several broad depressions resembling small bolsons occur south of the present summit. These depressions may represent secondary craters or possibly wind-blown depressions. *Aa* flows of much younger age than the major portion of the mountain occur on the southeast and north sides. That on the north, near Maunalei valley, is the less weathered. Nodules of clay like those so common on West Molokai and a few nodules of chert are found in the residual soil of the south side of the island.

Kahoolawe.—Kahoolawe is a barren island west of Haleakala inhabited by one Japanese caretaker. The vegetation has been destroyed by sheep and goats so that the surface of the island is barren, weathering basalt forming a red residual soil. Clouds of the soil blow out to sea with the strong trade winds. Seven cones and four cone-craters are shown on the U. S. Coast & Geodetic Survey contour map of the island (fig. 2).

Specimens were collected near Conradt's landing on the north side of the island. The shore cliffs are composed of a fine-grained, minutely vesicular olivine basalt of grey color which, under the microscope, shows olivine phenocrysts in a groundmass of glass, small feldspar laths, augite and magnetite crystals, and masses of limonite, the latter being in part in branching patterns.

East of the house fine-grained basalt of light grey color was collected. Microscopically the rock is uniform in grain and slightly glassy in composition, with ophitic and diabasic augites between feldspar laths. Magnetite is quite abundant in shreddy aggregates growing around the other crystals and sometimes included in them. Olivine crystals with limonite rims are present.

Pebbles of fine-grained, grey basalt were collected on the beach. They resemble in color a rock described to the writer as occurring on the southwest side of the

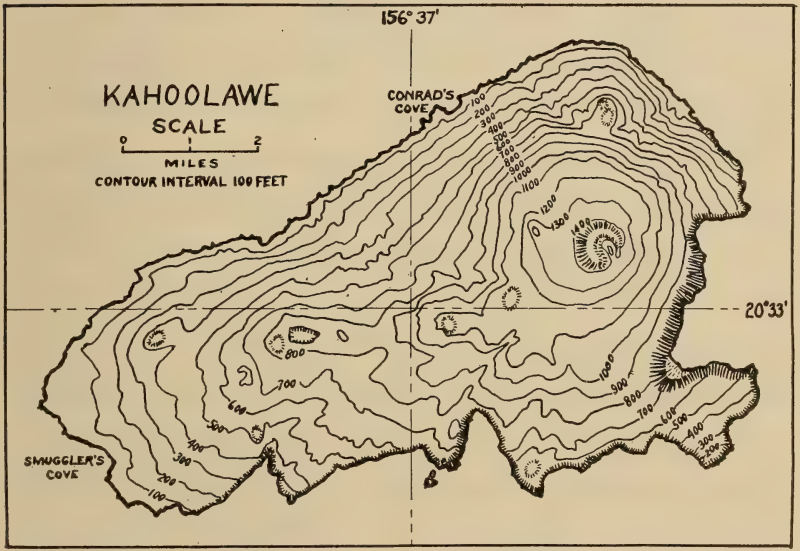

Fig. 2. Map of Kahoolawe, Hawaiian Islands, showing cones and craters. (Topography, U. S. Coast and Geodetic Survey.)

island. One specimen in this section is seen to be an altered tuff[6] with fragments of glass and calcic plagioclase accompanied by grains and granular aggregates of some other material imbedded in a very fine cryptocrystalline groundmass. The other material for the most part appears to be melilite, with a moderately high mean refraction, very low double refraction, parallel extinction on poor cleavage, and shows alteration products that look like zeolites. Some other material of higher double refraction may be pyroxene. The other specimen of grey

[6] The writer is indebted to Professor Charles H. Warren, of the Massachusetts Institute of Technology, for this microscopic description.

basalt from the beach is a fine-grained augite basalt free from olivine.

Maui.—The volcano of West Maui, as judged from the exposures and stream pebbles, has been built largely of olivine basalt. Covering portions of the eroded older rocks there is a veneer of trachyte as described later.

West Maui contains one feature not observed elsewhere. Deposits of fragments of subangular to rounded stratified material are found in Launiopoko, Waikapu, and Iao valleys and these streams are at present engaged in cutting into these deposits which rest unconformably on the sides of the older valleys. Ukumehame and Olowalu gulches were not examined and therefore it is not known whether or not the fragmental material is found there. None was seen in Kanaha Gulch above Lahaina.

The conglomerate, as it may be called, in each case fills an older, precipitously V-shaped valley and has become so well consolidated that it stands in vertical cliffs. In Launiopoko Gulch it occurs at an elevation of 1220 feet above sea-level on the west side of the stream just below the first water tunnel. In one vertical section 20 feet are exposed, showing blocks ½ foot to 5 feet in length in a sandy or tuffaceous matrix. Near the second tunnel, at an elevation of 1,360 feet, a thickness of 40 feet of the conglomerate, showing very coarse, unsorted blocks, occurs at and above the present stream bed. Toward the head of the gulch, at an elevation of 2,150 feet, 20 feet of conglomerate is exposed and in it are fragments of a true breccia 6 by 5 by 4 feet in diameter and lenses of water-worn pebbles.

Waikapu Gulch presents similar beds. Gravels occur at the entrance, near the flume, on the south side of the valley at an elevation of 1,000 feet and in the bottom of the gulch, 200 feet below. The deposits continue up the valley to an elevation of 900 feet, but they were not observed above the intake tunnel, elevation 1,050 feet, although at this place they form cliffs 60 feet high. The dip of the conglomerate beds is downstream at an angle of 6 degrees. The beds are sorted into coarse and fine, the subangular blocks in the former being 6 to 12 inches long, those in the latter 2 to 3 inches.

At the entrance to the Iao valley gravels are found at an elevation of 550 feet, 25 feet above the stream. Coarser gravels occur in a 20-foot vertical exposure at an elevation of 660 feet and other exposures are found north of Mr. W. H. Field's house, Kapaniwai. At the bridge near the Needle, elevation 900 feet, the stream is cutting into gravels and in the center of the valley there is a hill of decomposed rock consisting of angular and subangular fragments ½ inch to 3 inches in diameter.

The existence of similar deposits in three valleys at elevations ranging from 550 to 2,150 feet call for similar explanations. The partly stratified material might represent a volcanic breccia, mud-flow, or landslide material partly reassorted by the stream; or a true conglomerate deposited from a rapid, yet overloaded stream. It is difficult to account for the deposition of all the material in normal stream erosion as there appears to have been no agency which would cause a very rapidly flowing stream to drop gravels which would build so thick a deposit in a very steep-sided valley when the stream debouched from the valley over a steep talus cone. The gravels in the Launiopoko valley are found well toward its head where the stream must have been actively cutting. Also, there is no indication of a submergence of the island below present sea-level. In view of the evidence against normal stream-gravel origin, it is suggested that volcanic explosions took place long after the main volcano became extinct and that the conglomerate represents a breccia thus blown out and in part reassorted by the stream during the process of accumulation. The amphitheatral head of the Iao valley might be pointed to as excavated in part at least by such explosions, both because of its size, its geographically central position, and because of the large deposits of breccia near the narrow mouth. But normal stream erosion, given sufficient time under the existing climatic conditions with enormous precipitation on the high mountains and extremely little precipitation at sea-level, could excavate the Iao valley. The exact source of the explosions therefore remains uncertain, but it was probably near the head of the present Iao valley.

Haleakala, the volcano which built East Maui, is as yet only slightly dissected. The younger flows of this volcano and those of Mauna Kea, Hawaii, closely resemble each other in appearance—dense, aphanitic, bluish rocks —and in composition, olivine basalt to trachyandesite.

Haleakala has always been classed as an extinct volcano because no traditions concerning activity were re-

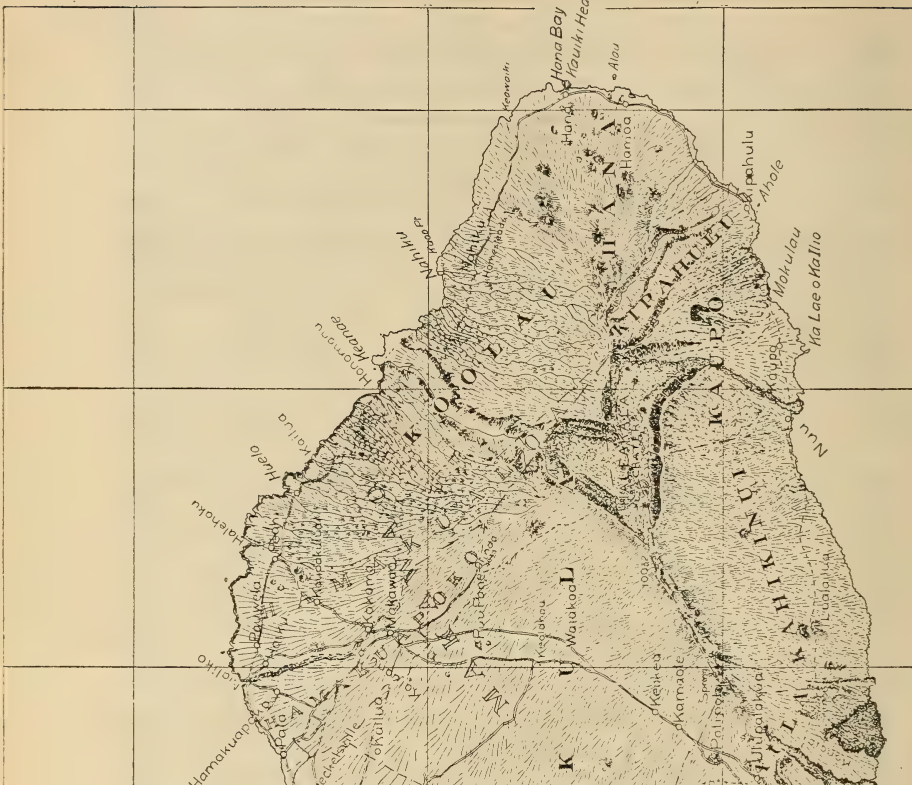

Fig. 3. Map of Maui, Hawaiian Islands, showing the distribution of trachyte (heavier shading) on West Maui superimposed on the older basalts, and the location of the 1750 flow on the southwest flank of Haleakala, entering the sea north of Keoneoio. The only occurrence of nephelite basalt known on Maui is in Kaupo gap, Haleakala, 2 miles north of the settlement Kaupo. (Map reproduced by the permission of C. H. Baldwin.)

ported to the early missionaries. Mr. L. A. Thurston, of Honolulu, has, however, authenticated a tradition to the effect that there was a lava flow from the southwest side of the mountain near sea-level about 1750.[7] The event took place about three generations ago and part of a Hawaiian village was destroyed by the lava.

The 1750 flow, east of Makana, issued from the black, breached cone called Pimoa. The rock is a very fresh aa basalt filled with olivine crystals. The aa streams have covered other fresh flows in the vicinity and have coalesced to form a rounded peninsula (fig. 3). No stone walls were seen covered by the youngest lava[8] as were covered by the Hualalai flow of 1801, but none would be expected in such a barren waste of lava flows unless within a few yards of the shore. The appearance of the lava and of the Pimoa cone from which it came, at an elevation of about 1,100 feet, are in accord with the tradition. This flow probably was the closing activity of the volcano as the cones in the crater of Haleakala must be dated as earlier. The volcano now appears to be extinct in spite of reports from one ranch on the side of the mountain that occasional underground rumblings are heard.

Rows of young cones are found on the sides of Haleakala arranged, in general, along lines radiating from the summit of the mountain. From many of the cones radial flows may be traced. Several rows of ash cones extend toward Hana, on the east side of the mountain, but the tropical jungle prevents an examination of the upper cones. Puu Kauiki, on the shore, is a red lapilli and ash cone traversed by olivine-basalt dikes. Parallel rows of cones extend from White's Hill the highest point of the mountain, toward Ulupalakua on the southwest. Near Ulupalakua they diverge into many lines from which the recent flows in that vicinity have poured into the sea. One of these lines of weakness in the mountain runs through Puu Olai, a red ash and lapilli cone near Makana, and through Molokini, the semi-circular tuff crater[9] be-

[7] Father Ed. Bailey was told in 1900 or thereabouts by a native that when the latter's great grandfather was a boy about 10 years of age a lava flow destroyed their village (Honoualua), running around a house from which a woman and child failed to escape.

[8] W. A. Bryan reports that a stone wall was buried by this flow (Natural History of Hawaii, Honolulu, 1915, p. 147) but this was not found by the writer.

[9] This tuff, of unknown composition, resembles that composing Diamond Head and Punchbowl, but no specimens of hard basalt were present in the collection of material made for the writer by the vessel of the Lighthouse Service.

tween Maui and Kahloolawe. Another line appears to extend in the direction of the summit of Kahoolawe, as if that island had arisen on the line as a volcano subsidiary to Haleakala. Few cones are found on the western side of the mountain, toward West Maui, and fewer cones, except those composed of trachyte, are found on the deeply-dissected West Maui Volcano.

Hawaii.—The Kohala Mountains, forming the oldest volcanic center on Hawaii, also show a number of radial rows of young cones. On the northwest flank of the volcano a row of large cones, from which lava flows have come, points directly toward Haleakala, which is a much younger volcano than Kahala, and suggests that Haleakala may bear the same subsidiary relation to Kohala that Kahoolawe bears to Haleakala.

Mauna Kea has more cones on its flanks than any other volcano in the Hawaiian Islands. The original summit sink, if one existed comparable to Mokuaweoweo on Mauna Loa, was completely buried by the ash eruptions. at the closing stages of activity in pre-historic times.

Mauna Kea lavas are not exposed in deep gulches and therefore only the surficial flows may be studied. From an ascent of the mountain, Daly finds evidence of a basaltic base capped by younger flows of trachyandesite which are partly covered by ash.[10] One of the younger flows has never been noted—a flow at Laupahoehoe which is younger than the wave-cut cliff which bounds Hawaii from Hilo to Waipio valley. The Laupahoehoe basalt issued from fissures near the mouth of the valley by that name and spread out into a small peninsula which projects beyond the sea-cliffs. This is the most recent flow near the base of the mountain.

Hualalai was last in activity with a lava flow in 1801, the flow being observed by one of the earlier mariners, but smoke issued from the mountain as late as 1823 and possibly as late as 1840-41.[11] Instead of a single flow in 1801, as has been previously supposed, two main streams of lava poured from the mountain and several ash cones were formed. An ascent of the mountain in 1915 from McGuire's ranch, together with a review of the Hawaiian traditions concerning the activity at the time, has shown that the eruption took place along one or more radial fissure-lines extending from near the summit of the moun-

[10] Magmatic differentiation in Hawaii, Jour. Geol., vol. 19, p. 299.
[11] J. D. Dana, U. S. Exploring Expedition 1838-42, Geology, p. 215.

tain in a northwest direction toward the sea near Makalawena. The greatest, and probably the first 1801 outbreak, occurred near the summit of the mountain at Kaupulehu, and from it lava streamed to the sea near Kiholo, 11 miles distant, destroying the Paiea fishpond and the Hawaiian villages at the shore. Farther down the mountain three small flows, each a hundred yards in length, are seen emanating from the same line of weakness at elevations of 2,400 to 4,000 feet; and 110 feet below the Kona-Kohala highway the Huehue flow broke out of a little cavern in the older pahoehoe at an elevation of 2,200 feet, flowed over a stone wall and poured down the slope of the mountain. The flow was apparently fed from a number of openings now concealed by the lava, as in the center of the flow, far below the road, there is a blackened cone. The flow entered the sea between Keahole Point and Makalawena. While the Huehue flow and the smaller flows above are pahoehoe, the larger flow on the north is aa.

Mauna Loa is being built up by flows from two major lines of weakness, a west-east line running from Mokuaweoweo in the direction of Olaa and a northeast-southwest line extending toward Kahuka. Flows have alternated on the two sides for a number of years until in May, 1916, and again in September, 1919, flows appeared in Kahuku near the 1907 flow.[12] Many cones are seen along the first line and it will be possible to study them with the new trail up the mountain. On the other side of the mountain cones are not as abundant. One of the larger, Puu o Keokeo, does not represent a separate crater as has been supposed.[13] Along the southwest shore from Kapua to Ka Lae rows of cones are seen following the shore-line. It is possible that these cones owe their origin to the reaction of seawater on the hot lava pouring into the sea, as was apparently the origin of the Nanawale cones in Puna at the end of the principal 1840 flow from Kilauea, and of the cones at the end of the 1868 Mauna Loa flow in Kau.[14] No similar tangential

[12] H. O. Wood: Notes on the 1916 eruption of Mauna Loa, Jour. Geol., vol. 25, pp. 322-336, 467-488, 1917.

[13] A suggestion by S. E. Bishop cited by Hitchcock in Hawaii and its Volcanoes, Honolulu, 1911, p. 148.

[14] Mentioned by W. L. Green, Vestiges of a molten Globe, vol. 2, p. 178, Honolulu, 1887. Also see observations by Rev. T. Coan on the 1885 Mauna Loa flow, cited by W. T. Brigham, Volcanoes of Kilauea and Mauna Loa, Mem. B. P. Bishop Museum, Honolulu, vol. 2, No. 4, p. 74, 1909.

lines of cones were seen farther up on the Mauna Loa mountain side.

The Kilauean pit craters will form another interesting field for investigation when trails are cut through the jungle from the row of pit-craters stretching from Kilauea, Keanakakoi, and Kilauea Iki through Alæ Alæ, Makaopuhi, and Napau to the row of cones in Puna near the 1840 flows. The transition between pit-crater and cone may be found to be a cone like Puu Huluhulu or the Cone Crater on the Kau Desert, with a large and deep pit in the center.

Although Rev. Titus Coan was living in Hilo at the time of the 1840 flow, all the flows of that date were not visited by him. Nor were they all visited by Wilkes, who arrived shortly after the flows ceased moving, if the native traditions are to be believed. These traditions speak of a flow not mapped by Wilkes, between Keiheiahulu and Kehena, in Puna, which crossed the Hilo-Kalapana road near Kalapana. The freshness of this flow favors the tradition that it is 1840 in date.

Pillow lavas have never been observed on the Hawaiian Islands, unless in a flow seen in cross section by Doctor T. A. Jaggar and the writer between Waipio and Waimanu valleys on the shore of Hawaii. The small tongues of pahoehoe lava which are so abundant at Kilauea are very different from true pillows seen elsewhere in the field.[15] Unfortunately the lavas which have run into the sea cannot be examined to determine if pillows have been formed by reaction with sea-water.

Distribution of Rarer Types.

Trachyte.—In the midst of the floods of olivine basalt which have poured from the slopes of Hualalai and of Mauna Loa, on Hawaii, around the north flank of the former, Dr. Cross found in 1902 the first trachyte, so described, noted on the Hawaiian Islands,[16] but Dr. E. S. Dana had already described a rock of unusual character, later shown to be trachyte, from Puu Launiopoko and from Puu Paupau (Mt. Ball) on West Maui.[17] The next

[15] At Porcupine, Ontario, and near Victoria, Vancouver Island. Professor J. V. Lewis, in a paper on the origin of pillow lavas (Bull. Geol. Soc. Amer., vol. 25, pp. 591-654, 1914), classes these tongues of pahoehoe as pillows. The best photographs published of the tongues are by I. Friedlaender, Ueber die Kleinformen der vulkanischen Produkte, Zeit. f. Vulk., Bd. 1, Hft. 1, 2, 4; especially Heft. 4, p. 51, "Zungenformes Ende eines Pahoehoe-Ström."

[16] Jour. Geol., vol. 12, pp. 510-23, 1904.

[17] This Journal, (3), vol. 37, pp. 441-67, 1889.

most salic lava known on the islands is one described by A. B. Lyons from the Waimea side of the Kohala Mountains,[18] Hawaii. Several new occurrences of trachyte were found by the writer on West Maui (fig. 3): on the northeast side of the volcano between Waihee and Kahakuloa gulches; on the north side between Honokahau and Honakahua gulches; and on the south side in the vicinity of Olowalu. One new occurrence was also found on Molokai.

On Hawaii the trachyte described by Dr. Cross from Puu Waawaa and from Puu Anahulu occurs in the former case as a cone of stratified ash, in the latter case as a terrace presenting steep faces on the south and west sides. Puu Waawaa is dissected by many ravines and is much older than the flows from Mauna Hualalai which surround it. The Puu Anahulu terrace, as seen from the south, appears to form a slope more nearly horizontal than that over which the flows from the south have streamed, but as seen from the north the terrace is clearly a portion of the normal slope of Mauna Kea. The terrace has been overrun by a pahoehoe basalt flow which may be seen to overlie the rough surface of the trachyte.

The Puu Anahulu trachyte represents a flow at least 5 miles in length and over 100 feet in thickness at the lower end. The source of the flow is believed to have been one of the visible volcanoes. Moreover, the conclusion is reached from a comparison of features at Puu Anahulu and Puu Waawaa with those of flows from Mauna Loa and of tuff cones on Oahu that no great age can be assigned to the trachyte of either of these occurrences and that the terrace represents a normal slope rather than an uplift or wave-cut bench. A careful search for elevated shorelines around the island of Hawaii from sea-level to an elevation of over 1,500 feet, made by Dr. T. A. Jaggar and the writer, showed sea-worn coral fragments and beach pebbles at various elevations up to 1,325 feet (at the residence of Miss Paris, Kealakakua), but as the Hawaiians carried such material inland long distances for house sites and for religious purposes, no positive proof of recent elevation of over 20 feet (that at Mahukona) anywhere around the island was found.[19]

[18] Idem, (4), vol. 2, pp. 421-9, 1896.

[19] C. E. Dutton (Hawaiian Volcanoes, U. S. Geol. Surv., 4th Ann. Rept., 1882-3, p. 98) speaks of three terraces at Hilea indicating uplift. Examination of similar terraces in several places showed that they have been constructed by lava flows.

No trachyte was noted in the field in the Kohala Mountains. The flows forming the sides of Waipio and Pololu gulches are in part composed of basalt, bluish grey in color with abundant feldspars and very little olivine seen in the hand-specimen. Similar feldspar basalts are characteristic of Wailau volcano, East Molokai.

On Maui the trachyte occurs as flows, cones, and, in one instance, probably as a volcanic neck. In every case observed the trachyte is younger than the main mountain mass and probably appeared when the dissection of the latter was well under way. The major portion of the erosian of the volcano followed the trachyte eruptions. West of Puu Launiopoko an olivine basalt flow may be younger than the trachyte, but the two rocks were not observed in contact.

Puu Paupau, above Lahaina, is a double conical hill, surmounting a spur between two gulches and composed of light-grey, schistose trachyte. The next exposure of trachyte to the southeast is Puu Launiopoko (there is an excellent exposure on the Lahaina-Wailuku highway). Above Puu Launiopoko on a facet at an elevation of 1,400 feet there is a flow of trachyte, evidently derived from a fissure eruption. Puu Kilea, back of Olowalu, and two nameless cones between Puu Kilea and Puu Launiopoko are composed of similar rock. A light-colored rock, apparently trachyte, is seen on the triangular erosional facets between Launiopoko and Ukumehame gulches and trachyte flows occur on the gently sloping plain west of the mouth of Olowalu Gulch. On the west side of Ukumehame Gulch, at the entrance, there is an inaccessible mass of white rock, apparently a volcanic neck of trachyte.[20] This rock may be seen from the Interisland steamers passing Maui.

Trachyte flows cover an area about 3½ miles in width and extend to an elevation of over 1,000 feet between Waihee and Hakahue gulches northwest of Wailuku. The trachyte has a maximum thickness of over 30 feet on the sides of Waiolai and other gulches. Besides the thin flows which cover the region the rock comprises cones, such as Puu Olai. Trachyte flows of an aggregate thickness of over 30 feet cover the facets between Honokahau and Honokahua gulches on the north side of West Maui, a distance of 2½ miles as traversed by the trail around the island.

[20] S. Powers, Intrusive bodies at Kilauea, Zeitschr. Vulk., 3, p. 32, 1916.

Microscopic examination of thin-sections of the grey, banded trachyte from Waiolai gulch, on the northeast side of West Maui, shows bands of chlorite, biotite, apatite, and limonite and occasional large phenocrysts of olivine in a rock composed principally of oligoclase feldspar laths with minor amounts of orthoclase feldspar, some altered olivines, secondary limonite, hematite, and sericite, microlites of unknown composition, and glass. A polished section shows no magnetite.

Trachyte from Puu Paupau shows less alteration. The feldspar, which composes almost the entire rock, is an albite-oligoclase and the groundmass contains orthoclase feldspar, olivine, apatite, magnetite or ilmenite (identified in polished section), limonite, biotite, and glass.

A thin-section of the trachyte from Waihee valley shows an alkali feldspar similar to the others. The subordinate constituents are glass, magnetite or ilmenite (quite abundant as seen in polished section), ægirine augite in greenish yellow laths, and biotite and apatite.

From Molokai a schistose, grey trachyte was collected by the writer. The source of the specimen is believed to have been stream gravel near the mouth of Wailau gulch and the rock is judged to occur in place somewhere on the rim of the precipitous and very large gulch.

The rock is composed almost entirely of phenocrysts of oligoclase[21] feldspar with subsidiary amounts of brown hornblende (now almost wholly changed to granular aggregates of ore, brown hornblende, and to a nearly colorless mineral, probably an amphibole) and augite. The groundmass is finely crystalline and consists of oligoclase, rarely orthoclase, abundant small brown hornblende crystals, augite and magnetite. There is a nearly colorless prismoid material that is probably secondary amphibole derived from the breaking-up of the primary brown hornblende. This trachyte differs from those on Maui and Hawaii because of the absence of a plate-like arrangement of the feldspar.

It has been supposed by Daly[22] that the origin of the trachyte on the Hawaiian Islands is connected with the absorption of limestone by the basaltic magma and subsequent differentiation. While only a small amount of

[21] The writer is indebted to Professor Charles H. Warren, of the Massachusetts Institute of Technology, for the description of this rock.

[22] Magmatic differentiation in the Hawaiian Islands, Jour. Geol., vol. 19, p. 314, 1911.

limestone may be necessary to cause such differentiation in a large amount of basalt, there are grave difficulties connected with the application of the theory of limestone control to islands which, so far as known, are built almost wholly of basalt. It is true that limestone occurs as a thin veneer on the margins of Oahu; that a very small amount of elevated limestone occurs around Kauai and Niihau, and that a single elevated reef has been traced a short distance on southwestern Molokai. Moderately wide coral reefs surround portions of Niihau, Kauai, and Oahu, but the reefs around the other islands are of very limited extent. The tuff cones Ulupau Koko Crater, Makalapu, Punchbowl, and Diamond Head, on Oahu, contain fragments of coral, but only from the immediately underlying reef, and no cones on Molokai, Maui, Hawaii, or Kauai are known to contain such fragments. The greatest difficulty with the theory is the fact that no limestone has been found interstratified with the basalt flows in any canyon on the Islands, although erosion has exposed many sections 2,000 to 3,000 feet below the former summit crater.

In order to have limestone available for fluxing a basaltic magma, it must occur at a depth of several hundred feet, for lava is injected as dikes and through fissures to the surface with great rapidity. Limestone at the required depth would apparently have to represent a deep-sea deposit of considerable thickness rather than a coral-reef deposit unless this portion of the Pacific gradually subsided as the volcanoes were built up.[23] That such deep-sea deposits exist in the lower portions of the huge volcanic piles is subject to discussion.

Nephelite basalt.—Rocks containing nephelite, usually as a very subordinate constituent, have been identified on

[23] H. A. Pilsbry has accounted for the present distribution of the land shells of the family *Achatinellidae* over the Hawaiian Islands by submergence during the Late Pliocene or Pleistocene, progressively separating the various islands. He maintains that the differentiation of the modern families of land shells took place largely in the Mesozoic and that "the hypothesis that the Hawaiian volcanoes rise from a pre-existing mid-Pacific ridge, now lost by subsidence, gives room in time and space for the derivation of the peculiar fauna" (p. xlvii) (Manual of Conchology, Second Series, vol. 22, pp. xlii-xlvii, 1912-4; also quotation and map by W. A. Bryan, Natural History of Hawaii, Honolulu, 1915, pp. 121, 291). P. Marshall, B. Koto, and others, however, have shown that andesites are the type of volcanic rock associated with continents, and Marshall maps the northern limit of the former continent of Oceania on this basis as passing not far north of Fiji (Oceania, Handbuch der regionalen Geologie, Heidelberg, 1912, Bd. 7, Heft. 5, fig. 3, p. 5).

only four islands of the group, Kauai, Oahu, Molokai, and Maui, but their presence is suspected on and near Niihau and on Molokini, a small cone between East Maui and Kahoolawe. With very few known exceptions they are confined to local centers of eruption and all but six of the local centers are tuff cones. In each instance of a local center the eruption has been long after the main volcano became quiescent. There is also a striking connection between the tuff cones and the shore lines at the time of eruption. All the cones were erupted near or through shallow water. More striking yet is the fact that nephelite has been found in rocks from all but two of the tuff cones at sea level in the Hawaiian Islands which have been examined petrographically. The two exceptions are Koko Head and Koko Crater, but additional collections may show nephelite-bearing basalt in these cones.

A list of occurrences of nephelite-bearing rocks in local centers of eruption is given below. Most of the tuff cones of which specimens were not available to Doctor Cross are difficult of access and therefore few additions to his identifications are possible.

Kauai: Crater Hill (Kilauea Crater), tuff cone, melilite-nephelite basalt. (Cross, Powers)

West Oahu: Laeloa Craters (named by C. H. Hitchcock. 1900)
- Puu Palailai, lava cone, nephelite basalt? (Powers)
- Puu o Kopolei, lava cone, nephelite basanite. (Cross)
- Puu Kapuai, scoria and lava cone, nephelite basalt. (Cross)
- Puu Makakilo, scoria and lava cone, nephelite basalt. (Powers)

East Oahu:
- Diamond Head, tuff cone, nephelite basanite. (Cross)
- Punchbowl, tuff cone, nephelie basalt. (Cross)
- Salt Lake Craters (2) tuff cones, nephelite basalt. (Cross, Powers)
- Mauumae Cone, tuff and scoria (northwest side), melilite-nephelite basalt. (Powers)
- Rocky Hill, lava cone (Moilili Quarry and Honolulu black ash), melilite-nephelite basalt. (Cross)
- Ulupau Crater, tuff cone, melilite-nephelite basalt. (Powers)
- Puu Hawaii Loa, tuff cone, melilite-nephelite basalt. (Powers)
- Koko Head, tuff cone, olivine basalt. (Powers)
- Koko Crater, tuff cone, olivine basalt. (Powers)

The composition of the tuff in the following cones is unknown:

Near Niihau: Kaula and Lehua, tuff cones.
Niihau: Kawaihoa, tuff cone.
West Oahu: Puu Kuua, scoria and lava cone, one of the Laeloa Craters.
East Oahu: Makalapu Crater, interstratified tuff and coral limestone.
Moku Maui, Mokulua, and Rabbit Islands, dissected tuff cones.
East Maui-Kahoolawe:
Molokini Island, tuff cone.

Known occurrences of nephelite-bearing rocks other than those listed above are given by Doctor Cross as follows: The first three localities are near together and the rocks probably came from one or more flows of a single young and undescribed crater. The fourth locality, a dike, may have been one of the feeders of the tuff cones.

Oahu: Kalili Valley, north edge, nephelite-melilite basalt.
Gulick Stream, west of Kamehameha School, nephelite-melilite basalt.
Half a mile east of Bishop Museum, nephelite-melilite basalt.
Dike in the Pali, east side, nephelite basalt.
West Molokai: Kalæ (north of Kaunakakei on the road to Kalaupapa), nephelite basinite. (Möhle)[24]
West Maui: Waihee Valley (?)
Near Lahaina (Möhle)
East Maui: Near Vierra's Ranch, Kaupo Gap.

All the proved occurrences of nephelite rocks, with possibly four to six exceptions, fall into natural groups: a solitary tuff cone on the eastern shore of Kauai; the five Laeloa Craters of West Oahu, roughly aligned on the dissected south flank of the old volcano; six to nine craters in the formerly submerged area of East Oahu near Honolulu, and the two or more cones in the faulted and deeply dissected region of East Oahu 12 miles northeast of Honolulu. The age of the cones of East Oahu is Pleistocene, as the age of the coral reefs through which they broke is either Pliocene or Pleistocene. The tuff cones of the other islands appear to have suffered the same amount of erosion as those of East Oahu and they

[24] Neues Jahrb., Beilag. Band 15, pp. 67-71, 1902.

were possibly connected with the same volcanic activity. Puu Palailai, the lowest of the Laeloa craters of West Oahu, is at a slightly higher elevation than any coral limestone in the vicinity and no contact of the lava with the limestone is exposed. Therefore the age of these craters is undetermined.

Olivine nodules.—Along the line of a new ditch from the western portion of the Lihue district to Koloa, Kauai, about one mile northeast of Puu Kahoaea, a basalt filled with masses of olivine has been excavated. The olivine nodules vary in size, the largest being 6 to 8 inches in diameter. They are rounded or subangular in outline and of a uniform composition throughout. In most cases they are smooth and rounded on the outside and they can be broken from the matrix. Vesicles frequently occur clustered around the inclusions, but they are not found elsewhere in the rock. The matrix is a fine-grained picritic basalt or limburgite of dark grey color. Olivine phenocrysts are present and the groundmass is composed of augite, olivine, iron ores, and abundant glass with a very small amount of plagioclase feldspar. The inclusions are a dunite composed principally of olivine with a very subordinate amount of diallage and very rare specks of iron oxide.

The striking features of the nodules are large size and abundance. They compose about half the volume of the rock. They are usually very fresh and the individual olivine crystals are frequently a quarter of an inch in length.

On account of the deep weathering which the region has undergone, it is impossible to determine whether the nodule-bearing rock is part of a dike or a flow, but it is probably a flow, since the nodule-bearing rocks have a rather wide lateral distribution. The inclusions are found northward to the Peohia stream. Smaller nodules occur in the basalts near both ends of the new tunnel between the Komooloa and Palikea streams and a few are found in the Waiahi and Iliiliula stream beds. Similar nodules occur in the Hanapepe River, especially in the main stream above the falls[25] and a few are found in the flows on the east side of Nawiliwili Bay. Olivine bombs have been found on Hualalai and on Mauna Kea,[26] and olivine nodules have been reported from Oahu. A

[25] W. Cross, op. cit., p. 13; collected by the writer above the falls.
[26] R. A. Daly, Jour. Geol., vol. 19, pp. 301-3, 1911.

rounded olivine nodule one inch by half an inch in diameter was found at Kapulena, northeastern Hawaii, near Waipio Gulch in the lavas from Mauna Kea.

The origin of the xenoliths raises a number of questions which have been discussed for many years,[27] but which cannot be treated here. It is difficult to conceive of the formation of the nodules from pre-existing rocks as no rock masses of similar composition are known in the Hawaiian Islands. Therefore it appears that they are cognate xenoliths formed in the early crystallization of the magma in depth under such conditions that olivine and diallage crystals of comparatively large size and uniform grain were formed.

Recent investigations of artificial melts and of field evidence concerning crystallization and gravitative differentiation have shown the early formation and frequent segregation and settling of olivine and the later resorption of olivine in the normal course of crystallization.[28] It has been held by Bowen that the formation of monomineralic rocks is possible only in the earliest stages of slow crystallization and that in this process "there must be a considerable period during which olivine is separating alone and also a considerable period during which pyroxene and plagioclase, although separating together for the most part, form only a small fraction of the total mass (liquid and crystal)."[29] If sudden eruption took place, segregations of olivine in the magma at this period of crystallization would be carried to the surface in the same manner in which inclusions are carried upward in dikes[30] and the xenoliths of uniform composition and rounded to subangular form would be frozen in a rock of quite different composition. Resorption would be limited in amount owing to the lowering of the tempera-

[27] A bibliography of papers on the origin of olivine nodules is given by F. Zirkel, Über Urausscheidungen in Rheinischen Basalten, Abh. math.-phys. Kl. k. sächischen Ges. Wiss., 28, no. 3, Leipzig, 1903. Also see E. O. Hovey, Trans. Amer. Acad. Nat. Hist., vol. 13, 1894; C. H. Richardson, Science, Oct. 22, 1897; and H. Rosenbusch, Mikroskopische Physiographie, vol. 2, p. 1195.

[28] Bowen and Anderson, The binary system MgO-Si_2, this Journal, vol. 37, 1914; O. Anderson, The system anorthite-forsterite-silica, ibid., vol. 39, 1915; N. L. Bowen, The ternary system: diopside-forsterite-silica, ibid., vol. 38, 1914; N. L. Bowen, Crystallization-differentiation in silicate liquids, ibid., vol. 39, 1915; Powers and Lane, Magmatic differentiation in effusive rocks, Trans. Amer. Inst. Min. Eng., vol. 54, pp. 442-57, 1916.

[29] The later evolution of the igneous rocks, Jour. Geol., vol. 23, Supplement, p. 79, 1915.

[30] S. Powers: The origin of the inclusions in dikes, Jour. Geol., vol. 23, pp. 1-15, 166-182, 1915.

ture and most of the xenoliths should therefore be sharply separated from the matrix.

Gabbro intrusives.—Intrusive gabbro has been described by Lindgren[31] from the Wailau Canyon on Molokai, by Cross[32] from the Waimea Canyon on Kauai, and by Daly [33] from Uwekahuna, at Kilauea, Hawaii. In the first locality a tropical jungle conceals the parent body, at the second locality the rock (probably a dike) has not been seen in place, but at Uwekahuna the intrusive is seen in cross-section with upper and lower contacts within reach in a few places.[34] An inclusion of gabbro in basalt was found by the writer in the Hanalei Valley, Kauai. Very ample petrographic descriptions of the Wailau and of the Kauai gabbros under the name kauaiite (Iddings, Cross), and of the typical Uwekahuna gabbro have been published.

The Uwekahuna intrusive occurs in the walls of the Kilauean sink north of the crater Halamaumau and the base of the olivine gabbro is 40 feet above the floor of the crater. The intrusive is about 650 feet long and 68 feet in maximum height, but it may be composed of two masses. Chilled upper and lower contacts with a uniform-grained rock between, prove the intrusive character of the mass and suggest rapid cooling. Olivine is lacking at the upper contact in the chilled phase which is one foot thick, but in the second foot the olivine begins to appear abundantly as tiny phenocrysts and within three feet the rock assumes its normal grain. Gas tubes are very abundant at the upper contact. Olivine phenocrysts 1/16 inch in diameter are present in the chilled base of the intrusive, while they are ¾ inch in diameter in the normal rock.

Thin sections of the upper contact show it to be remarkably sharp considering the porous nature of the overlying pahoehoe. The latter is largely glass, with magnetite, augite, and tiny feldspar laths. Alteration of the magnetite and glass has produced limonite and hematite, staining the feldspar laths and giving the rock a dull reddish color. Frozen to the pahoehoe is a vesicular gabbro consisting principally of glass with specks of augite

[31] U. S. Geol. Surv., Water Supply Paper 77, p. 14, 1903.

[32] Op. cit., 1915, p. 14.

[33] Jour. Geol., vol. 19, pp. 291-4, 1911; Proc. Amer. Acad. Arts & Sci., vol. 47, pp. 115-6, 1911.

[34] S. Powers. Intrusive bodies at Kilauea, Zeitschr. Vulk., Bd. 3, pp. 28-33, figs. 1-5, 1915.

and magnetite, minute laths of feldspar, and small augite phenocrysts. One and one half inches below the contact the gabbro is a fine-grained, glassy rock showing feldspar, augite, and magnetite, but no olivine in thin section. Some of the magnetite is in rods with spicular outgrowths. The glass occurs in streaks and bands of dark color between bands filled with feldspar, augite and interstitial, translucent glass. In the glassy areas small augite phenocrysts occur, but they are filled with and surrounded by magnetite grains. Seven and one-half inches below the contact the gabbro is a uniformly medium-grained rock with a little glass in patches. The component minerals are feldspar, augite, and magnetite. No olivine is present.

A laccolithic origin has been ascribed to the Uwekahuna intrusive by Professor Daly in view of what he took to be doming in the overlying pahoehoe beds. This appearance may be induced by erosion and it is not seen when the body is viewed from its own level.

A comparison of a lava-tube at Haena, Kauai, with the above intrusion has led the writer to suggest[35] that the latter may be a filling of a lava-tube or of two tubes side by side. The Haena tube is at least 240 feet long, 200 feet wide, and 25 feet in height. The floor is covered by a deposit of sand and débris of unknown thickness, washed in from a talus cone at the entrance. Both the Haena tube and the Uwekahuna intrusive have a roof of finely-vesiculated pahoehoe of great rigidity.

In the Hanalei valley, Kauai, near the falls, the writer found an inclusion of gabbro in basalt. The gabbro is a coarse-grained rock with large feldspars and less conspicuous augites. Under the microscope the minerals in order of abundance are seen to be feldspar (partly oligoclase with a secondary generation which may be orthoclase), purple augite, limonite, magnetite, apatite, and biotite. The iron ores occur as skeletal crystals resembling Chinese characters, as in the Wailau and Kauai gabbros. No olivine was observed. The rock is free from the vesicles so abundant in the greater part of the Kauai gabbro and is finer grained and contains less augite than the Wailau gabbro.

Age Relations.

A certain sequence of events can be traced in the life-history of volcanoes, and especially in basaltic volcanoes,

[35] Loc. cit.

from the first outbreak to the close of activity, which is frequently a lava flow after the mountain has been covered by ash cones and perhaps buried under a layer of ash. It is with the events toward the close of the life of the volcano that this paper has dealt. The volcano increases in height by extravasation from a summit crater until the lava finds an easier path to the surface by fissuring the mountain, thus pouring out flows and building cones on the sides while a sink is gradually formed at the summit by successive inbreaks when the lava is withdrawn down the feeding tube at the close of an eruption. Mauna Loa and Kilauea have both been active through historic time in building up the floor of the summit sink as well as in pouring out flows through fissures down the sides of the mountain. Increasing viscosity of the magma may lead to the formation of domes of the Pélée type, as in the historic record of Kilauea, and to lessened activity with a longer period between great eruptions. Finally, the gaseous lava which reaches the summit sink may begin the formation of cones over the latter and at last bury it. Mauna Kea and Hualalai may have possessed summit sinks now buried, while the process of burial was not completed at Haleakala.

It has been seen that the cones on the sides of the mountain have a tendency to a definite arrangment along radial and occasionally along tangential lines. While one group of these cones is formed near the close of the activity of the main volcano, as those of Hualalai, Mauna Kea, and Haleakala, another group may be formed after the close of the main activity and after the volcano has been actively eroded for a long period of time, as on Niihau, Kauai, East Oahu, East Molokai, and West Maui. Especially apparent in the case of the two westernmost islands is the long interval between the close of the principal activity and the revival of activity in cone-building. Similarly, revival of activity may occur on Haleakala, Hualalai, or Mauna Kea after these mountains have been deeply dissected. That there may still be activity along the line of the extinct volcanoes is indicated by the fact that fish were reported to have died in large numbers off Molokai in 1859; that in 1868 and 1877, concomitantly with activity on Hawaii, the fish in the brackish water fish-pond Nomilo, an old crater on the shore of Kauai, were all killed; and by the fact that in 1868 one of the earthquake epicenters appears to have been south of Kauai.

Toward the close of the evolution of the volcanic edifice another change appears to take place occasionally—the appearance of the more unusual rock types. Trachyandesite, in contrast to basalt, is found on the summits of Haleakala and Mauna Kea; trachyte forms a veneer over portions of West Maui and Mauna Kea (where it has been overrun by Hualalai and Mauna Loa flows); nephelite-bearing rocks appear in the young tuff cones and flows on East and West Oahu, in a young crater on Kauai, and probably in the youngest tuff cones on other of the older islands. These rarer types are almost completely lacking, so far as known, in the older rocks of any of the main volcanoes. The occurrences of these rarer types, which must be differentiates of basalt, seem therefore to indicate that such differentiation is characteristic of the closing stages of the Hawaiian vulcanism and that this differentiation proceeds separately in separate volcanoes or possibly contemporaneously in pairs of connected volcanoes. Each volcano has arisen at an intersection in a fracture system in the earth's crust, has been fed from the same primal magma, and has finally lost connection with this source. When this takes place differentiation may proceed in the magma chambers of the larger volcanoes and the extreme products of Hawaiian vulcanism, nephelite basalt and trachyte, may appear either at the close of the main vulcanism or in a later phase after extensive erosion.

ART. XX.—*On Ticholeptus Rusticus and the Genera of Oreodontidæ;* by F. B. LOOMIS.

In 1858 Leidy established the genus Merycochœrus, with *M. proprius* as the type species for Miocene oreodonts. Since that time the genus has been the one to which every Miocene oreodont with inadequate data has been referred, until the number of referred species became over a dozen. It is not entirely unnatural to do this; for the dentition of oreodonts remains strikingly uniform, while the shape of the skull and the character of the limbs change remarkably. By 1901 it had become obvious that more than one type of animal was included in the genus; and Douglass, using *M. superbus* as the type, gathered together a group of forms characterized by having heavy, elongated skulls, with long nasals, wide heavy zygomatic arches, a long heavy body and short stocky limbs, and established the genus *Promerycochœrus* with a half dozen species to start with, to which have since been added as many more. Very shortly after that Matthew published a description of the skull and most of the skeleton of *Merycochœrus proprius,* showing this to be a form with shortened nasals, a wide skull, and short limbs. This then established the character of the forms which could be referred to this genus and only one other was left in the group, namely *M. rusticus.*

It was the good fortune of the Amherst Expedition of 1919 to find in the Pawnee Creek Beds of N. E. Colorado a very perfect skull of *M. rusticus* together with considerable quantities of skeletal material. These beds carry only this one species of oreodont so there is very little difficulty in using all the skeletal material, though there was associated with the skull considerable of the skeleton, making the study of numerous other finds very easy. A glance at the complete skull shows that it is not to be associated with *M. proprius* genericly; but rather that it is associated with forms described by Douglass under the names *Ticholeptus brachemelis* and *T. breviceps,* though at the same time specifically different.

The type species of this genus is *Ticholeptus zygomaticus* Cope, which was figured by Scott in 1894 and by him referred to the genus *Merychyus.* The specimen lacks the nasal region and the feet, both parts much to be desired in determining the position of an oreodont. This skull of Cope's is less like the one I have than are the two of Douglass's descriptions, but the four (and perhaps *T. bannockensis*) make a very uniform group completely separated from the other oreodonts by having hypsodont dentition, medium length limbs, skulls with light zygomatic arches, and antorbital fenestra of considerable size.

As oreodonts are classified with reference to the whole skeleton perhaps more than any other great group it is essential that as rapidly as possible we should have more figures of the whole skull or better of the whole skeleton. This material is generally abundant in the various museums and it is desirable that for every species a complete skeleton should be described. The following is an outline of all that I can get in regard to *Ticholeptus rusticus*.

Ticholeptus rusticus Leidy.

Merycochœrus rusticus Leidy, 1870, Proc. Acad. Nat. Sci., Philad., p. 109.

Merycochœrus rusticus Leidy, 1873, Rep. U. S. Geol. Surv. Territories, p. 199, fig. 1-5, Pl. 17.

Merycochœrus rusticus Matthew, 1901, Mem. Amer. Museum Nat. Hist., vol. 1, p. 412 and figs.

In this species the skull is lightly built throughout, and moderately elongate, more so than in either *T. brachymelis* or *T. breviceps*. The orbit is set well back, its posterior margin being a little behind the back of the last molar, while in *T. brachymelis* it is over the back of this tooth, and in *T. breviceps* it is still further forward. The whole brain case is longer in this species than the others mentioned. The nasal bones are considerably shortened, ending just over premolar 3, while those of *T. brachymelis* and *T. breviceps* end over premolar 1. In all these this is an unusually short nasal, but not of the character of *M. proprius* so that it does not suggest the development of a proboscis as in that genus, but I would take it rather as indicating a snout more like that of modern pigs. Correlated with the shortening of the nasals is the position of the infraorbital foramen which in this species is just over the contact of premolar 4 and molar 1, while in the other two species it is further forward by the width of the fourth premolar. There is a large prelacrymal fenester situated rather far forward on account of the extension of the lacrymal bone on the front of the orbit. The zygomatic arch is decidedly light more so than in any of the closely related forms, and has no tendency to thicken along the rear margin, but continues as a thin plate into the lambdoidal crest. The sagittal crest is also light and low.

The tympanic bullæ are small and not inflated. The auditory meatus is inclosed in a bony tube of moderate length and opens obliquely upward, but not nearly as high up as in either Merycochœrus or Promerycochœrus. The mastoid plate is but moderately expanded. The premaxillæ are small and fused in the median line.

The dentition is not very distinctive, the teeth being

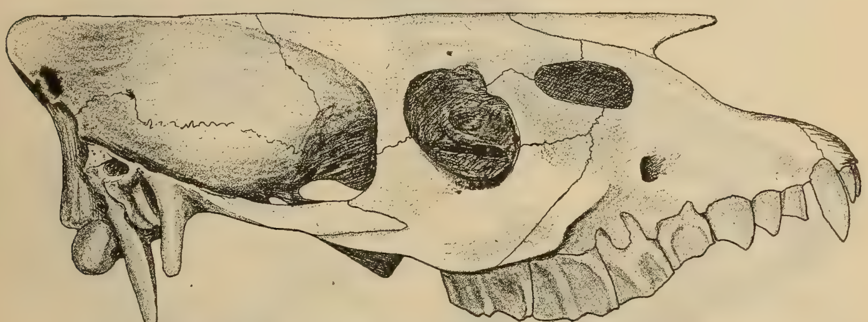

FIG. 1. Skull of *Ticholeptus rusticus* from the side, 2/5 nat. size.

moderately hypsodont, the molars increasing in size from front to back. The premolars are crowded so that in the upper jaw the first three stand obliquely in the maxilla bone. The canines are small and the only gap in the dental series of either jaw is the small interval between the canine and first premolar.

Most of the characters of the skeleton appear in the restoration, for which I had the skull, pelvis and scattered vertebræ and most of the fore limb as one associated specimen. The other parts are drawn from some twenty other finds two of which represented considerable portions of the skeleton associated. There was no complete back bone but vertebræ from every portion of it including the sacrum. The upper part of the femur was preserved in none of my material and is restored. Otherwise all the bones are drawn life size from one or another specimen and the whole photographed down. The pelvis is the only portion in which I feel any doubt but it was associated with the skull. To me it seems too long, especially the ilium but the animal is slenderly built. Without going into details, the features I would call attention to are that the feet are of the medium type, with metapodials comparable with those of Oreodon; the phalanges are short and stocky, especially the unguals, which are flattened from top to bottom in strong contrast to the same bones in Merychyus; the radius is of moderate length and has a considerable curvature; the tibia is rather stocky, and both radius and ulna and the tibia and fibula are entirely separate.

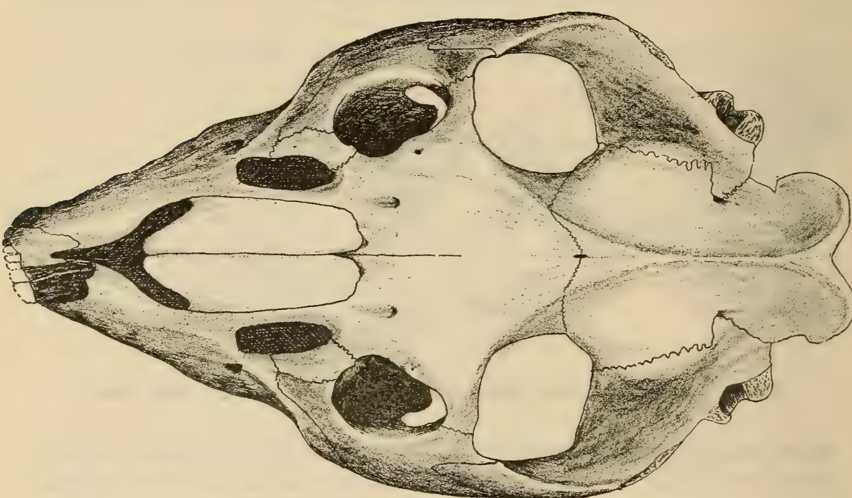

Fig. 2. Skull of *Ticholeptus rusticus* from above; 2/5 nat. size.

The following measurements will indicate the size of the animal, but it is to be remembered that there is considerable range in the figures for any one part of the skeleton, for we find both male and female, and younger and older individuals. I have taken for measurement those of the larger size, though there is less then 10% variation between the largest individuals and the smaller ones.

	mm.
Skull, length from incisors to occipital condyles	254
length of dental series	138
length of premolars	53
length of molar series	81

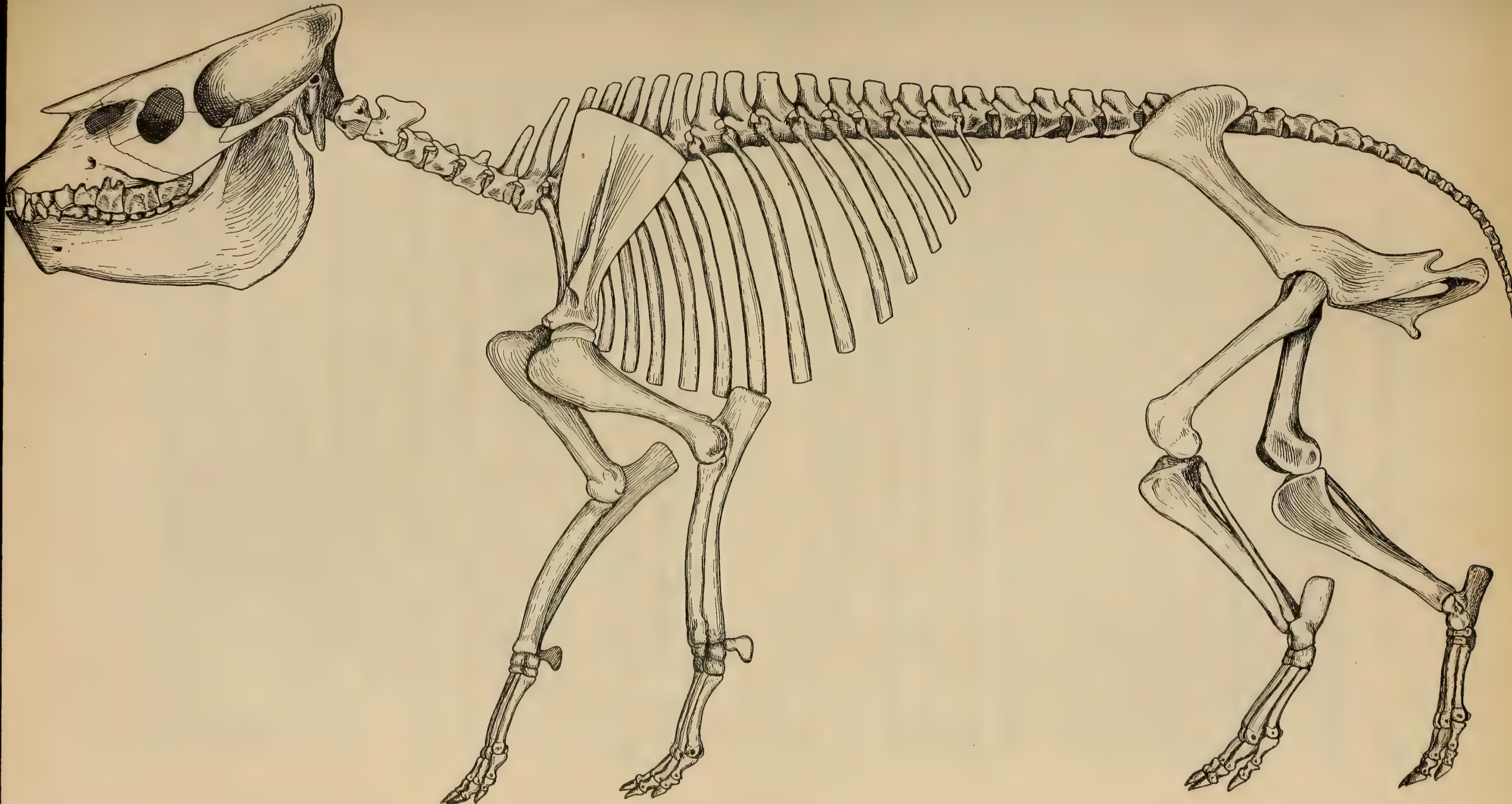

Fig. 3. Skeleton of *Ticholeptus rusticus;* 1/5 nat. size.

Lower jaw, length of dental series	132
length of premolars	48
length of molar series	74
Fourth cervical vertebra, length	22
Fourth dorsal-vertebra, length	24
Second lumbar vertebra, length	30
Humerus, length	153
Radius, length	124
Metacarpal III, length	63
Tibia, length	151
Metatarsal III, length	64

In order to place this skull it was necessary to make a comparative study of most of the genera of this family and as no such comparisons have been made for a long time, especially since the knowledge of many of the best known forms, I should like to offer the following notes and suggestions for the distinctions of various of the genera and for the relationships of different members of the family. In the case of many species which are founded on fragmentary jaws especially it is not possible to place them definitely.

Oreodontinæ.

Selendont artiodactyls, with the dentition typically $\frac{3}{3}$, $\frac{1}{1}$, $\frac{4}{4}$, $\frac{3}{3}$ and the teeth in closed series, the lower canine incisoform and the first premolar functioning as a canine; the feet with four functional toes.

A. Toes clawed, external crescents of molars strongly concave, teeth brachydont, orbit open behind—Agriochœridæ.
  I—Upper premolar 4 not molariform, protoconule present—Protagriochœrus.
  II—Upper premolar 4 molariform, protoconule absent—Agriochœrus.

B. Toes hoofed, external crescents of molars little concave, premolar 4 never molariform—Oreodontidæ.
  I—orbit open behind, incisors $\frac{2}{3}$—Protoreodon.
  incisors lacking in upper jaw—Hyomeryx.
  II—Orbit closed behind;
    1—limbs of moderate length;
      a—digit 1 in manus present as vestige, bulla small —Oreodon.
      b—(digit 1 unknown) bulla large—Eucrotaphus.
      c—digit 1 lacking, bulla large, teeth brachydont—Eporeodon.

* teeth moderately hypsodont—Mesoroedon.
** teeth strongly hypsodont, antorbital fenester—Ticholeptus.
*** teeth strongly hypsodont, no antorbital fenester, but groove on outside of premolars—Metoreodon.

2—limbs short and stocky.
a—skull elongate and heavy, teeth brachodont—Promerycochœrus.
b—skull short, nasals shortened, teeth hypsodont—Merychochœrus.
c—skull short, nasals very short, teeth hypsodont—Pronomotherium.

3—limbs long and slender, small antorbital fenester—Merychyus.

4—Limbs moderate length, both frontal and antorbital fenestra;
a—frontal fenestra small—Phenacocœlus.
b—frontal and antorbital fenestra confluent—Leptauchenia.
c—as above, but incisors $\frac{0}{2}$—Pithecistes.
d—as above but incisors $\frac{0}{1}$—Cyclopidius.

From their origin in the Upper Eocene the Oreodontiæ have stood out clearly from among the other selenodont artiodactyls, and though they survived to the latter part of the Pliocene were less adaptive than other artiodactyls, at the same time retaining through their history many of the primitive artiodactyl characters. The Uinta forms show that the group came off from that division of artiodactyls which retained the anterior intermediate cusp (protoconule), but to just which one of the later groups it is most nearly related is not and can not be determined definitely until more complete material from the Eocene is available. The group is peculiar in that its history is purely American, none of the forms participating in any of the migrations by which American types found their way to other continents.

The Uinta genera *Protoreodon* and *Protagriochœrus* are very close to each other and would hardly be separated were it not that some of the species of that period clearly are more closely related to the Oligocene generus Oreodon, others to Agriochœrus. These genera then represent the beginning of the divergence of the two closely related families. Both genera have the anterior intermediate cusp on the upper molars, both have the orbit open behind, in both the premolars are more crowded than in Agriochœrus and less crowded than in Oreodon. Protoreodon has the more closely set premolars and the outer crescents of the molars less concave, and the unguals are neither laterally compressed as for claws, nor broadly depressed as in some of the later oreodonts. In Protagriochœrus the teeth are less closely set, the molars have the crescents more concave, and the unguals are unknown. Hyomeryx represents a side line in which there is a tendency to lose the incisors of the upper set.

In the Oligocene, Agriochœrus is clearly set off as an independently developing family, by the feet developing claws, by a wide gap behind the canine before the premolars begin, by the fourth premolar above becoming molariform, and by the great concavity of the outer crescents of the upper molars. The genus is abundant and continues clear though the Oligocene running into a dozen larger and smaller species. Oreodon is a very abundant genus though with rather few species, *O. culbersoni* and *O. gracilis* being the most abundant. The manus retains digit 1 as a vestigial toe, certainly in *O. culbersoni* and *O. gracilis,* and this is the basis for the separation of Oreodon and Eporeodon. Two types of skulls very like each other are found but in *O. culbertsoni* the bulla is small; while the other form, otherwise very like this, has a large and inflated bulla. This inflated bulla is the basis of the genus Eucrotaphus with *E. jacksoni* as the type. Whether this is sufficient basis for a genus is doubtful but I should let it stand for the present until a study of the skeleton of *Eucrotaphus jacksoni* is made. That may show other characters justifying the genus and there must be material for the study though I have not found it. Whether *E. jacksoni* had the first digit of the manus retained or not is not known. In the development of the bulla it is more like Eporeodon than is Oreodon. These two genera as known today run through the Lower and Upper Oligocene. From the dwarf fauna found at Pipe Stone Springs, Montana, Douglass described two other genera of Lower Oligocene oreodonts, Limnenetes based on a skull which shows the orbit open behind; and so far as known this may well represent Protoreodon continuing on into the Oligocene: and Bathygenus based on a fragment of a lower jaw. This latter genus needs much more complete material in order to establish its independence and position. In the

Upper Oligocene the oreodonts lack the first digit of the manus and are termed Eporeodon which otherwise resembles especially Eucrotaphus having a large bulla. It still retains the brachydont dentition, though the forms have increased in size and it is to this genus that all the John Day forms are assigned.

The Lower Miocene produced a wealth of oreodonts, both as to numbers and as to variety of adaptations. The least modified genus is Mesoreodon which is distinguished from Eporeodon by the teeth having begun to show an increase in height, moderate hypsodonty and medium type of limbs being the distinguishing features of this genus. I can find no characters to distinguish the genus Merycoides (Douglass) from Mesoreodon, the dentition being perhaps less hypsodont, but however, already showing a beginning of the elongation of the teeth. The genus Mesoreodon then is typically a Lower Miocene one, only one species, *M. longiceps,* being found in the Middle Miocene, and this species might equally well be placed in the genus Ticholeptus for it has a small antorbital fenester, and seems to represent the transition from Mesoreodon to Ticholeptus. The line of less specialized oreodonts is continued into the Middle Miocene by the genus Ticholeptus represented by at least four species. This genus is distinguished by the increased hypsodonty of the molar teeth and by the large fenester in front of the orbit. It may turn out that the type species, *T. zygomaticus,* should be placed among the species of Merychyus as it has a slender narrow skull, but the point can not be settled until the feet are found. At any rate there is a group of four or five Middle Miocene oreodonts with the medium type of feet, medium type of elongation of the teeth and large fenestra in front of the orbits and this term is needed to designate a very distinct stage in the evolution of the group.

The genus Metoreodon so far as is known, that is the skull and jaws, seems also to belong to this group and extends the line into the Pliocene, but it is not a direct descendant of Ticholeptus for it has no antorbital fenester. For the same reason and because it is of more massive build I am confident it was not derived from Merychyus. It has the most advanced dentition of the oreodonts being strongly hypsodont and is distinct in that the premolars have an infolding of the enamel on the external side. To me the genus seems to be derived from Mesoreodon through some as yet unknown intermediate types. Metoreodon is the last survivor of the great family and continued until the middle of the Pliocene at least.

Merycochœrus, originally described by Leidy and based on jaws, has been the ''catch all'' for Miocene oreodonts. In 1901 Douglass separated Promerycochœrus and Pronomotherium from the mass of species described under this generic name. Then Matthew described in detail the type species *M. proprius* showing it to be a peculiar type with short limbs and a shortened wide skull, in which the nasals were very much reduced and the whole snout modified apparently by the development of a proboscis. So far I have seen no other species which could be associated with this one in this genus. Pronomotherium is the logical descendant of Merycochœrus with the snout still more modified and the nasals so far reduced and moved backward as to be actually behind the front of the orbits. The tremendously deepened lower jaw and hypsodont teeth make this type entirely distinct, and with it, this aberrant line died out at the end of the Miocene.

Another aberrant group which came off from Eporoedon and which was long associated with Merycochœrus but which probably had less in common with Merycochœrus than with other genera is Promerycochœrus, large animals with very short limbs, a heavy elongated body and a very heavy long skull, on which the zygomatic arches are especially wide and thickened. Of this fully described and illustrated genus no less than a dozen species are known ranging from the upper part of the Upper Oligocene through the Lower Miocene. One form, *P. montanus,* has indeed been described from the Middle Miocene but it is desirable to have more complete material of this species before being sure it belongs to this line.

Merychyus is another genus to which many fragmentary species have been referred. Its type species is *M. elegans* and with it belong several species, like *M. arenarum, M. minimus, M. harrissonensis, M. leptorhyncus,* all small, light built types, with long slender limbs and tiny hoofs so compressed laterally as to suggest the unguals of deer and a very perfect digitigrade mode of locomotion. Such species as *M. medius* and *M. major* are much heavier built and when better known will, I am sure, be assigned to other genera. In the case of *M. medius* some of my material shows it clearly had stocky limbs, a moderately heavy skull without an antorbital fenester, the whole being very like Mesoreodon. As known today Merychyus ranges from the Lower to the Upper Miocene.

In Phenacocœlus, Leptauchenia, Cyclopidius, and Pithecistes we have a group of highly specialized oreodonts in which the skull has a pair of frontal fenestra as well as the antorbital fenestra. Unfortunately except for Phenacocœlus the limbs have been very scantily described but where known they seem to be of moderate length and not stocky. The group is a progressive one, being more specialized in the order named above and very peculiar in that the nasals become fused to the premaxillæ bones. Phenacocœlus is the least specialized and has the frontal and antorbital fenestra separate, also moderately long and slender limbs. In Leptauchenia the skull is short and wide and the frontal and antorbital fenestra have become confluent, but the dentition is retained in full. Cyclopedius has the same general characters, but the incisors are reduced to $\frac{0}{2}$; while the little known Pichecists has gone a step further and has but one incisor (the third) still remaining in the lower jaw.

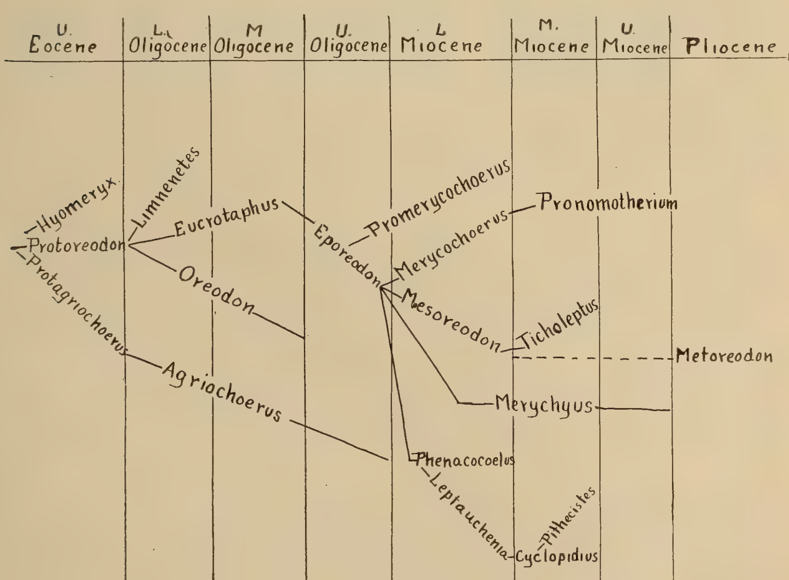

FIG. 4.—Diagram of the Evolution of the Oreodon.

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Amherst College, Mass.

Art. XXI.—*The Stratigraphy and Geologic Relations of the Paleozoic Outlier of Lake Timiskaming;*[1] by George S. Hume.

Introduction.

The Paleozoic outlier of the Lake Timiskaming district is situated just a few miles northeast of the mining town of Cobalt, Ontario, and about 130 miles north of the eastern part of the north shore of Lake Huron. The area, which includes about 250 square miles, is restricted to a number of islands at the northern end of Lake Timiskaming and a strip of country not over 9 miles wide extending as far north as Englehart. This outlier is completely surrounded regionally by more elevated rocks of Precambrian age.

Previous work.—Paleozoic rocks were first reported from the Lake Timiskaming district in 1845. The first contribution of any importance on the geology was made by R. Bell in 1894 in a paper entitled "The pre-Paleozoic decay of the crystalline rocks north of Lake Huron." In it the conclusion is reached that the Paleozoic rocks are later in origin than the depression which now forms Lake Timiskaming. This view was also held by Barlow (1897), who made a more extensive study of the district, the report of which was published in 1897. The Paleozoic rocks were ascribed to the Clinton and Niagaran formations, and from loose fragments Trenton fossils were also obtained. It was concluded that Trenton was present though concealed.

The regional relationships of the district, with especial reference to the Precambrian, have been studied particularly by W. G. Miller (1913) on the western or Ontario side of the lake, and by M. E. Wilson (1918) on the eastern or Quebec side. They have shown that the Paleozoic sediments are older than the formation of the Timiskaming trench, which was also studied somewhat by both Bell and Barlow previously.

In a short reconnaissance trip M. Y. Williams (1915) found Ordovician sediments of Trenton age on the western side of Lake Timiskaming, and for the first time proved the existence of a fault along the straight western shore of the lake. Faulting had previously been sus-

[1] Published by permission of the Director of the Geological Survey of Canada.

pected, although the actual proof was lacking. The discovery of Ordovician sediments stimulated interest in this outlier of Paleozoic rocks, and as the relationships of the younger to the older rocks gave promise of throwing much light on the history of the Laurentian plateau, the more detailed work was assigned to the writer, who undertook the present study in the following summer.

Scope of the work.—This paper is a synopsis of a report which will later be published in full by the Geological Survey of Canada. In the complete report the stratigraphic relations and faunal characteristics will be discussed in detail, and these, with the physiographic and structural features found in the area of Paleozoic rocks, will be applied to the regional history of the Laurentian plateau.

Acknowledgments.—The field work for this report was undertaken under the direction of Doctor M. Y. Williams of the Geological Survey of Canada, who gave valuable assistance on a short reconnaissance trip, and to whom the writer is further indebted for many helpful suggestions during the progress of the whole work.

In the preparation of the report, the work has been under the supervision of Professor Charles Schuchert of Yale University, to whom the writer wishes to acknowledge his thanks. Thanks are also due to Professors H. E. Gregory and Alan M. Bateman of Yale for helpful advice and criticisms.

Structure.

Regional relations.—It has been shown by Miller (1913) that there are three regional drainage systems along lines of fracturing or disturbance. The most pronounced of these water systems is in a northwest and southeast directions, including the drainage line of Lake Timiskaming and Long and Kinogami lakes farther north. This drainage system is parallel to many other water courses, among which the Montreal river is by far the most prominent.

The second system of drainage is in a northeast and southwest direction, and is best represented by a line through the northeastward extension of Lake Timiskaming at its northern end (see fig. 1). Continuing southwest, this line of water courses passes along the longer axis of Cobalt lake and about 4 miles of the Montreal river, where it turns sharply from a northwest and southeast direction to a northeast and southwest one between

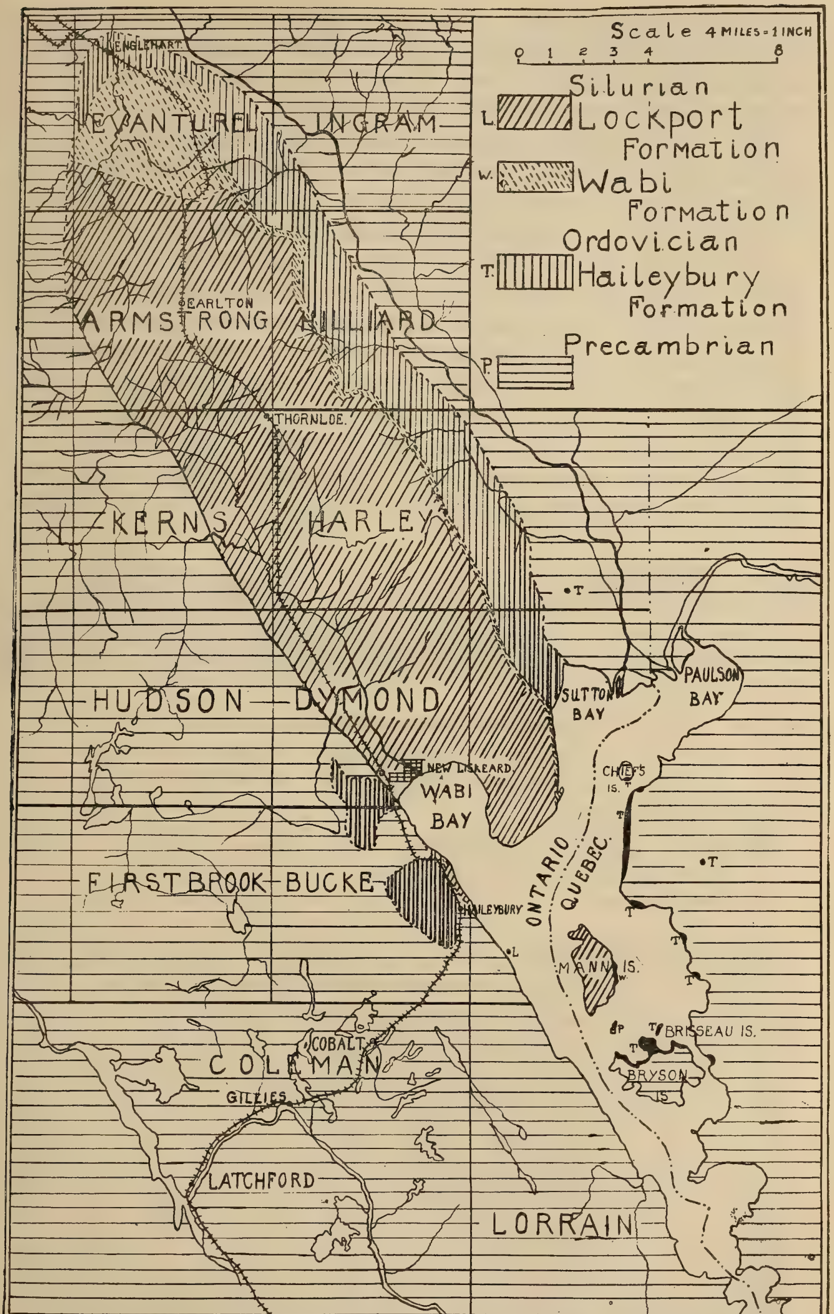

FIG. 1.—Map of the Paleozoic outlier of Lake Timiskaming area.

Latchford and Gillies. Various other lakes, including a line along the Matabitchuan river from the point where it enters Lake Timiskaming close to the outlet of the Montreal river, are parallel to this system.

The other system includes many lakes with longer axes in the north and south direction, and is best illustrated by the north and south part of Lake Timiskaming for about 10 miles north of the mouth of the Montreal river.

In the northern end of Lake Timiskaming it can be shown that the northwest and southeast system is conditioned by a large fault along the western shore of the lake, and the northeast and southwest system by warping, if not faulting. No definite information is available as to the north and south lines other than that which is suggested by their relationships to the other two systems.

Local evidence of faulting.—In regard to the northwest and southeast system of fracturing, a study of the Pale-

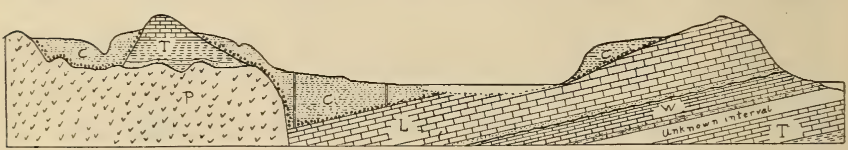

Fig. 2.—Section east and west through New Liskeard

Horizontal scale 2 miles = 1 inch
Vertical scale 800 feet = 1 inch

C, Post Glacial Clay.
L, Lockport formation. } Silurian.
W, Wabi formation. }
T, Haileybury formation—Ordovician.
P, Precambrian.

ozoic rocks has revealed the presence of a fault which is responsible for the straight western shore of Lake Timiskaming, and a fault-line scarp extending about 18 miles northwest from the head of the lake. The thickness of the various formations involved along this fault shows the displacement to be from 800 to 1000 feet, with the downthrow side to the east. The rocks on the eastern side of the fault are Silurian, with a westward dip, and near the fault at New Liskeard station a well boring has shown that they are covered by post-glacial deposits over 240 feet thick (see fig. 2). At an elevation of over 250 feet higher, on the west side of the fault, Ordovician occurs in flat-lying beds, while on the fault-line scarp itself, Silurian strata outcrop at various places, with beds tilted over 50°

to the east. North of the lake, at a higher elevation Precambrian rocks outcrop to the west of the fault-line, while Silurian occurs to the east, so that the faulting relationships are clearly evident. The scarp decreases in elevation to the north, due to the irregularities of the surface having been completely obliterated by the later deposits of post-glacial clay. South of Percy island, near Haileybury, no Paleozoic rocks are found on the western side of the lake. On the contrary, the lake is here bounded by Precambrian rocks in high cliffs which are in line with the fault-scarp shown in the Paleozoic rocks farther north.

In regard to the northeast and southwest fracture system, which includes the northeast extension of Lake Timiskaming at the northern end and its continuation southwest in a line through Cobalt lake and the Montreal river between Latchford and Gillies, it is known that a fault is present at Cobalt. This fault has a displacement of 400-500 feet, the downthrow side being to the northwest. A depression of the surface, which the railway follows, extends from Cobalt to Lake Timiskaming, and no Paleozoic rocks are found south of this line on the western side of the lake. On Mann island the rocks are Silurian, showing varying dips, mostly to the north and west. On Brisseau and Bryson islands to the south, Ordovician rocks occur, the sequence suggesting a northerly dip for the strata in this part of the lake. On Wabi peninsula the rocks have a southerly component to the dip, so that between Mann island and Wabi point there is at least a downwarped portion under the lake and faulting is not improbable.

Age of faulting.—Since the Silurian rocks have been broken by the faulting, and glacial and post-glacial materials are undisturbed, it is obvious that the faulting is post-Silurian and pre-glacial. The presence of a fault-line scarp, now over 150 feet high, which was over 400 feet high before the depression at its base was partly filled with post-glacial clay, is in favor of a date for faulting much nearer the Pleistocene than the Silurian. The fault-scarp is relatively slightly dissected by stream action, so that it is believed it could not have been earlier than the Cenozoic, and the probability is that it is late Tertiary, perhaps connected with the widespread crustal instability and accompanying earth movements which took place in Pliocene time.

The relationships of the northeast and southwest line of fracturing through Cobalt to the fault on the northwest and southeast line along the western shore of Lake Timiskaming, are not clear. Since a number of prospects and mines have been found near the general line of disturbance which includes Cobalt, it has been argued (Miller 1913) that mineralization has been connected with this fracture zone. At Cobalt the faulting is later than the Nipissing diabase, and it may be that shortly after the intrusion of the diabase sills, with which mineralization is connected, the fracture system was inaugurated, at least along the line here indicated. However, whatever the time of origin, the evidence is clear that there was crustal movement subsequent to the deposition of the Silurian about Lake Timiskaming. It is this later movement that has given rise to the renewed faulting now shown in the present fault-line scarp along the western shore of the lake and northwest of it.

Physiography.

Terraces and beaches.—Following the retreat of the continental glaciers, a lobe of ice blocked the southern drainage system through Lake Timiskaming and the Ottawa valley (Coleman 1909) causing the formation of a large glacial lake (south of the Continental Divide) which Wilson (1918) has called Lake Barlow. The deposits of Lake Barlow consist of very evenly stratified clays in which terraces were formed due to the subsidence of the lake in stages depending on the height of the outlet. These terraces now appear at 35, 110, and 140-170 feet above the level of the lake.

Beaches belonging to Lake Barlow are also known west of Haileybury and New Liskeard. The beaches to the south are at a slightly lower elevation than those farther north, the elevation being about 280-290 feet above the level of the lake.

Tilting to the south and post-glacial faulting.—Subsequent to the retreat of the ice, there seems to have been some response to isostatic readjustment, due to the release of load. Miller (1913) has stated that at Cobalt slight post-glacial faulting has taken place. No similar movement could be detected in the area of Paleozoic rocks, because of the weathered condition of the clays. However, the fact that Blanche river flows for many miles in a straight course parallel to the northwest and southeast system of fracturing suggests the influence of structural relations. Post-glacial faulting along an old fracture line, such as occurred at Cobalt, may have fractured the clay sufficiently to determine the position of the river course. However, as no proof of any movement in the clay could be found, the river may owe its present position to normal development on a gently sloping clay plain.

During this period of readjustment to isostatic equilibrium, with which post-glacial faulting is probably connected, there seems to have been a regional tilting to the south in this district. As has already been stated, the more northerly beaches are at a slightly higher elevation than those farther south. Also clay deposits are known in the vicinity of the Continental Divide at an elevation of about 1100 feet (Wilson 1918), while at Haileybury the highest reported occurrence is at an elevation of 775 feet (Coleman 1909). This represents a slope of approximately 5 feet per mile. The slope of the country from Englehart along the Blanche river to the north end of Lake Timiskaming is of the same order of magnitude. This does not mean a tilting of 5 feet per mile, because undoubtedly part of this was original slope, and until further detailed leveling work is done the amount of tilting can not be definitely stated.

Relation of Physiography to Structure.

Overdeepening of the Timiskaming trench.—A study of the regional map reveals that at about the mouth of the Montreal river there is an intersection of the three fracture systems. The great northwest and southeast line is represented by the straight course of the Montreal river, the northeast and southwest system by a line through the Matabitchuan river and a number of lakes to the southeast, and the north and south system by the straight north and south portion of Lake Timiskaming for 10 miles north of the mouth of the Montreal river. This point of intersection must therefore be a much disturbed and fractured part of the Timiskaming drainage system. Below the mouth of the Montreal river, soundings made in the lake show a maximum depth of 470 feet or an elevation for the bottom of the lake about 110 feet above sea level. The outlet at Mountain rapids has an elevation of about 415 feet, so that the portion of the lake south of the Montreal river has been much overdeepened. This is the more striking when it is considered that this portion of Lake Timiskaming represents a trench with rugged shores that rise 400-600 feet to the elevation of the Laurentian plateau.

Various theories such as warping (Pirsson 1910) and glacial scour have been advocated to explain this overdeepening, but no very satisfactory conclusions have been obtained. As the continental glaciers moved in a direction S. 7° W. to S. 18° W. (Barlow 1897), or across the Timiskaming trench, the theory of ice action has been rejected for the most part. However, lists of striæ made by Barlow clearly show that a subcurrent of ice was deflected down the Timiskaming trench, and it is suggested here that glacial scour on the fractured and broken materials south of the intersection of the three regional fracture systems at the mouth of the Montreal river has been responsible for the overdeepening that is now evident from numerous soundings. At the north end of Lake Timiskaming, the western shore is now known to be the result of a fault of 800-1000 feet displacement. It is therefore of some significance that the deepest soundings south of the Montreal river are invariably found towards the western side of the lake. However, as yet, faulting in this part of the Timiskaming trench has not been actually demonstrated.

Character of the Paleozoic Floor.

When the transgression of the middle Ordovician sea overspread the continent from the Arctic, it advanced over a land mass that had much the same sort of relief as is found on the present Laurentian plateau. The surface was very irregular and in the Timiskaming area knobs and ridges that were more than 200 feet high may have been islands during the early submergence. There is a fringe of Ordovician rocks on the north shore of Bryson island, where these rocks everywhere dip away from the island 10° to 12°. Precambrian rock, which forms the main portion of the island, rises 190 feet above the water level, the slope of the Precambrian surface on which deposition took place being responsible for the dip of the Ordovician strata. As Bryson island has been rounded off by glacial action, it is probable that the relief of the

Paleozoic floor was considerably over 200 feet at this place.

Brisseau island, just north of Bryson, shows Ordovician beds dipping away from the island on all sides from a nucleus of Precambrian quartzites which outcrops on the northeast corner. The relief indicated is over 50 feet. At many other places these irregularities of the Paleozoic floor are quite evident, the character of the floor being similar to what has been reported from other districts of the Laurentian shield where the contact of the Paleozoic and Precambrian rocks has been studied.

The Paleozoic Formations of Lake Timiskaming.

Middle Ordovician: Haileybury formation.—The middle Ordovician in the Lake Timiskaming district is represented by rocks of Trenton age that are here called the Haileybury formation. From a diamond drill core obtained from west of Haileybury, the thickness of the whole formation is about 250 feet. In this diamond drill core, at the base of the Paleozoic there are 50 feet of red clay and shales resting on the Precambrian. This red material is thought to represent the reworked material of the old regolith encountered by the advancing sea and redeposited on protected portions of the Paleozoic floor. It is therefore only under exceptional conditions that the red clay has been preserved and it is now met with in but a few places. For the most part, the Haileybury formation begins with conglomerates and sandstones resting unconformably on Precambrian rocks. The conglomerates and sandstones are in the nature of a tangential deposit and therefore hold different time relations in the various places of their occurrence. As the sea advanced, the lower depressions were first filled by sediments, and later the transgression over the higher knobs and ridges resulted in the deposition of conglomerates at the base which are higher stratigraphically than those deposited on the lower parts of the old floor. The sandstones, which are coarse in the basal beds, or just above the conglomerate portion of the formation, grade upwards into finer calcareous sandstones, and these in turn are followed by red, green, and gray shales. The top member of the Haileybury consists of 40 feet of slightly magnesian limestone, and it is in this zone and as well in a few feet of the lower shales that most of the fauna was found.

Some of the more important fossils are as follows: *Receptaculites oweni, Streptelasma corniculum, S. angulatum, Columnaria alveolata, C.* (*Palæophyllum*) *stokesi, Halysites quebecensis, Plasmopora lambii, Pleurocystites squamosus, Dalmanella testudinaria, Platystrophia trentonensis, Rhynchotrema increbescens laticostatum, R. minnesotense, R. inequivalve, Strophomena emaciata, S. incurvata, S. trentonensis, S. trilobita, Fusispira* cf. *angusta, F. convexa, F. nobilis, Hormotoma gracilis, H. trentonensis, Liospira angustata, L. progne, Lophospira* cf. *elevata, Maclurina cuneata, M. manitobensis, Maclurites crassus, M. crassus macer, Trochonema umbilicatum, Narthecoceras crassisiphonatum, Ooceras cordatum, Orthoceras amplicameratum, Vaginoceras multitubulatum, Bumastus trentonensis, Ceraurus dentatus, Isotelus gigas.*

Of these, the corals are particularly common in the upper shales, and this level is suitably called the *Streptelasma corniculum* zone. The upper limestone is more especially characterized by large gastropods of the *Maclurea* type, after which the zone has been named.

The fauna shows close resemblances to that of the Nelson River limestone of Hudson bay (Savage and Van Tuyl 1919), and equivalent strata of Trenton age occur at Frobisher bay, Baffin land (Schuchert 1910), in Manitoba (Dowling 1898), and in Wisconsin, Minnesota, and Iowa. Several fossils suggesting a similar faunal association have also been reported from the Port Clarence limestone of Alaska (Kindle 1911). This fauna, then, belongs to a widespread transgression of the sea from the Arctic in Trenton time. Towards the base of the upper limestone member, or *Maclurea* zone, there is a fossil crinoid and cystid horizon having *Pleurocystites squamosus.* This fossil occurs in the Hull limestone of the Trenton of the Ottawa region, and it appears probable that its stratigraphic height is about the equivalent of the Kirkfield crinoid horizon of southern Ontario.

Upper Ordovician: Richmond.—No Richmond outcrops in this area, although it would be expected to occur from the known widespread marine transgression of this time. Between the top of the Haileybury formation and the lowest known Silurian, there is a stratigraphic interval calculated to be about 40 feet. This undetermined interval may possibly contain Richmond strata, but as it is completely covered by younger deposits, this supposition could not be established.

Silurian: Wabi formation.—The base of the Silurian system, or of what is here called the Wabi formation, is nowhere exposed in the Timiskaming area. The lowest strata are green shales with thin layers of limestone that contain a great many ostracods, particularly *Leperditia hisingeri fabulina,* after which the zone has been named. Higher up, these shales grade into thin-bedded magnesian limestones, the whole thickness of this formation being about 120 feet. In the limestone beds there is one horizon that contains a great many small Hormotomas, and consequently the upper limestone member has been designated the *Hormotoma* zone. Fossils are not plentiful in this formation, but among the most characteristic are: *Leperditia hisingeri fabulina, L. hisingeri, L. arctica, Zygobolbina williamsi, Hormotoma* sp., *Pterinea* cf. *brisa, P. elegans, P. occidentalis, Camarotœchia? winiskensis, Rhynchospira lowi,* and a number of other long-ranging brachiopods.

In other areas where a fauna similar to this has been found, *Virgiana decussata* occurs below the *Leperditia hisingeri fabulina* zone. In the Timiskaming area, the *L. hisingeri fabulina* zone is almost at the base of the exposed part of the section, and if the *Virgiana decussata* zone is present, it is in the unknown interval previously described.

A fauna similar to that of the Wabi formation occurs in the Port Nelson and Severn River limestones of Hudson bay (Savage and Van Tuyl 1919), and undoubtedly these strata are of equivalent age. In the Lake Timiskaming district, there are fewer species, although this may be due to the fact that exposures of the formation are not of great extent and the collecting places are very limited.

Savage and Van Tuyl (1919) have correlated rocks of this age in the Hudson Bay region with the lower part of the Stonewall formation of Manitoba and with rocks of equivalent age in eastern Wisconsin (the upper part of the Mayville limestone), and the northern peninsula of Michigan. In the Dyer Bay dolomite of the Lake Huron district, *Zygobolbina williamsi* was first found (Williams 1919). This is perhaps the only diagnostic fossil so far known common to the Wabi formation and to the Cataract of southern Ontario. If the strata in which this ostracod is found can be taken as about the same stratigraphic height in the two areas, then the lower beds of the Wabi are equivalent to the top part of the Cataract. This means that most of the Cataract of southwestern Ontario is not represented in the Timiskaming area, where 75 feet of deposits occur above the strata containing *Zygobolbina williamsi.*

The Wabi formation thus seems to belong to a transgression of the sea from the Arctic which spread also over the Hudson Bay district, Manitoba, eastern Saskatchewan, and south into eastern Wisconsin and northern Michigan. It probably united in part with the southern invasion of the sea at this time, but the slight intermingling of faunas in the two basins of deposition is opposed to any close connection between the two seas.

Silurian: Lockport formation.—The Lockport is the most extensive formation of the Lake Timiskaming area, and consists of magnesian limestones about 186 feet thick. It is separated at the base by a slight disconformity from the top of the Wabi formation, and although this break does not appear to be a great discordance, yet it represents the time of the Clinton and Rochester of New York.

The Lockport begins with a layer of sandstone 1-2 feet thick, but which very rapidly changes upwards into thin-bedded magnesian limestones. The top portion is marked by thicker bedded, more resistant strata which are an approach to dolomites in composition.

The fauna is marked by corals and cephalopods, although brachiopods are also common in parts. Among the more common fossils are: *Caninia stokesi, Cyathophyllum articulatum, Favosites favosus, F. gothlandicus, F. hispidus, F. niagarensis, Halysites catenularia, H. catenularia microporus, H. catenularia feildeni, H. labrinthicus, Heliolites megastoma, Strombodes pentagonus, Syringopora bifurcata, S. dalmani, S. verticellata, Clathrodictyon vesiculosum, Pentamerus oblongus, Orthis* near *davidsoni, Actinoceras backi, A. rotulatum, A. vertebratum, Discosorus conoideus, D. remotus, Huronia bigsbyi, H. distincta, H. minuens, H. obliqua, Orthoceras alienum, O. franklinense, Encrinurus ornatus, Calymene niagarensis.*

These fossils show a striking similarity to those of the Lockport of the Lake Huron district. Many of the corals in the Timiskaming area have been reported by Williams

(1919) from the Fossil Hill coral horizon on Manitoulin island, and many of the cephalopods have been found on Drummond island. From the Attawapiskat coral reef and Ekwan River limestone, Savage and Van Tuyl (1919) have reported many new species of which there are no representatives in the Timiskaming district. The fauna of the rocks of this age in the Hudson Bay region is decidedly dissimilar from that of Lake Timiskaming, and this probably means that there was a land barrier between the two basins of deposition for at least a part of Lockport time. Towards the top of the Timiskaming section, northern forms like *Cyathophyllum articulatum* and *Halysites catenularia feildeni* occur. These have not been recognized further south, and it would seem that there was a direct migration route from the north in late Lockport time.

It has generally been assumed that the Niagaran inundation of the continent from the Arctic was widespread over the western part of the Canadian shield, but the probable presence of a land barrier in early Lockport time shows that there were restrictions to this sea that have not been previously suspected. Savage and Van Tuyl (1919) have shown that the Niagaran rocks of Hudson bay have closer faunal relations with equivalent strata in Wisconsin than with those in Ontario and New York, and as the Timiskaming Lockport is very similar to that of Ontario, the barrier seems to have been responsible for this faunal distribution.

In the Timiskaming area, *Pycnostylus elegans* occurs. This, with *P. guelphensis* and some other forms suggesting Guelph time, occurs in the Hudson Bay region. However, Williams (1919) has shown that *P. elegans* and *P. guelphensis* occur also in the transition Eramosa beds between the Lockport and the Guelph. Hence these fossils alone can no longer be taken as indicating Guelph. It is surprising that none of the typical Guelph assemblage of fossils such as are so characteristic of the Guelph of southwestern Ontario and New York have been found in the north, and it seems certain that none of this typical Guelph occurs in the Timiskaming district or in the Hudson Bay region.

The presence of the European forms of crinoids and trilobites long ago reported by Weller (1900) from the Chicago series shows direct communication with Europe during Niagaran time, and the only possible connection seems to be by way of the Arctic. *Megalomus* has been reported from Alaska (Kindle 1907) and also occurs on the island of Gotland with *Trimerella*. These occurrences probably mean that the Guelph sea connected with the Arctic ocean, but that the waterway must then have been restricted to the western or Cordilleran geosyncline, while in Lockport time it transgressed more widely over the Canadian shield. *Pycnostylus guelphensis* has also been found in Manitoba, but none of the other typical Guelph fossils occur here, and hence it is not certain whether Guelph is actually present or whether this species comes from the equivalent of high Lockport beds such as the Eramosa beds of Ontario. It is possible that with further field work over suitable areas in the northwestern part of Canada, a Guelph fauna will yet be found and furnish a connecting link between the Arctic and the interior Guelph basin of Ontario and New York.

Devonian.—From the known paleogeography, it would be expected that rocks of late Middle Devonian time should occur in the Timiskaming area, but none are now present. It is possible that erosion may have completely removed them, but if so, that erosion must have taken place prior to the faulting that gave rise to the present fault-scarp along the west side of Lake Timiskaming. The downthrow side of such a fault would be a favorable place for preserval, but the highest rocks now found belong to the Lockport formation.

Post-Glacial Clay Deposits.

The clay deposits of Lake Barlow, which form a part of the northern Ontario Clay Belt south of the Continental Divide, have already been spoken of in connection with terraces. The clay is very evenly stratified in alternate light and dark bands each less than one half inch in thickness. Each two bands represent one complete cycle of deposition, and on the basis of De Geer's results in Sweden, are regarded as of one year. Over a great part of the Clay Belt, no thickness over 30 feet has been previously reported for the clay. However, at the head of Lake Timiskaming, where the clay has accumulated in the depression formed on the downthrow side of the northwest and southeast fault, a much greater thickness occurs. Even above the present surface level the clay is over 150 feet thick, and from calculations made on the average thickness of the bands, this represents at least 2000 years for deposition. In a well drilling at Uno Park 216 feet of clay were passed through, and at the town of New Liskeard near Wabi creek there was 100 feet. It is possible that this may not all be stratified clay, but as the New Liskeard well does not represent the maximum depth nearer the fault-line to the west, it is thought that 250 feet for a total thickness of the clays would be a very conservative estimate. This would mean at least 3600 years for the duration of Lake Barlow. It therefore appears certain that this lake lasted at least 2000 years, but the probability is that the larger figure of 3600 is more nearly correct.

Economic Geology.

Water supply.—The fault which has formed the straight western shore of Lake Timiskaming and its continuance seen in the fault-line scarp northwest of it, has brought about a tilting of the Paleozoic strata to the west in all of the area on the east side of the fault-line. Except for a ridge of rock extending northwest from Wabi peninsula, the whole surface is now covered by the clay deposits of Lake Barlow. These clays are relatively impervious to water, and the settlers have found that surface wells are for the most part unsuitable for human use. The problem of water supply is therefore very important to the agricultural development of this district, and in many places deep well boring has been done. In the final report a list of such well records will be published and a detailed account given.

In the low plain which includes the valley of Wabi creek and a strip of country to the west of Earlton and Thornloe and east of the Paleozoic boundary on the west, a great many wells have been obtained and artesian wells are not uncommon. The rocks under this plain dip west, but on the east they outcrop as a ridge stretching northwest from Wabi peninsula. It has been found that between the clay and the underlying westward dipping limestone there is a layer of bowlders which are the glacial materials left on the retreat of the continental ice sheets. This layer of bowlders is very favorable for the permeation of water along the upper surface of the limestone, and it has been found that good wells frequently develop as soon as the layer of bowlders is tapped.

On the ridge of rock extending northwest from Wabi peninsula, there is no possibility of obtaining artesian wells, and the chances for finding water close to the surface are not good. The top part of this ridge is of resistant rock, but at lower horizons shales occur, and the erosion on these less resistant strata has caused the ridge to be bounded on the east by a rather steep cuesta face which extends northwest from the west side of Sutton bay. East of this cuesta face, the country is very little above the level of the lake, but rises gradually towards the north. In this flat, extending as a narrow strip not more than 3 to 4 miles wide, there is again suitable structure beneath the clay for favorable water supply, and already one artesian well has been found. In the part of the Clay Belt underlain by Precambrian rocks there is a possibility of finding water on the contact of the Precambrian and clay deposits in the depressions between the knobs and ridges of rock.

Limestone.—Limestone of the Lockport formation is used in the manufacture of lime, and rock of both the Lockport and Haileybury formations has been used as building stone.

In the sulphite plant of the Abitibi Power and Paper Co., Iroquois Falls, limestone low in magnesium content is required in the manufacture of paper pulp. Rock of the Haileybury formation has been used for this purpose, but the present quarry is rather unsuitable on account of the alteration that has occurred in the top weathered portion. However, it is hoped that more favorable results can be obtained from a new quarry.

Clay.—The banded clay of Lake Barlow has been used in the manufacture of brick and tile. The clay contains too high a percentage of lime to make the best brick-forming material, but by the addition of finely ground diabase from the Cobalt mills, instead of sand, which is not available, a suitable quality of building brick is obtained.

There are red clays and shales at the base of the Haileybury formation that may be of future economic importance. These clays and shales in a diamond drill core from the west of Haileybury were 50 feet thick. Mr. Keele of the Department of Mines of Canada has investigated this material and finds it to be satisfactory, as it does not begin to soften below a temperature of about

2600° F. According to Mr. Keele's report, it would be suitable for cupola and stove lining, and also for the manufacture of vitrified wares such as paving blocks.

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Art. XXII.—*A Fossil Sea Bean from Venezuela;* by Edward W. Berry.

Geologists too frequently neglect opportunities for collecting fossils and this lack of appreciation is especially deplorable when working in remote parts of the world. All the more credit is therefore due Mr. C. F. Bowen for the fossil plants collected by him during a geological reconnaissance in Venezuela during 1919. These will be the subject of a subsequent contribution to the Proceedings of the U. S. National Museum. Meanwhile I desire to call particular attention to the remarkable fruit contained in the collection representing the leguminous genus Entada. It may be called in honor of the collector.

Entada boweni sp. nov.

Seed of large size, about 5.25 cm. in diameter, reniform in surface view and depressed elliptical in cross section. The surface view would be almost perfectly circular except for the pronounced sinus at the hilum. The sclerotest or hard lignified seed-coat is gone from the face of the specimen exposing the thick reniform upper cotyledon. The inner face of the lower cotyledon is shown in the upper left hand corner of the specimen where a portion of the upper cotyledon is broken away. Where the two cotyledons join the plumule or hypocotyl is conspicuous, indicating the incipient germination of the seed before it was buried by sediment. The outer surface of the cotyledon is slightly furrowed as in the existing sea bean. The central area is slightly collapsed exactly as would be the case in the modern bean if the cotyledons were somewhat softened and the central air cavity collapsed by pressure. Around the greater part of the edge of the seed the sclerotesta is preserved, being replaced by what is presumably marcasite. This test is thick and about 3 mm. in diameter around the edges. The specimen was collected from dark shales overlying a sandstone at Mesa Pablo about five miles south, 84° west of Escuque on the south side of the Caus River, inland from Lake Maracaibo, Venezuela. The age is Tertiary but has not as yet been more definitely determined, although it is probably Miocene.

The counterpart of the specimen if present in the shale was not collected and I assume it carried the face of the test and the small fragment of the upper cotyledon which is missing.

I have dissected a number of seeds of the existing *Entada scandens* and their correspondence with the fossil is most remarkable, the only difference being the partially developed plumule or hypocotyl in the fossil which as I have suggested above was probably due to germination. The cotyledons appear to have become infiltered with ferruginous salts before they had time to rot and were subsequently slightly flattened by pressure causing the escape of gas from the central intercotyledonary cavity on which the buoyancy of the seed normally depends.

Fig. 1.—Fossil Entada from the Tertiary of Venezuela.

There are not many plants growing in the American tropics that have the distinction of having their seeds used as snuff or tinder boxes by the natives of northwestern Europe. The seeds of the snuff box, sea bean (*Entada scandens*) are mentioned in Norse literature as early as 1632 as of inorganic origin and were often considered to have been formed by the waves and called solvent stones, the name indicative of some imaginary virtue. In both Norway and the Faroe Islands they were called Vette Nyre which Sterpin (1676) translates as Fairies or Magic Kidneys. It is therefore not a matter of surprise that they were used as charms. Molucca beans, as they were also called, were and probably still are, among the fisher folk of the Shetland and Orkney islands, considered an efficacious remedy for dysentery. Naturalists before the close of the 17th century had recognized their leguminous nature and surmised that they had been drifted to Europe from the Antilles by the Gulf Stream, although in the popular mind even among the educated their marine origin and magic properties have lingered for over 250 years.

Entada scandens is probably the best known tropical plant distributed by ocean currents since its large lenticular dark kidney colored seeds have been for ages cast up by the waves on the eastern shores of the Atlantic from the Azores northward to Nova Zembla. Their seafaring qualities and vitality are remarkable as is the distribution of the parent plant, since it is found in all of the tropics and yet presents certain anomalies in its range that have puzzled botanists since the days of Hooker and Darwin. It is normally a climber with truly gigantic pods, more or less constricted between each seed cavity, and belongs to a genus with some 15 existing species about half of which are African. There are 3 or 4 in the American tropics, one or two in the southeastern Asiatic region and one in Madagascar. Most of these are not strand plants and although *Entada scandens* also grows in inland situations it is as a strand plant that it is principally known, since it frequents mangrove associations and the jungle behind tropical beaches.

Some botanists dispute the identity of the old and new world form but as regards the broader questions of distribution they may be considered identical since if specifically distinct they are so closely related as to demand direct filiation. Guppy, who has given us what is probably the best account of the question, finds some difficulty in its occurrence on both shores of Central America but this is the least of the difficulties since the littoral flora of the present day largely antedates the present geographical conditions. This question, in the case of Entada, as well as the home of the direct ancestor of *Entada scandens* would appear to be set at rest by this discovery of an almost identical form in the Miocene of Venezuela, since it antedates the latest seaway across Central America. The fossil is also so much like the existing sea bean that one is justified in assuming that it, like its descendant, was distributed by ocean currents, its occurrence in a clay lens in what appears to have been a rather widespread marine series of deposits adding some probability to this conjecture. Not all strand plants are cosmopolitan and there is a certain amount of contrast between the American and West African tropics on the one hand and those of the Western Pacific and Indian oceans on the other. Many factors are involved not the least important of which is the age of the types. At least I judge this to be the most important since of the forms common to the two areas Rhizophora, Sophora and Canavalia have been found in the Eocene around the old Gulf of Mexico and now Entada turns up along the Miocene shore of the Caribbean. The occurrence of the Nipa palm in the Eocene of the new world points in the same direction.

Guppy considers the sea bean absent along the east coast of South America. Whether or not our information on this point is complete or not I do not know but if is true it is in accord with my conception of the line of travel in the Tertiary which was from America eastward to West Africa despite the fact that the present North and South Equatorial currents would favor the reverse direction of migration.

Entada has not certainly been found fossil heretofore except in the case of subfossil seeds of the existing sea bean on the Scandinavian coast, which might well prove a stumbling block to future paleobotanists and climatologists were they unacquainted with their origin and means of transportation. Unger long ago described two different species of fossil pods and referred them to Entada. These were *Entada primogenita*[1] from the Miocene of Radoboj in Croatia and *Entada polyphemi*[2] from the Oligocene of Sotzka in Styria. They are both large and the second is suggestive of Entada, but as Schenk points out at length,[3] they also resemble other leguminous pods and are inconclusive although not entirely improbable.

There can not be the slightest doubt regarding the botanical affinity of the present fossil since it agrees in every detail with the existing species. It adds another to the considerable list of plants of the sea drift that have been discovered in recent years in the American Tertiary tropical and subtropical floras.

Johns Hopkins University, Baltimore, Md.

[1] Unger, F., Sylloge. Bd. 2, p. 36, pl. 11, fig. 22, 1862.
[2] Idem, fig. 23.
[3] Schenk, A., Palaeophytology, p. 702, 1890.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Melting Points and Thermoelectric Behavior of Lead Isotopes.*—The several kinds of lead produced by the spontaneous transformation of radioactive elements appear to be absolutely identical in their chemical reactions, and hence, like several other similar cases of isotopes, they cannot be separated by chemical means. The isotopes of lead vary, however, in their physical properties, such as atomic weight and specific gravity, and it has been shown by Richards and Wadsworth, several years ago, that the atomic volumes of these isotopes—the ratios of their specific gravities and atomic weights—are practically identical.

Further knowledge in regard to the physical properties of samples of isotopic lead is a matter of much interest, and Theodore W. Richards and Norris F. Hall have recently made an important contribution to this subject. Using a sample of Australian radioactive lead derived chiefly from the transformation of uranium, they first compared its melting point with that of ordinary lead after carefully purifying both samples to such an extent that the maximum impurity probably did not amount to more than 5 parts in 100,000. The heating and cooling curves during melting and solidification were carefully compared by the use of thermoelectric measurements. It was thus found that the difference in melting points of the two specimens of lead differing to the extent of 0.8 in atomic weight is, if appreciable, not over 0.05° C., and it is concluded that it is fairly safe to assume that the kinds of lead not only have very nearly the same melting point, but also (since the sample consisting chiefly of the lighter isotope doubtless contained ordinary lead) they mix, or rather mutually dissolve without affecting the melting point.

The authors found also that there is no thermoelectric effect produced by wires of ordinary lead and the radioactive Australian lead, and it has been found by Bridgman, using the same samples of lead, that there is no difference, beyond the range of experimental error, in the electrical conductivity of the two kinds of lead, nor in the effect of pressure or temperature upon their conductivity.—*Jour. Amer. Chem. Soc.*, **42**, 1550.

H. L. W.

2. *Intermolecular Transpositions of Atoms of the Same Kind.* Von Hevesy and Zechmeister have studied the question of the exchange of identical atoms between different molecules in a novel way. They prepared compounds of ordinary lead and of a radioactive isotype of lead, put two different ones of two kinds into solution together, separated the compounds, and by testing their radioactivity determined whether or not an exchange of atoms had taken place.

There was found, as was undoubtedly to be expected from what is known of the behavior of electrotypes in solution, an entirely uniform exchange of atoms when simple lead salts, such as lead acetate and formate, were dissolved in water and the sparingly soluble formate was allowed to crystallize by cooling the solution. A complete exchange was obtained also by dissolving the nitrate and chloride in pyridine, as well as when plumbic and plumbous acetates were dissolved in glacial acetic acid and lead peroxide was precipitated by dilution.

On the other hand, it was found that when the lead in one of the compounds was firmly combined with carbon in an organic substance no exchange took place. This was the case when lead chloride and tetraphenyl-lead were dissolved in pyridine, and when lead nitrate and diphenyl-lead nitrate were dissolved in dilute ethyl alcohol. These results were, of course, to be expected, but the confirmation of the expectation is interesting. *Bericht,* **53,** 410. H. L. W.

3. *The Action of Aqua Regia on Gold-Silver Alloys in the Presence of Ammonium Salts.*—W. B. Pollard has found that the well known difficulty of dissolving gold containing much silver in aqua regia can be overcome to a large extent by the addition of an ammonium salt to the reacting liquid. The ammonium salt dissolves the silver chloride produced and thus removes the black protecting film otherwise formed. Attention is called to the fact that nitric acid and ammonium chloride were used by the alchemists for dissolving gold, a method which doubtless facilitated the solution of alloys rich in silver.

In the course of these experiments the formation of a dark brown salt was observed upon cooling concentrated solutions of auric, silver and ammonium chlorides. To this triple salt the formula $3AgCl.4AuCl_3.8NH_4Cl$ was given, but it may be observed that the investigator used very drastic operations in preparing the compound for analysis, including extraction with ether in a Soxhlet apparatus and heating it until ammonium chloride sublimed, so that it seems possible that the salt was partially decomposed by these operations, and that the rather complex formula ascribed to it may be incorrect.—*Jour. Chem. Soc.,* **117,** 99.

4. *The Probable Existence of Deposits of Soluble Potash Salts in the United States.*—It has been generally believed that the German potash deposits were formed under peculiar conditions in connection with rock-salt deposits, whereby the more soluble constituents of the evaporated natural brines were preserved, while it is supposed that in most other rock-salt deposits these more soluble, potash-rich portions have been carried away in solution and lost. Consequently, since no beds of potash salts have been encountered in connection with the salt deposits of the United States, the opinion appears to prevail that they do not exist here.

H. D. Ruhm, however, takes a different view of the matter, mentioning the accidental discovery of the deposits at Stassfurt, the difficulty encountered in Germany in finding other deposits, and the very slight amount of search for potash that has been made in this country. He argues with much plausibility that there must certainly be potash deposits even in the eastern and central parts of the country, he points out the enormous advantages of discovering and developing them, and urges Government aid for this purpose.—*Jour. I. and E. Chem.*, **12**, 837.

H. L. W.

Obituary.

Dr. Joseph Paxson Iddings died on Wednesday morning, September 8th. Although it was known that his health had been failing for some time, his early death was not anticipated even by his most intimate friends until within a few days of its occurrence.

Dr. Iddings was one of the most widely and favorably known of American petrologists and his name will ever be associated with the development of microscopic petrology. He was connected with the U. S. Geological Survey from 1880 until 1895 and was professor of petrology at the University of Chicago until 1908, since which time he had devoted himself mainly to his private work, living at his country home in Brinklow, Montgomery County, Md. He was a man of excellent training, a careful, conscientious and philosophic worker and, since his retirement from his professorship, had travelled extensively throughout the principal volcanic fields of the world with a view of completing his studies in vulcanism and volcanic products. His best known publications are: H. Rosenbusch's Microscopical Physiography of the Rock Making Minerals, 1898 (a translation): Rock Minerals, 1906; Igneous Rocks, 1909; and the Problem of Vulcanism, 1914. He was also one of the most active of the joint authors of the Quantitative Classification of Igneous Rocks. Numerous other of his writings are to be found in the periodicals and publications of the Geological Survey, among which may be mentioned the reports on rocks of the Eureka District, Nevada (Monograph XX) and of the Yellowstone National Park (Monograph XXXII).

Dr. Iddings was a man concerning whom it is difficult to speak in a wholly impersonal manner by one with as strong a feeling of attachment as the writer. He was not merely a geologist, but a man of broad culture and a gentleman, one who was always disposed to recognize the best in any one and overlook that which was less favorable; a clean, healthful minded man of gentlemanly bearing such as made him friends wherever he went, and his loss will everywhere be deeply deplored. Geo. P. Merrill.

John Marcus Blake of New Haven, Conn., died on September 21, at the age of eighty-two years. He was a man of varied gifts, much interested in crystallography; his first publication in this Journal was in vol. **41**, pp. 308-311, 1866, and the last in vol **46**, pp. 651-662, 1918.

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[FOURTH SERIES.]

Art. XXIII.—*The Crystal Structures of some Carbonates of the Calcite Group;* by Ralph W. G. Wyckoff.

The crystal structure of calcium carbonate has been previously studied, using the spectrometer.[1] At the same time measurements were made upon the crystallographically similar iron and manganese carbonates, which indicated that they had the same structure as calcite. The present study of the crystals of the calcite group was originally undertaken in the hope that the additional information which Laue photographs furnish would serve to place the oxygen atoms with considerable accuracy. Some information might thereby be supplied regarding the existence of definite carbonate (CO_3) groups of atoms in the crystalline solid.

The carbonates of calcium, iron, and manganese occur naturally in excellent crystals. Good crystals of magnesite ($MgCO_3$) and especially of smithsonite ($ZnCO_3$) are rarely found. The other members[2] of this "isomorphous" group of substances are the cobalt salt, which has been found as a mineral (spherocobaltite) and has been prepared artificially, and cadmium carbonate, which is found in isomorphous mixtures with zinc carbonate. Crystals of nickel carbonate have been made which also seem to belong to this same group. Of these various compounds, however, only individual crystals of calcite, magnesite, rhodochrosite ($MnCO_3$), and siderite ($FeCO_3$) were available for this work.

The method of study is essentially the same as that of Nishikawa[3] and has been used with cæsium dichloriodide[4] and sodium nitrate.[5]

[1] W. L. Bragg, Proc. Roy. Soc. A, 89, 468, 1914; W. H. Bragg, Phil. Trans., A, 215, 253, 1915.

[2] Dolomite, which is often included in the calcite group, will not be discussed.

[3] S. Nishikawa, Tokyo Sugaku-Buturigakkwai Kizi (2) 8, 199, 1915.

[4] R. W. G. Wyckoff, J. Am. Chem. Soc., 42, 1100, 1920.

[5] R. W. G. Wyckoff, Phys. Rev. (2), 16, 149, 1920.

The Structure of Calcite.

Crystallographic Data:[6]—Calcite has the symmetry of the ditrigonal scalenohedral class of the hexagonal system (holohedry of the rhombohedral division).

α (the angle between the rhombohedral axes) $=101°55'$.

The reflection measurements[7] give the ratio of the order of the reflection to the number of molecules associated with the unit of structure. There are, of course, two possible fundamental units, a rhombohedron and an hexagonal prism. Assuming the former, if n is the order of the reflection and m is the number of molecules associated with the unit, and using the value of $d/n = 3.04 \times 10^{-8}$ cm.,[7] the ratio n^3/m becomes,

$$\frac{n^3}{m} = 2{\cdot}08.$$

This very strongly suggests a second order of reflection from a rhombohedron containing four molecules of calcium carbonate.

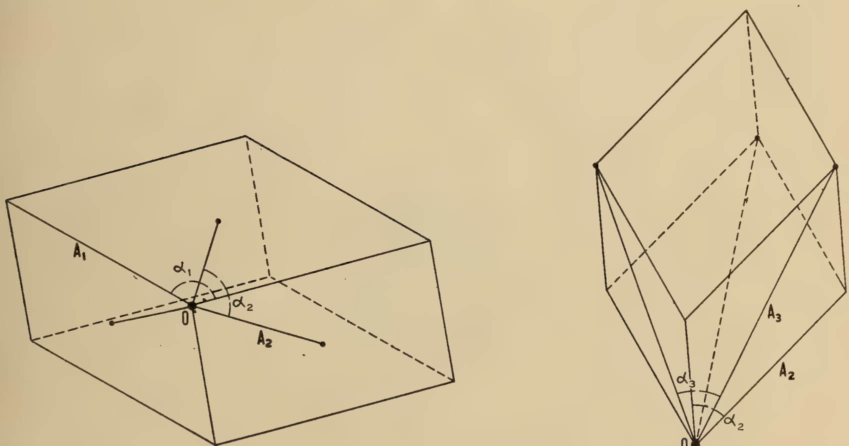
The specimens used in the present instance were from a clear piece of Iceland spar. Photographs of the L-series lines of tungsten, using this material as a grating, gave spacings that agreed with the previous measurements to within the limit of error of the experiment.

Laue photographs were prepared by passing the X-rays through sections ground parallel to the basal plane, (111), and through a cleavage piece. Exposures were taken with the rays normal to these faces, (111) and (100), and also inclined at small angles to the normal. These plates averaged about 350 spots apiece. The indices of the planes producing the spots were determined by plotting the photographs in gnomonic projection. When the crystallographic axes ($\alpha = 101°55'$) are used to determine the indices of the reflecting planes, there does not seem to be any *simple* agreement with the observed pattern; such agreement, however, is obtained if axes are chosen which are the diagonals of the faces of the rhombohedron formed by the first set of axes. It is this second set of trigonal axes which will be used in the computations. The relation between the two sets of axes is shown in fig. 1, A.

[6] P. Groth, Chemische Krystallographie II, 204, 1908.
[7] W. L. Bragg, op. cit.

At the same time the distance of each spot from the central image and the approximate intensity of each reflection were noted. The pattern obtained, when the X-rays are passed not quite normal to the (111) plane, is shown diagrammatically in the center of fig. 2. The pattern given in fig. 3 is obtained when the plane is (100).

The Method of Projection.—Because the gnomonic projection[8] seems to offer, for this purpose, a number of advantages[9] over the familiar stereographic[10] projection, the manner of its application will be briefly mentioned.



A B

FIG. 1.—A_1=original crystallographic axes; A_2=axes used in the computations; A_3=axes of the true unit of structure.

This form of projection has two more or less obvious advantages. The indices of the reflecting planes are much more easily obtained and the method is capable of a general routine application not only to all systems of crystals but equally to various orientations of a crystal. This second fact is especially important in the present instance because patterns which are somewhat unsymmetrical are of greatest value. A decided saving in time is thus effected by being able to treat such photographs by routine methods.

The positions of the *normals* to the *planes* which are

[8] F. Rinne, Ber. Verhandl. K. Sächs. Ges., 67, 303, 1915.
[9] Thanks are due to F. E. Wright, of this Laboratory, for pointing out some of the advantages to him.
[10] W. L. Bragg, Proc. Roy. Soc. A, 89, 248, 1913.

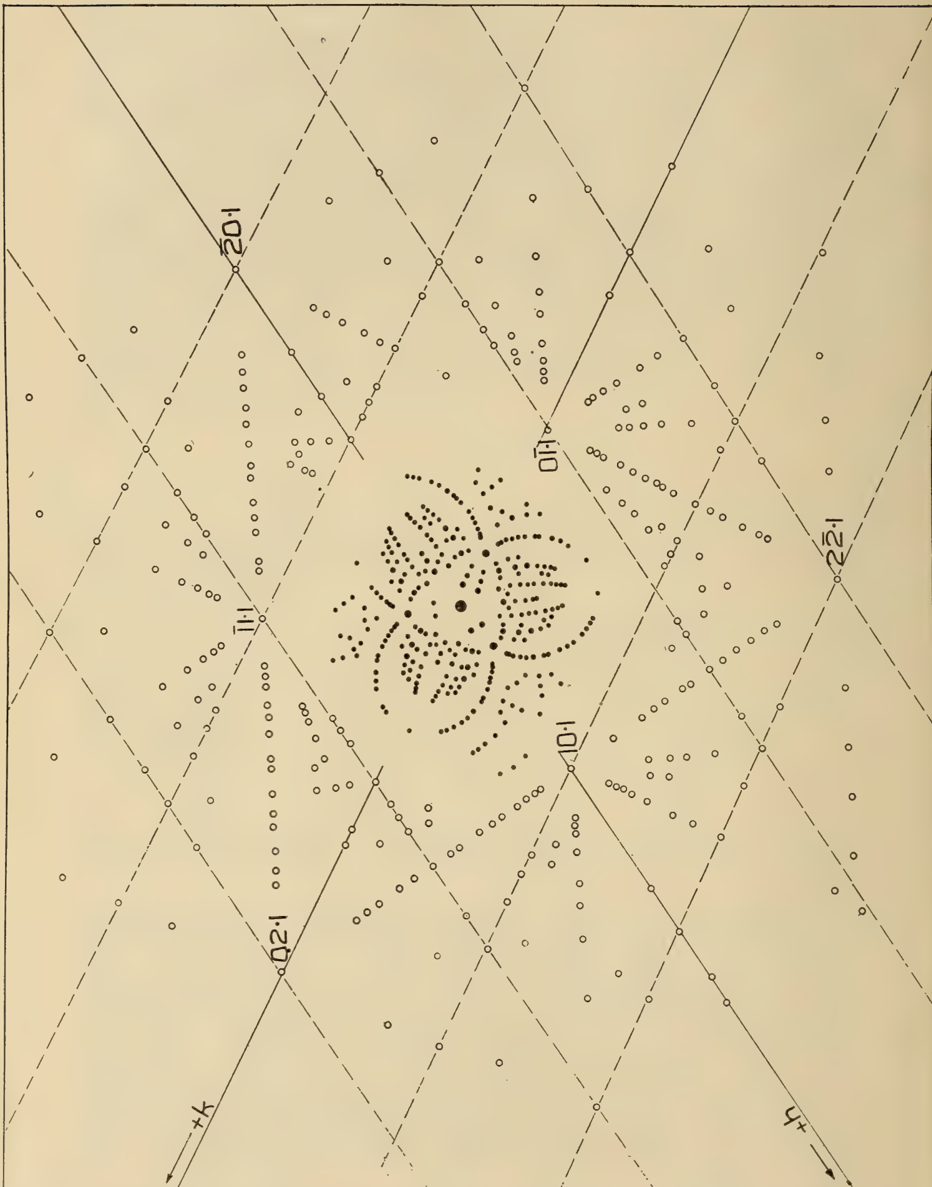


Fig. 2.—A gnomonic projection of the Laue pattern obtained by passing X-rays through a basal (111) section of rhodochrosite ($MnCO_3$). The direction of the rays is approximately normal to the (111) plane. Calcite gives a nearly identical pattern.

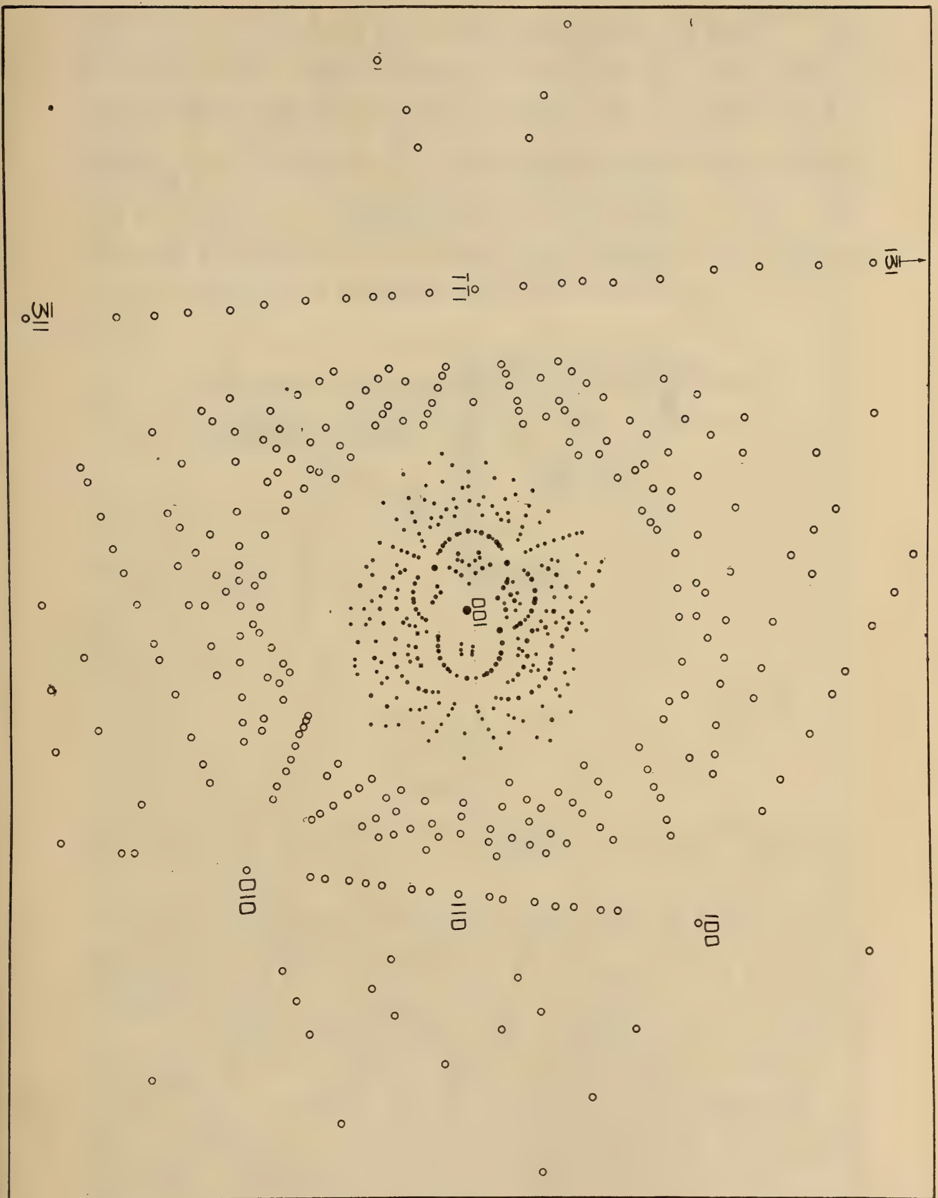


FIG. 3.—A gnomonic projection of the Laue pattern obtained by passing X-rays through a cleavage piece of calcite in a direction nearly normal to the cleavage plane.

reflecting the X-rays are plotted in the gnomonic projection. Both the crystal and the eye are considered to be at the center of the sphere of projection. The plane of the projection is a tangent-plane normal to the direction of the incident X-ray beam (fig. 4). Thus B is the projection corresponding to A. In the gnomonic projection,[11] zones of planes lie along straight lines and if the rays pass parallel (or nearly parallel) to an axis of the crystal, the indices of any plane can be obtained directly from the co-ordinates of its position on the projection.

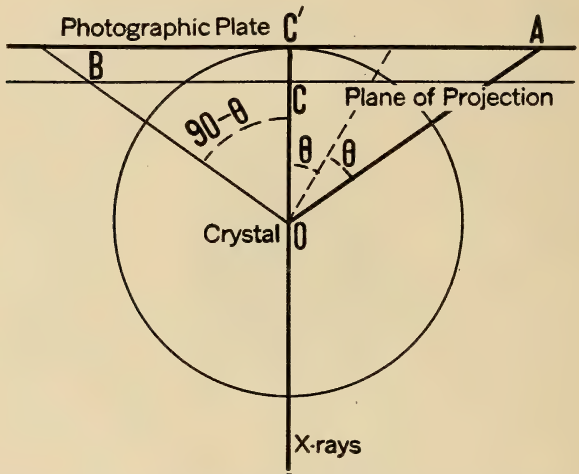


FIG. 4.—The method of representing the reflection of a plane (in a Laue photograph) in gnomonic projection.

The following procedure has been found to reduce the time required for reading a Laue photograph to at least one-third or one-fourth of that needed if a stereographic projection is prepared. The accuracy under ordinary conditions of working is also appreciably greater.

An exact reproduction of the positions of the spots in the photograph is prepared in the center of the paper upon which the projection is to be made. A spot and the projection corresponding to it lie on a straight line which passes through the central spot (*C*, *C′*, fig. 4). The distance from a spot to the center C′ is the product of the

[11] The gnomonic projection, its properties and uses to the crystallographer, will be found in V. Goldschmidt, ''Ueber Projektion u. Krystallberechnung'' (1887), or in H. E. Boeke, ''Die Gnomonische Projektion'' (1913). A simple discussion is given by C. Palache in Am. Mineralogist, 5, 67, 1920.

distance from the crystal to the plate, C′O, into tan 2θ. BC, the distance of the projection of the plane producing spot A from the center C, is equal to the distance CO, the radius of the sphere of projection, multiplied by cot θ. Then by the use of a straight edge and a table or special scale connecting tan 2θ and cot θ, it is possible to record the distance of a spot from the center and to locate its position on the projection with a single setting.

The pattern may be reproduced in the center of the paper in a number of ways. Either of the following two has been found convenient. The photograph may be made on X-ray film instead of plate. This film is mounted on the paper and the positions located on the projection by directly pricking through the film with a sharp pin. This is the quicker method but it destroys the film. It is much better to make a contact print from the photograph and to prick through this print.

For drawing the projection from this reproduction a ruler carrying a special scale is most convenient. It is desirable that this ruler be pivoted on a pin through the drawing table, so as to be moved on the paper about an axis through the center of the projection. Such a ruler is shown in fig. 5. Of course, a different scale will be required for each distance of *crystal to plate*, but since distances of 3, 4, and 5 cm., usually the last two only, are all that are required in ordinary practice, three or even two rulers are sufficient. These rulers can be prepared very simply from the tables I, II, and III. It is best to use a sphere of projection of the same radius at all times so that all projections may be comparable one with another. One having a radius of 5 cm. is commonly used. With this radius most of the projected spots that occur will lie beyond the reproduction of the photograph in the center, but still the projection is not too large to be con-

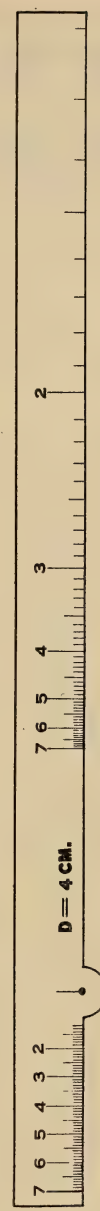


Fig. 5.—A ruler used in preparing the gnomonic projection of a Laue photograph. On the right hand is the special projection scale; the left hand scale is an ordinary millimeter ruler.

tained on a piece of 50 × 65 cm. drawing paper. These tables, then, hold for a sphere of projection of 5 cm. radius. They are calculated as follows (fig. 4):

C′O = distance from crystal to plate (3, 4, or 5 cm.).
C′A = distance from any spot to central spot on photographic plate.

$$\theta = \tfrac{1}{2} \tan^{-1} \frac{C'A}{C'O} = \text{angle of the reflection.}$$

BC = distance on projection corresponding to spot distant x from the central spot.
BC = 5 cot θ.

The manner of making the projection is the same whether the crystal is set to give a symmetrical or an unsymmetrical photograph. As already stated, an unsymmetrical photograph is more useful in interpreting the structure of crystals because in this case the same kind of a plane occurs at different distances from the center of the photograph and reflects X-rays of different wave lengths. The amount of dissymmetry desired for this purpose is in most cases relatively slight, however, and does not produce enough distortion in the projection to cause trouble in determining the crystallographic indices (fig. 7). The accompanying figures illustrate the manner of projection and the way of obtaining the indices of planes. (Figures 6, 7 and 2.)

If the indices of the reflecting planes are to be obtained from the coördinates of their projected positions, it is necessary that one of the axes be approximately normal to the plane of the projection. For cubic, tetragonal, and orthorhombic crystals X-rays may be conveniently passed through sections cut normal to any of the three axes. The coördinate systems on the projection in these cases are always rectangular, though the unit lengths along the axes will be different if the system is orthorhombic, or if the rays travel along an *a*-axis of a tetragonal crystal. The lengths of the axial units in every case can, of course, be obtained in the usual manner from a knowledge of the axial ratio. If the crystal is hexagonal, as it is in the present case, the photograph is best taken with the rays normal to a basal section. The coördinate axes are then of equal length and make an angle of 60° with one

TABLE I.

Data for preparing ruler when distance from crystal to plate is 3 cm.

Left side of ruler cm.	Right side of ruler cm.	Left side of ruler cm.	Right side of ruler cm.
0.90	34.06	2.75	12.85
.95	32.35	2.80	12.68
1.00	30.80	2.85	12.52
1.05	29.41	2.90	12.37
1.10	28.16	2.95	12.22
1.15	27.01	3.00	12.07
1.20	25.96	3.10	11.80
1.25	25.00	3.20	11.54
1.30	24.12	3.30	11.30
1.35	23.29	3.40	11.07
1.40	22.54	3.50	10.87
1.45	21.83	3.60	10.67
1.50	21.18	3.70	10.49
1.55	20.57	3.80	10.32
1.60	20.00	3.90	10.15
1.65	19.47	4.00	10.00
1.70	18.97	4.10	9.85
1.75	18.49	4.20	9.72
1.80	18.05	4.30	9.58
1.85	17.63	4.40	9.46
1.90	17.24	4.50	9.34
1.95	16.87	4.60	9.22
2.00	16.51	4.70	9.12
2.05	16.18	4.80	9.02
2.10	15.86	4.90	8.92
2.15	15.56	5.00	8.83
2.20	15.27	5.10	8.74
2.25	14.99	5.20	8.66
2.30	14.74	5.30	8.58
2.35	14.49	5.40	8.50
2.40	14.26	5.50	8.42
2.45	14.03	5.60	8.35
2.50	13.81	5.70	8.27
2.55	13.60	5.80	8.21
2.60	13.40	5.90	8.14
2.65	13.21	6.00	8.09
2.70	13.02		

Table II.

Data for preparing ruler when distance from crystal to plate is 4 cm.

Left side of ruler cm.	Right side of ruler cm	Left side of ruler cm.	Right side of ruler cm.
1.20	34.06	3.10	14.61
1.25	32.77	3.20	14.25
1.30	31.57	3.30	13.92
1.35	30.45	3.40	13.60
1.40	29.42	3.50	13.31
1.45	28.45	3.60	13.03
1.50	27.58	3.70	12.77
1.55	26.74	3.80	12.52
1.60	25.96	3.90	12.29
1.65	25.23	4.00	12.07
1.70	24.55	4.10	11.86
1.75	23.90	4.20	11.67
1.80	23.29	4.30	11.48
1.85	22.73	4.40	11.30
1.90	22.19	4.50	11.13
1.95	21.67	4.60	10.97
2.00	21.18	4.70	10.82
2.05	20.72	4.80	10.68
2.10	20.28	4.90	10.54
2.15	19.86	5.00	10.40
2.20	19.47	5.10	10.28
2.25	19.09	5.20	10.15
2.30	18.72	5.30	10.04
2.35	18.38	5.40	9.93
2.40	18.05	5.50	9.82
2.45	17.74	5.60	9.71
2.50	17.44	5.70	9.62
2.55	17.14	5.80	9.52
2.60	16.87	5.90	9.43
2.65	16.60	6.00	9.34
2.70	16.35	6.10	9.26
2.75	16.10	6.20	9.18
2.80	15.86	6.30	9.10
2.85	15.63	6.40	9.02
2.90	15.42	6.50	8.95
2.95	15.20	6.60	8.88
3.00	15.00	6.70	8.81
		6.80	8.74
		6.90	8.68
		7.00	8.61

TABLE III.

Data for preparing ruler when distance from crystal to plate is 5 cm.

Left side of ruler cm.	Right side of ruler cm.	Left side of ruler cm.	Right side of ruler cm.
1.50	34.06	3.60	15.50
1.55	33.01	3.65	15.33
1.60	32.02	3.70	15.16
1.65	31.10	3.75	14.99
1.70	30.24	3.80	14.84
1.75	29.41	3.85	14.69
1.80	28.65	3.90	14.54
1.85	27.92	3.95	14.40
1.90	27.23	4.00	14.26
1.95	26.58	4.10	13.98
2.00	25.96	4.20	13.73
2.05	25.38	4.30	13.48
2.10	24.82	4.40	13.25
2.15	24.29	4.50	13.02
2.20	23.78	4.60	12.82
2.25	23.29	4.70	12.62
2.30	22.84	4.80	12.43
2.35	22.39	4.90	12.25
2.40	21.97	5.00	12.07
2.45	21.57	5.10	11.90
2.50	21.18	5.20	11.74
2.55	20.81	5.30	11.59
2.60	20.45	5.40	11.44
2.65	20.11	5.50	11.30
2.70	19.78	5.60	11.17
2.75	19.47	5.70	11.04
2.80	19.16	5.80	10.91
2.85	18.87	5.90	10.79
2.90	18.58	6.00	10.67
2.95	18.31	6.10	10.56
3.00	18.05	6.20	10.45
3.05	17.80	6.30	10.35
3.10	17.55	6.40	10.25
3.15	17.32	6.50	10.15
3.20	17.09	6.60	10.06
3.25	16.87	6.70	9.97
3.30	16.65	6.80	9.88
3.35	16.44	6.90	9.80
3.40	16.24	7.00	9.72
3.45	16.05		
3.50	15.86		
3.55	15.68		

another (fig. 2); in this way the indices of a plane are expressed by their Bravais-Miller symbols. Then, if the fundamental lattice is really rhombohedral so that it is desirable to refer the planes to the rhombohedral, *i. e.* deformed cubic, axes, the necessary transformation to Miller indices may be made with the aid of the familiar transformation:[12]

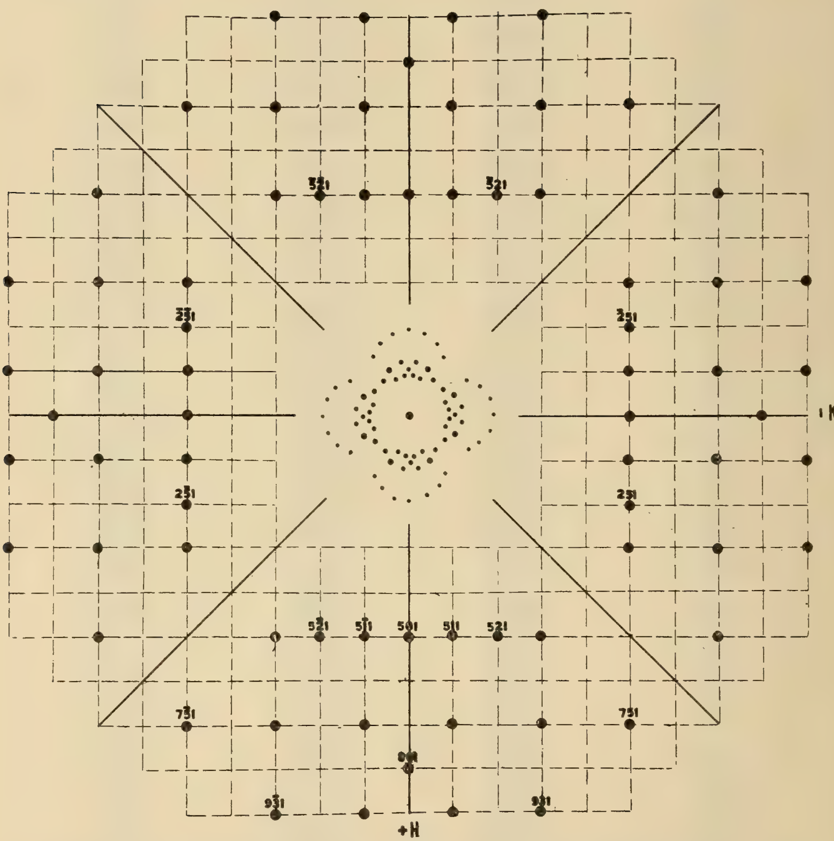


FIG. 6.—The gnomonic projection of a simple Laue photograph (X-rays parallel to the *c*-axis of rutile). The indices of the reflecting planes are directly obtained from the coordinates of their projected positions.

$$h = 2\mathrm{H} + \mathrm{K} + \mathrm{L}$$
$$k = \mathrm{K} - \mathrm{H} + \mathrm{L}$$
$$l = -2\mathrm{K} - \mathrm{H} + \mathrm{L}.$$

H K L, suppressing as unnecessary the third index, are the Bravais-Miller indices, and $h\ k\ l$ are the Miller indices.

[12] P. Groth, Physikalische Krystallographie, p. 434, 1895.

In the case of calcite and rhodochrosite only those planes are found reflecting for which the value of H K · L fulfills the following conditions

$$\frac{2H + K + L}{3} = \text{whole number}$$

$$\frac{K - H + L}{3} = \text{whole number}$$

$$\frac{-2K - H + L}{3} = \text{whole number}$$

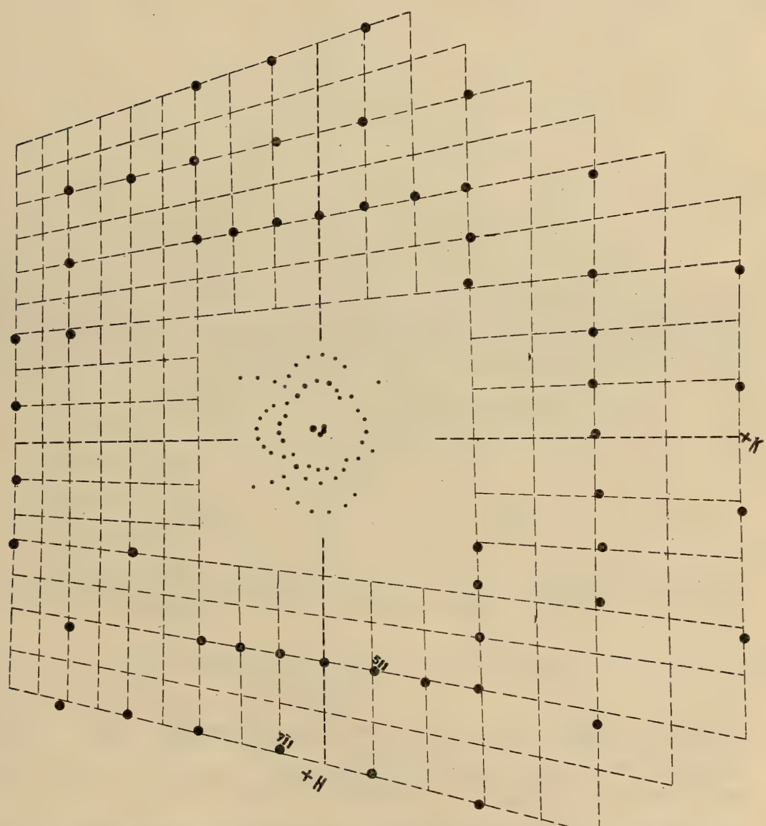


FIG. 7.—The gnomonic projection of an unsymmetrical Laue photograph. The rays were passed through the section of rutile used for Figure 6 at a considerable inclination to the *c*-axis. There is no difficulty in getting the indices of these planes.

The preponderance of such planes is to be expected when the fundamental lattice is rhombohedral but not when it is hexagonal, and serves as a convenient criterion for distinguishing between the two possible units of structure.

It may sometimes happen that, in order to get reflections from more planes than can be obtained from one crystal section, it is desirable to use sections cut parallel to some more complicated plane of the crystal. For instance, in order to get reflections from more planes of calcite and rhodochrosite, photographs were taken through

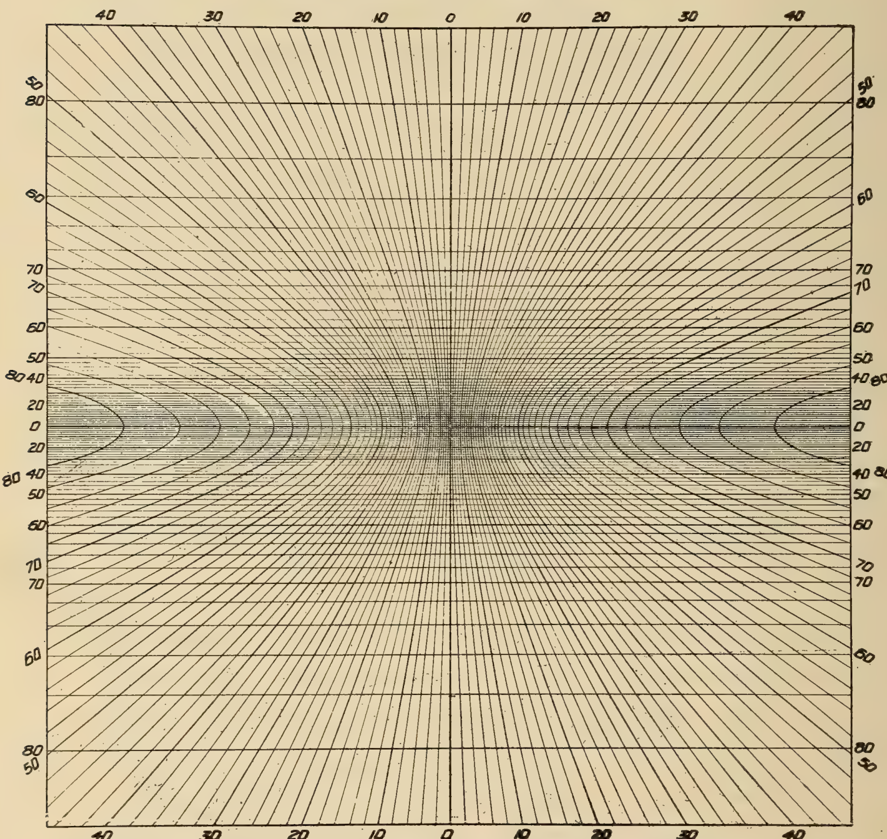


Fig. 8.—The gnomonic net. If this figure is enlarged so that it is *70 cm.* on a side, it will serve as a net for sphere of radius of *5 cm.*

cleavage pieces. The indices of planes reflecting in such a photograph may be found if several of the most important planes are recognized, by getting the indices of the various zone axes; or quite simply, the gnomonic net of H. Hilton[13] may be employed. The projection has simply to

[13] H. Hilton, Mineralogical Mag. 14, 18, 1904.

be rotated until the symmetrical pattern is obtained and then the indices may be read off as before. This is done, as he points out, by first turning the plot so that the line joining the center with the point P, which is to become the center of the projection, will be perpendicular to the straight (longitude) lines of the net and then by moving all the points through the necessary angle along the hyperbolas (of latitude). It can be done quite simply by working on tracing paper or cloth over the net. The gnomonic

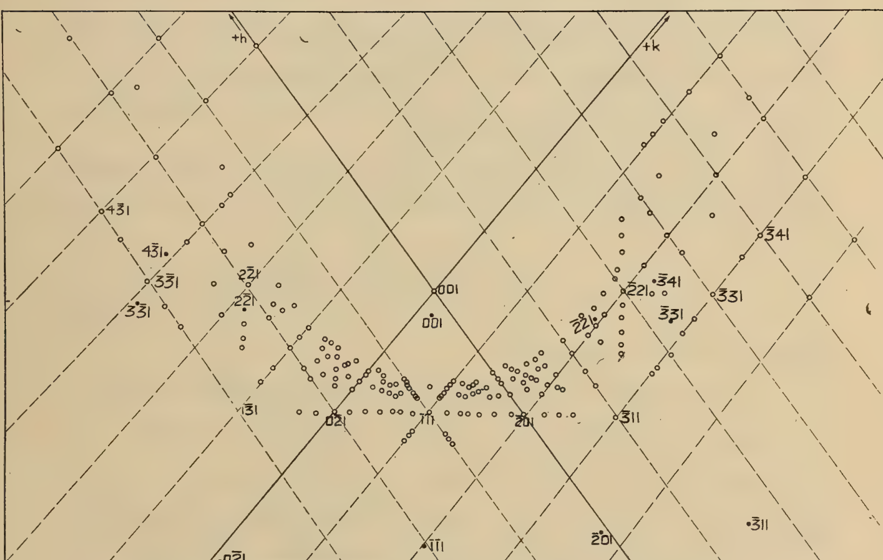


FIG. 9.—The "symmetrical" pattern obtained by rotating the projection of fig. 3 through an angle sufficient to throw the (110) plane to infinity. The indices of the planes can now be read from their coordinate positions.

net, as given by Hilton, cannot be used because it does not extend to great enough angles.

The computations necessary for constructing a 65° net have been given.[14] The values necessary to extend it to 80°, as is required for this purpose, may be obtained in the same way. A reduction of such a net is given in fig. 8. If this is enlarged photographically so that it is exactly 70 cm. on a side, it will serve as a net for a sphere of *5 cm.* radius.

In order to determine the indices of the reflecting planes in a photograph through a cleavage piece of calcite,

[14] G. F. H. Smith, Zs. Kryst., 39, 142, 1904.

the following procedure was used. First a gnomonic projection of the pattern was prepared in the customary manner (fig. 3). The position of the (110) plane (crystallographic axes) is readily found from a knowledge of the distance from the crystal to the plate and from the crystallographic data. If now the plane of the projection is rotated through an angle sufficient to throw the projection of this plane to infinity, a symmetrical pattern will be obtained from which the indices of a majority of the planes may be readily obtained (fig. 9). It will be observed that this pattern is really the specialized case of a triclinic pattern in which the axes are of equal length. The indices of those planes which pass off the projection when it is rotated can afterwards be determined on the original projection from their zonal relations.

The Data from the Laue Photographs.—The spacing between like planes in the rhombohedral lattice is given by the expression[15]

$$d = \frac{c\sqrt{1 + 2\cos^3 a - 3\cos^2 a}}{\sqrt{(h^2 + k^2 + l^2)\sin^2 a + 2(hk + hl + kl)(\cos^2 a - \cos a)}}$$

where $d =$ the spacing,

$c =$ length of the side of the unit rhombohedron,

$a =$ the angle between the trigonal axes, and

$hkl =$ the Miller indices of a plane.

a is here to be taken for the second set of axes; c, the length of the side of the corresponding unit, is readily obtained from the spacing measurements. Since the distance of any reflection from the central spot on the photographic plate has been measured and since the distance from the crystal to the plate is known, sin θ, where θ is the angle of reflection, can be obtained. Consequently $n\lambda$, where n is the order of the reflection and $\lambda =$ the wave length of the reflected X-rays, can be determined for each spot by using the customary expression, $n\lambda = 2d \sin \theta$. When the values of $n\lambda$, so obtained, were plotted against the estimated intensities of the spots, and those points which correspond with planes of the same *form* were connected together, a series of curves, one above another, was obtained. It was thus possible to compare many planes of different forms in the same wave length. These curves are portions of curves which represent in shape the

[15] A. W. Hull, Phys. Rev., (2) 10, 661, 1917.

effect of the X-ray beam upon the photographic plate. Some planes seem to be reflecting rays shorter than any existing in the original beam values of ($n\lambda < 0.25$ A. U.). It was observed, however, that each of these planes has indices that are all odd. By taking a new set of axes, which have the directions of the diagonals of the faces of the rhombohedron made by the axes of the second set, these "half order" reflections become first order reflections of twice the previous values of $n\lambda$, thus removing all

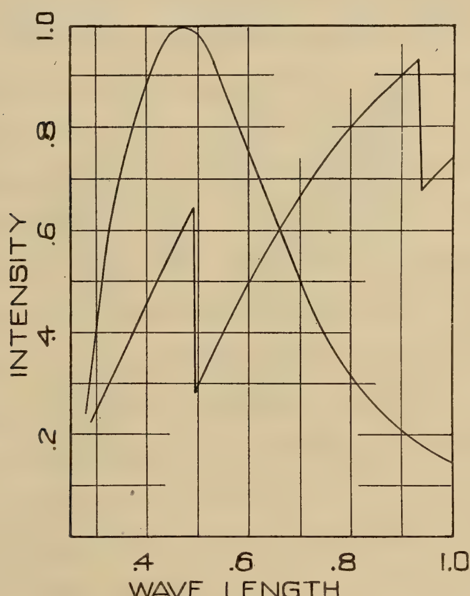


FIG. 10.—The smooth curve represents the relative intensity of X-rays of different wave lengths for the "white" radiation from tungsten when the voltage across the tube is 50,000 volts. The other gives the calculated amount of absorption of a certain thickness of silver bromide.

anomalies in the results from the photographs. This transformation of axes is the same that had to be applied to sodium nitrate.[16] The relations between the three sets of axes that have been considered are shown in fig. 1. The transformation from the second set of axes (those used in considering the Laue photographs) to the new set of axes (to be used in determining the arrangement of atoms) may be effected by the following expressions:

[16] R. W. G. Wyckoff, op. cit.

$h = K + L$; $k = H + L$; $l = K + H$, where H, K, L, are the indices according to the second set and $h\ k\ l$ those according to the new axes.[17] Calculations show that there are two molecules associated with the new unit rhombohedron.

The Effect of the Voltage applied to the Tube upon the Resulting Photograph.—It is a matter of considerable importance to know the general shape of the curve obtained after plotting *$n\lambda$ against intensity* for the various spots. The following considerations were made in order to determine the effect upon the curve of impressing different voltages upon the X-ray tube and to find out if filtering screens would prove useful. Two factors are known to influence the photographic effect of a beam of X-rays: the distribution of energy in the beam from the tube, and the selective absorption by the silver "emulsion" of the plate.

The relative intensity of the X-rays of different wave lengths in the region of the "white radiation" from a tungsten target for a certain voltage is shown in fig. 10.[18] The higher the voltages, the greater becomes the intensity of the X-rays of all wave lengths and the shorter is the wave length of maximum intensity. The X-ray spectrum of tungsten has been mapped for various voltages[19] and careful measurements have been made in the region of the white radiation for voltages up to 50 kilovolts.[20]

It has also been shown that the effect of X-rays upon the photographic plate, at any rate in this region of the X-ray spectrum, is quite closely proportional to the absorption by the silver bromide of the plate.[21] If this proportionality is assumed to be true, the relative effect of X-rays of different wave lengths can be simply calculated from the mass absorption coefficients of silver and bromine. The absorption can be represented over a considerable range of wave lengths with some degree of accuracy by the equations:[22]

[17] This transformation of course applies equally well to the passing from the crystallographic to the second set of axes. A change in the opposite direction can be made by remembering that $H = k + l - h$; $K = h + l - k$; $L = h + k - l$.

[18] C. T. Ulrey, Phys, Rev., (2), **11**, 401, 1918.

[19] A. W. Hull, Proc. Nat. Acad. Sci., **2**, 265, 1916.

[20] C. T. Ulrey, op. cit.

[21] C. G. Barkla and G. H. Martyn, Phil. Mag., (6) **25**, 296, 1913.

[22] W. Kossel, Verhandl. deutsch. phys. Ges., **16**, 898, 1914.

$$\frac{\mu}{\rho} = A\,\lambda^{b} \text{ for } \lambda > \lambda_A \quad \text{and}$$

$$\frac{\mu}{\rho} = A'\,\lambda^{b} \text{ for } \lambda < \lambda_A$$

where $\frac{\mu}{\rho}$ is the uncorrected (for scattering, which actually is quite negligible here) mass absorption coefficient. A and A′ are constants for a particular atomic number Z and are roughly linear logarithmic functions of the atomic number. b is constant for a particular element and has values for different elements lying between 2.55 and 2.90.

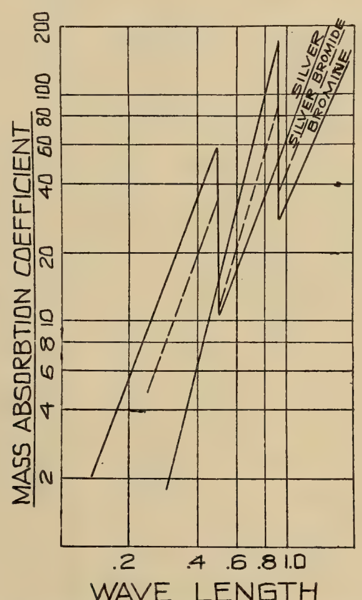


FIG. 11.—The mass absorption coefficient-wave length curves for silver, bromine and silver bromide.

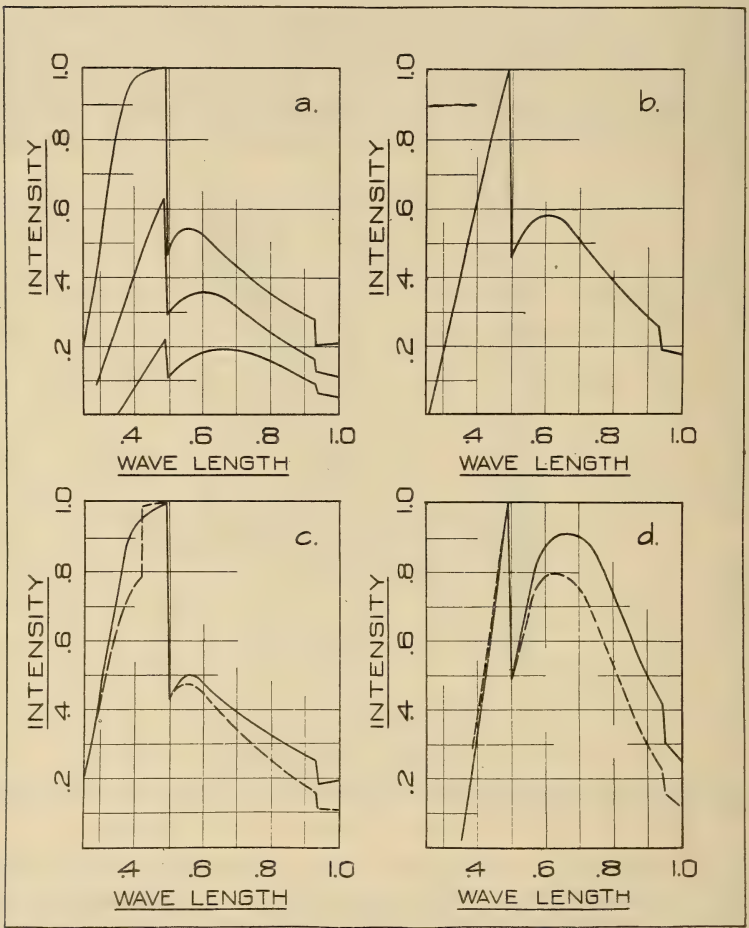
On this basis the absorption curve for silver can be written, knowing that A = 66, A′ = 389, b = 2.65, and λ_A the critical absorption wave length of silver, $= 0.49 \times 10^{-8}$ cm. This curve is shown in fig. 11. The information concerning the absorption of bromine is meager, but assuming the above relations, an approximation to its absorption curve can be obtained.

$A = 0{\cdot}004\ Z^{3{\cdot}14}$, $A' = 0{\cdot}0195\ Z^{2{\cdot}58}$; $\lambda_A = 0{\cdot}93 \times 10^{-8}$ cm.;[23]

[23] R. Glocker, Phys. Zeit. 19, 66, 1918.

b is taken to be 2.65. The resulting curve for bromine is also given in fig. 11. The curve for silver bromide then is obtained by combining these two absorptions, remembering that 108 grams of silver react with 80 grams of bromine. (Fig. 11.) The *amount* of X-rays absorbed

FIG. 12.



by a convenient thickness of AgBr can be readily obtained from this mass absorption curve and is shown in fig. 10.

Since there is an uneven distribution of energy in the different wave lengths, the effect on the photographic plate is to be obtained by combining this curve (fig. 10) with wave length-intensity curves, like those of Ulrey[24] for

[24] C. T. Ulrey, op. cit.

different voltages. The smooth curve of fig. 20 is the curve for 50,000 volts. The graphs of fig. 12*a* show the effect on the plate when the voltage across the tube is respectively (1) 40 K.V., (2) 50 K.V., and (3) 60 K.V. The last, and tallest, (3), is calculated using what seem to be the most probable values at hand. The full curves of figs. 12 *b, c, d* are the same ones as those of fig. 12*a,* but now each is calculated on the basis of unit effect at the point of maximum absorption. These are more useful because it is the *shape* of these curves that is of importance; greater intensity can always be obtained by a longer exposure. All agree in showing the greatest effect upon the plate at the position of maximum absorption for silver. In the case of the lowest voltage (40,000) the intensity is seen to rise rapidly to the maximum (fig. 12*d*) and then drop, a state of affairs particularly desirable since the radiation here is very nearly monochromatic. The intensity then rises again between the first and second reflections to another maximum nearly as important as the first, after which it falls off till the critical absorption of bromine is reached, when it takes a further fall. At still lower voltages the continued shift of the maximum in the direction of longer wave lengths would shortly dwarf the silver absorption peak into insignificance compared with the second maximum. This is highly undesirable because only the short wave lengths are useful, for the reason that a reflection in the neighborhood of $n\lambda$ equal to the longer wave length maximum might be either a first order for this region, the second order of a much shorter wave length, or both together.

At 50 K.V. the intensity distribution curve has its maximum near the critical absorption value for silver, and as a result the relative effect of this region of wave lengths is great. Fig. 12*b* shows that the second maximum has become insignificant. As the voltage is made still higher (60 K.V.) the further shift of the intensity curve (fig. 12*c*) towards short wave lengths results in there being a considerable spectrum range, just shorter than the critical value of silver, over which there is a marked effect upon the photographic plate. At the same time the longer wave length maximum has disappeared. Raising the voltage to a higher value would cause this process of increasing the effect of the shorter wave lengths to continue so that the point would soon be reached where the maximum effect would no longer remain at the critical absorption value for silver but would shift towards the shorter wave lengths, more as the voltage is raised.

It is of interest to inquire how closely these relative absorption curves for various voltages approach to a curve for the effect of an X-ray beam upon a photograph plate which would be ideal for Laue photographs. Such a curve would start from zero, rise quite rapidly to a decided maximum (in actual practice this would be the critical silver value ($\lambda = 0.49$) and immediately fall off to a negligible value. Monochromatic radiation, on the one hand, is not desired because so few planes would be in a position to reflect the particular wave length for one setting of the crystal; on the other hand, if the curve rises but slowly over a considerable range of wave lengths, many planes will produce weak spots because they are reflecting X-rays which are not particularly intense. If, again, there is a considerable effect upon the plate for wave lengths *longer than* $n\lambda = 0.49$, there will be produced a considerable number of useless reflections. The result in either of these last two cases is simply that more work is required to interpret the Laue patterns because of the presence of a large number of not particularly valuable reflections. There should be no radiation shorter than half the critical value for silver

$$\frac{0{\cdot}49\ \text{A. U.}}{2} = 0{\cdot}24^5\ \text{A. U.},$$

for otherwise it would be impossible to use the values in the neighborhood of $n\lambda = 0.49$ as assuredly of the first order. This state of affairs is most nearly met by the curve for 50,000 volts. At appreciably higher voltages there is radiation in the wave lengths shorter than 0.25 A.U.; if, again, lower voltages are used, the energy in the wave lengths around 0.49 A.U. becomes small so that a very long exposure is necessary and the second useless maximum becomes relatively of great importance. Except at voltages too low to be useful, the relative amount of energy in the wave lengths about the critical absorption of bromine is so small that the break in photographic effect at this point is negligible.

It was thought that the use of *filters* might furnish a more ideal curve. Such screening might be employed either with a higher voltage to cut down the extremely short wave lengths, or it might serve to reduce the importance of the long wave lengths, especially for low voltages across the X-ray tube. The dotted curve of fig. 12*c* shows the *relative* effect of a screen of tin thick enough to absorb one-tenth of the radiation at $\lambda = 0.49$ A.U. for a voltage of 60 K.V. The change of the shape of the curve is not very emarkable and the new one does not show enough advantages to repay the loss in useful wave lengths by absorption. Under the ordinary conditions of experimentation if would not be feasible to use higher voltages and cut down the very short wave lengths, less than $\lambda = 0.25$ A.U., by appropriate screens because of the absorption of these materials in the region of $\lambda = 0.45 — 0.49$ A.U.

The material most effective in reducing the intensity of the longer wave lengths is a substance, like aluminum, which shows no selective absorption in the region of the spectrum employed. This kind of filtering would only be serviceable in improving the lower voltage curves. Fig. 12*d* gives the curve obtained by interposing a thickness of aluminum sufficient to reduce $\lambda = 0.49$ in the 40 K.V. plot to 90 per cent of its unscreened value. Even neglecting the loss of valuable radiation, the result is not as good as the unscreened 50 K.V. curve. Neither does an aluminum filter improve the 50 K.V. curve sufficiently to make its use worth while.

The conclusions to be drawn from this discussion are:

(1) That the most useful Laue photographs are obtained by operating a tungsten tube, if this is used, at 50 K.V.

(2) That the use of various screens is not desirable. Of course this discussion has assumed that the photographic effect of X-rays was proportional to the amount of their absorption in the silver bromide of the plate, an assumption which seems sufficiently correct for the present purpose.

The Calculations from the Laue Photographs.—The symmetry of calcite is that of the point group D_3^d.[25] Of the six space groups which have this symmetry, four have Γ_h, the hexagonal lattice, as the fundamental lattice. The calculation of $\frac{n^3}{m}$ from the spectrum measurements and the nature of the planes producing reflections in the Laue photographs lead to the conclusion that the fundamental lat-

[25] A. Schönflies, Krystallsysteme u. Krystallstructur, 1891.

tice is rhombohedral, Γ_{rh}. Calcite must then be assigned to one of the two space groups D^5_{3d} or D^6_{3d}, which have Γ_{rh} as the underlying lattice. These two space groups are derived from the space group D^7_3 by multiplying it by an inversion. D^7_3 is obtained by placing a point group D_3 at each point of the lattice, Γ_{rh}. If the point of inversion is at the intersection of a trigonal axis and a perpendicular digonal axis, D^5_{3d} results; if the inversion is about a point midway between two such intersections, D^6_{3d} is obtained.

The coördinates of equivalent points of the space group D^5_{3d} are then:

$$x\,y\,z,\ y\,z\,x,\ z\,x\,y,\ \bar{y}\,\bar{x}\,\bar{z},\ \bar{x}\,\bar{z}\,\bar{y},\ \bar{z}\,\bar{y}\,\bar{x},$$

$$\bar{x}\,\bar{y}\,\bar{z},\ \bar{y}\,\bar{z}\,\bar{x},\ \bar{z}\,\bar{x}\,\bar{y},\ y\,x\,z,\ x\,z\,y,\ z\,y\,x.$$

Those of D^6_{3d} are:

$$\begin{array}{ccccccccc} x & y & z; & y & z & x; & z & x & y; \\ \tau_x - x, & \tau_y - y, & \tau_z - z; & \tau_x - y, & \tau_y - z, & \tau_z - x; & \tau_x - z, & \tau_y - x, & \tau_z - y; \\ \bar{y} & \bar{x} & \bar{z}; & \bar{x} & \bar{z} & \bar{y}; & \bar{z} & \bar{y} & \bar{x}; \\ \tau_x + y; & \tau_y + x, & \tau_z + z; & \tau_x + x, & \tau_y + z, & \tau_z + y; & \tau_x + z, & \tau_y + y, & \tau_z + x; \end{array}$$

where

$$\tau_x = \tau_y = \tau_z$$

is a translation of half the length of a side of the unit rhombohedron (half a primitive translation) in the direction of the subscripted axis.

All the special cases of these two space groups where the twelve equivalent points are reduced to one, two, three, four and six equivalent positions, can be obtained by equating one equivalent point with each of the others. (The length of the side of the unit equals one.)

D^5_{3d} —

One equivalent point.

(*a*) 0 0 0. (*b*) 1/2 1/2 1/2

Two equivalent points.

(*a*) $u\ u\ u,\ \bar{u}\ \bar{u}\ \bar{u}$.

Three equivalent points.

(*a*) 0 0 1/2, 0 1/2 0, 1/2 0 0.

(*b*) 0 1/2 1/2, 1/2 1/2 0, 1/2 0 1/2.

Six equivalent points.

(*a*) $u\ \bar{u}\ 0,\ \bar{u}\ 0\ u,\ 0\ u\ \bar{u},\ \bar{u}\ u\ 0,\ u\ 0\ \bar{u},\ 0\ \bar{u}\ u.$

(*b*) $u\ \bar{u}\ 1/2,\ \bar{u}\ 1/2\ u,\ 1/2\ u\ \bar{u},\ \bar{u}\ u\ 1/2,\ u\ 1/2\ \bar{u},\ 1/2\ \bar{u}\ u.$

(*c*) $u\ u\ v,\ u\ v\ u,\ v\ u\ u,\ \bar{u}\ \bar{u}\ \bar{v},\ \bar{u}\ \bar{v}\ \bar{u},\ \bar{v}\ \bar{u}\ \bar{u}.$

D^{6}_{3d} —

Two equivalent points.

(*a*) 0 0 0, 1/2 1/2 1/2.

(*b*) 1/4 1/4 1/4, 3/4 3/4 3/4.

Four equivalent points.

(*a*) $u\ u\ u;\ \bar{u}\ \bar{u}\ \bar{u};\ 1/2-u,\ 1/2-u,\ 1/2-u;\ u+1/2,\ u+1/2,\ u+1/2.$

Six equivalent points.

(*a*) 1/4 3/4 3/4; 3/4 3/4 1/4; 3/4 1/4 3/4; 1/4 3/4 1/4; 3/4 1/4 1/4; 1/4 1/4 3/4.

(*b*) $u\ \ \bar{u}\ \ 0;\ \ \bar{u}\ \ 0\ \ u;$
$1/2-u,\ u+1/2,\ 1/2;\ u+1/2,\ 1/2,\ 1/2-u;$
$0\ \ u\ \ \bar{u};$
$1/2\ \ 1/2-u,\ u+1/2.$

(*c*) $u\ \ \bar{u}\ \ 1/2;\ \ \bar{u}\ \ 1/2\ \ u;$
$1/2-u,\ u+1/2,\ 0;\ u+1/2,\ 0,\ 1/2-u;$
$1/2\ \ u\ \ \bar{u};$
$0,\ 1/2-u,\ u+1/2.$

Two molecules of $CaCO_3$ are to be associated with the simplest unit of structure—that corresponding with the newest set of axes. Since in neither group are found four cases of one equivalent point, the two calcium atoms must be equivalent and the two carbon atoms must also be equivalent one to the other. The oxygen atoms must either be all equal (at six equivalent positions), or four alike and two different, or three sets of two like atoms, or lastly two sets of three like atoms. This last arrangement is improbable because it is to be supposed that the three oxygen atoms associated with each carbon atom would be similarly related to this carbon atom—a state of affairs impossible with two sets of three equivalent positions. The above conditions are only fulfilled by arranging the atoms of $2CaCO_3$ in any one of the following ways.

Space Group D^5_{3d}.

(*a*) $Ca = u_3\, u_3\, u_3$ and $\bar{u}_3\, \bar{u}_3\, \bar{u}_3$.
$C = u'\, u'\, u'$ and $\bar{u}'\, \bar{u}'\, \bar{u}'$.
$O = u\, \bar{u}\, 0,\ \bar{u}\, 0\, u,\ 0\, u\, \bar{u},\ \bar{u}\, u\, 0,\ u\, 0\, \bar{u},\ 0\, \bar{u}\, u.$

(*b*) Ca and C same as (a).
$O = u\, \bar{u}\, 1/2,\ \bar{u}\, 1/2\, u,\ 1/2\, u\, \bar{u},\ \bar{u}\, u\, 1/2,$
$u\, 1/2\, \bar{u},\ 1/2\, \bar{u}\, u.$

(*c*) Ca and C same as (a).
$O = u\, u\, v,\ u\, v\, u,\ v\, u\, u,\ \bar{u}\, \bar{u}\, \bar{v},\ \bar{u}\, \bar{v}\, \bar{u},\ \bar{v}\, \bar{u}\, \bar{u}.$

(*d*) Ca and C same as (a)
$u''\bar{u}''u'',\ \bar{u}''\bar{u}''\bar{u}'';\ u_1u_1u_1,\ \bar{u}_1\bar{u}_1\bar{u}_1;\ u_2u_2u_2,\ \bar{u}_2\bar{u}_2\bar{u}_2$

(*e*) Ca and C same as (a).
O = 0 0 1/2, 0 1/2 0, 1/2 0 0; 0 1/2 1/2,
1/2 1/2 0, 1/2 0 1/2.

Space Group D^6_{3d}.

(*f*) Ca = 1/4 1/4 1/4, 3/4 3/4 3/4, or 0 0 0, 1/2 1/2 1/2.
C = 0 0 0 , 1/2 1/2 1/2, or 1/4 1/4 1/4, 3/4 3/4 3/4.
O = 1/4 3/4 3/4, 3/4 3/4 1/4, 3/4 1/4 3/4, 1/4 3/4 1/4,
3/4 1/4 1/4, 1/4 1/4 3/4.

(*g*) Ca and C as in (f).
$O = u\, \bar{u}\, 0;\ \bar{u}\, 0\, u;\ 0\, u\, \bar{u};\ 1/2-u,\ u+1/2,\ 1/2;$
$u+1/2,\ 1/2,\ 1/2-u;\ 1/2,\ 1/2-u,\ u+1/2.$

(*h*) Ca and C as in (f).
$O = u\, \bar{u}\, 1/2;\ \bar{u}\, 1/2\, u;\ 1/2\, u\, \bar{u};\ 1/2-u,\ u+1/2,\ 0;$
$u+1/2,\ 0,\ 1/2-u;\ 0,\ 1/2-u,\ u+1/2.$

All but a very few of the planes that are reflecting in the first order have indices that are two odd and one even. This fact points clearly to a body-centered structure for calcium carbonate. None of the arrangements developed from the space group D^5_{3d} is body-centered. Also any arrangement which might conceivably be built up from D^5_{3d} to contain the necessary mass would give reflections from different planes which would be strongly affected by the value of $h + k + l$; such a state of affairs is contrary to experimental results. Consequently it may be concluded that the space group of calcite is D^6_3 .

The intensity of reflection by a plane whose Miller indices are *h, k, l* can be represented as *proportional* to the following expression:

$$\text{Intensity} \propto f\left(\frac{d}{n}\right)\left\{ \left[\sum_m \rho_m \cos 2\pi n\,(hx_m + ky_m + lz_m)\right]^2 + \left[\sum_m \rho_m \sin 2\pi n\,(hx_m + ky_m + lz_m)\right]^2 \right\}$$

where the summation is taken from each atom m in the unit of structure. ρ_m is the scattering power of the atom m; its coördinates are x_m, y_m, z_m. If the inverse-sine-square law held, then $f\left(\frac{d}{n}\right)$ would of course be $\left(\frac{d}{n}\right)^2$, where d is the spacing of planes $h\ k\ l$ in the unit and n is the order of the reflection.

In arrangement (f) if the calcium atoms are placed at (1/4 1/4 1/4) and (3/4 3/4 3/4) and the carbon atoms at (0 0 0) and (1/2 1/2 1/2), the first order reflection by a plane ($h\ k\ l$) in the crystal can then be written:

$$A^2+B^2 \propto \text{Intensity}$$

$$A = 2\overline{Ca}\left\{\cos\frac{\pi}{2}(h+k+l)\right\} + \overline{C}\left\{1+\cos\pi(h+k+l)\right\} + \overline{O}\left\{\cos\frac{\pi}{2}(3h+k+3l) + \cos\frac{\pi}{2}(h+3k+l) + \cos\frac{\pi}{2}(3h+k+l) + \cos\frac{\pi}{2}(h+k+3l) + \cos\frac{\pi}{2}(h+3k+3l) + \cos\frac{\pi}{2}(3h+3k+l)\right\}$$

$$B = 2\overline{Ca}\,(0) + 2\overline{C}\,(0) + \overline{O}\left\{\sin\frac{\pi}{2}(h+3k+3l) + \sin\frac{\pi}{2}(3h+3k+l) + \sin\frac{\pi}{2}(3h+k+3l) + \sin\frac{\pi}{2}(h+3k+l) + \sin\frac{\pi}{2}(3h+k+l) + \sin\frac{\pi}{2}(h+k+3l)\right\}.$$

$\overline{Ca}$, $\overline{C}$ and $\overline{O}$ are the scattering powers of calcium, carbon and oxygen respectively. In case all the indices are odd, or two are even and one is odd (the sum $h+k+l$ is odd), both the A and the B terms disappear. This is also true if the positions of calcium and carbon are interchanged. But since several first order reflections are found from planes having one odd and two even indices, this arrangement must not be the correct one.

A term which will be proportional to the intensity of reflection if the atoms are arranged according to (g) may similarly be written:

$$A^2 + B^2 \propto \text{Intensity}$$

$$A = 2\overline{Ca}\left\{\cos\frac{\pi}{2}(h+k+l)\right\} + \overline{C}\left\{1+\cos\pi(h+k+l)\right\} + \overline{O}$$
$$\{\cos 2\pi u(h-k)(1+\cos\pi s_1) + \cos 2\pi u(l-h)(1+\cos\pi s_2) + \cos 2\pi u(k-l)(1+\cos\pi s_3)\}.$$

$$B=\overline{O}\,\{\sin 2\pi u(h-k)(1-\cos\pi s_1) + \sin 2\pi u(l-h)(1-\cos\pi s_2) + \sin 2\pi u(k-l)(1-\cos\pi s_3)\},$$ where
$$s_1=h-k+l,\ s_2=k-h+l,\ s_3=h+k-l.$$

When all the indices are odd or two are even and one is odd, this expression reduces to

$$A = 0$$
$$B = 2\,\bar{O}\,\{\sin 2\,\pi\,u\,(h-k) + \sin 2\,\pi\,u\,(l-h) + \sin 2\,\pi\,u\,(k-l)\}.$$

When they are two odd and one even:

$$A = 2\,\bar{C} \pm \bar{C}a + 2\,\bar{O}\,\{\cos 2\,\pi\,u\,(h-k) + \cos 2\,\pi\,u\,(l-h) + \cos 2\,\pi\,u\,(k-l)\}.$$
$$B = 0.$$

FIG. 13, *a*

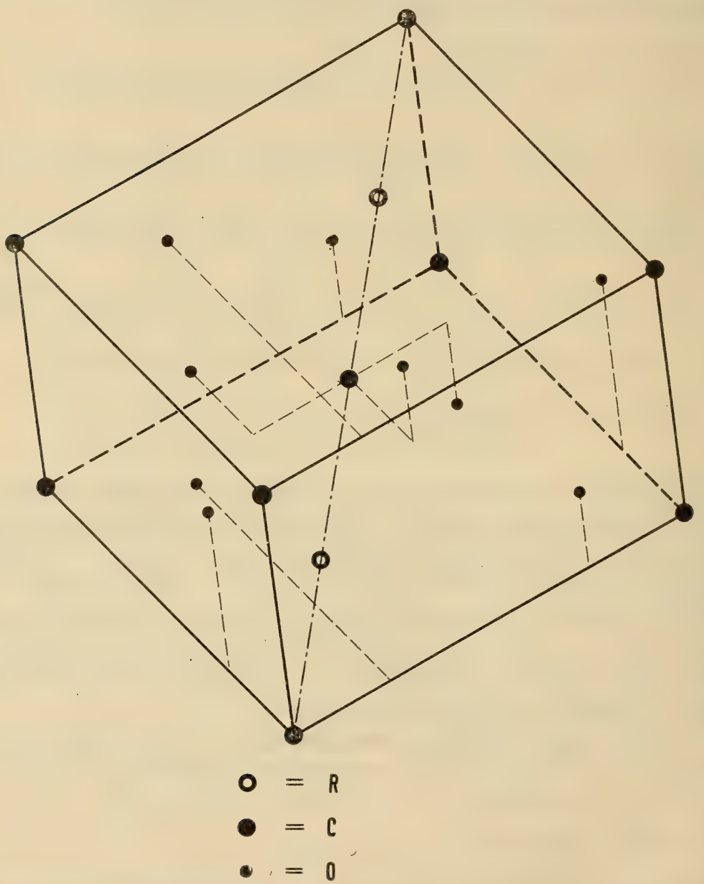
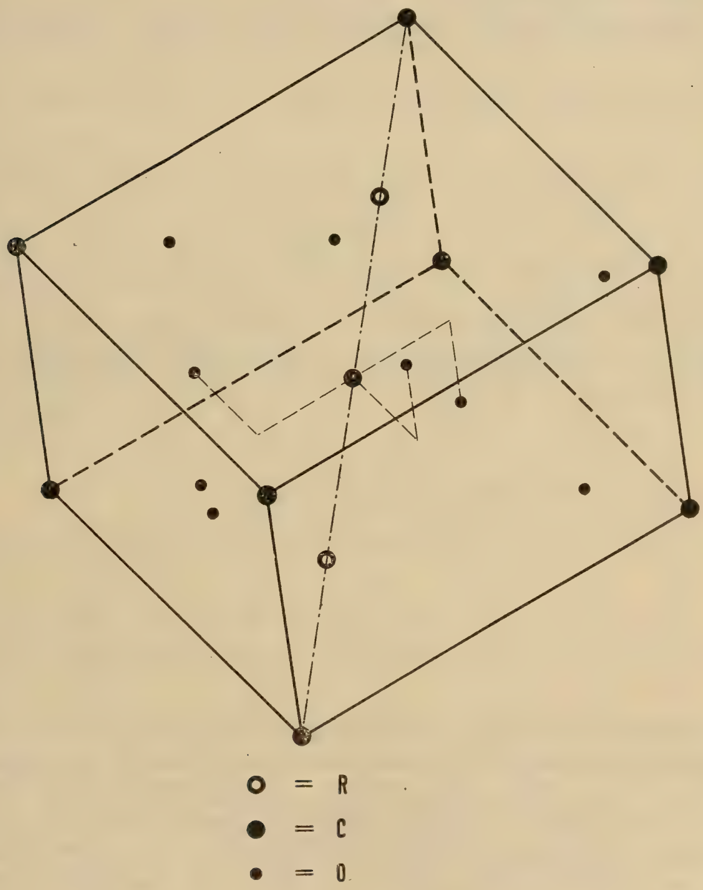


FIG. 13.—The arrangement of the atoms in the unit of structure of members of the calcite group, RCO_3.

If $(h+k+l)$ is divisible by four, the calcium term should be added to the carbon and oxygen terms; if on the other hand, this sum can be divided by two only, the emplitude contributed by the calcium atoms should be of opposite sign to that of carbon and oxygen.

The calcium and carbon terms in these equations should be interchanged if the positions of these atoms in the unit are the reverse of those assumed here. Otherwise the expressions are the same in the two cases.

FIG. 13, *b*



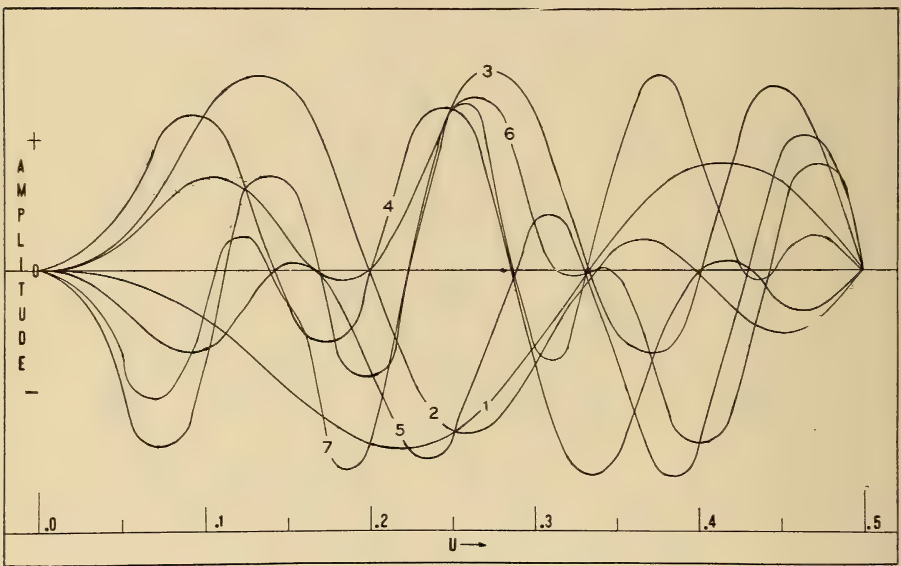
In the present instance case (*h*) can always be expressed in terms of case (*g*), (*u* of course being different in the two cases), so that the structure of calcite has been shown to be that of the special case (*g*) of the space group D^6_{3d}.

The arrangement of two molecules of calcium carbonate in the unit of structure according to (g) is shown in fig. 13.

It now remains to determine, as accurately as may be, the position of the oxygen atoms, to place calcium and carbon in the correct one of their two possible positions and to compare the final structure as thus obtained with the results of experiment.

The first of these objects is best attained by considering

FIG. 14.



the planes having all odd indices or two even and one odd indices, wherein the reflection is due solely to oxygen atoms.[26] In the photographs, consideration has been given not only to all such planes as appear but also to *all* planes of this sort which could possibly give a reflection in *any* of the photographs. Those of part B (Table

[26] It should be pointed out that if the law connecting the atomic number of the reflecting atom and intensity of reflection were definitely known, and if it were possible to photometer the reflections with accuracy, the position of the oxygen atoms could be obtained probably with very much less work by using some of the planes with one even and two odd indices. Conversely, from a knowledge of the exact position of all the atoms (as determined here with the aid of the planes reflecting only oxygen atoms) it should be possible, as soon as an accurate photometering can be made, to get information concerning the law of reflection itself.

IV), though favorably situated for reflection, do not show upon the plates. Fig. 14 represents the curve obtained by plotting the relative amplitudes for the planes of part A (Table IV) that are to be expected if u has a value between zero and one-half of the length of a side of the unit when the arrangement is that of (g). Clearly since all of these planes are found to give reflections, they must agree in giving large amplitudes at the particular value of u corresponding to the position of the oxygen atoms. Fig. 15 is a similar curve for those planes which *do not* appear (part B). It is to be expected that the amplitude of all these planes should be slight at the value of u for oxygen.

An inspection of these two curves shows that the oxygen atoms must lie close to positions defined by $u = 1/4$. Furthermore, from the second curve it can be concluded that the value of u for calcite is somewhere between $u = 0.24$ and $u = 0.26$. This seems to be as accurate a placing of the oxygen atoms as the photographs permit without making rather uncertain assumptions concerning the influence of mass and spacing of like planes upon reflecting power.

TABLE IV.

A (PLANES APPEARING)

hkl	Relative spacing	Curve No.	hkl	Relative spacing	Curve No.
$02\bar{1}$	.436	1	720	.174	3
$24\bar{1}$	.254	2	$46\bar{1}$	.173	4
052	.244	2	$\bar{6}01$	.173	5
$\bar{3}\bar{4}2$	.202	3	$\bar{2}45$	.170	5
610	.196	3	294	.156	4
896	.175	1	$\bar{7}02$	.139	7
			$28\bar{1}$	.137	6

B (PLANES NOT APPEARING)

hkl	Relative spacing	Curve No.
$13\bar{1}$	.325	3
540	.224	5
$35\bar{1}$	.206	1
$26\bar{1}$	.179	2
$55\bar{1}$	.179	8
$\bar{4}43$	.154	6
085	.149	7
$75\bar{1}$	.149	4

The conditions of symmetry permit the placing of the carbon atoms either at the corners and center of the unit or along the diagonal at $u = 1/4$ and $u = 3/4$, and the considerations thus far advanced do not distinguish between these two possible arrangements. This choice cannot be made without the use of the relation between mass and scattering power. But by using such a relation and by making photometric measurements of two planes, reflecting the same wave length and having the same relative spacing, one plane having $h+k+l$ divisible by four so that the calcium term is added to the carbon term and the other plane having $h+k+l$ divisible only by two so that the two amplitudes are opposite in sign, the carbon and calcium atoms could be placed with respect to the oxygen atoms. Or planes having the same kind of a sum $(h+k+l)$ but different values of the difference between the two odd indices, that is, divisible by four or two only, might be compared. The same result, however, can be very simply obtained with the spectrometer. This of course has already been done,[27] and, as would be expected from the fact that the forces operating between carbon and oxygen seem much stronger than those between calcium and oxygen, the oxygen atoms lie closer to the carbon atoms. This arrangement was assumed in writing the expressions for amplitude.

The arrangement of the atoms in the unit of structure (fig. 13) of calcite *must* consequently be as follows:

Ca = 1/4 1/4 1/4; 3/4 3/4 3/4.
C = 0 0 0; 1/2 1/2 1/2.
O = $u\ \bar{u}\ 0$; $\bar{u}\ 0\ u$; $0\ u\ \bar{u}$; $1/2 - u$, $u + 1/2$, $1/2$; $u + 1/2$, $1/2$, $1/2 - u$; $1/2$, $1/2 - u$, $u + 1/2$, where u has a value very close to one-fourth and probably lying somewhere between 0.24 and 0.26. The angle between the axes of this simplest unit is 46° 6′ and the length of the side of the unit of structure is 6.16 A. U.

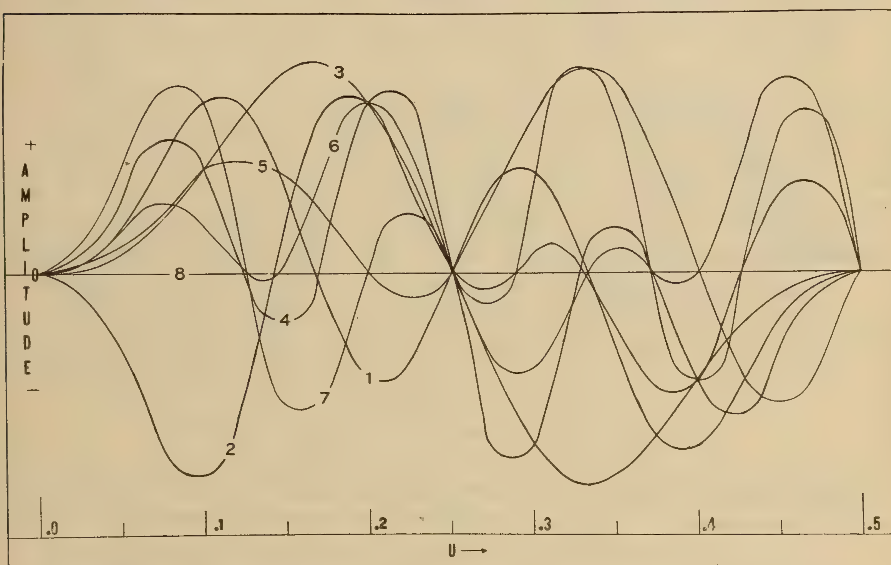
The unit which has previously been figured[28] is not the simplest unit of structure. Calculations, like those which have just been made, on the basis of such a unit, would have been much more complicated and could not have been carried out so as to place the oxygen atoms uniquely without the aid of those uncertain assumptions commonly

[27] W. L. Bragg, op. cit.

made in spectrometer measurements. This more complicated model[28] is useful because it gives a truer idea of the relations of the different atoms to one another than can be gained from a single unit cell. The relation between the two representations can be readily noted with the aid of fig. 1.

An attempt has been made to carry through this determination of crystal structure with the least possible use of the two empirical laws connecting intensity of reflec-

FIG. 15.



tion with atomic number of the reflector and the spacing of like planes. In order to find out whether the carbon or the calcium atoms were closer to the oxygen atoms it was necessary to assume that these atoms scatter *roughly* in proportion to their weights. This is the only step of the process where such use has been necessary. Otherwise it has been sufficient to make use of the theory of space groups and to assume that oxygen has an appreciable scattering power. Such determinations as this, where the structure can be *uniquely* obtained without the aid of one or the other, and especially of either, of the "laws" of reflection, are of interest because of the oppor-

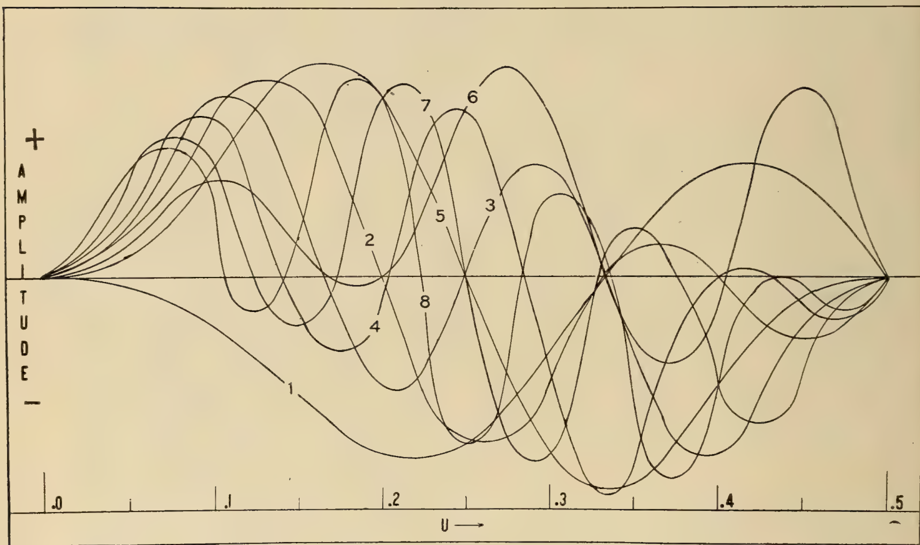
[28] W. L. Bragg, op. cit.; W. H. Bragg and W. L. Bragg, X-rays and Crystal Structure, p. 117, 1918.

tunity that they give of testing these "laws". Again they are perhaps more certainly correct because they do not have so empirical a basis.

The more accurate determination of the reflections from the (100) cleavage face has given the following ratio of intensities:[29]

$$100 : 12.1 : 10.1 : 4.5.$$

Fig. 16.



The expression proportional to the intensity of reflection for the calcite arrangement becomes for any order n when applied to the 211 (new axes) plane:

$$A = 2\,\bar{C} + 2\,\overline{Ca} + 2\,\bar{O} + 4\,\bar{O}\cos \pi nu.$$
$$B = O.$$

Intensity $= f\{(34 + 16\cos 2\pi nu)^2\}$, if $\bar{C}$, $\overline{Ca}$, and $\bar{O}$ are taken proportional to the atomic numbers of the respective elements. Assuming the normal decline of intensity with order, the calculated ratio of intensities becomes for $u = 0.25$,

$$100 : 5.6 : 7.0 : 6.5.$$

[29] W. H. Bragg, op. cit.

The agreement is rather surprisingly good when the special nature of the "normal decline" is taken into account.

The Crystal Structure of Manganese Carbonate (Rhodochrosite).

The specimens used in this study were slightly pinkish transparent rhombohedrons from Lake County, Colorado. Material from this locality had previously been analyzed and found to be nearly pure manganese carbonate.[30] The value of the axial ratio of $MnCO_3$ determined from one of these rhombohedrons agreed exactly with that given by Dana.[31]

The size of the unit of structure of rhodochrosite was obtained by making a comparison spectrum of the L-series lines of tungsten from the cleavage, (100), faces of $MnCO_3$ and $CaCO_3$. Taking the value of $CaCO_3$ as accurately known, the spacing for $MnCO_3$ was obtained by finding first the distance from the crystal to the plate, using the calcite spectrum and then applying this distance to the measurements of the $MnCO_3$ spectrum. The spectrum was taken upon a film curved to the arc of a circle of about 10 cm. radius.

$$\sin\theta = \frac{n\lambda}{2d} \qquad 2\,\theta \text{ in radians} = \frac{x}{r} \text{ where}$$

x = distance of line on film from the central image, and
r = distance from crystal to film.
d/n for calcite was taken to be 3.04×10^{-8} cm.

From these data and from measurements of x on the film, the ratio of d/n for the (100) face of $MnCO_3$ was found to be 2.83×10^{-8} cm. This value is considerably different from that already determined.[32] Neither locality nor composition was given for the rhodochrosite previously used, so that no explanation of this disagreement can be offered.

A series of Laue photographs was prepared using a section cut parallel to the (111) plane. A single photograph was made through a cleavage piece. The patterns obtained were similar to those from calcite and required the same treatment in projection and identification of re-

[30] E. T. Wherry and E. S. Larsen, Jour. Wash. Acad. Sci. 7, 365, 1917.
[31] This determination was made by H. E. Merwin of this laboratory. Dana, System of Mineralogy, p. 278, 1892.
[32] W. L. Bragg, op. cit.

flecting planes. Again the large majority of the planes which appeared in the first order region had one even and two odd indices according to the third set of axes (as chosen for calcite). This second transformation was here required for the same reason as previously given for calcite. The fundamental lattice is again Γ_{rh} and consequently the space group is either D^5_{3d} or D^6_{3d}. D^5_{3d} and special case (f) of D^6_{3d} were eliminated as with calcite and the expression proportional to the intensity of reflection for the single remaining special case, since (g and h) are identical, is like the previous equation, if Mn is substituted for Ca.

In the present instance many more planes were found which reflect only oxygen atoms than appeared on the calcite plates. Typical planes are given below:

Plane	Relative Spacing	No. of Curve (fig. 16)	Plane	Relative Spacing	No. of Curve
$02\bar{1}$	.436	1	$53\bar{1}$	.206	3
$31\bar{1}$	.326	5	$34\bar{2}$	.202	6
$42\bar{1}$	.254	2	610	.196	6
250	.244	2	$64\bar{1}$	.173	4
764	.222	1	$5\bar{3}3$	.157	7
$15\bar{1}$	.212	8	$75\bar{1}$	.148	7
241	.208	6	913	.145	7
			$86\bar{1}$	.130	8

On these curves (fig. 16) there are three positions at which all the planes would have an appreciable amplitude, one at either side of $u = 1/4$ and one about $0.3 = u$. The value of $u = 0.23$ is improbable from a number of considerations. For instance, the spectrometer measurements[33] point to the value of u being appreciably greater in the case of rhodochrosite than with calcite. Also, if u has this position, the appreciable reflection by the plane $1\bar{3}1$ is not compatible with the very favorable conditions which obtain for planes following curve 6. For similar reasons the position about 0.30 is equally improbable. A reflection from the plane 443 which has a large amplitude for $u = 0.30$ but only a slight one for $u = 0.27$ was not found although the plane was in a good position to give a reflection. The appearance of plane $86\bar{1}$ in spite of its

[33] W. L. Bragg, op. cit.

complicated nature, and the relative weakness of all the planes having all odd indices, except planes giving curve 7, cannot be satisfactorily accounted for if $u=3$. It must consequently be concluded from these data that u has a value near to 0.27, certainly not appreciably greater than 0.27 and probably between 0.26 and 0.27. A more accurate placing of the oxygen atoms is not possible without the use of assumptions concerning the influence of spacing upon intensity of reflection.

The dimensions of the unit of structure of rhodochrosite and the positions of the atoms within this unit are then as follows (fig. 13):

Length of side of unit rhombohedron $= 5.61^8 \times 10^{-8}$ cm.
Angle between axes $= 47° \ 46'$.
C atoms at (000) and (a/2 a/2 a/2).
Mn atoms at (a/4 a/4 a/4) and (3a/4 3a/4 3a/4).
O atoms at $(u\,\bar{u}\,0)$, $(\bar{u}\,0\,u)$, $(0\,u\,\bar{u})$, $(a/2 - u, u - a/2, a/2)$, $(u - a/2, a/2, a/2 - u)$, and $(a/2, a/2 - u, u - a/2)$,

the length of the unit is written as a. The value of u is close to 0.27.

The Structure of Siderite ($FeCO_3$).

Siderite and rhodochrosite have almost identical axial ratios.[34] Comparison spectra against the (100) faces of calcite and siderite gave the spacing of the latter as 2.81×10^{-8} cm.,—a value which is practically the same as that for rhodochrosite (2.83×10^{-8} cm.). A series of Laue photographs through a basal section gave patterns which were not distinguishable from those of rhodochrosite.[35] The structures of these two compounds, then, are identical within the limits of these experiments.

The Structure of Magnesite ($MgCO_3$).

Only one specimen of $MgCO_3$ was available for study. This was a short six-sided prism. The pattern obtained showed the same characteristics and reflections from the same kinds of planes as did those from other members of the group, but the crystal was so imperfectly constructed that careful measurement was impossible.

[34] Dana, op. cit.
[35] Measurements of refractive index (by H. E. Merwin) indicated that the specimens used here were about 95% $FeCO_3$.

The Nature of these Compounds in the Light of their Crystal Structures.

These substances are conveniently considered as an assemblage of an equal number of metal atoms and carbonate groups. The rhombohedron of calcite is then simply a deformed sodium chloride arrangement: the carbonate groups holding positions analogous to those of the negative chlorine atoms of NaCl and the calcium atoms corresponding to the sodium atoms. It is of interest in this connection to see if there is any evidence for the actual existence of a carbonate group in the crystals of the calcite group.

On the basis of the structure just determined and taking $u = 0.25$, the distance between the carbon atom in calcite and each of its three nearest oxygen atoms is found to be 1.21×10^{-8} cm. The distance of a calcium atom from the nearest oxygen atoms is 2.30×10^{-8} cm.; and the shortest distance of calcium atom to carbon atom is 3.04×10^{-8}. The corresponding distances for rhodochrosite are: carbon to oxygen $1.22^5 \times 10^{-8}$ cm.; oxygen to manganese 1.96×10^{-8} cm., carbon to manganese 2.83×10^{-8} cm. These values are the same in siderite as in rhodochrosite. The distance between carbon and the three oxygen atoms arranged closely about it is thus seen to be the same in the two cases within the limit of the experimental determination of the value of u, though the other distances between atoms vary quite widely. This is what would be expected if the combining forces of the oxygen atoms were directed in large measure toward the carbon atoms with the formation of a CO_3 group, and if the crystal were then built up as a result of the attraction between these groups and metal atoms. There is thus distinct evidence for the existence of definite groups of associated atoms in the crystals of the calcite group.

There is good reason to believe that the constituent atoms, or groups of atoms, in a large class of crystals are electrically charged.[36] These carbonates have the structure and in general the behavior that they would have if their crystals were an assemblage of metal "ions" bearing two positive charges and of carbonate "ions" with

[36] Discussed by R. W. G. Wyckoff, Journ. Wash. Acad. Sci., 9, 565, 1919.

two negative charges. That the attracting forces are not, however, preponderantly the electrostatic forces arising from these charges is shown by the decrease in size of the unit of structure when the presumably larger manganese atoms take the place of calcite atoms.

From the point of view of the present knowledge of the structure of the atom and the electronic nature of chemical bonds, calcium carbonate (or manganese carbonate) can be simply represented in one of two ways. The determination of crystal structure has shown that all three oxygen atoms *must* be similarly related to a carbon atom. The neutral atom of carbon with an outside cluster of four electrons tends to add on four more and close its ''cluster'' of eight.[37] Oxygen, with six electrons in the outermost ''ring'', has a still greater tendency to acquire two electrons, while calcium readily loses its two outside electrons. If one is willing to believe that the atoms of oxygen are able to acquire completely the four electrons from carbon as well as the two from the metal atom, leaving them to carry four and two positive charges respectively while each oxygen atom is doubly negative, then calcium carbonate *must* be represented somewhat as in (A), fig. 17. If this is the true state of affairs the distance from carbon to oxygen would have been different in calcium from that in manganese carbonate. If, as is perhaps a more probable arrangement, the carbon and oxygen atoms are held together by *sharing* electrons, the representation would be according to (B) fig. 17.[38] In this second possibility the carbonate group and the metal atom *may* be charged.

If all the *atoms* in the crystal are assumed to be electrically charged, then the outside electrons may, *but need not,* be thought of as arranged at the corners of a cube.[39] If, on the other hand, they are not *all* of them ''ions'', then a cubical arrangement of the outside electrons of the atoms is in this case *impossible.*

[37] I. Langmuir, J. Am. Chem. Soc., **41**, 868, 1919; R. W. G. Wyckoff, op. cit.

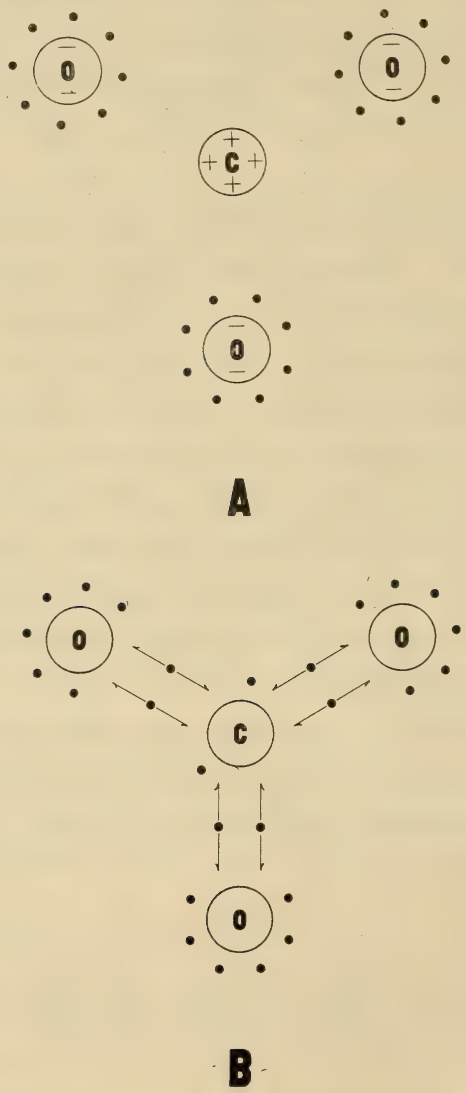
[38] In this figure the outside elections are represented by black circles. In B the two electrons represented as close to the carbon atom would be symmetrically placed on the axis of the group, at equal distances above and below the plane of the paper.

[39] I. Langmuir, op. cit.

The Occurrence of Faces and the Crystal Structure of Calcite.

The method of Goldschmidt[40] has been used to discuss the various faces found upon calcite and to arrange them

Fig. 17.



[40] V. Goldschmidt, Zs. Kryst., 28, 1, 414, 1897.

according to the probability of their occurrences.[41] A knowledge of the crystal structure of a substance furnishes the basis for the same sort of discussion.

Evidence has been adduced to show that the carbon and oxygen atoms in calcite act together in single unit groups and that these groups and the calcium atoms are arranged, as are the atoms in sodium chloride, alternately throughout the entire mass of the crystal. This is the arrangement to be expected if the calcium atoms and carbonate groups attract one another and at the same time repel like atoms or groups.

Any plane containing either carbon atoms (as centers of carbonate groups) or calcium atoms, or both, is the plane of a *possible* crystal face. In general, however, the forces tending to draw a calcium or carbonate particle down upon a face will be greatest for planes that are thickly studded with atoms so that such faces will have the greatest tendency to grow and will, if enough crystals are considered, have the commonest occurrence.

Those planes having the greatest relative spacing will contain the greatest number of points of the lattice. This spacing and consequently the relative density (in atoms) of the various kinds of faces of calcite can be simply obtained by assuming half the points of a rhombohedral lattice occupied by carbon, as center of the carbonate group, and the other half by calcium, by using the kind of expression previously used in the determination of the crystal structures.[42] It can be roughly stated that the simpler the *Miller* indices of a face, the more atoms it contains per unit area.

Planes in calcite are of two kinds: some will contain either all calcium or all carbon atoms (that is, carbonate groups), the others will contain both calcium and carbon atoms. Those planes all of whose indices are odd (using the ordinary crystallographic axes) are of the first kind, all others are of the second sort. The essential factor, other conditions being equal, in determining the development of a face is what seems commonly to have been termed the ''pulling down force'', that is, the resultant attraction at a point exerted in a direction normal to the plane and towards the face. For planes of the same relative spacing and consequently of the same atom density,

[41] H. P. Whitlock, Proc. Am. Acad. Sci., 50, 289, 1915.
[42] A. W. Hull, op. cit.

those having all odd indices would clearly exert much the stronger attraction for atoms of the opposite sort than those composing the plane itself.

From these considerations, then, it should be possible to arrange the possible planes of calcite in the order of their tendencies to grow and hence, presumably, of their relative occurrences under comparable conditions. In the actual growth of crystals, other factors have been shown to have very marked effects, notably the fact that the faces are probably not *truly* plane for atomic distances but may be many layers thicker at one point of a face than at another, convection currents in the mother liquor, and foreign substances dissolved in the mother liquor which, by their presence, change the surface tension of the solution with respect to the various faces. The natural crystals that have been observed have come from so relatively few localities and have grown under such uncertain conditions that an arrangement in the order of the occurrence of their faces based upon *any* simple considerations can be expected to be only roughly fulfilled. As nearly as can be determined, however, the development of the faces on crystals of calcite is in general agreement with the point of view outlined above. A criterion is incidentally furnished for discussing the cases of doubtful planes as well as the proper set of indices to be ascribed to rare planes where several sets are possible. Of course, the crystallographic relationships are most conveniently expressed in the Bravais-Miller indices and it may be said that that plane, of several possible planes, is most probable which will give upon transformation the simplest Miller indices. This test is in a sense the reverse of that previously used to establish the rhombohedral character of the fundamental lattice. It is quite as useful but not, however, as sharp a test in the present case as it was before, because much more complicated planes are found as faces than commonly give X-ray reflections.

In the present instance the cleavage plane (100) is the one of greatest atom density. That this condition alone does not determine the direction of cleavage, however, is made clear by the fact that diamond and zinc sulphide, both with the same crystal structures, have, one of them octahedral, the other dodecahedral, cleavages. Two factors seem to be of importance in determining cleavage: the resultant attraction at any point in the plane and the attraction normal to the plane exerted by the atoms in the plane upon an atom above it. That is, the difference between these two factors as well as the magnitude of the first one (the attraction in the plane) must be very great if cleavage is to be possible. All the other crystals which have been shown to have the sodium chloride arrangement, such as other alkali halides, sodium nitrate, magnesium oxide,[43] show perfect cubic (100) cleavage.

The other commonly developed faces of calcite, as $e(01\bar{1}2)$, $f(02\bar{2}1)$, $M(40\bar{4}1)$, $\phi(05\bar{5}4)$, $v(21\bar{3}1)$, and $y(32\bar{5}1)$ are the dense planes of the rhombohedral structure.

Various members of this carbonate group have been shown to have both the same general arrangement of atoms within the unit of structure and units of about the same size and shape. They are commonly said to be isomorphous with one another. Calcite and sodium nitrate[44] have not only the same sort of grouping of atoms in the unit but the size and shape of the unit and the absolute distances apart of corresponding atoms are practically *identical* in the two cases; yet they are not isomorphous (as the term is now commonly used). The crystal structures of calcite and sodium nitrate are more nearly alike than are those of calcite and rhodochrosite, for instance. It is in strict accordance with their crystal structures that sodium nitrate will grow in parallel orientation upon a crystal of calcite but not upon a crystal of any of the other members of the group.[45] The difference in the crystal structure of calcite on the one hand and rhodochrosite and siderite on the other may account for the fact that while a complete series of mix crystals of the last two is known,[46] calcite and either of the other two are not known to show complete miscibility.

Conclusions.

1. A probably unique solution has been obtained for structures of calcite and rhodochrosite. Of the assumptions commonly made in crystal structure study, the only one required in these determinations was that the atoms

[43] W. P. Davey and E. O. Hoffman have studied MgO powder (Phys. Rev., (2), 15, 333, 1920). The present method of analysis has indicated the same structure for large and perfect crystals.

[44] W. L. Bragg, op. cit.; R. W. G. Wyckoff, Phys. Rev. (2), 16, 149, 1920.

[45] T. V. Barker, Zs. Kryst., 45, 1, 1908.

[46] W. E. Ford, Trans. Conn. Acad. of Arts and Sci., 22, 211, 1917.

reflect X-rays in an amount roughly proportional to their atomic numbers.

2. The structure of siderite is shown to be so nearly the same as that of rhodochrosite as to be indistinguishable by the means at hand. Magnesite is shown to give the same sort of pattern, and hence to have the same general arrangement of atoms, as the other members of the group.

3. The positions of the oxygen atoms as determined by the present method and by the spectrometer results, are compared. The ''normal'' decline of intensities is in surprising agreement with the reflections.

4. The use of gnomonic projection in studying Laue photographs is mentioned and a ruler is described, the use of which reduces the time and labor of making such projections.

5. The effect of the voltage impressed on the X-ray tube upon the character of the Laue photograph is considered and the best conditions for operating a tungsten tube for this work are stated.

6. A criterion is suggested for determining, in the case of an hexagonal crystal, whether the fundamental unit is a rhombohedron or an hexagonal prism.

7. Evidence is obtained from these crystal structures to show the existence of groups of atoms, as carbonate groups, in the crystal.

8. It is pointed out that unless *every atom* in the crystal is electrostatically charged, the outside electrons of the atoms making up these crystals *cannot* be arranged at the corners of cubes.

9. Some connections are pointed out between the development of faces on calcite and its crystal structure, and a means is indicated of deciding the most probable indices of a plane, when they are in doubt. The bearing of these structures upon the question of what constitutes a series of isomorphous substances is mentioned.

Geophysical Laboratory,
Carnegie Institution of Washington,
June, 1920.

ART. XXIV.—*Entelodonts in the Marsh Collection;* by EDWARD LEFFINGWELL TROXELL.

[Continued from p. 255.]

PART II. THE GENUS ARCHÆOTHERIUM.

GENERIC CHARACTERS OF ARCHÆOTHERIUM LEIDY.

Archæotherium ranges in size from that of *A. clavus* to that of *A. crassum;* the known species are limited to the Oligocene, generally Lower or Middle. As distinguished from *Entelodon* Aymard, it has longer diastemata separating the premolars; premolars more primitive in having double roots (exception: P_3 of *A. marshi,* sp. nov.) and less primitive in their small size and the consequent greater separation; P^3 not so wide posteriorly; P^4 not quadrate but invariably with a notch on its anterior face; anterior cusps of the lower molars higher than those posterior. (As to the skull, one finds great difficulty in accepting the published reproductions of the cranium of *Entelodon magnus* as trustworthy evidence of the very unusual features represented.)

As distinguished from *Pelonax* Cope, the chief features of *Archæotherium* are the generally double-rooted premolars, the smaller size of the mental tubercles, and the much smaller size of the animal as a whole. As distinguished from *Dinohyus,* medium incisor never known to be absent; P^3 always much longer than wide, anterior and posterior cones unequal in lower molars; dependent process generally large, posterior end of malar bone may end before the glenoid cavity; processes may be relatively large on chin, and the generally long chin and long premaxillary have the incisors separated. *Dinohyus* is, moreover, twice as large as the smallest species of *Archæotherium* and is known only from the Lower Miocene.

ARCHÆOTHERIUM CLAVUS GROUP.

Archæotherium clavus (Marsh).

Holotype, Cat. No. 12035, Y. P. M. Middle Oligocene, White River, Nebraska.

Following is the original description of this species (Marsh 1893, p. 409).

"*Elotherium clavum,* sp. nov.

"On Plate IX, figure 1, is shown a skull of *Elotherium,* with the brain-cast in position, which agrees in many respects with the skull figured on the preceding plate, and described above (*E. crassum*). When first figured, the former skull was referred to *E. crassum* (*Dinocerata,* p. 65, 1884), but a more careful comparison proves it to be distinct. It is considerably smaller than *E. crassum,* and the malar process is quite slender and tapering below. It extends directly downward, and hence is not seen in the top view of the skull. The length of this skull is sixteen inches, measured from the front of the premaxillaries to the back of the occipital condyles. The dentition agrees, in the main, with that of *E. crassum,* the last lower molar in each having four cones only, and no heel. The malar arch and the dependent angle of the lower jaw will distinguish it from *E. mortoni.* The type

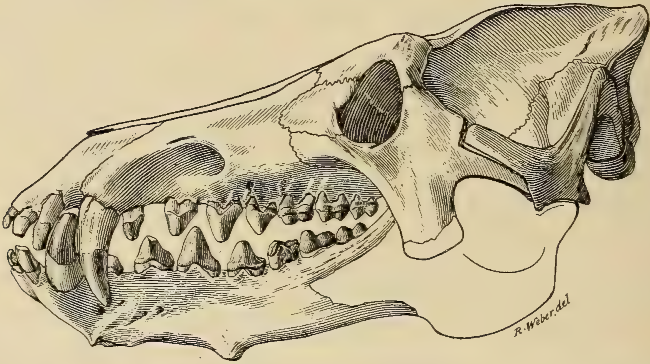


Fig. 1.—*Archæotherium clavus clavus* (Marsh). Holotype. Cat. No. 12035. Side view of skull and jaws. One-fifth nat. size.

specimen here figured is from the *Oreodon* beds, near the White river, in southern Dakota."

Two points are offered in contradiction to the description above, viz: there *is* a definite heel on M_3 and the dependent processes from the malar *do* swing outward. In 1909 Peterson made this a subspecies under *A. mortoni* Leidy, but here it is raised again to the rank of a full species on the basis of the description which follows:

In this species (figs. 1-3), the skull is slender and the framework of the zygomatic arch is light, this being in harmony with the longer, more slender canines. The dependent process from the jugal is very narrow; it seems to point neither forward nor backward, but is of course swung outward; its anterior edge is in line with the middle of the orbit. The posterior process has a notch to receive the end of the temporal bone, and in this species the distance from the orbit to the notch is relatively great. From the notch backward the bone is narrow and extends almost to the glenoid cavity, but the glenoid surface is not cut away to receive it.

The temporal in its outward course from the cranium forms a wall reaching to the outer extremity of the glenoid cavity, above which it ends in a straight narrow vertical edge; the corner folds back very slightly and forms a depression posteriorly. Anteriorly from this edge and the border of the glenoid fossa, there extends a rather straight and narrow process to fit into the notch on the jugal or malar bone. The distance from the condyle to

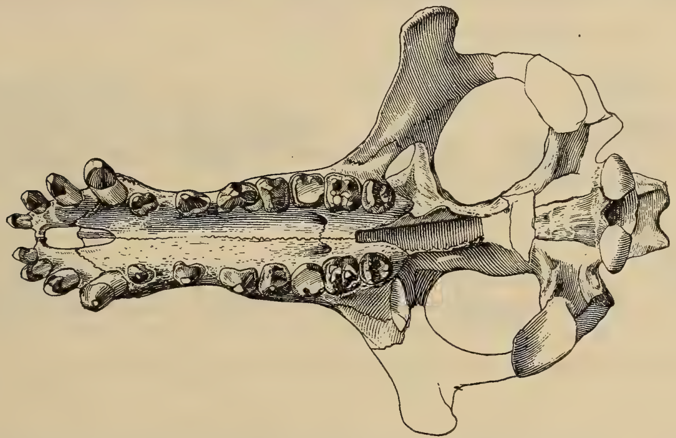


FIG. 2.—*Archæotherium clavus clavus* (Marsh). Holotype. Cat. No. 12035. Palatal view. One-fifth nat. size.

the upper side of this process is relatively small, 25 mm., further indicating the slenderness of the general structure.

On the anterior wall of the temporal there is no foramen as in *A. crassum,* but a slight tuberosity may be seen.

The occipital condyles are set wide apart, are long and narrow themselves, and are very narrowly grooved on the ends. There is no fossa above the condyle, nor any foramen, as is found in the other species. The alveolar border, especially at the canines, descends well below the palate, arching the latter. The posterior edge of the infraorbital foramen lies over the middle of P^3 and opens slightly downward. The upper rim of the orbit has a sharp edge and the frontals, though crushed, show a smooth, deep fossa without evidence of supra-orbital foramina. The frontals anterior are very narrow, because the lachrymal, approximately square, is high in front of the orbit. The jugal occupies a very small area on the face; on the other hand the maxillary forms no part of the arch anteriorly. The vertical position of the orbit is very similar in all the species; its anterior edge lies over the metacone of M^2.

The upper incisor teeth are pyramidal or subtetrahedral, recurved and slender. They are slightly flattened, with sharp corners postero-externally and antero-internally. The upper canine, already slender and long, is worn on the anterior side in such a way as to emphasize its slenderness. It is recurved.

P^1 is situated very near, in fact, fairly beside the canine, and therefore assumes a diagonal position. Though

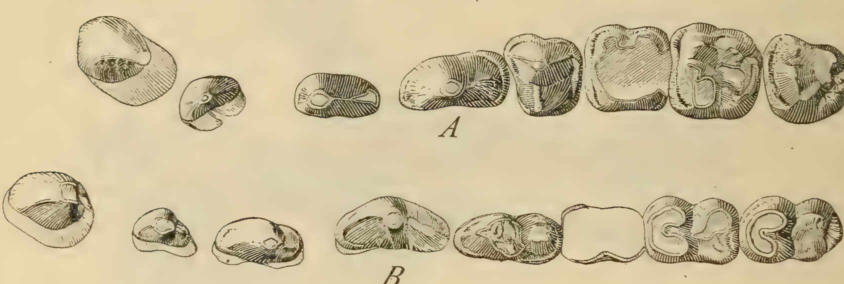


FIG. 3.—*Archæotherium clavus clavus* (Marsh). Holotype. Cat. No. 12035. Crown view of (*A*) upper, and (*B*) lower teeth. One-half nat. size.

small, it is as large as those found in much larger species. P^2 is relatively large, is well separated from P^1, but is close to P^3.

A noticeable thing about the third upper premolar is its concavity internally, and as a consequence the wider posterior heel, which gives the tooth an unusual thickness, 15.4 mm. Both fore and aft are developed cingular edges. A serrated fold runs to the point of the cone, and the heel is very rough. It not only has the platform mentioned by Leidy, but also a cingulum back of that. Postero-internally is a roughened area bordered by ridges running vertically. The third premolar joins the fourth without a diastema.

P^4, implanted with three fangs, is much more molariform, but is composed of two cusps only. The outer cone, or protocone, which may really be the protocone and tritocone combined, is considerably stronger and points straight out from the maxillary; the inner cone, the deutercone, points slightly forward (the cusps are indicated on figs. 17, 18). The general form is quadrate or trapezoidal, with a notch or angle in the antero-internal corner. The inner border is more straight than rounded as in other species. The dimensions, longitudinal and transverse, are equal. Cingula are present, both front and rear, and are especially developed before and behind the deuterocone.

The first upper molar, as in most specimens, is much worn, although the individual would not be judged as very old. The outline is almost square as contrasted with those species in which M^1 is rounded or more irregular, and in contrast with M^2 in the same specimen, which is much wider anteriorly. In the manner of wear, this tooth is deeply hollowed out and is sheared off on one inner corner.

M^2 has straight edges and sharp corners to an unusual degree, but it is very much narrower behind than across the proto- and paracones. It is for this reason even broader than it is long, and the base of the paracone is very heavy. It is considerably larger than M^1 and very much larger than M^3. By the lakes remaining, it can be seen that the hypoconule and protoconule are well formed and there are well developed cingula, both anterior and posterior.

M^3 is almost triangular and shows distinctly a diminution in the tooth series by this terminal member. In its greater width anteriorly it resembles slightly the tooth in front, but the back and inner sides form an almost continuous curve. The outer and front sides are quite straight, and the base of the paracone stands prominently between them. The protocone has a position midway fore and aft, and has encroached on the hypocone so that the latter is scarcely visible; it is, in fact, smaller than the metaconule and is nothing more than a heel, continuous with the hypostyle. The metacone is also lower than the metaconule, which already shows a lake of dentine by reason of the wear. There is a very strong cingular shelf anterior.

The diastemata separating the teeth of this species show some interesting features: Between $I^{2.3}$, 6 mm.; I^3-C^1, 12.6 mm.; C^1-P^1, 2 mm.; $P^{1.2}$, 14.3 mm.; $P^{2.3}$, 5.5 mm.; $P^{3.4}$, zero.

Like the skull, the lower jaws indicate a slender animal. The premolar teeth are thin transversely, though extended antero-posteriorly. The anterior mental tubercle is entirely behind the canine and has its backward edge near the beginning of the symphysis. It is small and compressed parallel with the chin border, and extends only a little way from the ramus; the chin is rounded in front and the small tubercle under the anterior root of P^4 has a rather sharp point which curves almost imperceptibly upward.

The large mental foramen lies under the anterior root of P^1 and just above the mental tubercle; another lies below the middle of P^2 and between them are two small foramina practically on the same line. The coronoid process is narrow transversely, but forms a rather large angle antero-posteriorly. It is only slightly out of the line of the teeth. The nearness of the masseteric fossa makes the process more slender.

The lower canine is shorter but not more slender than that above; it curves upward, then slightly inward and backward. The enamel covers the teeth low.

P_1 is separated from C_1 7.5 mm. and from P_2 6 mm. It is large relative to much larger species, stands high on its two roots, slopes slightly backward, and is set straight in the ramus. P_2 is very large, though compressed, is long and narrow and stands high on its roots. It is considerably recurved and has cutting edges and cingula anterior and posterior. P_3 is about 3 mm. from P_4; the crown itself is high, narrow, and long antero-posteriorly. The slender point is recurved and from it there extend ridges down to the cingula both front and back. There is no shelf, but a wide roughened area slopes to the posterior side. Its diameter antero-posteriorly is 29 mm. and transversely 12.3 mm. P_4 has an antero-posterior diameter of 28.8 mm. and a transverse one of 12.8 mm. It is also long and narrow, but not high. It is especially wide posteriorly where the heel forms a broad shelf. In the middle and anterior it is narrow. The protocone stands almost erect and the roots are not large.

On one of the first lower molars, the enamel is completely worn away, on the other, half of the tooth is sheared off on the outer side. This wearing away exteriorly gives a valuable hint as to the motion of the jaws and bears out the general observation that the lower molars grind inward in the process of mastication.

In M_2, the metaconid, as is the usual case, has a double point on the cusp. This may really be the meta- and paraconids closely combined (see cusp indications, fig. 18). Both are found in some earlier forms such as the artiodactyl *Trigonolestes.* Taking into consideration that in *Archæotherium* the posterior cusps are never as high as those anterior, the hypoconid is strongly developed; on the other hand, the entoconid is weak. A distinct posterior heel may be seen. M_3 is much like M_2 except that a very marked posterior heel and a less strong hypoconid are observed. The posterior half of the tooth seems to be rotated inward, throwing its vertical axis out of parallel with the first half.

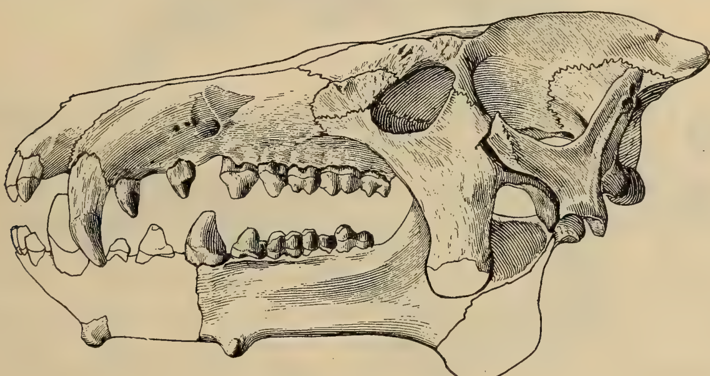


FIG. 4.—*Archæotherium clavus darbyi,* subsp. nov. Holotype. Cat. No. 10032. Side view of skull and jaws. One-fifth nat. size.

Archæotherium clavus darbyi, subsp. nov.

Holotype, Cat. No. 10032, Y. P. M. Oreodon beds (Middle Oligocene), Harrison, Nebraska.

This specimen (figs. 4-8) consists of a nearly complete skull, the posterior portion of which is almost perfect. The tips of the dependent processes are lacking, also the right premaxillary and the body of the ramus. The specimen was found by Mr. Fred Darby on the Peabody Museum Expedition of 1914, in the *Oreodon* beds near Harrison, Nebraska.

The zygomatic arch at once strikes one with its interesting and perhaps unique features. The structure is moderately heavy in comparison and the dependent process in its narrowest part is 48 mm., or 14 mm. broader than that of *A. clavus;* the depression immediately beneath the orbit and the great breadth make it like *A. marshi* (fig. 10). The posterior process of the jugal bends down sharply at its tip and becomes flat and broad where it rests in the corner notched out of the border of the glenoid cavity. This seems to be a unique feature in the species, although skulls referred to *A. mortoni* are reported to have it.

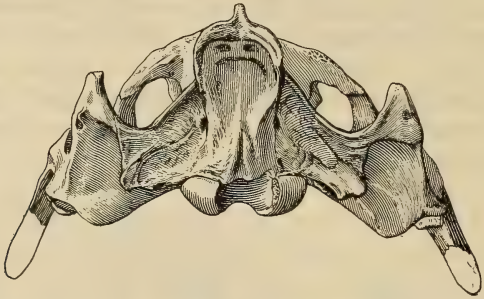


Fig. 5.—*Archæotherium clavus darbyi,* subsp. nov. Holotype. Cat. No. 10032. Back view of skull. One-fifth nat. size.

The outer end of the temporal forms a heavy broad edge with a peculiar fossa near the summit of the tubercle (see fig. 5), the nature of which is unknown. Where the upper border of this bone curves forward into the anterior process, it is about 35 mm. from the condylar surface. The anterior process of the temporal curves upward and inward to join the jugal, and is similar, in its greater width vertical, its sigmoid curve ventral, and its general massiveness, to that of *A. marshi.* It is very different in this respect from the type of *A. clavus clavus* (fig. 1).

The supra-occipital is very well preserved and shows a far overhanging crest. The crest divides and sends out two wings posteriorly, but even before it divides, it covers a deep depression on the under side in which are two distinct pits. Flying buttresses, as it were, extend outward and forward, joining with the temporal and exoccipital bones above the external auditory meatus. Immediately above the condyles, a marked fossa may be seen, but the foramen shown in some species appears only on one side. The posterior border of the infra-orbital foramen is over the anterior edge of P^3; it is rounded and not flat or oval as in other specimens.

The foramen ovale leading through the temporal and opening forward is plainly shown near the suture of the tympanic. Around the tympanic bullæ, which are only slightly convex, are grouped several foramina, chief among which is the rounded lacerum posterius, situated at the postero-internal angle of the bulla, and immediately back of it and almost adjoining it, the hypoglossal foramen. What appears to be the eustachian foramen lies on the anterior end of the tympanic bulla; the foramen orbitale and the optic foramen open into the point of the V-shaped groove within the orbit; the anterior palatine foramina open forward into grooves, opposite the front half of M_2.

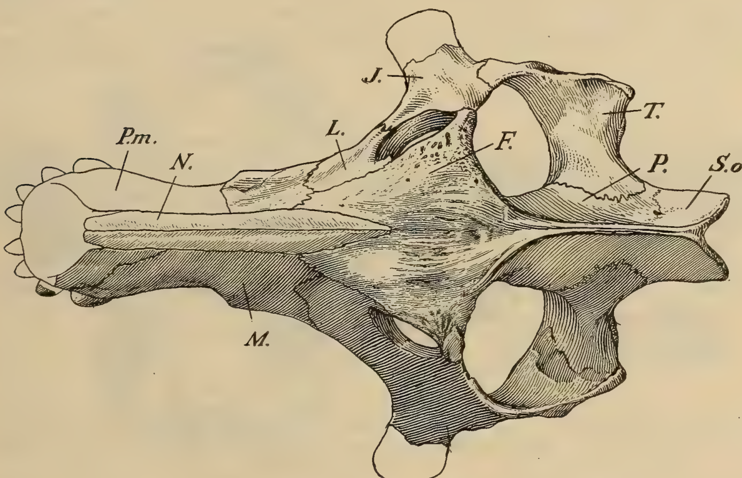


FIG. 6.—*Archæotherium clavus darbyi,* subsp. nov. Holotype. Cat. No. 10032. Top view of skull. One-fifth nat. size. *F,* frontal; *J,* jugal; *L,* lachrymal; *M,* maxillary; *N,* nasal; *P,* parietal; *P.m,* premaxillary; *S.o,* supra-occipital; *T,* temporal.

The frontals near the border of the orbit are heavy, rugose, folded with a deep central fossa. The narrow edge of the parietal border forward blends into the roughened surface above and behind the orbit. A single, minute, supra-orbital foramen may be seen near the mid-line of the skull. The anterior end of the frontal is broad; on the other hand, the lachrymal is narrow and extends far from the orbit of which it forms only a small part. The jugal sends out a long point on the face, but it is high, and the maxillary actually forms a part of the arch.

The canine is more strongly recurved and more robust than that of the type of *A. clavus clavus.* P^1, like P^2, is relatively small. P^2 is separated about 16 mm. from P^3.

P^3 is touching P^4; the sides of the tooth are flat or slightly convex, and the posterior heel is not especially wide. The cingula are weak and the ridges wanting or worn smooth. P^4 is shaped like that of the type of *A. clavus clavus,* except that the sides are rounded, it is wider than long, the cingula are less strong, and the tooth is relatively small. M^1 is subquadrate, but the inner side is shorter antero-posteriorly.

M^2 is rounded but flat anteriorly. It has not the trapezoid form like that of the type of the species. The base

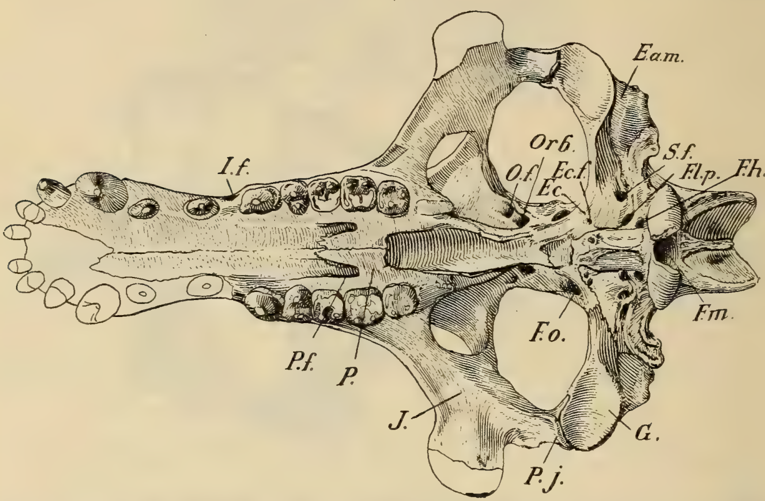


FIG. 7.—*Archæotherium clavus darbyi,* subsp. nov. Holotype. Cat. No. 10032. Palatal view of skull. One-fifth nat. size. *E.a.m,* external auditory meatus; *Ec,* eustachian canal; *Ec.f,* external carotid foramen; *F.h,* hypoglossal foramen; *F.l.p,* foramen lacerum posterius; *F.m,* foramen magnum; *F.o,* foramen ovale; *I.f,* infra-orbital foramen; *O.f,* optic foramen; *Orb,* orbital foramen; *P.f,* palatine foramen; *S.f,* stylomastoid foramen.

P, palatine bone; *J,* jugal or malar with its posterior process, *P.j,* occupying a part of the glenoid cavity, *G,* of the temporal or squamosal.

of the paracone is no larger than the base of the metacone. M^3 is round or slightly oval, due to the strong lobes of the para- and hypocones. There is a moderate cingulum anterior only, and no heel. The protocone is forward of the mid-line. The hypocone is strong. (See cusp indications, figs. 17, 18.)

The body of the ramus and the branches back to P_3 are missing with the exception of one anterior mental tubercle. This tubercle is entirely different from that of *A. clavus clavus* in form, but resembles more the knob-like process of *A. marshi*: round, heavy at the end, and slightly recurved. The posterior mental tubercles are unusually long, about 30 mm. from the side of the ramus, slender, rounded, pointed, and curved upward; they are compressed at the base and attached widely on the ventral borders of the rami.

The coronoid process arises well outside the line of the molars; it is compressed rather than rounded, but sends wide branches downward and also backward on the front and upper sides of the masseteric fossa. This fossa is deep and oval in form, extends to the condyle, and its

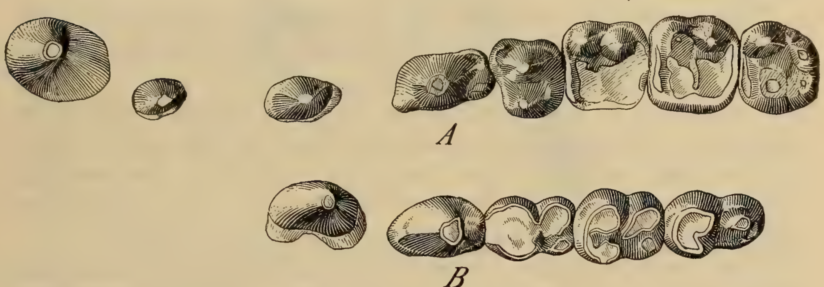


FIG. 8.—*Archæotherium clavus darbyi*, subsp. nov. Holotype. Cat. No. 10032. Crown view of (*A*) upper, and (*B*) lower teeth. One-half nat. size.

ventral border is gentle, not an abrupt edge. On the inner side of the coronoid and just in front of the mandibular foramen, there is a marked rugosity for the insertion of the temporal muscle. The condyle is rather blunt on both ends.

The crown of P_3 has a long protoconid and is high on its roots; it is thick, recurved, short antero-posteriorly, and is separated from P^4 by 4 mm. The tooth is much worn, but probably never was very rugose even on its posterior heel.

P_4 measures 25×14.8 mm. It is relatively very short and thick. The heel is a shelf of moderate extent. The widest part of the tooth is through the hinder part of the main cone, while the heel narrows instead of increasing in width as in *A. clavus clavus*.

M^2, although the entoconid is weak, seems to show little difference in the height of the anterior and posterior lobes. An unusual feature is the absence of a heel in M_3, distinguishing it from the other specimens present.

The ratios to *A. mortoni* Leidy (see below) show a range of 45 per cent; it is from 17 to 25 per cent more slender through the facial part. The teeth are more nearly the same size, but the diameters of P^3 are out of all proportion, being shorter and much wider. The posterior heel in the older specimen of Leidy is relatively much wider.

In many respects this small skull bears a closer resemblance to *A. marshi* (figs. 10-12), than to the type of *A. clavus clavus.*

Archæotherium sp.?

Cat. No. 10286, Y. P. M. Probably Cedar Creek beds, Colorado.

This specimen of uncertain taxonomic position consists of the left side of the skull up to and including the fourth premolar, together with the rami.

On the jaws are enormous anterior mental tubercles which are triangular in section, large at the outer ends, and extend widely from the rami. In this respect the specimen resembles somewhat *Pelonax potens,* but in the latter the processes extend more nearly downward.

The teeth are like those of *A. clavus darbyi* in being thick and in having smooth surfaces. There is another resemblance between these two specimens in the rugose supraorbital border of the frontals and in the wide but thin dependent process from the jugal.

P_1 is double-rooted. P_4, a very low and thick tooth, measures 30.5×16.2 mm. Its greatest thickness is just in front of the heel, which is neither wide nor extensive.

The first and second lower molars seem to have had no heel or talonid but on the third a weak heel is shown by the small lake.

The very deep groove outside of and in front of the glenoid fossa, for the reception of the point of the jugal, seems to be unique in this specimen.

Summary of Archæotherium clavus Group.

A. clavus clavus (Marsh): holotype, Cat. No. 12035; referred specimens, Cat. Nos. 10213, 10289.

A. clavus darbyi, subsp. nov.: holotype, Cat. No. 10032; referred specimen, No. 10173.

A. sp.?: Cat. No. 10286.

Specific characters of A. clavus clavus.—The smallest of the entelodonts, distinguished from *A. mortoni* by the wide heel, the narrow crown, and the flat outer side of P^3, by the great antero-posterior extent of P_4, and by the extreme slenderness of the face (70 to 79 per cent) in front of the orbits.

This sub-species may be generally known by the slender processes and general structure of the zygomatic arch, the lack of foramina on the anterior wall of the temporal, the jugal forming no part of the glenoid cavity, the smoothness of the frontals above the orbits, the wide lachrymal,

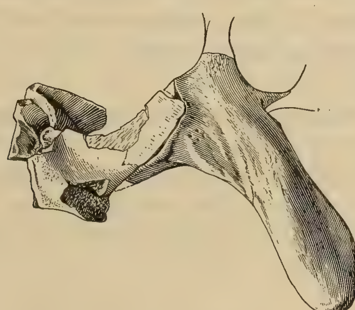


FIG. 9.—*Archæotherium crassum* (Marsh). Holotype. Cat. No. 12020. Side view of zygomatic arch and dependent process. Compare Fig. 10. One-fifth nat. size.

the large double-rooted premolars (especially P^2), the first premolar set at an angle in the maxillary, the long slender canines, the sub-quadrate P^4 having equal dimensions, the straight-sided M^2, narrower behind, the subtriangular M^3, and the strong heels on all the teeth.

The associated specimens are Nos. 10213 and 10289, both young individuals which correspond closely in the size of the permanent teeth and in the small anterior mental tubercles, as yet probably undeveloped.

A. clavus darbyi, subsp. nov.—An allied type of entelodont, constituting a subgroup, is represented by the specimen No. 10032, and with it another, No. 10173. It seems to approach more closely *A. mortoni* than *A. clavus clavus* does, but it is distinguished from that species by the greater transverse diameter of P^3, 119 per cent, contrasted with its short antero-posterior diameter, 87 per cent.

In comparing with the type of *A. clavus clavus,* a similarity prevails in size and in a few generalities, but it differs in many details of structure and in the more massive proportions; the dependent process from the jugal is nearly a half broader; the posterior process is heavy, curves downward and its flattened end actually forms a part of the glenoid cavity (cf. *Dinohyus*). The anterior process from the temporal is deep and has a sigmoid curve on its lower border; the frontals are folded and grooved, very rugose over the orbits and wide anteriorly, and the lachrymals are correspondingly narrow. The anterior mental tubercle is not compressed, but is rounded and heavy at the end; the posterior tubercles are long and slender; a larger diastema exists before and also behind P^2. P^4 is wider than long. The teeth are in general heavier, smoother, and possess less of cingula and talon; especially the premolars are shorter and wider, except that the posterior heels are laterally compressed.

Following are shown the ratios of the two type specimens at hand, compared to the type of *A. mortoni* Leidy.

	*A. mortoni** mm.	Ratio D/M %	*A. clavus darbyi* mm.	Ratio C/M %	*A. clavus clavus* mm.	Ratio C/D %
Height of nasal suture above alveolus of P^3	89.0	74.7	66.5	71.2	63.4	95.3
Breadth of nasal at same place	15.7	78.3	12.3	70.1	11.0	89.4
Ant.-post. diameter of P^3 at base	31.7	86.7	27.5	91.5	29.0	105.4
Transverse diameter of P^3 at base	12.6	119.0	15.0	121.4	15.3	102.0
Ant.-post. diameter of P^4 at base	19.0	95.8	18.2	110.5	21.0	115.3
Transverse diameter of P^4 at base	22.2	98.2	21.8	94.6	21.0	96.3
Height of face from middle nasal suture to palate	63.5	83.4	53.0	78.7	50.0	94.3
Same height at P^4	76.2	81.4	62.0	78.3	59.7	96.3

* Measurements taken from Leidy's type description and reduced from inches to millimeters.

The great range in the ratios between the types of *A. mortoni* Leidy and *A. clavus* Marsh is sufficient to separate the two species. The incompleteness of Leidy's type, however, makes it almost impossible to compare other specimens with it and to work out the finer distinctions between the species. The main differences are: the relatively greater antero-posterior diameter of P^4 in the

Marsh type, the much greater transverse diameter posterior of P^3, the greater slenderness of the face, the roughness of the enamel, and the much smaller size.

Archæotherium sp.—This specimen is undoubtedly *Archæotherium,* as shown by the double-rooted premolars, and not *Pelonax,* but because of the great anterior tubercles it resembles *P. potens.* The structure of its arch, the wide, flat dependent process, the thick premolars, the smooth teeth without heels, the general size, and the rugose frontals resemble *A. clavus darbyi,* subsp. nov.

Archæotherium crassum Group.

Archæotherium crassum (Marsh).

Holotype, Cat. No. 12020, Y. P. M. Probably Cedar Creek beds (Middle Oligocene). Colorado.

In 1873 Marsh described this specimen (fig. 9) which was discovered three years before near Gerry's Ranch, Colorado, in part as follows (1873, pp. 487-8).

"A large suilline mammal, which probably belongs in the genus *Elotherium,* is indicated by portions of two skeletons[5] in the Yale Museum. These specimens present some features not before observed in any Ungulates. The most striking of these is a very long process descending from the malar bone, and giving attachment to the masseter muscle. This process resembles somewhat the downward prolongation from the zygomatic arch in some Edentates and Marsupials, but it is longer, and more compressed. The radius and ulna were separate, or very loosely united. The third and fourth metacarpals were nearly equal in size, and the second and fifth larger than the corresponding bones of the pes. In the latter the first digit was wanting, and the fifth rudimentary. The hoof phalanges were short. The tail was long, and quite slender. This species is intermediate in size between *E. mortoni* and *E. ingens.*

"*Measurements.*

	mm.	
Length of malar process below squamosal suture	130.0	[174][6]
Length of symphysis of lower jaws[7]	144.0	
Antero-posterior diameter of lower canine	32.5	
Transverse diameter	28.5	
Transverse diameter of humerus at distal end	81.0	
Transverse diameter of radius at distal end	75.0	
Transverse diameter of head of tibia	81.0	
Length of third metatarsal[8]	102.0"	

[5]The "rather smaller specimen" mentioned is treated on a later page, being the paratype, Cat. No. 10036.

[6] The measurement of 130 mm. should be about 174 mm., due to the fact that the tip of the bone is now in place.

[7] This measurement was undoubtedly from specimen No. 10037, doubtfully of the same individual.

[8] This length of 102 mm. for the third metatarsal is an impossibility.

Additional measurements have been taken to supplement the list of Marsh, as follows:

	mm.
Length of malar process below the orbit	202.6
Width of process at narrowest point	52.0
Greatest width distal	62.0
Diameter of thinnest part	22.0
Length of anterior process of temporal, measured from edge of glenoid cavity	103.0

The holotype is known by the complete zygomatic arch (fig. 9), one humerus and both right and left radius and ulna; of each of these a portion of the shaft is missing. There is also the proximal end of the other humerus and of a tibia; one fore foot is nearly complete and there are other foot bones, including a part of the pes; there exist also a few fragments of vertebræ and ribs.

The zygomatic arch, the first ever described, with the long slender process from the malar, is unusually interesting. The width of the process is only about one-fourth of its length; it hangs wholly out of line of, and behind the orbit, and the tip which curves slightly backward is thickened and knob-like. The anterior edge of the blade is thin, extended forward, and rounded inward slightly. In its downward course the first third is thicker and forms an arch concave inward; through the center it narrows slightly and completes a sigmoid curve by thickening outward at the rounded tip.

The sutural surface, which comes in contact with the temporal, forms a notch, then a long backward extension in a nearly flat plane. The inner edge of this plane is bevelled off at an angle of about 50°. The slender process from the temporal, which fits into the notch on the jugal just described, extends upward and forward, but curves sharply inward and ends in a blunt rounded point.

The border of the glenoid fossa is not "cut away" to permit the tip of the jugal to form a part of the actual surface of the condyle. The fossa itself is not high anteriorly, and the edges are rounded, not sharp. It is not long in lateral extent, as compared to some other species, and the whole surface seems to be more nearly symmetrical, not extended diagonally. Above there is a slight depression posteriorly, instead of on the outer surface as in *A. marshi* (fig. 10).

The canal of the external ear is beautifully shown, uncovered by the absence of the tympanic between the exoccipital and the temporal; the opening is very large externally, but narrows rapidly inward, curving forward to the end of the portion of the bone preserved, which includes a half of the foramen ovale on the lower front side but does not form a part of the cranium wall.

Within the opening of the external auditory meatus, two foramina lie on the posterior wall of the temporal near the outer extremity of the tympanic; likewise on the opposite side of the temporal are two foramina, one of which is quite large.

Archæotherium crassum (*Marsh*), *paratype, Cat. No. 10036.*—In Marsh's publication of the description of *Archæotherium crassum* he referred to two skeletons, and of the second he said:

"A rather smaller specimen, apparently of the same species, afforded the following

"*Measurements.*

	mm.
Length of symphysis	122
Depth of jaw below first premolar	57
Depth below last lower molar	69
Space occupied by lower molar series	216
Space occupied by three lower true molars	76"

To those of Marsh, these dimensions have now been added:

Lower jaws

	mm.
Narrowest part, ventral, behind the anterior mental tubercles	49
Narrowest part, anterior to mental tubercles	63
Anterior mental tubercles, lateral extent	116
Posterior mental tubercles, lateral extent	143

Marsh here gave the measurements of a specimen which is found to be that now bearing the catalogue number 10036, consisting of the lower jaws only, with most of the teeth broken away. The incisor teeth extend out at a wide angle and the whole alveolar border seems more open and spread than in other specimens. P_1 is double-rooted and is not set near the canine. P_2 appears to be relatively large; while P_4 has a large flat heel which is not as wide as the base of the cone in front of it. The talonid on M_3 is not large, but a well developed cingulum encircles the hypoconid of M_2; this is not seen elsewhere. M_2 is relatively wide anteriorly.

A feature which excites one's curiosity is the thick bony or dentine sheath around the roots of the anterior teeth back to P_4. It greatly enlarges the size of the root up to the enamel border. In one place on the left P_2 posterior, this sheath ended very bluntly or else actually covered a part of the enamel.

The two sets of tubercles are subequal in length; those anterior are heavier, while those posterior are compressed dorso-ventrally. It seems probable that their great lateral extent may be correlated with the wide spread of the lower teeth. Each of the tubercles is twisted upward and forward, and in each case the dorso-posterior corner, bent upward, is the longer. The chin is flat or slightly concave transversely.

The anterior mental foramen is not large; it lies directly over the anterior tubercle and under the front part of P_1. Another small foramen may be seen under P_2.

Archæotherium crassum, specimen No. 10037.—This third specimen has given rise to much speculation as to whether it is or is not a part of the holotype of *A. crassum*. The larger part of ninety or more fragments have been matched together to form a portion of the lower jaw, a maxillary and the dependent process from the jugal presenting a most intricate problem in their preparation.

The specimen is somewhat larger than *A. marshi* (fig. 10), but has a double-rooted first lower premolar. It came from Gerry's Ranch, northeastern Colorado.

Summary of Archæotherium crassum Group.

A. crassum (Marsh): holotype, Cat. No. 12020; associated specimens, Cat. Nos. 10036, 10037, 10288.

Specimen No. 10037, alliance based on: (1) great resemblance of form of dependent process; (2) similarity of size; (3) found at the same time, 1870, and place, northeastern Colorado; (4) possibility of its being the same individual because of no duplication of parts, similarity of material itself, as well as form of dependent process, and because Marsh borrowed the measurement from this symphysis for his description of the holotype.

Specimen No. 10036 is associated with *A. crassum* because of: (1) same accession number as the holotype, and probably same locality, (2) similarity of form to rami of No. 10036, (3) Marsh's description of it as the paratype.

Following are the characters of this species as taken from the holotype of *A. crassum:* Narrow but thick dependent process with a width about one fourth the length and having a sigmoid curve; the tip is turned backward in a rounded lobe; a thin edge extends forward; the process hangs from not far back of the rear line of the orbit, and all its parts are rounded or oval and not flat; slender processes form the suture between the jugal and the temporal, and that from the jugal does not reach the glenoid cavity, cf. *A. clavus;* this cavity, the edges of which are not sharp, is wide rather than long and is rounded and more nearly symmetrical than they are ordinarily.

Added to the features enumerated for the holotype are these characters from the associated specimens of the group: large mental processes situated well forward of the bifurcation, the posterior side of these longest, i. e., recurved; flat chin anteriorly; body of symphysis heavy and long; premolar teeth large, double-rooted, with small diastema. (Specimen No. 10036 is about one fifth smaller than specimen No. 10037.)

Archæotherium marshi Group.

Archæotherium marshi, sp. nov.

Holotype, Cat. No. 12025, Y. P. M. Lower Oligocene. Cheyenne River near French Creek, South Dakota.

The original description of this specimen (figs. 10-12) was made by Professor Marsh (1893, pp. 408-409), in amplification of his species *A. crassum,* and speaking of the entelodont material which had been gathered together. He says in part:

"Explorations begun by the writer in 1874, in Nebraska and Dakota, resulted in finding several additional specimens, and others have since been obtained in the same region during the explorations made for the U. S. Geological Survey. Still other very perfect specimens have been secured by the Yale Museum, so that now ample material is available for investigating both the present species and its near allies.

"On Plate VIII of this article [Pl. I, A] is represented, one-eighth natural size, a skull of *Elotherium crassum,* which is one of the most perfect ever discovered. The lower jaws are in place, and the nearly complete dentition is present and in fine condition. Figure 1 shows this skull as seen from the left side, with the jaws shut closely together, as found. One of the most noticeable features is the long dependent process (*m*) on the malar bone, which in this species extends downward to the inferior margin of the lower jaw, in front of the angle. This is the case when these processes are somewhat expanded transversely, as shown in figures 2 and 3, which represent the skull as it lay in the matrix. Another peculiar feature shown in figure 1 is the series of processes on the lower jaw, the first (*a*) being the dependent, everted angle of the ramus; the second (*b*) a protuberance under the third lower premolar; and the third (*c*) a process below the base of the canine. These processes are well shown, also, in figure 3.

"Seen from above, in figure 2, the most noteworthy features are the small space occupied by the brain in the parietal region (*p*), the widely expanded malar processes (*m*), and the narrow, elongated facial portion. In this figure, the lower jaw is not represented. In figure 3, which shows the skull and lower jaws in position and seen from in front, many interesting points are shown. Copies of the original drawings of figures 1 and 2 will be found in von Zittel's Palæontology, Vol. IV, p. 337.

"The feet of *Elotherium* have hitherto been known only imperfectly from fragmentary portions, but the extensive material already referred to has enabled the writer to make out their entire structure in the present species. In figures 4 and 5 of Plate VIII, the manus and pes are represented, one-sixth natural size. It will be seen that in each foot there are only two functional digits, corresponding to the third and fourth in man. The first digit is entirely wanting, and only remnants remain of the second and fifth."

It is important to note that this is the specimen often mentioned in the literature as the apotype of *A. crassum* (fig. 9). It is the purpose in this chapter to point out the differences between it and *A. crassum,* and to give this well-known specimen a separate specific designation.

In its whole structure, except in the body of the ramus and in the size of certain premolars, which are quite rudimentary, the skull is robust, heavy, and massive. The stout-rooted canines, the thick and wide process from the jugal, the mental tuberosities, all indicate this.

The zygomatic arch is a structure of great strength; the dependent process, measured from the temporal suture, has a length of 140 mm., which is 34 mm. *less* than that of the holotype of *A. crassum,* while at the same time the width of 62 mm. is greater by 10. Thus the slenderness of the present specimen is 44.3 per cent; that of *A. crassum* holotype is 30 per cent.

From the eye socket the lengths of the processes in the two specimens are about equal, some 200 mm. The process in *A. crassum,* on its anterior general border, is in line with the posterior border of the orbit; in the specimen now being described it is some 30 mm. further back. The process itself is symmetrical on its anterior and posterior sides, while the type of *A. crassum* has a flange anteriorly not duplicated behind. The lower end is very much thickened, is broad, and is roughened for muscle attachment.

The posterior process from the malar does not fit into any notch on the glenoid lip nor above it. The post-orbital branch of the malar is heavy but has a marked fossa

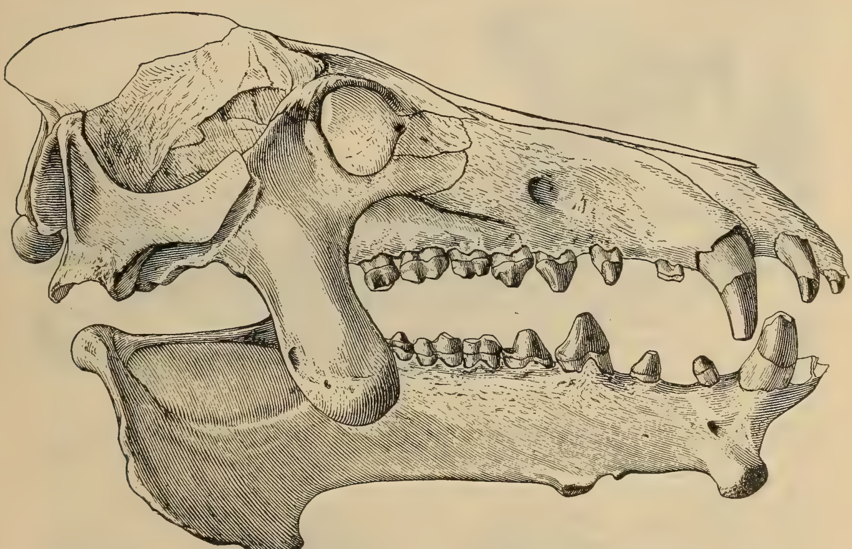


Fig. 10.—*Archæotherium marshi,* sp. nov. Holotype. Cat. No. 12025. Side view of skull and jaws. Compare Pl. I, A, as apotype of *A. crassum.* One-fifth nat. size.

on its outer surface; none is to be found in the holotype of *A. clavus clavus* nor of *A. crassum;* rather, in the latter the cross-section is almost oval. On the process which extends forward from the temporal (and measured from the condyle), the vertical diameter is very great, over 58 mm. This process has a strong sigmoid curve on its ventral border; it is very wide in contrast to that of *A. crassum,* which has no such curve. The glenoid cavity is not cut away on its border to receive the end of the malar process, nor is it notched above the fossa as in *A. clavus clavus.*

On the anterior wall of the temporal is a very large foramen which occurs doubled in the type of *A. crassum.*

The occipital condyle is not long but is thick vertically, and on its upper side the articular surface has a distinct edge; above it there is a slight depression within which opens a foramen. A unique feature is to be seen in the posterior ending of the maxillary in a very thin process inclosing between it and the pterygoid process of the palatine, a post-palatine foramen. The maxillary at the suture with the malar is strongly convex; this is in har-

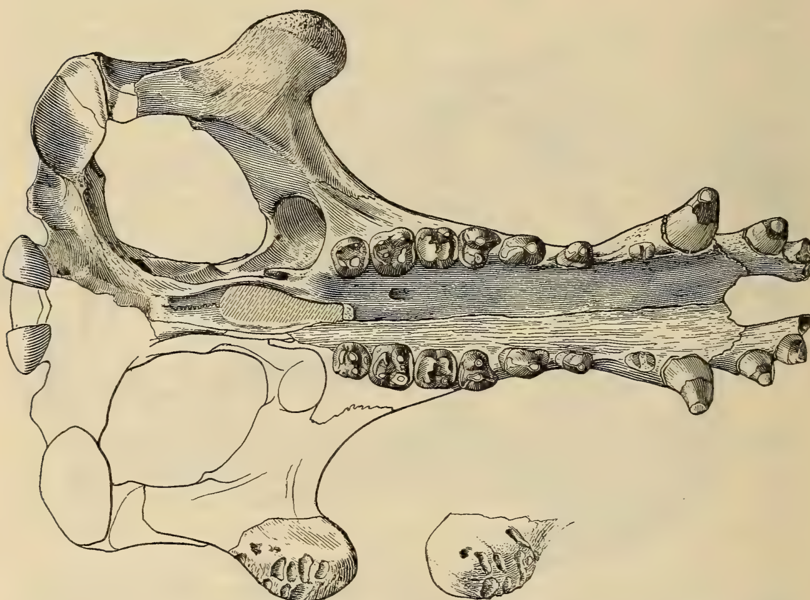


Fig. 11.—*Archæotherium marshi,* sp. nov. Holotype. Cat. No. 12025. Palatal view of skull. Note the teeth marks on the tip of the left dependent process. About one-fifth nat. size.

mony with the general heavy structure. The alveolar border is very shallow and the palate and the palatine processes of the premaxillaries, forming the roof of the mouth, are broad and flat. The molar series is crushed in, closing the area of the hard palate about 20 mm. on one side.

The orbit is bounded above by a narrow rim beyond which there is a small depression. In the frontal here, there are many longitudinal folds, and the boundary with the parietal is marked by a strong ridge which leads to the sagittal crest. This is the only specimen at hand which has well marked supraorbital foramina; these lead into channels forward. The frontals are narrow anteriorly. The lachrymal occupies but a small part of the orbit; it is narrow and extends upward and forward, giving room for the end of the malar, which is large and high on the face; in consequence the zygomatic arch begins on the maxillary. The anterior border of the orbit is over the middle of M^3.

The extremely heavy canines and incisors are large in proportion to the massive skull. The third upper incisor is actually broader at the root than the canine of the type of *A. clavus clavus.* This third incisor is recurved and

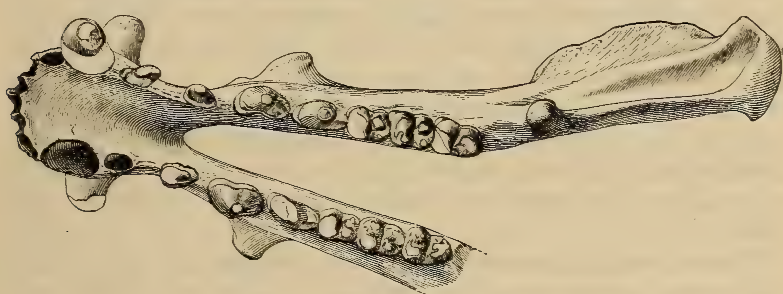


FIG. 12.—*Archæotherium marshi,* sp. nov. Holotype. Cat. No. 12025. Crown view of lower jaws. One-fifth nat. size.

caniniform; it is triangular, with the posterior side rounded and flattened. The canine from the heavy root tapers rapidly and is not so strongly recurved.

P^1 is merely rudimentary, is separated from the canine, and is situated squarely in the maxillary. P^2, separated from P^1 by a diastema of 23 mm., is also very small, and is directed forward at an angle. It is about 10 mm. from P^3, which begins the series of five functional teeth; P^3 is wide posteriorly, its inner face almost flat; the enamel is smooth, with hardly a trace of cingulum or ridge. P^4 is subtriangular, with the corners considerably rounded. It has the usual notch in front of the deuterocone. The antero-posterior dimension is longer than the transverse.

M^1 is almost circular, but the base of the hypocone is indented; the form seems to be peculiar to this specimen. M^2 is subquadrate, but with all the corners rounded and much wider anteriorly where the base of the paracone is very heavy. It is much larger than M^1; has the cusps grouped closely together and the cingula distinct, but weak on the corners. M^3 is round except for the prominent base of the paracone. The metacone is very much undeveloped, likewise the hypocone; the hypostyle is not as prominent as in *A. clavus clavus,* and there is no posterior heel.

Along with the great development of the zygomatic arch and its dependent process, we find greatly enlarged tubercles on the lower jaws (see fig. 12). The anterior mental processes are about half below the large canines, and are well in front of the beginning of the symphysis. They are rounded, flat on the bottom, and larger at the ends, which hook backward. The chin is flat in front of the tubercles and only slightly convex near the incisive border. The symphysis is short and the body of the ramus relatively light in this specimen.

The processes below the fourth premolars do not extend so far laterally from the rami, but they are compressed and spread anteriorly to join small secondary tubercles. The posterior outer corner is rounded up and backward.

The coronoid process rises well outside the line of the molars as in specimen No. 10032. It is round, thick, and heavy, although the antero-posterior dimension is not great and the masseteric fossa encroaches from below, causing the branch down and forward, and that running back, to be narrow and rounded. The masseteric fossa is large and deep like that of a carnivore and is roughly pentagonal in form. The border below forms a strong buttress running to the tip of the condyle.

The mental foramen lies above the mental tubercle and below P_1. Apparently other smaller foramina lie further back.

There exists a considerable difference in size between the alveoli of I_1 and I_3; I_2 is intermediate. The very heavy lower canine is scarcely a half longer than it is thick as viewed on the inner side. Although broken, it does not seem to be much recurved. The enamel covers less than the upper half.

P_1 is remarkable in having but a single root. It is unusual because, although its age is Lower Oligocene, it is more advanced in its evolution than other species of the Middle Oligocene. It is very small, almost vestigial, curves strongly backward, and is placed near the canine. P_2 is separated from P_1 by a distance of 25 mm. and from P_3 by 13.6 mm. Like P_1, it is rudimentary and very small; but is shorter and thicker and sits low on its roots. The outer side is very convex, the inner almost flat. It is strongly recurved and has cutting edges and cingula.

P_3 is situated very close to P_4 but does not touch it. It is very high on its roots, which are heavy and slope backward. The inner side is flat, the outer convex, and the two diameters have the proportion of 1:2. A sharp ridge extends from the cone to the roughened area above the cingulum.

P_4 has approximately the same antero-posterior diameter as P_3, but is a little thicker. It has a very low crown and sits low on the roots, which point strongly backward as if to exert strong pressure in that direction. The heavy protoconid is also strongly recurved. The very narrow but long shelf-like heel, higher in the center, joins a ridge running from the point of the cone.

M_1 is a much worn tooth on which an obscured talonid may be seen. The entoconid is weak, the hypoconid relatively strong, and there does not seem to be the great disproportion in height between the anterior and posterior cones seen in *A. clavus clavus;* the anterior cones are slightly wider than those posterior.

M_2 is considerably larger than M_1 and appears to have a double-cusped metaconid. The entoconid is small and weak; on the hypoconulid there is a small lake indicating its relative prominence (cusps indicated on figs. 17, 18).

The double-cusped metaconid of M_3 is as large as the protoconid, but the entoconid is much weaker than the hypoconulid or heel.

Summary of Archæotherium marshi Group.

A. marshi, sp. nov.: holotype, Cat. No. 12025; referred specimen, Cat. No. 10290.

In this group there are two specimens, both from South Dakota. The new type is the splendid skull (figs. 10-12), which has been taken for the apotype of *A. crassum* by all writers heretofore. The chief characteristics distinguishing it from the holotype of *A. crassum* are: the heavy zygomatic arch with the large posterior process from the jugal, and its sigmoid border, which joins the wide process from the temporal; the wide symmetrical dependent process, its position far behind the orbit, the sharp edges of the deeper glenoid cavity, and its geographical location.[9]

The additional features which separate it from the *A. crassum* group as a whole are: the small body of the ramus, the short symphysis, the long diastema, and especially the single-rooted P_1 and the small size of it and of P_2.

The second specimen, No. 10290, assigned to this group and referred to the new species, has the single-rooted premolar, is similar in proportions, but is a sixth larger than the holotype *A. marshi*. It differs also in having a much less full angle on the ramus, in having blunt, not slender, coronoid processes, and in having a much wider posterior heel on P_4.

[9] From the correspondence with L. W. Stilwell concerning the purchase of this specimen, it is evident that it came from the north bank of the Cheyenne River between French and Battle creeks, and that the horizon is lower Oligocene, associated with *Brontotherium* and *Hyracodon*. Further evidence of this is found in the green sandstone matrix and the red stain of the bones so characteristic of the *Titanotherium* beds.

TO BE CONTINUED.

ART. XXV.—*The Age of the Dakota Flora*[1]; by EDWARD W. BERRY.

Nothing is more profitless than controversies regarding geological boundaries or the precise age of those fossil floras or faunas that existed at or near horizons where geologists have been pleased to consider that such boundaries should be drawn. There are certain conclusions, however, in Twenhofel's otherwise admirable paper on the Cretaceous of Kansas which appeared in the April number of this Journal that should not be allowed to pass unchallenged lest it be thought that they have the support of the fossil flora. These are that the Cheyenne-Kiowa-Reeder series of southern Kansas and the Mentor-Dakota series of central Kansas, and the extension of the Dakota in Nebraska, are synchronous with the Washita division of the Texas section and therefore Lower Cretaceous in age, and that the boundary between Lower and Upper Cretaceous, or between Comanchean and Cretaceous as Twenhofel prefers to call them, falls in Kansas between the Dakota and the Benton.

Twenhofel recognizes that Comanchean is not the equivalent of the Lower Cretaceous of the rest of the world, and that these Kansas formations, as well as the Washita division of Texas, are probably to be correlated with the Cenomanian stage of Europe and are therefore Upper Cretaceous according to European standards. What he fails to recognize is the results that logically follow from his conclusions when the Cretaceous of other parts of the United States are considered.

The flora of the Dakota group as elaborated by Lesquereux comprised a great many species of fossil plants from Kansas and Nebraska and some from as far northeast as Minnesota and as far west as Colorado. Many were without definite localities and no particular attention was paid at that time to their stratigraphic position. It has become increasingly clear of late years that "Dakota flora" was not a unit and had no precise stratigraphic value. A study of new collections made from known stratigraphic horizons would be the only means of clearing up this problem. There is, however, another if less

[1] Published with the permission of the Director of the U. S. Geological Survey.

satisfactory method of attack that must serve until such a study can be made, and that is to consider all of the members of the so-called Dakota flora that occur at known geologic horizons in other areas in one category, and those that have not been recorded at other and known horizons in a second category that must remain under suspicion until their horizon has been determined.

I have recently determined the collections of fossil plants from the Cheyenne sandstone of southern Kansas and from the Woodbine formation of northeastern Texas for the U. S. Geological Survey. The Cheyenne sandstone rests on red beds and is overlain by the Kiowa marine beds. It is, therefore, referable to the Washita division of Texes and presumably corresponds to a part of the Mentor of central Kansas. The Woodbine formation lies between the Washita division and the Eagle Ford formation—the latter the Coastal Plain equivalent of the Benton. The Woodbine has commonly been correlated with the Dakota. Both the Cheyenne sandstone and the Woodbine formation contain floras that would be called Dakota floras in the sense that the "Dakota flora" means merely Upper Cretaceous flora. The two have not a single species in common and such "Dakota" forms as occur in the Cheyenne are all forms limited to Cheyenne and so-called Dakota, associated with older species never recorded from the Dakota, whereas most of the Woodbine species are "Dakota" species that have been recorded from very many localities in such formations as the Bingen sand, the Tuscaloosa, the Raritan, Magothy and Black Creek formations.

The Cheyenne flora is no more closely allied to the Woodbine flora than the latter is to that of the Montana group. It is, therefore, no more proper to speak of Dakota flora in connection with the Cheyenne, and presumably also in connection with the Mentor, than it would be to call the Benton fauna a Kiowa fauna or vice versa.

Any Cretaceous formation containing dicotyledonous leaves and known or thought to be earlier than the Benton has usually been said to contain a Dakota flora and this was apparently the only criterion employed in the recent field work. That there is a Dakota flora that is not Comanchean must be obvious to anyone who has followed the study of the Atlantic Coastal Plain Cretaceous or consulted the various correlations that have been published from time to time by Clark, Stanton, Stephenson and the writer.

The Woodbine, for example, is in part continuous with the Bingen sand of Arkansas which contains a flora, and which represents all of the Upper Cretaceous in Arkansas below the Exogyra ponderosa zone. The Woodbine appears to be the same age as the Tuscaloosa of Alabama which also contains many "true Dakota" plants and which I have advanced reasons for considering as in part contemporaneous with the Eutaw formation—the eastern correlative of the Eagle Ford and Benton. That there is a comparable relationship in Texas between the Woodbine and Eagle Ford seems likely but has not yet been demonstrated.

There is a similar Dakota element in the floras of the Raritan and Magothy formations, and in the Carolinas the plant beds are a part of the Black Creek formation which contains a considerable marine fauna, as does also the Magothy formation in New Jersey. Invertebrate paleontologists have been inclined to correlate any traces of marine organisms in these beds, even in a formation as old as the Raritan, with the Senonian of Europe, whereas I have argued from the floral evidence that these beds should be correlated with the Turonian. There is absolutely no question but that they are all not only Upper Cretaceous but post Comanchean.

The floral evidence in all of these cases is overwhelmingly in favor of considering these floras more closely related to their known successors than to their known ancestors and this remains true despite the very considerable dicotyledonous element in the Patapsco formation of Maryland and Virginia, which I have correlated with the Albian stage of Europe and with the Fuson formation of the western Black Hills region.

Undoubtedly it is confusing to continue talking about a Dakota flora that is a composite, but which it is difficult from regarding as an entity implied by its having a name. I have tried to avoid this in a measure by speaking of a "true Dakota" flora, meaning thereby the equivalent of that of the Woodbine formation of Texas, and those of corresponding age elsewhere, as opposed to such floras as that found in the Cheyenne sandstone and at other localities throughout the West that have mistakingly been thought to come from the Dakota sandstone.

The Woodbine flora appears to me to be intimately associated with the Benton transgression. Moreover I have long been of the opinion that the Washita fauna is of Cenomanian age and therefore Upper Cretaceous, which so far as I can learn, is the opinion of every competent paleontologist who has studied the faunas. I might mention Böse's work in Mexico or that of Whitney on the fauna of the Buda limestone. It is also not without interest in this connection that such of the Fredericksburg and Washita echinoids, ammonites, and other forms that have an outside range, or the most closely related forms, in northern Africa or South America, occur respectively at horizons which European paleontologists have determined as Albian and Cenomanian, or even Turonian in some cases.

Possibly if the United States were smaller our paleontologists could see beyond its borders, and then perhaps even the magic of diastrophism might lose its potency.

Art. XXVI.—*An Occurrence of Naumannite in Idaho;* by Earl V. Shannon.[1]

A specimen in the National Museum collections has recently been examined and found to consist almost entirely of naumannite, the rare selenide of silver which has not heretofore been reported from the United States although known from several mines in Mexico.

The specimen in question was collected by George H. Eldridge in 1893 from the Silver Stopes of the De Lamar Mine, at De Lamar in the Silver City district, Owyhee county, Idaho. This mine was noted for large bodies of rich ore which in part occurred as a white to gray or bluish clay which filled fissures and which contained large amounts of a silver mineral in grains, shot, or larger masses. This silver mineral which was malleable and sectile was commonly supposed to be argentite. The specimen which has been found to consist of naumannite was collected as a typical nodule of the argentite occurring in the clay and it is quite possible that the silver in a large part of such ore was in the form of the selenide rather than the sulphide.

[1] Published by permission of the Secretary of the Smithsonian Institution.

The specimen of naumannite is an irregularly rectangular flat nodule completely coated with grayish clay. The interior is composed of the naumannite which has a dark blue-gray color with metallic luster and a faintly shining gray streak. It is exceedingly sectile and quite malleable. Where broken the fracture is hackly and irregular, the perfect cubic cleavage reported for naumannite not being manifest. The color is quite unlike that of argentite and the mineral does not tarnish readily as does the sulphide. The hardness is 2.5 and the specific gravity as determined on a sample not entirely free from clay is 6.527. The pure mineral does not equal 7.0 sp. gr. as compared with 8.0 given for naumannite in textbooks. The descriptions of naumannite from previously reported localities do not emphasize the extremely marked malleability and sectility of the mineral. Aside from the clay which coats the outside of the naumannite and is distributed through it, the only other mineral present is marcasite which occurs as disseminated small grains in the silver mineral. After deducting clay and marcasite the analysis yielded the following results:

Analysis of Naumannite.

	Per cent.
Silver	75.98
Selenium	22.92
Sulphur	1.10
	100.00

The presence of sulphur replacing a portion of the selenium is interesting as indicating an isomorphous gradation toward argentite. Lead, which commonly occurs in naumannite from European localities, is absent as are copper, gold, zinc, bismuth, antimony, arsenic and tellurium.

Many tons of such ore as that from which the above described specimen came, were mined and the silver mineral was passed as argentite. It is not improbable that silver selenide has been similarly overlooked in other western silver ores although the distinctive reactions of selenium are so easily recognized that it is the work of but a moment to prove its presence or absence.

U. S. National Museum, Washington, D. C.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *An alleged Allotropic Form of Metallic Lead.*—About five years ago it was observed by H. Heller that compact metallic lead, when placed in contact with acidified solutions of lead salts, undergoes after a time a remarkable change, becoming filled with cracks at first and finally falling to powder. It was concluded that an allotropic form of lead was thus produced, similar to the well-known change of ordinary tin into the grey modification. This view was confirmed by Cohen and Helderman, who studied the phenomenon by means of the dilatometer; they believed that no chemical reaction took place. and decided that the allotropic form was more dense than ordinary lead.

A. Thiel has now studied and discussed this matter very thoroughly, and has reached the conclusion in a very convincing way that this is no case of allotropy at all, but a peculiar case of chemical action. He finds that the action takes place only when lead nitrate is present in the solution, and that a well-known chemical reaction takes place, dissolving the lead with the formation of lead nitrite. The peculiar action throughout the mass of the metal is explained by Thiel as due to the presence of a more readily attacked eutectic existing between the original crystals of the metallic lead. The arguments are very convincing, and it appears that the powder is certainly not an allotropic form of the metal.—*Berichte,* **73**, 1052. H. L. W.

2. *The Estimation of small amounts of Iron as Thiocyanate.*—Richard Willstätter, in connection with the analysis of certain physiological preparations, where the amounts of iron to be determined were often between 0.1 and 0.02 mg., has applied the colorometric method using ammonium thiocyanate with hydrochloric acid. Although this method has been frequently used in the past, the author has found that the previously described methods of procedure could be much improved. He uses a far larger excess of the thiocyanate than has been customary, thus obtaining a much more intense color. The solution to be analyzed is compared with a standard solution of known strength by adding 0.5 to 1 cc. of each 0.5 cc. of concentrated hydrochloric acid, and then 40% solution of ammonium thiocyanate sufficient to bring the volume to 50 cc. There are certain precautions to be taken in comparing the colors. The red color gradually fades, evidently from the reduction of the ferric salt by the thiocyanic acid, hence the colorimetric readings must be made promptly. Another difficulty is the fact that the ammonium thiocyanate usually contains a little iron and gives a reddish solution, but the author has found that the 40% solution becomes colorless by boiling it for a short time, and that it remains without color after cooling.—*Berichte,* **53**, 1152. H. L. W.

3. *Glucosane.*—Gélis observed in 1860 that when glucose is heated to 170° C. it loses water and is converted into a brown,

amorphous, scarcely sweet, unfermentable substance. He assumed that the substance consisted chiefly of the anhydride of glucose $C_6H_{10}O_5$ (that is, $C_6H_{12}O_6—H_2O$) to which he gave the name glucosane, but he did not succeed in isolating it in a state of purity. Since that time it appears that no further study of the substance has been made until recently when AMÉ PICTET and PIERRE CASTAN have taken up its investigation. They have found that by slightly modifying the original method of preparation, heating the glucose only to a temperature of 150-155° under a much diminished pressure (15 mm. of mercury), there is a regular disengagement of water without any oxidation or profound decomposition, and after cooling, a nearly colorless solid mass is obtained. The glucosane obtained in this way can be crystallized from methyl alcohol solution, and the authors have confirmed the formula $C_6H_{10}O_5$. They have found also that the substance gives interesting reactions, and it is expected that the study of the products will lead to precise conclusions in regard to the structure of the two isomeric glucoses.—*Comptes Rendus*, **171**, 243. H. L. W.

4. *A new Method for the Determination of Zirconium.*—In view of the difficulties connected with the methods heretofore employed, MELVIN M. SMITH and C. JAMES have made the application of selenious acid for the purpose of precipitating zirconium and have found the method very satisfactory. This reagent has the advantage over nitroso-phenyl-hydroxylamine (cupferron) in giving a separation from moderate quantities of iron. It gives also a separation of zirconium from aluminium and the rare earths, and in the presence of an excess of hydrogen peroxide a separation from titanium. The precipitation should be made in hydrochloric acid solution containing not over 7% of the strong acid, and the precipitate is washed with water containing about 3% of the acid. It is then ignited and the oxide is weighed. The method does not give a separation from thorium, but this element appears to be absent from most zirconium ores. For the separation from phosphoric acid and for other details the original article must be referred to.—*Jour. Amer. Chem. Soc.*, **42**, 1764. H. L. W.

5. *The Stability of Sucrose in Acid Vegetable Juices.*—H. COLIN calls attention to the fact that in many sweet fruits, such as oranges, etc., cane sugar exists in the presence of free acid the concentration of which is more than sufficient to produce the inversion of the sugar to glucose. Many authors have called attention to this circumstance with surprise, and it has even been suggested recently that possibly the sugar and acid might be contained in separate sacs in such fruits. Colin explains this stability on the ground that the acid vegetable juices contain alkaline salts, chiefly potassium salts, of the acids, and that it is well understood that salts of weak acids by their presence greatly diminish the hydrogen ionization of the acids, and consequently their power of inverting sucrose. He has shown experimentally that mixtures of vegetable acids with their potassium salts,

similar to the mixtures contained in natural juices, cause the inversion of cane sugar far more slowly than the free acids alone at the same concentration.—*Comptes Rendus*, **171**, 316.

H. L. W.

6. *The Einstein Displacement of Solar Lines.*—As is now well-known, there are three consequences of Einstein's theory which are amenable to experimental observation or investigation, namely: (a) the motion of the perihelion of the orbit of the planet Mercury, (b) the apparent displacement of the positions of the stars on the celestial sphere due to the passage of the light from the stars through the gravitational field of the sun, and (c) the displacement toward longer wave-lengths of spectral lines radiated near the edge or "limb" of the sun. The first two predictions seem to have been fulfilled quantitatively as well as qualitatively, but the third deduction from theory seemingly was not verified by the earlier spectroscopic observations.

The second paper by L. Grebe and A. Bachem seems to remove the last practical objection to Einstein's theory of gravitation. The first part of the paper deals with the spurious photographic displacements arising from the juxtaposition of partially or completely unresolved emission or absorption lines. By making a careful microphotometric study of three spectrograms of the solar absorption lines,—the source of which is now ascribed to nitrogen,—the authors were able to select nine lines in the ultra violet that are free from the contaminating influence of superposed lines of metallic origin. The wave-lengths of these nine lines range from 3844.378A to 3873.504A.

Expressed in terms of the equivalent Doppler effect, the final result was that the displacement amounted to 0.56 kilometers per second. This agrees with the value predicted by Einstein's theory, 0.6 km. per sec., within the limits of error of the calculation. By way of comparison, the authors quote the following data for such lines as were previously investigated by other observers and which pertained to the same list of nine lines. Schwarzschild (7 lines) 0.63; St. John (5 lines) 0.32; Evershed and Royds (2 lines) 0.67. The weighted mean of all four data is 0.54 km. per sec., which is as close to Einstein's datum as may be expected at this immediate time. The least and the greatest displacements obtained for different lines by Grebe and Bachem were 0.3 and 1.2 respectively. *All* of the displacements were toward the red. It appears, therefore, that the discordant and non-confirmatory results published heretofore were due to the inclusion of lines the positions of which were seriously influenced by the superposition of adjacent metallic lines.—*Ztschr. f. Physik*, **1**, 51, 1920.

H. S. U.

7. *Practical Physics;* by Robert Andrews Millikan and Henry Gordon Gale. Pp. x, 462, with 476 figures. Boston, 1920 (Ginn and Co.).—This volume is a revision of the authors' "A First Course in Physics" carried out in collaboration with Willard R. Pyle. (See **36**, 423, 1913.) In many respects this

latest edition is more attractive, interesting, and instructive than the preceding revised edition. Important improvements have been made in the problems, and the number of full-page inserts has been more than doubled. Special, but not undue, emphasis is laid on the automobile, on the aeroplane, and on the extraordinary developments in physics for which the world war was largely responsible. The book is intended for beginners and it may be used, if desired, even in the second year of the high school. Accordingly, the present edition unquestionably merits the earnest attention of all who are engaged in introducing the subject of physics to students. H. S. U.

8. *Herschel;* by Hector Macpherson. Pp. 78, 1 portrait. London, 1919 (Society for Promoting Christian Knowledge).—This little book belongs to the series entitled "Pioneers of Progress: Men of Science" edited by S. Chapman. In it the author has presented in charming style an inspiring outline of the life and scientific career both of the elder Herschel and of his devoted sister Caroline. The practical value of the book is increased by the appendix which gives the chief dates in Herschel's life and also a classified list of bibliographical references. It is to be hoped that this volume will be generally brought to the attention of graduate students in astronomy and physics so that they may be lured into the fascinating, but too often neglected, field of the history of the great pioneers of science. H. S. U.

9. *Journal de Physique.*—This journal, founded by J. Ch. d'Almeida in 1872, has begun its sixth series as the *Journal de Physique et le Radium.* It is the official organ of the Société Française de Physique and the scientific editor is M. P. Langevin. Volume 1, No. 1, pp. 1-32, bears the date of January to July, 1920. (Address 12 Place de Laborde, Paris, VIII; foreign subscription 40 francs.)

II. Geology and Mineralogy.

1. *Contributions to a history of American state geological and natural history surveys;* by George P. Merrill. U. S. Nat. Mus., Bull. **109**, 549 pages, 37 plates, 1920.—At last Doctor Merrill has been enabled to present his history of the state geological and natural history surveys of the United States. The work has to do with such organizations established by law in thirty-six states up to the year 1885; in the remaining states and territories no surveys had been provided for up to that time. Here we learn of the essential doings of these various state surveys, and the laws under which they operated. The whole is made alive with good portraits of seventy-seven leading state geologists, and what a pleasure it is to see the countenances of men some of whom have heretofore been only names to us!

To Denison Olmsted, an enthusistic graduate of Silliman at Yale, belongs the honor of being the first to attempt a state survey (in 1821), "for developing and extending the internal resources of the state" of North Carolina, and all he asked for was $100 to defray his travelling expenses. Even so, the Board of Internal Improvements did not consider itself authorized to make the contract. Two years later, Olmsted renewed the proposal, and the Legislature authorized the Board of Agriculture to have such a survey made and to provide for the "geological excursions" of Olmsted, appropriating $250 annually for four successive years. In 1825, Elisha Mitchell took over the work, since in that year Olmsted returned to Yale.

Credit for the first successful state survey, however, is due to the great Edward Hitchcock, another student of Silliman. This geological survey was organized in Massachusetts in 1830, and started with $1,000. Then followed in rapid succession the surveys of Tennessee (1831), Maryland (1834), New Jersey, Connecticut, and Virginia (1835), Maine, New York, Ohio, and Pennsylvania (1836), Delaware, Indiana, and Michigan (1837), New Hampshire and Rhode Island (1839), etc.

We congratulate the historian of American geology on the completion of this volume, which finds a fitting place on our shelves beside his widely known "Contributions to the history of American geology," 1906. C. S.

2. *Handbuch der regionalen Geologie.*—It will interest American geologists to know that during the Great War the following parts of this excellent and all-embracing work have appeared: Heft 18, Die Oesterreichischen und Deutschen Alpen bis zur Alpino-Dinarischen Grenze (Ostalpen), by Franz Heritsch, 1915, pp. 153; Heft 19, entralasien, by Kurt Leuchs, 1916, pp. 138; Heft 20, The British Isles and the Channel Islands, by thirteen authors, edited by J. W. Evans, 1917, pp. 354; Heft 21, Grönland, by O. B. Böggild, 1917, pp. 38; Heft 22, Kleinasien, by A. Philippson, 1918, pp. 183. C. S.

3. *The American Diceratheres;* by O. A. Peterson. Mem. Carnegie Mus., 7, No. 6, pp. 399-477, pls. 57-66, 37 text figs., 1920. —Peterson's recent memoir on the genus *Diceratherium* is an interesting and very valuable contribution to our knowledge of the extinct rhinoceroses. He shows in a very clear and thorough manner, by the use of fine figures, plates, and descriptions, the distinctive features of the type specimens and in greater detail of the important group *D. cooki* Peterson. Firmly but tactfully and without prejudice he throws out those species founded upon inadequate types, but in so doing shows a proper regard for such an ancient type as that of *Rhinoceros* (? *Diceratherium*) *hesperius* Leidy, saying: "In my opinion these remains are generically and specifically unidentifiable, but hold the historic position of being the first material of the Rhinocerotidæ obtained in the John Day region of Oregon." He has declared no less than a dozen specific names "incertæ sedis" or "synonyms";

and it is evident from such a wholesale slaughter as he has been forced to make that species should not be made on separate teeth or a single bone, unless they represent an unusual discovery, just such as that of Leidy's first description of rhinoceroses from the Great Basin.

This review offers an opportunity to criticize the custom followed here and by some other authors of attempting to discriminate between the "generic" and "specific" characters. Such characters are relative, and are generic or specific only in relation to some other definite type specimen. A safer way perhaps is to use the term "distinctive features," as so many writers do.

Finally, an important step is taken in this memoir in correlating definitely the upper John Day beds with the so-called Lower Miocene of the Great Plains. It seems that the paleontological evidence for this is overwhelming, as has been suggested by many writers—Merriam, Matthew, Osborn, and Peterson himself in earlier papers. There is a growing conviction, however, that the dividing line between Oligocene and Miocene should not be *within* the John Day formation, but at its top, and therefore that the lower Rosebud comes at the level of the Upper Oligocene of the Old World. E. L. TROXELL.

4. *Atlas der Krystallformen;* by VICTOR GOLDSCHMIDT. Volumes III-V, Heidelberg, 1916-18 (Carl Winters Universitäts buchhandlung).—Volumes I and II of the great work undertaken by Professor Goldschmidt, were published in 1913 and noticed in volumes **36** (p. 313) and **37** (p. 284) of this Journal. All those who have had the opportunity to study these volumes closely, must have appreciated keenly the care and thoroughness with which the author had carried on his work. We have now received volumes III, IV, and V of the same work each consisting as heretofore, of 2 separate parts, one of the tables and the other of text. Volume III bears the date of 1916 and includes the species from danalite through the feldspar group. There are 247 tables which are described in the accompanying text; nearly 1,250 figures are devoted to the feldspar group alone. Volume IV is dated 1918 and includes species from fergusonite to ixionolite; this embraces 133 tables. Volume V extends from kainite to margarosanite with 123 tables. It is impossible not to marvel at the perseverance and energy of the author in carrying on so large a work to the extent noted in this brief summary, and in accomplishing its publication in the same excellent form as heretofore under conditions so unfavorable both on the personal and material side. All interested will now look forward with confidence to the completion of the whole. The original prospectus (see vol. **35**, p. 553) mentioned "five or six volumes" as the number looked forward to, but the material accumulated by the author thus far seems to show that the original estimate was much too small. In any case, he is to be congratulated on what he has accomplished by his arduous labors, and on his

almost unparalleled contribution to crystallography and mineralogy.

5. *Beiträge zur Krystallographie and Mineralogie;* by Victor Goldschmidt. Heidelberg (Carl Winters Universitäts buchhandlung).—It is interesting that the author of the Atlas noticed above should have had the time and energy to initiate the new publication of which the title is here given. Volume I of 264 pages, with 25 plates and 72 text figures, embraces 5 parts and as now received, bears the dates from 1914 to 1918. Seventeen original papers are here included; of these, one of particular interest is the opening article by Professor Goldschmidt on "Krystallographie and mineralogie," which gives a broad view of what the science has accomplished and may look forward to in the future. The first number of the second volume (1919) has also been received. It embraces 4 articles covering 25 pages with 7 colored plates of remarkable execution and interest. The paper on the complex twins of pyrargyrite is of particular interest especially in connection with the plates which illustrate it.

Obituary.

Professor John Nelson Stockwell, of Cleveland, died on May 18, 1920, in his 89th year. In his death, America has lost one who belonged in the group of eminent astronomers, which included Gould, Hall, Newcomb, and Hill. Born near Northampton, Mass., his parents moved to Ohio in 1833, where he was educated in the common schools. In 1852 he acquired Bowditch's translation of Laplace's *Mécanique Céleste,* which fixed his career in mathematical astronomy.

He was closely associated for 42 years with Dr. B. A. Gould, who published many of his researches in the Astronomical Journal; he also made numerous contributions to other journals. The well known "Memoir on the Secular Variations of the Eight Principal Planets" was published in 1873. Dr. Stockwell was the first professor of mathematics and astronomy in the Case School of Applied Science from 1881-1888, when he gave up teaching to devote himself to research. His "Theory of the Moon's Motion" appeared in 1875. In later years he made extensive researches on eclipses since the year 3784 B. C. In his 88th year he published a new method for attacking the problem of the ocean tides, and about the same time prepared a paper on Hill's method for finding the Maximum Lunation, which will shortly appear in the Astronomische Nachrichten.

Always of mild and gentle manner, Dr. Stockwell was much beloved by a wide circle of friends, and his record of devotion to pure science for 70 years is one which has left a lasting impression on his time.

T. J. J. See.

M. Armand Gautier, the distinguished French chemist, died at Cannes a few months since in his eighty-third year.

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Established by BENJAMIN SILLIMAN in 1818.

THE

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FOURTH SERIES

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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXVII.—*The Nature of Paleozoic Crustal Instability in Eastern North America*; by Charles Schuchert[1]

It is now three years since Professors Eliot Blackwelder and Rollin T. Chamberlin began a correspondence with the writer looking toward a time when we three might offer a nomenclatorial scheme expressive of our conclusions regarding the diastrophic epochs and their classificatory relations that would be acceptable to geologists. In the meantime the Great War came on and our contemplated joint efforts have as yet come to no visible results. However, as the writer has long been interested in the times of earth movements and their classification into minor and major crustal deformations, he was stimulated by this correspondence to apply himself more vigorously to gathering the evidence of the times of diastrophism, and especially in the eastern and mid-continent regions of North America. Many interesting results have been attained, but the data at hand are not fully assembled or completely understood. Therefore this presentation is of a preliminary character, and in the nature of a report of progress.

In addition to various terms that have been proposed from time to time for North American crustal deformations, there are now in print three distinct and different tabulations of the known orogenic periods. The first of these appeared in June, 1914, and was by R. T. Chamberlin.[2] The second, by Eliot Blackwelder,[3] was written be-

[1] Presented before the Geological Society of America at its meeting in Boston in December, 1919.
[2] Jour. Geology, 22, 315-345, 1914.
[3] Ibid., 633-654.

fore he was aware of Chamberlin's work, but was printed three months later. The third, published in 1915, was by Schuchert.[4]

Early in 1917, Blackwelder stated in a letter: "On one thing I think we are all agreed, and that is, that orogenic epochs, or disturbances, or revolutions, or whatever else they may be called, are coming to have due recognition, and that it is inevitable that some system of naming them will be adopted by the geological fraternity." At the present time, the writer offers no complete nomenclatorial scheme, but seeks rather to point out when some of the Paleozoic crustal deformations took place, along with the times of most marked detrital sedimentation, and something as well in regard to the geographic extent of these two sets of diastrophic criteria.

The structural relief of the lithosphere, or crustal deformation, is thought to be essentially due to earth shrinkage, and the resulting diastrophism is of two categories. (1) The wider and more significant diastrophisms, the negative movements, have in the course of geologic time brought into being the oceanic basins as seen to-day. The continents are therefore for a time left standing as horsts. (2) The other type of crustal movement is orogenic and positive, i. e., is mountain-making, folding the continents along narrow belts which are the former sites of geosynclines.

Dana, in the fourth edition of his famous Manual of Geology,[5] says: "The origin of the shape of the earth's mass" is "geogenic work, [and] pertains to astronomy." We would say that it pertains as well to geophysics and geology. He further states that "The origin of continental plateaus and oceanic depressions, and of all movements in the earth's crust through geological time not involving orogenic work . . . [has] been termed by G. K. Gilbert epeirogenic, or continent-making."

Sir Archibald Geikie says,[6] in regard to the deformations: "Major Powell proposed the use of the term 'diastrophism' to denote all the processes of deformation of the earth's crust. Elevation, subsidence, plication, and fracture are all diastrophic. Mr. Gilbert[7] has fur-

[4] Pirsson-Schuchert Text-book of Geology, 1915.
[5] Dana, J. D., Manual of Geology, 4th ed., p. 376, 1895.
[6] Text-book of Geology, 4th ed., p. 392, 1903.
[7] Gilbert, G. K., U. S. Geol. Survey, Monog. 1, pp. 3, 340, 1890.

ther subdivided diastrophism into orogeny or mountain-making and epeirogeny or continent-making.[8] Orogenic movements are displayed in the narrower waves of uplift in the terrestrial crust, and are associated with the more energetic manifestations of diastrophism, while the epeirogenic, so far as known to us, are rather displayed in slow secular deformation of the crust.''

The term epeirogenic signifies continent-making, i. e., the broad vertical movements within the continental masses. Therefore to keep our ideas of the epeirogenic changes, measured from the sea-level, which in the main are upward or positive, distinct from the broad movements of the oceanic basins, which as a rule are downward or negative, we propose to refer to the latter as *oceanogenic.* We would also include under oceanogenic results the consequent eustatic changes in the level of the marine waters. We should be careful in using these terms, however, to note the fact that we do so only in a relative sense, i. e., relative to the strand-line of the oceans, the plane for measurements of the heaving or sinking masses, because, since the earth is a shrinking mass, and the continents are accordingly to be looked upon as horsts, the sum of the movements of both the continental masses and the oceanic areas is downward. Nevertheless, under this hypothesis the denser oceanic sectors shrink the most, while the lighter continents as a whole appear to be moved outward or upward, but in reality stand still as horsts. It is therefore the eustatic or worldwide movements of the variable oceanic level that give us the datum-plane from which we measure the amount of continental protuberance.

We would then define orogeny as the resultant of the lateral movements of the lithosphere, producing marked foldings or faultings, or both, that may be accompanied by igneous intrusions. The orogenies are believed to be due to earth shrinkage setting up in the lithosphere long-enduring accumulations of strains that eventually attain the breaking point, finding relief in orogenic epochs when folding and faulting take place at the surface. Periodically recurring epochs of orogeny are coming

[8] The Century Dictionary writes these terms epirogeny and epirogenic, and defines them as ''pertaining to movements by which changes of level have occurred without special orogenic results; noting continent-making movements or the up-and-down movements or oscillations of continental areas.''

more and more into recognition, and it is inevitable that some system of naming them will be adopted by geologists. Sometimes a single region is affected, as is the case in the minor late Ordovician orogeny known as the Taconic, when eastern North America was folded from about Pennsylvania northeastward across Newfoundland, a distance of upward of 1300 miles. At other times, more than one continent was folded, as was the case in the major orogeny that took place toward the close of the Paleozoic, or the more recent ones of Mesozoic and Cenozoic times. We therefore see that the shrinkages taken up by the orogenies differ in their power to fold the lithosphere, and in their geographic extent. Whether they can be grouped into two or more categories so as to be of value in delimiting periods and eras of time, or whether they have all gradations of strength between the lesser (the disturbances) and the greater ones (the revolutions), is a most interesting problem of which more will be said in the conclusion of this paper.

The writer holds that the crustal deformation of a given time and region should have an independent name, and that this term should be applied to all of the chains of mountains comprised in the region of identical movement. On the other hand, there has been synchronous or nearly synchronous orogenic work going on in different continents, or in different parts of the same continent, or in succession on either side of an oceanic basin or orogenic realm. To all of these independent provincial orogenies it is proposed eventually to give distinct geographic names.

In addition to the epeirogenic and orogenic movements of the continents, there are the gradual warping deformations known as the bradyseisms (from the Greek words *bradus* and *seismos*, meaning slow earthquake), but as to the significance and terminology of these gentle movements nothing will be said at the present time.

Finally, it seems to be advisable that in Historical Geology all of the orogenies of a period of time be grouped under a distinctive term. The speaker did this in his text-book, using geographic names of broad areas, as Cascadian, Grand Canyon, etc. A better terminology was, however, invented earlier by T. C. Chamberlin and ably seconded by his son Rollin in the terms Devonides, Silurides, etc., and it is this latter method that we had best agree upon.

The geologist sees and describes the orogenies, and he often measures the height of the mountains from their internal structure, and their geographic extent either from their actual presence or from their roots as now preserved in the structure of the earth. The stratigrapher, however, sees yet other mountains reflected in the sediments, the sites of which may never be discovered. Surely when we see more than 10,000 feet of Upper De-

FIG. 6.—Orogenic provinces in eastern North America.

vonian marine sediments piled up in eastern Pennsylvania, with a rapidly increasing accumulation of detritals beginning in Hamilton time, we are justified in postulating a region of orogeny to the eastward in Appalachia, and of the time of the crescendo of deposition (see Fig. 6). The proof that long rivers brought this sediment from a mountainous area that lay to the east and northeast is seen in the internal structure of the White Mountains of New England, the Monteregian hills of Quebec, and the Acadian Mountains of New Brunswick and Nova Scotia. And when we proceed from Kansas to southern Oklahoma, or from Missouri to central Arkansas, and note that the Pennsylvanian formations of from 1000 to 3000 feet thickness swell out to 10,000 and even to considerably more than 18,000 feet locally, we are again justified in postulating mountains to the southeast in Llano (Fig. 6), the roots of which are in all probability now buried under the deposits laid down later by the Gulf of Mexico marine invasions of Cretaceous and Cenozoic time. These two examples are both marine fossil deltas, and they are a striking attestation of orogenic work, indicating mountains whose presence and geographic position are postulated from the migrated, fragmented mountains now seen in the marine formations mentioned. There are in addition many other such cases of marine sedimentation, though of less striking record.

We see therefore that great piles of marine deposits are indicative of mountains and of crustal deformations. In all similar cases of marine sedimentation, it is very probable that the regions of orogenies lie more or less far away from the places of clastic accumulation. In the case of thick masses of fresh-water or continental deposition, on the other hand, the record of orogeny is far better, for these depositions take place in, or at least near, the areas of the mountains themselves. One such example—and it is a brilliant one—will be cited in some detail because it brings out clearly a succession of orogenies, in fact, four of them, all taking place during Mississippian and Pennsylvanian times. This is in the region of New Brunswick and Nova Scotia, in the Acadian province (see Fig. 6), in the area now being studied by Dr. Walter A. Bell of the Geological Survey of Canada, who kindly presented me with the following facts. Succeeding the late Devonian orogeny already referred to, were developed the Lower Horton arkoses and agglomerates, and the Albert series of New Brunswick, which together have a thickness of up to 3400 feet. The fossils seemingly indicate very early Mississippian time, and this conclusion is further borne out by the underlying and overlying formations. Then followed the first Carboniferous crustal movement, apparently not as vigorous a one by far as that of the Devonian. Again we have basal arkoses, in the Upper Horton *Estheria*-bearing beds of more than 700 feet thickness, and then about 1100 feet of Windsor semi-marine red beds, gypsum, and dolomites, the last of which have an abundance of peculiar marine organisms. The age of all of these deposits is late Mississippian. Then a time of marked mountain-making again set in, and this, the second orogenic period, appears to have been the strongest of the four Carboniferous deformations, for it removed the sea permanently from the entire area of the Maritime Provinces of Canada. It seemingly took place during latest Mississippian time. The succeeding deposits, by their overlapping and transgressive character, all show more or less of an angular unconformity beneath. The first of these Pennsylvanian fresh-water deposits are the conglomerates of southern New Brunswick, followed by the Lower Westphalian coal series of New Glasgow, the Fern Ledges of St. John, and in part the Millstone Grit of the Sydney area and Prince Edward Island, together having a thickness of more than 5,000 feet. Next came the third orogenic movement, of about middle Westphalian time, resulting in the conglomerates of the Joggins, Parrsboro, and New Glasgow areas, and the late Westphalian coal series of the Joggins basin, with a total thickness of more than 6800 feet. Now followed the last of the four Carboniferous deformations, one of the latest or post-Westphalian time, and this elevation gave rise to the higher conglomerates of the Joggins area and the Lower Stephanian coal series of Sydney, whose thickness is not less than 2100 feet. In Prince Edward Island, the thickness just mentioned appears to swell out to nearer 6000 feet. There was another deformation later, since none of the Carboniferous strata remain in their original attitude of deposition.

The term orogeny has to do, as we have seen, with the making of mountains, and the defined names that we apply to the result of a given deformation, as the Acadian Mountains, point out the place and time of their making. For instance, the Acadian Mountains rose in late Devonian time and extended from the New England States through New Brunswick and Nova Scotia into Newfoundland. On the other hand, we need a term to direct attention to mountains that we do not see, and may never see, but whose presence is clearly demonstrated in the thick and often coarse sedimentary deposits resulting from their waste. We therefore propose to use the term *oroclasy* (from *oros,* mountain, and *klao,* break in pieces), for the process which results in the broken and fragmented materials of mountains, or *oroclasmata,* such as testify to the former presence of mountains elsewhere than in the places where these oroclastic deposits now lie.

It may be urged that the thick accumulations of sediments are not reliable in indicating the exact time of deformation. In other words, it is thought that mountains may last longer than a geologic period, or at least considerably longer than the time of a geologic series. We may grant the uncertainty, yet a close analysis of the inherent evidence, both physical and organic, in the formations composing the record, indicates that the time values deduced from the oroclastic deposits are certainly as reliable as, and usually far more so than, those gained by the method of determining orogeny from the study of angular unconformities.

Our correspondence with Blackwelder also shows that we wanted to establish the time of origin and the duration of the orogenies, and whether they can be grouped into minor and major deformations. Or, as the speaker has elsewhere stated, into disturbances and revolutions. The opinion appears to be widely prevalent among geologists, however, that there are all grades of orogenies, and some good geologists further hold that the deformations may not all develop toward or at the close of the periods and eras. In regard to these opinions, and first as to the revolutions, the writer remains as firm as heretofore in the belief that they are developed only toward the close of the eras, and that they do delimit them, but apparently not at the accepted boundaries of our text-books. It appears that during the long-enduring revolutions the provincial and regional orogenies follow one another in succession, and that similar movements appear more or less synchronously on either side of the Atlantic realm. Not only this, but at these times orogeny is far more widespread and more intense than at other times. In consequence of the marked protuberances of the lithosphere, we see usually the development of much cooled and even glacial climates that bring on fundamental changes in the life of these times. Hence the term "critical periods," conditions of the environment that bring on critical times for the plants and animals and quicken greatly their evolution into the biotic dawn of a new era.

Now let us look into some of the revolutions, and first the one closing the Paleozoic. The appended graphs (see Figs. 1-5) show that the Pennsylvanian in many places was a time of marked crustal instability. In eastern North America and in western Europe this instability is apparent in the Mississippian or Lower Carboniferous, but it is in the Pennsylvanian that the crustal unrest becomes marked. The graphs show that in a given province there may be only two orogenies during this period (Appalachia), while in others there are three (Llano) or four (Acadia and Europe), if we count those at the very beginning and close of the Pennsylvanian. On the other hand, these deformations are not all synchronous, and it therefore appears that in eastern North America there are six times of crustal movements. Such marked crustal instability we see in no other period of the Paleozoic. Before the middle of the Permian had passed, there was another time of mountain-making, but in general the closing period of the Paleozoic was a time of high lands, cool and arid climates, and a crustal instability more like the periods of pre-Carboniferous times. During the Permian, the marine organic world, although still dominantly Paleozoic, was slowly changing toward the aspect of the Mesozoic, but the life of the lands, facing far more strenuous environmental conditions, was rapidly taking on the expression of the medieval world.

If diastrophism were to be the sole or even the dominant criterion for delimiting the eras, we would be obliged, in Pennsylvania and West Virginia, to close the Paleozoic with the fresh-water Dunkard formation of earliest Permian time, because in these states there are no later Paleozoic deposits. In eastern Canada, the Paleozoic would be closed at about the same time or possibly a little later. On the other hand, in Texas, New Mexico, and Arizona, the dominant orogeny falls in the later Pennsylvanian, and if we take this movement as our sole guide in Historical Geology, then some of the latest Pennsylvanian and all of the Permian goes into the Mesozoic era. The marine faunas, however, are not of the medieval type, and are a standing protest against such a reference.

Let us examine into another critical period, the orogenies of the Laramide revolution, and here again the evidence appears to lead to other conclusions than the accepted ones of our text-books. The Laramide revolution as such began in Laramie time. Then there was a long pause, during which the Lance, Ft. Union, and equivalent fresh-water deposits were laid down, with their included Mesozoic mammals and dinosaurs. Following this time of deposition, came the post-Laramide orogeny of Epi-Mesozoic time, one that apparently was even more marked than that of the Laramide movement. On these mountains glaciers appeared, and in the valleys was deposited the Wasatch series with its modernized mammals, clearly of Cenozoic time. The question now arises, which one of these two periods of orogeny shall delimit the Mesozoic? The writer seems to be gradually working toward the second one, in which case all of the Lance, Ft. Union, and their equivalents will go into the Mesozoic. If this is done, it will seemingly solve many of our field and faunal perplexities, but our botanical friends and possibly other stratigraphers will continue to have different views.

In this connection, we should also draw attention to the Nevadian deformation closing the Jurassic, when mountains were made all along the Pacific states, apparently from Lower California into Alaska. Some years ago Lawson pointed out this marked time of orogeny and said that it had the import of those at the close of eras. Certainly it is by far a more marked deformation than any of those which are usually ranked as disturbances, though one can not yet grant that it has the same importance as the Appalachian and Laramide revolutions. If we follow Lawson in his interpretation of the significance of this crustal movement, the Triassic and Jurassic will be of one era, and the Comanchian and Cretaceous of another. In this event we would be adopting a classification useful for America, but not applicable everywhere. That we can not follow Lawson in this is plain, because no European would think for a moment of relegating the Jurassic to an era that would not also embrace the Cretaceous. However, what we want more especially to point out here is that while most of the orogenies can be classified into disturbances and revolutions, yet the Nevadian deformation has not the significance of a revolution, because the majority of continents are not in movement in late Jurassic time, as they are during the Appalachian and Laramide revolutions.

Another case similar to the Nevadian orogeny is the western European Caledonian deformation, when grand mountains were made all the way from Britain across Norway far into arctic Spitzbergen. This movement developed the very thick Old Red sandstone, through whose fossils we get the first good vista of the animals of the fresh waters and of the first known land floras. But where is the student of Historical Geology who would divide the Paleozoic into two eras, one to embrace the pre-Devonian periods, and another the post-Silurian ones? If the Europeans did this, would we Americans follow their example, since we have no Caledonides and have great difficulty in deciding where the line should be drawn between the undeformed Silurian and Devonian formations? We would be more in favor of dividing the Paleozoic into two sub-eras at the close of the Devonian, for at this time we have decided mountain-making and of a strength not far from that of the Caledonides. And in this the Europeans might agree.

In regard to the minor orogenies, the disturbances, the writer's views have changed somewhat with wider knowledge. We now know that the deformations do not *all* fall at or near the close of the accepted periods, as was formerly stated. It is still true, however, that most of them do occur in the last third or fourth of the periods as they are now defined. The exceptions to the rule are that mountains were made in Europe between the Lower and Middle Cambrian, the Upper Cambrian and Ozarkian, the Middle and Upper Ordovician, and the Tournacian and Visean or the Waverlian and Tennessean (see Figs. 4 and 5). These are facts, however, that appear only to make for a dismembering of the old and accepted periods. A revision of the periods, on the basis of diastrophism, would then place all of these orogenies in the latter part of the redefined periods. On the other hand, there are yet other orogenies that do not point this way. In Newfoundland, block-faulting and apparently folding as well occurred after Normanskill time of the Middle Ordovician (see Fig. 2). The most striking exception to the rule, however, is the Pennsylvanian, with its various crustal pulsations; according to the regions studied there are either one or two that fall near the middle of this period. If in addition we take cognizance of the thick sedimentary deposits, then orogeny also took place in earliest Champlainian and late Lower Devonian times. From the evidence cited and illustrated in the graphs (Figs. 1-5), we therefore learn that there is some irregularity in the time appearance of the disturbances. The few exceptions, however, are not sufficiently striking to prove that the disturbances have no value for the delimiting of the periods. On the contrary, the great majority of the orogenies appear toward the close of the periods, and are variable in the extent of the geographic areas affected. With a better knowledge of the seemingly few erratic crustal pulsations, they may be seen to be either of decidedly minor strength, or in some other way not to bear heavily against the theory of regularity in the periodically recurring diastrophisms. We therefore conclude that the great majority of disturbances take place during the closing epoch of the periods, that they are variable in their geographic extent, and that the revolutions are made up of a series of successive orogenies that finally bring on the critical periods, resulting in the quickened evolution of the earth's plants and animals. All of these conclusions are brought out more clearly in their chronogenetic, spatial, and marine-submergence relationships in the graphs, Figures 1 to 5, which should now be studied.

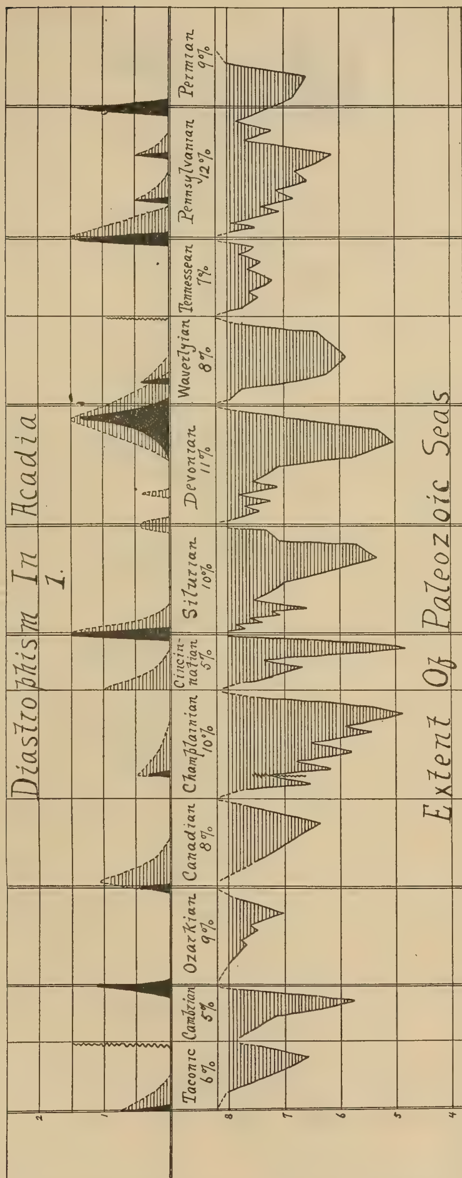
EXPLANATIONS OF FIGURES

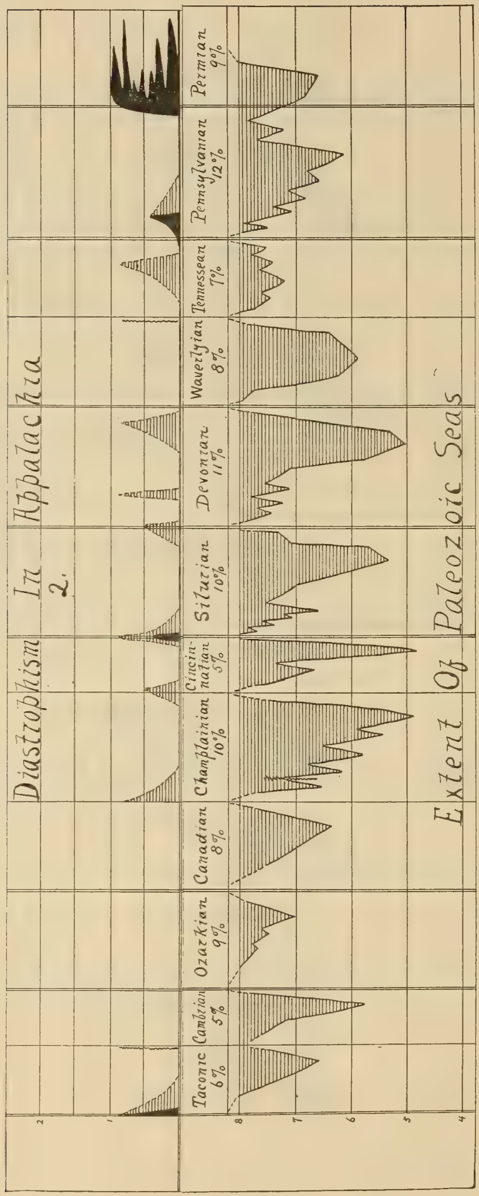
Fig. 1.—Diastrophism in Acadia in relation to time, space, and North American marine submergences. Solid black pyramids indicate the time of the orogenies and their geographic length in thousands of miles. Lined pyramids, the time and spatial relations of the thick and coarse sediments (oroclasmata). The amount of sea transgressions is in millions of square miles. Spiral vertical lines indicate time and extent of marked disconformities.

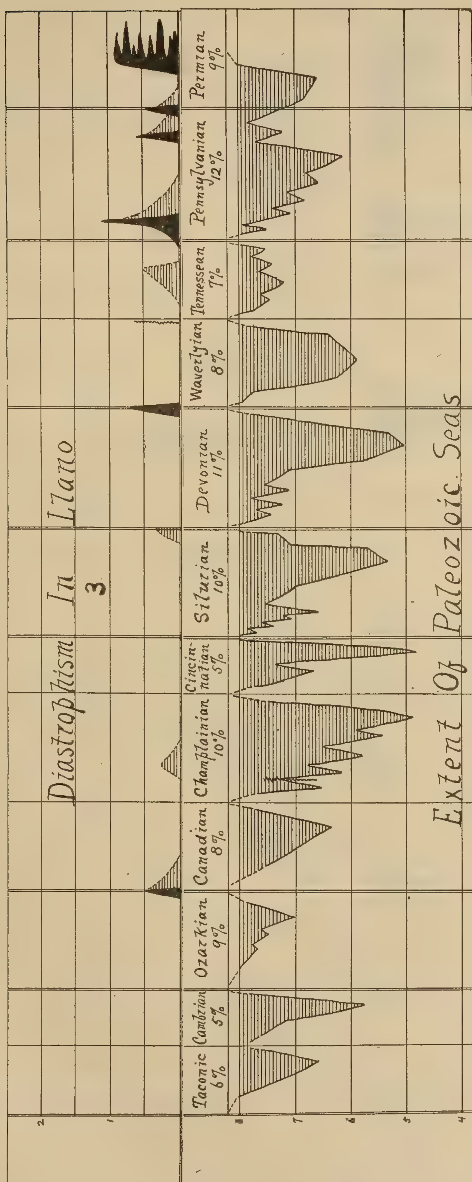
Fig. 2.—Diastrophism in Appalachia in relation to time, space, and North American marine submergences. Rest of explanation as in fig. 1.

Fig. 3.—Diastrophism in Llano in relation to time, space, and North American marine submergences. Rest of explanation as in fig. 1.

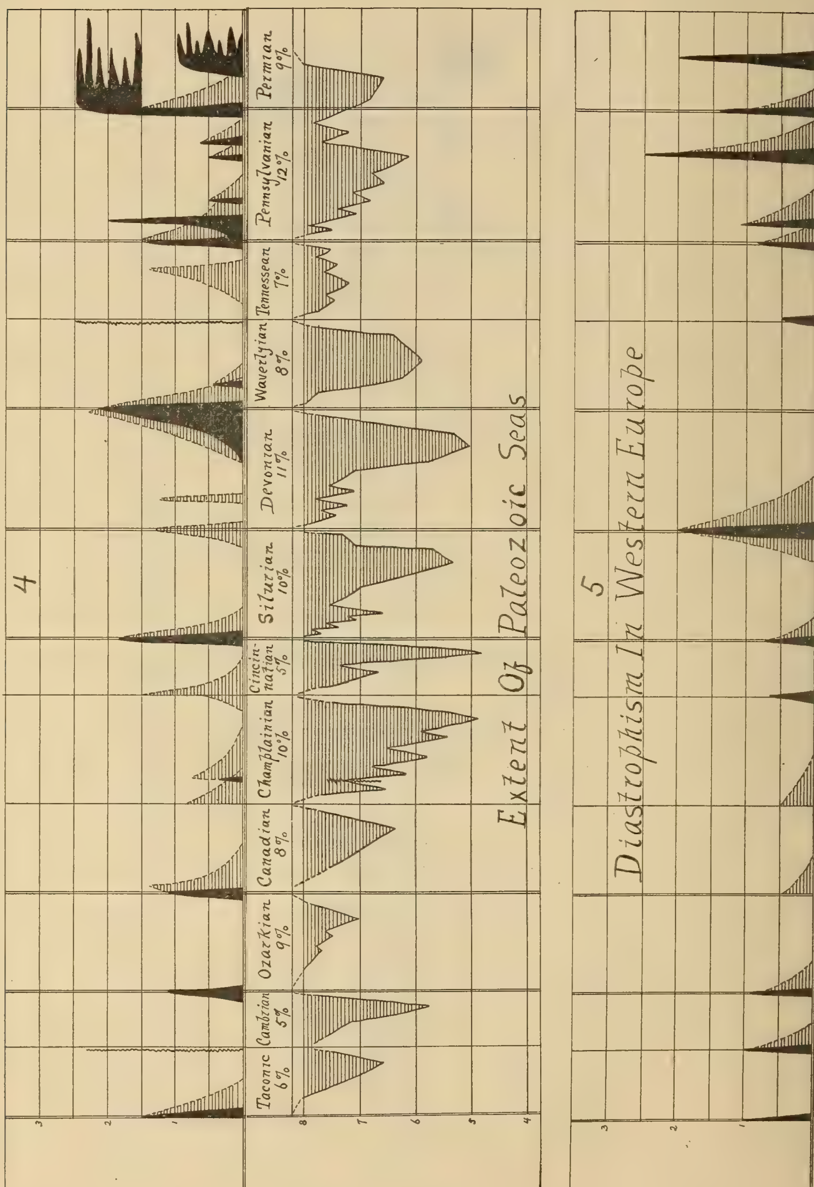
Figs. 4 and 5.—Diastrophism in eastern North America and western Europe in relation to time, space, and North American marine submergences. Rest of explanation as in fig. 1.


Diastrophism In Acadia
1.
Extent Of Paleozoic Seas
Taconic 6%
Cambrian 5%
Ozarkian 9%
Canadian 8%
Champlainian 10%
Cincin-natian 5%
Silurian 10%
Devonian 11%
Waverlyian 8%
Tennessean 7%
Pennsylvanian 12%
Permian 9%
2
1
8
7
6
5
4


Diastrophism In Appalachia
2.
Extent Of Paleozoic Seas
Taconic 6%
Cambrian 5%
Ozarkian 9%
Canadian 8%
Champlainian 10%
Cincin-natian 5%
Silurian 10%
Devonian 11%
Waverlyian 8%
Tennessean 7%
Pennsylvanian 12%
Permian 9%
2
1
8
7
6
5
4



Diastrophism In Llano
3
Extent Of Paleozoic Seas
Taconic 6%
Cambrian 5%
Ozarkian 9%
Canadian 8%
Champlainian 10%
Cincin-natian 5%
Silurian 10%
Devonian 11%
Waverlyian 8%
Tennessean 7%
Pennsylvanian 12%
Permian 9%


Diastrophism In Eastern North America
4
Extent Of Paleozoic Seas
5
Diastrophism In Western Europe
Taconic 6%
Cambrian 5%
Ozarkian 9%
Canadian 8%
Champlainian 10%
Cincinnatian 5%
Silurian 10%
Devonian 11%
Waverlyian 8%
Tennessean 7%
Pennsylvanian 12%
Permian 9%
3
2
1
8
7
6
5
4
3
2
1

Art. XXVIII.—*Notes on the Tertiary Intrusives of the Lower Pecos Valley, New Mexico;* by Douglas R. Semmes.

Introduction.

In the central part of Chaves County remote from other evidences of igneous activity there occur two large and prominent dikes and an igneous sill intruding the Permian Red-beds that form the surface throughout the area. The two dikes are to be found on the eastern side of the Pecos in that comparatively level area broken only by occasional low sandstone—or caliche-capped mesas, that extends from the Pecos River to the bluffs of the Llano Estacado, some fifty miles to the east. Neither dike can be traced across the Pecos, but to the northwest on the western side of the river, as indicated on the accompanying map (fig. 1), there occurs a sill, now exposed by erosion to form a prominent north-facing scarp, which from its lithologic character appears to be related to the dikes, though there can be found no actual connection between them.

The topography of this part of the Pecos Valley is the characteristic red-bed type of mesas, "breaks" and intervening mesquite and cactus covered plains. The elevation of the river in this portion of its course is about 3,500 feet, from which the country rises rather rapidly to the peaks of the Sierra Blanca on the west, almost 12,000 feet above sea-level, and on the east to the Staked Plains, about a thousand feet above the river. From the "breaks" of the plains, or the cap-rock, to the foothills of the mountains the Pecos Valley is approximately one hundred miles in width.

Stratigraphy.

The following section represents the formations that are to be found in the area under discussion, though the entire section is not represented in any one particular locality. The two lowermost formations of the Pennsylvanian underlie the series in the Rio Grande Valley, but they are not exposed east of the divide and it is not certain that they are at all represented in the Pecos Valley.

Fig. 1.—Map of a portion of Southeastern New Mexico.

Age	Formation	Thickness	Lithologic Character
Recent	Caliche	0-50	Surface layer of redissolved calcium carbonate, usually conglomeratic with numerous irregular limestone fragments and some water worn pebbles. Sometimes underlain by pebble beds and unconsolidated sands.
Tertiary (?)		10-40	Massive pebble conglomerates, locally known as "concrete." Usually found

Age	Formation	Thickness	Lithologic Character
			capping mesas, lying unconformably upon the Red-beds.
Cretaceous	Sierra Blanca Series	1500-2500	Coal seams, interbedded sandstones and shale and occasional thin limestone with a massive, coarse-grained, buff sandstone near base (Dakota?) This series is sometimes found underlain by variegated shales, thin beds of limestone, sandstones and conglomerates; presumably the Morrison formation.
Permian	Red-beds	700	Red shales and sandstones with occasional thin beds of gypsum.
	(Gypsum series)	300	Massive white and reddish beds of gypsum with alternating red shales and sandstones, giving rise to a solution type of topography with sink holes, sometimes filled with water (Bottomless lakes).
Permian	San Andreas limestone	650	Massive layers of compact, grayish, fossiliferous limestone with occasional layers of shale and sandstone. Massive coarse-grained friable buff sandstone near base.
	Local Unconformity.		
Pennsylvanian	Yeso	1000	Red shales underlain by alternating reddish shales, limestones and layers of gypsum. Highly folded where exposed in the vicinity of Capitan Mountain. Base unexposed.
Pennsylvanian	Abo	800±	Exposed near Alamogordo. Alternating red sandstone and red sandy shales.
Pennsylvanian	Magdalena Group (Madera limestone)	1500-2000	Exposed near Alamogordo. Massive bluish gray and dark bituminous limestone.

Areal Geology.

Magdalena Group.—The Magdalena group as exposed toward the foothills of the Sacramento Mountains near

Alamogordo consists of a series of siliceous limestones, shaly limestones, and sandstone in the lower part, and massive gray and dark limestone (Madera) toward the top, the series aggregating some 1,500 feet in thickness.[2] This massive limestone is not exposed in the Pecos Valley, but it is possible that it has some representatives in this area now buried beneath the Permian sediments.

Abo Sandstone.—The Abo sandstone, the basal member of the Manzano group, is also exposed near Alamogordo. The formation consists of a series of red sandstone and sandy shales with occasional thin layers of gypsum. The Abo is unexposed in the Pecos Valley.

Yeso Formation.—This formation as developed in the Sacramento Mountains near Alamogordo consists of 1,000-1,200 feet of red shales, thin-bedded gray cherty limestone and occasional layers of massive gypsum. On the eastern flank of the mountain near Lincoln the series is again exposed in part and there consists of red shales and shaly sandstones some 200 feet thick overlying a series of alternating red and greenish shales and sandstones and thin-bedded fossiliferous limestones. That portion of the Yeso which is exposed in this locality aggregates about 1,000 feet in thickness and is sharply folded, lying unconformably below the San Andreas limestone. Farther away from the Capitan Mountains the Yeso appears to show less intense folding, and where last exposed near Picacho it is only slightly unconformable with the overlying San Andreas. There is little doubt that it will be found approximately conformable with the Permian series if encountered by the drill in the Pecos Valley.

San Andreas Limestone.—The Sacramento range, which is actually a dissected limestone plateau, is formed by continuous limestone formations from its western edge to where this limestone dips below the red-beds of the Pecos Valley. This limestone where exposed near Alamogordo has been correlated with the San Andreas, by Darton,[3] which if correct undoubtedly indicates that the limestone developed from Roswell westward to the Sierra Blanca and the Sacramentos is equivalent to the

[2] N. H. Darton: A Comparison of the Paleozoic sections in Southern New Mexico. U. S. Geol. Survey, Prof. Paper 108, pp 31-55, 1917.
[3] Op. cit. p. 50.

San Andreas.[4] The San Andreas limestone of the Pecos Valley, extending across the Sacramento Mountain dips gently to the east and finally disappears under the Red-beds just west of the Pecos River. The tributaries of the Pecos have extensively dissected this limestone area and in the case of the Rio Hondo the San Andreas limestone has been completely cut through and the underlying Yeso exposed near Lincoln.

Red-beds.—Above the San Andreas there occurs an extensive series, 250 to 300 feet in thickness, of massive white and red crystalline gypsum with some interstratified red shales and sandstones. This east-dipping series of gypsum beds gives rise to a belt of striking solution topography characterized by extensive slumping and actual flowing of gypsum, sink-holes, caverns, and "bottomless" lakes, which crosses the Pecos River diagonally in the central portion of the area.

Beyond the gypsum belt the upper Permian red sandstone and shales form the surface eastward to the bluffs of the Staked Plains and there disappear beneath the cover of caliche. The normal dip is approximately 30 feet to the mile in a direction just south of east. The thickness of this upper sandstone phase of the Red-beds is difficult to determine but there are at least 700 feet of sediments represented.

Cretaceous Series.—In the Sierra Blanca coal field in Lincoln County the Cretaceous formations according to Wegemann[5] consists of a coal-bearing series 630 feet in thickness comprising shales, sandstones, and occasional thin limestones throughout which occur several seams of bituminous coal. Beneath the coal-bearing strata occur shales, sandstones, and limestones, shales predominating, which aggregate 1,000 feet in thickness and which in the lower part have been correlated with the Benton. These formations are underlain by massive coarse-grained buff sandstones, 175 feet thick, often forming prominent escarpments, which has been tentatively correlated with the Dakota. Underlying the Dakota there occurs a series of variegated shales with thin beds of limestone, white

[4] The San Andreas limestone of the Alamogordo section has been actually traced across the Sacramento Mountains and definitely correlated with the limestone west of Roswell by Mr. Dorsey Hager of New York City.

[5] Carroll H. Wegemann: Geology and Coal Resources of the Sierra Blanca Coal Field, Lincoln and Otero Counties, New Mexico, U. S. Geol. Survey, Bull. 541, 1914. pp. 418-452.

sandstone and conglomerates which is considered a possible representative of the Morrison formation. These sediments lie in a structural basin and show frequent intrusions of igneous rock in the form of dikes and sills. The upper member of the Carboniferous series, the San Andreas limestone, is found out-cropping at varying distances from the coal field, but at no point was it found directly associated with the Cretaceous strata.

Tertiary (?) Conglomerates.—In the vicinity of Melena Station about 15 miles northeast of Roswell there occur massive beds of poorly consolidated gravel, locally known as "concrete", which lie unconformably above the Red-beds forming prominent mesas. This material though unfossiliferous is regarded as probably of Tertiary age.

Caliche.—The redissolved and poorly cemented limestone material that rests unconformably upon the older rocks, which has been termed caliche, is to be found capping the table lands throughout the Pecos Valley. Beneath the Caprock of the plains, which is of similar material, the caliche is underlain by unconsolidated sands and gravels of apparently Recent age. In the Pecos Valley the caliche is the only formation other than the river alluvium that is not cut by the igneous intrusions.

Intrusives.

The igneous intrusives of the Pecos Valley in some cases form pronounced topographic features and are locally well known to the inhabitants of the area, who have in many cases prospected their contacts for the precious metals, but they have never been fully described in any publication with which the writer is familiar.[6] These intrusives appear to be confined to the area north of Roswell, though the source or center of igneous activity from which they are derived is still uncertain. The two dikes are almost exactly parallel and extend eastward until covered by the drifting sands in the area just west of the Caprock, so that it is not all impossible that they might be derived from some center of igneous activity now concealed beneath the Plains. On the other hand other intrusives are to be found west of the Pecos and there also

[6] The dikes east of the Pecos River have been mentioned by C. A. Fisher: Geology and Underground Waters of the Roswell Artesian Area, New Mexico, U. S. Geol. Survey, Water Supply Paper 158, 1906. p. 8.

occur the more extensive though probably earlier intrusives that form the backbone of the southernmost extension of the Rockies.

Railroad Mountain Dike.—Railroad Mountain dike extends as a prominent ridge (fig. 2) from Sec. 4, T-8-S, R-26-E to Sec. 28, T-8-S, R-31-E, Chaves County, a distance of 30 miles in a general east-west direction. To the east it becomes lost in the sands before passing under the Plains and on the west it abruptly disappears beneath the

Fig. 2.—Railroad Mountain dike. Looking east.

river deposits just west of the Pecos and does not come to the surface on the western side of the river. As indicated by its name the dike forms a ridge sometimes sixty to eighty feet high and a hundred or more feet in width, much resembling an abandoned and partially dissected railroad embankment. The width of the dike is remarkably constant being approximately 74 feet at both extremities (fig. 3), which would indicate that the exposed portion represents only a fraction of the entire extent of the intrusion. Where the dike first appears just east of the Pecos the trend is N 89° E, striking directly for Capitan

Mountain. From this point eastward it trends more to the north running approximately N 86° E for a few miles and then N 78° E until lost in the sands.

The trend of the dike is approximately normal to the general strike of the formations through which it cuts, and in consequence the side walls vary in character with the formation. The contact zones are comparatively narrow, in some cases the contact effects being only recognizable a few feet from the contact. In other places typical contact zones are to be seen, the walls being thoroughly recrystallized and many of the more common contact minerals being developed. In most part, however, the effect of

Fig. 3.—Railroad Mountain dike as exposed along the eastern banks of the Pecos River. Looking east.

intrusion seems to have been merely a slight baking of the country rock. Numerous prospect holes have been dug along the entire length of the dike but little mineralization seems to have occurred. A few samples showed very low gold values.

The dike rock is a massive,, dense, dark blue, medium-grained, granitoid rock composed of pyroxene (diallage) and olivine in a felt-like mass of interlocking lath-shaped crystals of plagioclase (fig. 4). Considerable magnetite is scattered throughout, which is undoubtedly a primary constituent. Almost no secondary alteration other than a slight amount of sericitization has occurred, a fact that explains the resistance of the dike rock to erosion and its consequent occurrence as a prominent topographic feature. The rock should be classified as an olivine gabbro. The interlocking feldspar aggregate is quite common in dike rocks (diabases), but the composition is of a more basic character than most of the other intrusives of the area.

Devil's Racetrack Dike.—This dike extends from Sec. 15, T-10-S, R-26-E to Sec. 7, T-10-S, R-29-E, Chaves County, a distance of approximately 15 miles. Like Railroad Mountain it can be traced eastward until lost in the

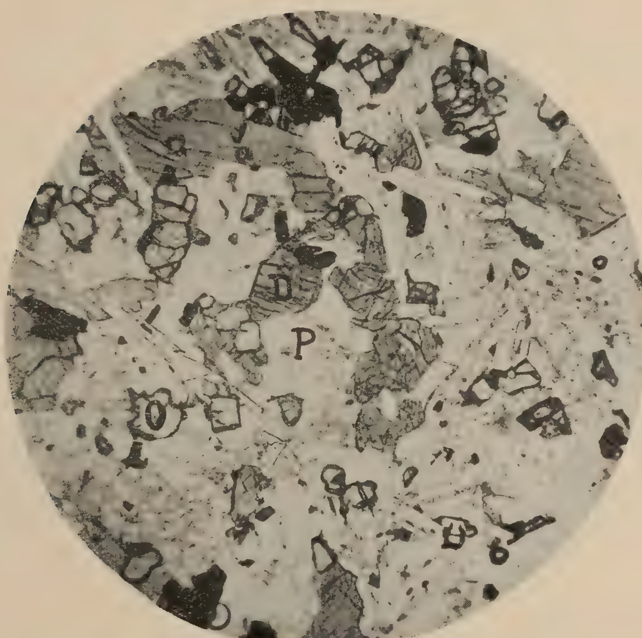


FIG. 4.—Photomicrograph of Railroad Mountain dike. 50 X. Showing diallage (D), olivine (O), and magnetite (opaque) in a matrix of interlocking plagioclase crystals (P).

Mescalero sands, and to the west it disappears beneath the caliche-capped plains east of the Pecos River, some 15 miles northeast of Roswell. No traces of it can be found in the gypsum bluffs that form the east bank of the Pecos about six miles west of the point where it disappears. Devil's Racetrack in contrast to Railroad Mountain forms no topographic feature but on the contrary is sometimes expressed on the surface by a slight depression, the dike rock being more readily eroded than the country rock.

The contact effects, resulting in the baking of the wall rocks for some feet from the contact, have given rise to two belts of resistant rock—the contact zones—between which lies the dike forming a slight depression, the whole resembling somewhat a modern race-course. Toward its western end the width of the dike is 32 feet but it widens to the east and where last seen showed a width of 47 feet. This increase in thickness to the east is decidedly suggestive and indicates that both of these dikes are possibly

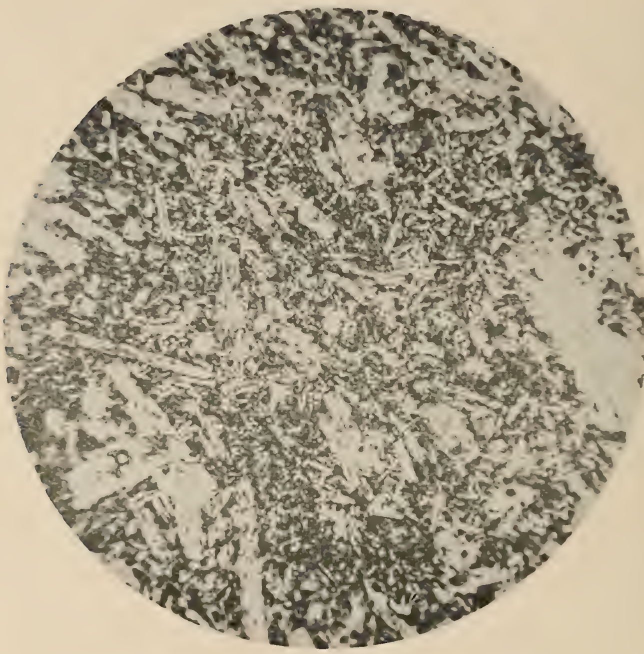


Fig. 5.—Photomicrograph of Devil's Racetrack dike. 50 X. Showing diabasic texture. Magnetite and secondary amphiboles in the interstices of the lath-shaped feldspars (P).

associated with some concealed center of igneous activity farther to the east. The trend of the Devil's Racetrack is exactly the same as that of Railroad Mountain (N 89° E) toward its western exposure. About Sec. 15, T-10-S, R-28-E, the trend changes to N 85° E and continues eastward in this direction as far as it can be traced. The contact effects are confined to zone varying from 1 to 10 or 12 feet in width and consist for the most part of a mere baking of the country rock. Numerous prospects have been made along this dike but no appreciable mineralization appears to have taken place other than a limited amount of pyritization.

This intrusive is a fine-grained, slightly porphyritic, bluish gray rock composed of augite and magnetite in a matrix of lath-shaped feldspar crystals, showing typical diabasic texture (fig. 5). Extensive secondary alteration has taken place, the feldspars being highly kaolinized and the augite almost wholly altered to secondary amphiboles, consequently the rock is easily weathered giving rise to no topographic feature other than a slight depression where the dike cuts a resistant formation. The composition is intermediate between the andesites and the basalts, but

Fig. 6.—Dunlap sill. Looking east.

neither megascopically or microscopically does it resemble a normal basalt, so the intermediate term augite-andesite is adopted instead.

Dunlap Sill.—About eight miles south of the post-office of Dunlap there occurs a sill intruding the Red-beds, that can be traced for almost four miles along its outcrop from Sec. 1, T-4-S, R-22-E, through Secs. 32 and 33, T-3-S, R-23-E, to Sec. 3. T-4-S, R-23-E, and throughout most of the area it forms a prominent scarp facing north (fig. 6). This intrusive like the dikes already described is not directly associated with any center of igneous activity, and it lies some fifty miles northeast of the extensive, though decidedly more acidic, intrusive that forms the

Capitan Mountain and the other andesitic sills occurring in the Yeso series in that locality.

The Dunlap sill is approximately eighteen feet in thickness and shows two distinct phases; an upper differentiation phase about a foot or less in thickness, which is decidedly porphyritic, the feldspar occurring as phenocrysts, and of a composition approximating that of a monzonite. Beneath the upper phase lies the main body of the sill; a medium-grained dark resistant igneous rock, which from examination by a hand glass appears to have the composition of a diorite.

The contact effects are insignificant. Beneath the intrusive the baked shales are not over three inches thick though in places some of the effects of the intrusion can be seen in the shales a foot or two below the contact.

The sill is apparently conformable with the bedding and is gently inclined to the south; the normal dip in this area, however, is almost due east.

Sills in the San Andreas in Ruidoso Valley.—In the Ruidoso Valley about fifteen miles southwest of the juncture of Rio Ruidoso and Rio Bonito at Hondo the San Andreas limestone and the red shales and sandstones immediately underlying are intruded by numerous sills of general grano-diorite or quartz-monzonite composition. Some of these sills are of considerable extent, traceable for a mile or so in the steep walls of the valley, and varying in thickness up to fifty feet. These sills are of slightly more acidic character than the intrusives that have been described. Quartz is an abundant constituent and they are as a rule of coarse granitoid texture.

Sills in the Yeso near Arabela.—At the eastern foot of the Capitan Mountains near the Mexican town of Arabela the Yeso series occurs highly folded against the flanks of the Capitan intrusion (fig. 7). For a mile east of the contact these formations can be traced, frequently repeated by sharp and sometimes overturned folds. Farther to the east the series disappears under the San Andreas limestone, dipping 6° to the east. Between the folded Yeso and the San Andreas there occurs a series of red shales and sandstones about 100 to 200 feet in thickness, presumably upper Yeso, which shows comparatively slight folding; a transitional phase from the folded formations to those slightly tilted overlying ones.

Into this folded series numerous intrusions have taken place, some of which are of considerable extent. The general composition of these intrusions, which are predominantly sills, is that of an andesite,[7] and the sills are conformable with the stratification being also highly folded, showing conclusively that the intrusion took place prior to the folding. Andesite sills were also found in the red shale series lying just under, and approximately conformable with, the San Andreas limestone.

Sills and Dikes in the Sierra Blanca Series.—The Sierra Blanca coal-bearing series which is regarded as Upper Cretaceous or possibly of post-Laramie age is widely intruded by sills and dikes of the general composition of those found near Capitan (diorites and monzonites). Just east of Capitan on the Lincoln road an andesite dike trending N 24° E and about 15 feet thick crosses Salada

Fig. 7.—Generalized cross-section from Capitan Mountain to Agua Azul, showing the crumpled Yeso strata underlying the relatively undisturbed San Andreas limestone. Scale 3 inches to the mile.

Creek, cutting the massive sandstones of the lower part of the series. Just west of Capitan on the highway to Carizozo the coal-bearing upper series is intruded by dioritic sills twenty-five or more feet in thickness. The series has also been locally faulted and the coal in many places shows the effects of the intrusion.

Summarizing the above, the intrusives of the Pecos Valley that are apparently of related origin and similar age, inasmuch as they are generally similar in composition and mode of occurrence, are seen to occur not in any one formation but in every series represented in the area, with the exception of the recent sediments, from the Yeso beds near Capitan to the Upper Permian Red-beds just west of the Cap-rock, and the Upper Cretaceous or possibly Eocene coal-bearing formations of the Sierra Blanca series.

[7] The term andesite is used by the writer to include also the basic andesites (augite-andesites), classified as basalts by some writers.

Structure.

The structure of this portion of southeastern New Mexico is that of a gently inclined east-dipping monocline rising gradually on the west from the Pecos River and the Red-bed area beyond to the crests of the Sacramento Mountains, and there breaking off forming steep scarps to the west. Toward the lower part of these escarpments, near Alamogordo, the Paleozoic series from the Pennsylvanian down lies conformably beneath the Permian and rests upon the pre-Cambrian granites.

On the eastern side of the divide the exposed members of the Manzano group show structure in wide contrast to that on the western slope. The pronounced unconformity below the San Andreas limestone is very striking. Fan-shaped and overturned folds frequently occur, the whole series being repeated many times within a short distance. The lower portion of the Yeso series is unexposed but at least 800 feet of these folded sediments can be recognized. Nearer the Pecos River in the eastern portion of the district the general east dip of the Permian strata is broken by occasional sharp and elongated anticlinal ridges, the best example being the Border Hills, 25 miles west of Roswell. These anticlines are similar in strike and in structure, being sharp, fan-shaped folds, expressed in the surface as prominent ridges, sometimes rising several hundred feet above the surrounding country, and showing a general trend of N 10° E to N 40° E.

Toward the west of this eastward-dipping monocline of Carboniferous strata, and encircling the peaks of the Sierra Blanca, the Cretaceous coal-bearing strata lie in a structural basin some thirty miles long (N-S) and twenty miles wide. A large amount of igneous material showing variations in composition and mode of occurrence has been intruded into these sedimentary series. This igneous material can readily be divided into those larger intrusives of more acidic composition that form the Sierra Blanca, Capitan, Jicarilla and Pajarito Mountains; and the smaller or more basic intrusives such as have been discussed, which dissect and permeate all of the sedimentary rocks of the area. These larger intrusives are probably older than many of the smaller ones, for near Nogal Peak the larger monzonite intrusive is cut by later diorite (?) dikes.

Age of the Intrusives.

Toward the end of the Cretaceous mountain-making movements were inaugurated throughout the entire area now occupied by the Rocky Mountains and these movements were accompanied by extensive intrusions of batholithic character outlining many of the present ranges. Similar movements continued and a great series of minor intrusives and some lava flows were injected into the Paleozoic and Mesozoic sediments surrounding the area involved. This period of igneous activity extended throughout the middle of the Tertiary with unabated intensity, and was represented still later (in late Tertiary, Quaternary and Recent times) by the outpouring of the extensive basaltic flows of northern and western New Mexico.

That the larger intrusives of the Sierra Blanca region are of post-Cretaceous age is evident from the fact that they intrude Cretaceous sediments. Lindgren (et al.) considers[8] all of the monzonitic and dioritic intrusives of similar character to these to be early Tertiary age. If the upper member of the Sierra Blanca is actually of post-Laramie age as intimated by Wegemann[9] some of the dioritic intrusions are undoubtedly late Eocene or even younger in age. From field observations the writer feels that the more basic and less extensive intrusives (diorites and gabbros) are younger than the more acidic intrusives (monzonites, quartz-monzonites, and grano-diorites) forming the mountain masses. This is borne out by the fact that diorite dikes intrude the monzonite near Nogal Peak. Moreover, the fact that these two classes of intrusives are distinct in composition and mode of occurrence suggests that they represent earlier and later stages in igneous activity.

Incompetency near Lincoln.—As has been noted the Yeso formation, intruded by the large monzonite intrusion that forms the Capitan Mountains, is sharply folded though the overlying San Andreas limestone is only slightly tilted. Moreover the Yeso is extensively intruded by andesite sills that are folded with the adjacent strata. This shows quite conclusively that the folding must have taken place subsequently to the intrusion, that is in early Tertiary time. The overlying limestones, however, deposited in the Permian have not been folded. The only adequate explanation of such structural conditions that suggests itself to the writer is that the relatively incompetent Yeso shales, gypsum beds, and lime-

[8] Waldemar Lindgren, L. C. Graton, and C. H. Gordon: The Ore Deposits of New Mexico, U. S. Geol. Survey, Prof. Paper 68, pp. 35-40, 1910.
[9] Op. cit. p. 428.

stones crumpled between the massive San Andreas limestone above and the igneous rock, or even the massive sandstones of the Abo and limestones of the Magalena group which should be found below. This explanation is supported by the fact that the Yeso crumpled series changes gradually through an upper series of slightly folded red shales to the unfolded limestone above. If there was an actual unconformity and accompanying erosion interval one would expect a sharp contact between the two, but such a break cannot be found. Incompetency on such a scale is unusual, possibly unique, but the existing structural conditions are difficult to explain in any other way.

Age of the Folding in the Roswell Area.—The two dikes east of the Pecos and the sill near Dunlap can be considered, therefore, to be later Eocene or younger in age. It is possible that these intrusions may represent later stages in Tertiary igneous activity, when the basaltic intrusives and extrusives originated, and may even be derived from some source quite unrelated to intrusives of the Sierra Blanca area, such as a concealed center of igneous activity under the Llano Estacado. In this case the dikes may be of middle or late Tertiary age.

The age of the folding that has given rise to the peculiar and characteristic sharp, elongated anticlines in the limestone area west and southwest of Roswell cannot be definitely ascertained, but it is not unreasonable to suppose that at the time of the intrusion of the larger bodies of igneous rock and the crumpling of the Yeso, the stresses that were set up in the overlying limestone were relieved by buckling along lines roughly parallel to the trend of these intrusions. The age of the folding in this case would be early Tertiary, though it is quite possible that it may have occurred at a much later date, for there are indications of even Recent movements expressed in the caliche that occurs throughout the area. The determination of the approximate age of this folding should be of interest from the point of view of oil and gas production, for should it be conclusively shown that the folding in this area is of comparatively recent age one might reasonably conclude that relatively little oil would now be entrapped.

University of Alabama,
University, Alabama.

ART. XXIX.—*Entelodonts in the Marsh Collection;* by EDWARD LEFFINGWELL TROXELL.

[Continued from p. 386.]

PART III. THE LARGER GENERA AND SPECIES.

PELONAX POTENS GROUP.

Pelonax potens (Marsh) Peterson.

Holotype, Cat. No. 12042, Y. P. M. ? Upper Oligocene, Colorado.

This specimen (figs. 13, 14), originally described by Professor Marsh, in 1893 (p. 410), consists of the lower

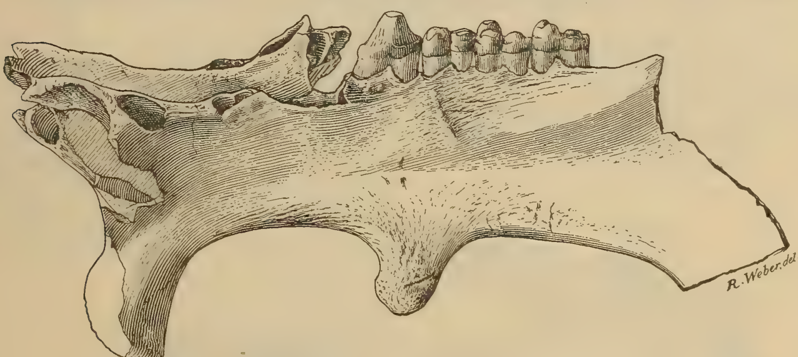


FIG. 13.—*Pelonax potens* (Marsh) Peterson. Holotype. Cat. No. 12042. One-fifth nat. size.

jaws without ascending rami and has only the tooth series P_4-M_3; it is from Colorado and of probable Upper Oligocene age.

The very large anterior mental tubercles, for which this specimen is noted, point downward, forward and outward equally. Because of their great length these processes resemble those of *P. ramosus* Cope. They are oval in section but have a strong ridge on the upper edge. The second set of tubercles below P_4M_1 are compressed transversely, extend downward strongly and are correspondingly long.

The first premolar is situated close to the canines and is single-rooted. The second premolar is double-rooted, but because the roots are small and not deep-set, one supposes the tooth was vestigial. Premolar three, which was confusingly shown in Peterson's drawing (1909, p. 60), is a heavy double-rooted tooth strongly sloping backward. P_4 also is a heavy tooth, with rather a small protocone bounded before and behind by definite shelves.

The first molar is much smaller than the others, but they are all similar in form, having strong fifth cusps or heels. The valleys are rather wide open, and the anterior tubercles, like those of *Archæotherium*, are high. The anterior and posterior halves of the tooth in each case are about equal in width. A small diastema, 9 mm., separates C_1 from P_1; P_1 and P_2 are separated about 32 mm.

The jaw is very narrow as measured across the diastema behind P_1, 79 mm.; the symphysis is relatively short, 158 mm., but the rami are deep relative to their length; the depth below P_2 is 92 mm. and that below M_2, 106 mm.

Pelonax bathrodon (Marsh) Peterson.

Holotype, Cat. No. 12030, Y. P. M.

This species (Pl. I, B) was originally referred to *Ammodon* by Marsh (1893, p. 410, pl. IX), but it differs from

FIG. 14.—*Pelonax potens* (Marsh) Peterson. Holotype. Cat. No. 12042. Crown view of lower jaws. One-fifth nat. size.

the paratype of *A. leidyanus* in being considerably smaller, and in having high anterior tubercles and broad transverse valleys; it closely corresponds to the size[10] of the type of the genus *Pelonax* Cope, and resembles it in many respects, including the possession of a strong posterior heel.

Summary of Pelonax potens Group.

This group takes for its center the holotype of Marsh's *P. potens,* of which the principal features are: the un-

[10] Peterson (1909) has made an error in representing the type of *P. ramosus* Cope as about one-half that shown by Cope.

usually large mental tubercles, both anterior and posterior; the very short symphysis; the deep rami set closely together; the single-rooted P_1 and very small two-rooted P_2; the large P_3 and the broad P_4 with a short narrow heel, and finally the well developed talonids on the lower molars.

Peterson has put this species under *Pelonax* Cope; it resembles the type, *P. ramosus,* in having a single-rooted first premolar and in possessing very large tubercles on the jaw, but it is about one sixth smaller and has a double-rooted second premolar. In spite of this great difference,

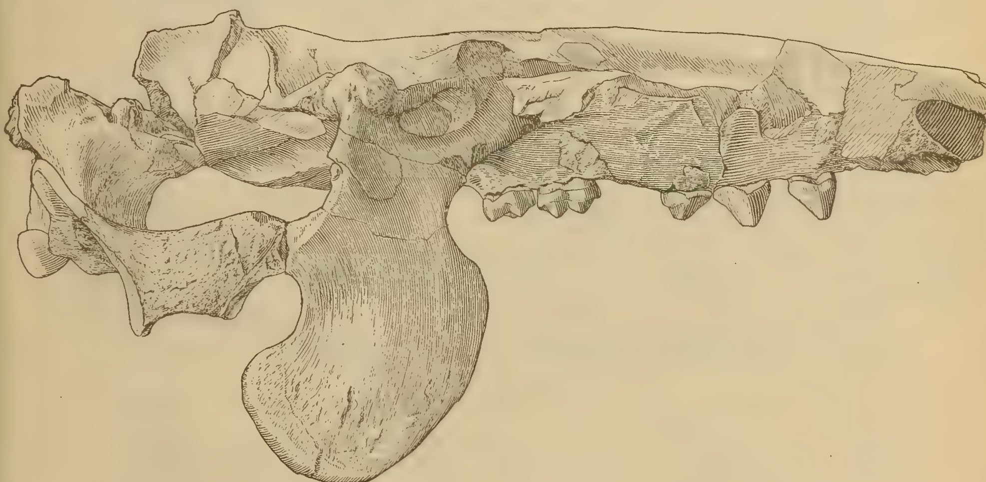


FIG. 15.—*Megachœrus zygomaticus,* gen. et sp. nov. Genoholotype. Cat. No. 10008. Side view of skull, injured by crushing, showing the enormous extension of the malar bone. One-fifth nat. size.

it is probably nearer to *Pelonax* than to any other designated genus.

P. bathrodon resembles Cope's published description of *P. ramosus* in size and in the high anterior tubercles.

MEGACHŒRUS ZYGOMATICUS GROUP.

Megachœrus zygomaticus, gen. et sp. nov.

Genoholotype, Cat. No. 10008, Y. P. M. ? Upper Oligocene, South Dakota bad lands.

In addition to the fact of its great size, this unusual elothere (figs. 15, 16) has the relatively largest dependent process of described specimens. In its extreme breadth it measures 136 mm., while that of the gigantic *Dinohyus hollandi* would measure about half as much. The process is unique also in that it swings posteriorly in a wide sweeping curve, so that its greatest antero-posterior dimension would be about 200 mm. Looked at from in front, it shows merely a rather thin strip running from the orbit, and for most of its extent is not thicker than 20 mm. Only at the point of sending off the process to join the temporal does it thicken to about 30 mm.; it is thin on the margin.

Measuring across the tips of the dependent processes, the width of the skull would be something over 600 mm., and the length is estimated to be 760 mm.

The posterior process from the malar bends down as it joins the temporal; it is thin on the outer side, and straight, but on the inner side is curved strongly downward, and the tip actually forms a part of the surface of the glenoid cavity. The distance from the notch to the orbit is 68 mm.

The anterior process from the temporal is triangular in section, probably had a sigmoid lower border and apparently extends to a slender point; it is deep, and the distance from the glenoid surface to its upper internal angle is 58 mm.

The vertical outer edge of the temporal is very slender above the condyle and has a distinct depression posteriorly, bounded by a narrow margin extending backward.

The infraorbital foramen lies over the middle of P^3 and is directed upward only slightly. The superciliary border is heavy, but in front of the orbit the rim is thinner. Unlike most entelodonts, the frontals form great smooth planes; *Dinohyus* has a deep depression just in front of the parietal boundaries, and other genera have deep foldings and a rugose surface. In this specimen a very faint ridge defines the frontals posteriorly, and there are no foramina.

The teeth (see fig. 16) in some respects seem to resemble those of *D. hollandi:* rugose, angular, irregular. P^1 is very small, is two-rooted and directed strongly forward as indicated by the alveolus. P^2 is rather stout, leans slightly forward, is convex on both sides, strongly so on the outer, and is pitted posteriorly; it is not curved backward nor inward. The widest part is just behind the cusp, and it narrows abruptly before and behind. P^2 is separated from P^1 by about 55 mm. and from P^3 by 11 mm.

P^3 is pyramidal, very angular, but rounded on the outer side; it is doubly convex, narrow on the anterior end, and very wide posteriorly. It is much pitted on the inner and back surfaces, with a strong ridge on the former, and on

FIG. 16.—*Megachœrus zygomaticus,* gen. et sp. nov. Genoholotype. Cat. No. 10008. Palatal view. One-fifth nat. size.

the rear outer corner, but no posterior heel. Below the cingulum there is a smooth enamel band around the base.

Premolar four in its general form bears resemblance to no other genus present: three sides form right lines, but the inner is curved; especially important is the absence of the anterior notch so uniformly found in the family. The tooth is wider than long (34 × 31 mm.); is completely encircled with a cingular ridge (except a short space on the outer side) which posteriorly is heavy, and it has a sharp longitudinal valley deeper on the rear side. The straight anterior side of this tooth resembles that of the much smaller *Entelodon magnus* of Europe.

The first molar is irregularly squared, the anterior side is rounded, the exterior bilobed. Postero-internally, the sides combine in a smooth curve except that at the root there is a sharp corner. The inner side is vertical and the tooth is not wider at the roots as in *M. latidens* (fig. 17). The cingula are strong and especially notable exteriorly and interiorly between the lobes.

The second molar, subquadrate, is a little wider in front and on the outer side; postero-internally the corner is rounded. The cusps are widely separated and the proto- and metaconule and also a metastyle and a mesostyle can be seen. Though the outer cusp seems to arise from the cingulum, it is still the hypocone, and shows the source of its development. (See cusp indication, figs. 17, 18.) The internal cusps, especially when slightly worn, form lophs and resemble those of some perissodactyls. This tooth, a little larger than M^1, has a length of 40 mm. and a width of 42.5 mm. anteriorly.

The third molar is roughly triangular, having all the corners rounded off. The sides are straight on the front and outer faces and form an acute angle because of the prominence of the base of the paracone. The cingulum is strong anteriorly, but there is none externally. The protocone is slightly in front of the mid-line; the protoconule is scarcely more than a small ridge; the hypocone is weak but stronger than the cingular cusps; the metacone is small and worn and the heel is very indefinite.

Of this specimen, the skull only is known, which is well preserved up to the alveoli of the canines.

Summary of Megachœrus zygomaticus Group.

This specimen Peterson referred to the genus *Pelonax;* it is here made the type of a new genus and species, *Megachœrus zygomaticus,* and the important characters which distinguish it from all other American genera are: the small P^1 separated from P^2 by a long diastema, the less deep valleys on the molars and the low cusps, the strong angle on the inner face of P^3, the very irregular and pitted premolars, the great breadth of the nose anterior to the orbits, the broad smooth frontals without foramina, and especially the lack of a notch on the anterior side of P^4 and the extraordinarily large and oddly shaped dependent process from the zygomatic arch.

MEGACHŒRUS LATIDENS GROUP.

Megachœrus latidens, sp. nov.

Holotype, Cat. No. 10009, Y. P. M. Probably Upper Oligocene, near Cheyenne River, South Dakota.

This, like specimen No. 10008, is a very large animal; of it there is preserved the central portion of the skull with

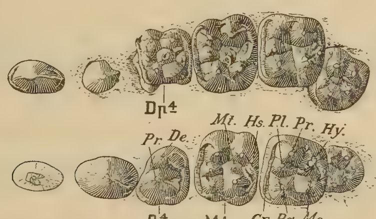


FIG. 17.—*Megachœrus latidens*, sp. nov. Holotype. Cat. No. 10009. Crown view of upper molars and premolars. Note the deciduous premolar, Dp^4, still in place. One-fifth nat. size. Dp^4 and P^4, deciduous and permanent fourth premolars; M^1, first true molar. *Cn*, cingulum; *De*, deuterocone; *Hs*, hypostyle; *Hy*, hypocone (on M^2 closely associated with the metaconule); *Me*, metacone; *Mt*, metaconule; *Pa*, paracone; *Pl*, protoconule; *Pr*, protocone.

the molars and premolars (fig. 17), except P^1, and both rami (fig. 18). These are the remains of a young entelodont which still retains some of the milk teeth and of which the last molars are just cutting through.

But few details of the skull itself are worth noting: the infraorbital foramen has its edge over the anterior root of P^4 and opens slightly upward. The upper rim of the orbit was probably rather smooth like most of the surface of the frontals. One small foramen is visible near the center line, where appears a slight fold possibly due to crushing.

All the permanent teeth of this young animal are uniformly corrugated on the surfaces which have not been exposed, but it is evident that the sides soon wear smooth, not to mention the triturating surfaces. From the food or the tongue itself, the inner sides are worn most smooth, but the outer surfaces are also polished, to a less degree, by the food and cheek muscles. It is a general rule that the more aged the teeth, the smoother the enamel, especially on the inner side.

P^2 (see fig. 17) is rather stout, directed slightly forward, is convex on both sides, especially exteriorly, has its slopes rounded not angular (cf. *M. zygomaticus,* fig. 16), is not pitted, has a weak cingulum, both posterior and anterior, and only two ridges running to the apex of the cone. It is wide anterior to the cone but narrows rapidly at the end beyond.

P^3 had not fully erupted, but has been uncovered in preparation. It is smoothly oval, has a fine sharp ridge from the cone on the postero-exterior corner, and a relatively smooth heel. The cingula are very faint or entirely lacking.

Premolar four has its outer and back sides square and straight and the inner side rounded, but, unlike *M. zygomaticus,* and like most species of *Archæotherium,* the front side is indented. The deuterocone seems to be small, but the tooth is considerably wider than long, 39 $\times$ 35 mm. The cingulum, which is especially strong posteriorly, does not appear on the outer and inner sides. The tooth is rounded rather than angular.

The molariform, deciduous premolar four still covers the permanent tooth on the left side. Its cusp arrangement is faithfully patterned after the first true molar.

The first molar shows a strong protoconule and a strong metaconule well separated from the hypocone. There is also a hypostyle continuous with the cingulum and the hypocone. Though the tooth is subquadrate, the long slope of the inner face gives it a peculiar appearance and increases the transverse diameter greatly, the width being 45.5 mm. and the length 40 mm.; the outer side is bilobed and of these, that of the metacone extends farthest out.

The second upper molar is also subquadrate but is wider in front and is rounded behind. The hypocone and metaconule are almost united. The cusps are all nearly equal in size, but the base of the protocone is rather wide. A small cusp on the posterior edge may be considered as a hypostyle.

M^3 is not erupted but its surface has been plainly exposed. The front and outer sides are straight, while the other two form a regular curve. The cingulum in front does not extend on to the corners strongly. The hypocone is a small double cusp, but the protoconule is strong; the paracone and metacone are equal, but the base of the latter is large.

The things of particular interest in the lower jaws (fig. 18), are the great slenderness of the branches and the great width of the molars compared to their length. Unfortunately the tubercles are broken away and the chin is crushed, but the great width across the alveoli of the canines and the flatness of the chin imply rather large tubercles. The processes midway on the rami are below a point between P_4 and M_1; the bases are oval in cross-section and the tubercles probably hung down as well as

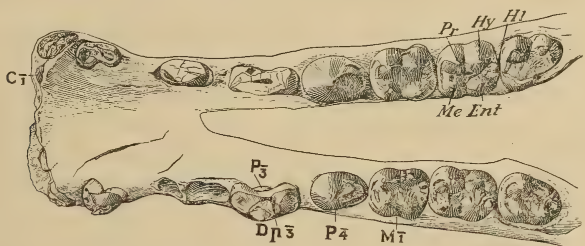


FIG. 18.—*Megachœrus latidens,* sp. nov. Holotype. Cat. No. 10009. Crown view of lower jaw. Dotted lines show permanent canines appearing. One-fifth nat. size. C_1, permanent canine; P_3 and Dp_3, permanent and deciduous third premolars; P_4, fourth premolar; M_1, first molar. *Ent,* entoconid; *Hl,* hypoconulid; *Hy,* hypoconid; *Me,* metaconid; *Pr,* protoconid.

outward. They were thin and not very extensive along the borders of the rami.

The symphysis is very short but the groove above is shallow and widely open. The coronoid process rises outside the line of the molars, is thin, especially posteriorly, and is approached closely by the masseteric fossa; this depression is not extensive vertically and does not have an abrupt margin.

The permanent canines are just coming in and the tips are barely visible (dotted lines, fig. 18). The first deciduous premolar is only 10 mm. behind its canine; it is 25 mm. in front of Dp_2. Dp_3 is very long but narrow; beneath it can be seen the tip of P_3, the characters of which are not known.

P_4 in its general form resembles that tooth in *Ammodon leidyanus* in that its single cusp is evenly rounded, minutely striated, and has a strong ridge leading from the apex to the broad, roughened, shelf-like heel inclosed by a strong cingulum. *A. leidyanus* differs in having two ridges and many tubercles on the posterior heel, and in its much greater size; the diameter antero-posterior is 53 mm., transverse 33.5 mm. Of *M. latidens,* antero-posterior 44 mm., transverse 29 mm.

The lower molars at once distinguish themselves by their great size, much greater width, the wide open valleys, the smaller tubercles of uniform height, and the equality in size to each other.

The first lower molar has a double cusp on the metaconid (paraconid and metaconid combined?), making it a little larger than either the proto-, ento-, or hypoconid, which are about equal in size. The anterior cones are rather close together, while the small entoconid is separated by a wide valley on both sides. There is a double cingulum anteriorly and a strong heel posteriorly; a sharp valley exteriorly between the proto- and hypoconids leads down to a circular cusp or basal pillar which does not appear markedly on the second or third molars. M_1 is wider posteriorly than anteriorly (35 and 32.5 mm. respectively); its length is 39.6 mm.

The four cusps of M_2 form a rectangle; the metaconid, almost a single cusp, is largest, while the entoconid is slightly smaller than the two others. The valley between the anterior cones is wide but not deep, the transverse valley is deeper and narrower at the bottom; the area between the posterior cusps is broad, shallow, and roughened. There is an enlarged cusp on the heel.

M_3 has even broader valleys, and because the entoconid is so small, the posterior half of the tooth is broad and flat. A small cusp constitutes the heel. As in M_2, there is a double cingulum, anterior.

This tooth is totally different in structure from M_3 of *Pelonax bathrodon,* which has very high anterior cusps, and from the paratype of *A. leidyanus,* which has very sharp valleys and long posterior cusps.

As to the geological age, we have to depend upon a statement in a letter from L. W. Stilwell, dated April 20, 1889, referring to this specimen, in which he says it "was found on top of the *Oreodon* beds east of the Cheyenne''; the locality was a few miles east of the mouth of French and Battle creeks.

Ammodon leidyanus (Marsh).

Genoholotype, Cat. No. 12040, Y. P. M. Miocene, New Jersey.

The holotype of this species (Pl. I, C, D), P_4, described by Marsh in 1893 (p. 409), is more oval and smooth than that of *D. hollandi,* and much larger. The paratype, No. 12041, M_3 (the wear on the posterior side suggests M_2), is near *D. hollandi* in size, slightly longer, but has the same width; nevertheless has narrower valleys between the high cones, and the heel is developed into a fifth strong cusp, the hypoconid. The anterior cusps are not much higher than those posterior, but because of the sharp valleys all seem to stand unusually high.

This specimen is considerably larger than any entelodont known; it comes from the Miocene of New Jersey. These facts, in connection with its unique features, undoubtedly separate it generically from all the specimens found on the Great Plains.

Summary of Megachœrus latidens Group.

M. latidens, sp. nov., is here referred to the new genus, but it is widely separated in many striking features from the genoholotype, viz: the premolars are smoothly rounded, not angular nor pitted; the fourth premolar has a good notch anteriorly; there is an unusual slope on the inner side of M^1, and the tooth has great breadth; M^3 is rounded. It is near *M. zygomaticus* in size, in the cusp development of the upper molars, and in the greater width than length of P^4. In the smooth oval character of P_4 it approaches *A. leidyanus,* but it has not the double ridge from the cone, the great broad heel, the size, nor the geological age of that genus. Its age is probably that of the *Protoceras* beds.

It is distinctly separated from all other known forms by the equal size and great breadth of the lower molars, by the low, subequal cusps and open valleys, and by the wide, gradually sloping side of M^1. The teeth are as large as those of *Dinohyus,* but other dimensions show that the latter was one sixth greater.

Chœrodon caninus Group.

Chœrodon caninus, gen. et sp. nov.

Genoholotype, Cat. No. 11665, Y. P. M. Middle John Day, Oregon.

Well preserved skulls or skeletons from the John Day beds of Oregon are very rare, but one exceptionally complete skull and jaws (figs. 19, 20) of an entelodont was secured by Professor Marsh in 1876. It was found by William Day in Turtle Cove, in beds which Sinclair says (1905, p. 134) belong to the *Diceratherium* zone of the

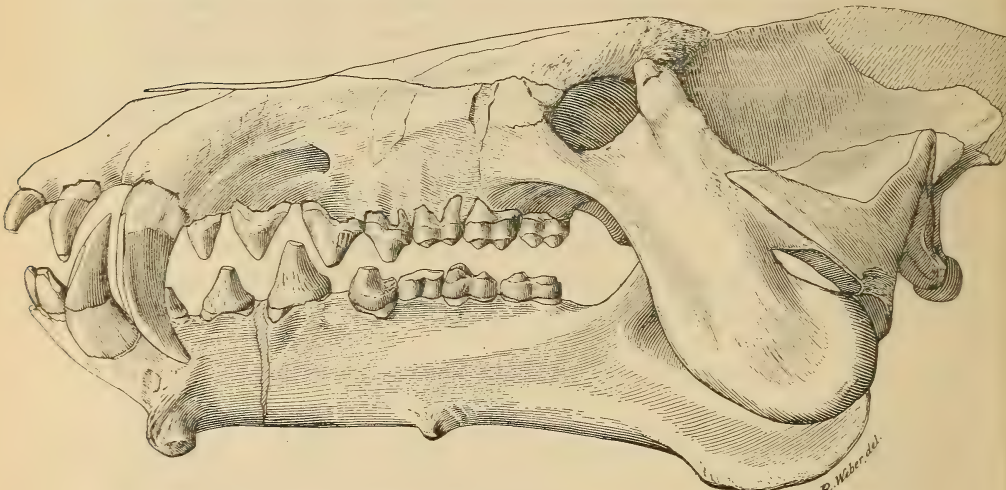


Fig. 19.—*Chœrodon caninus*, gen. et sp. nov. Genoholotype. Cat. No. 11665. Side view of skull and lower jaws. One-fifth nat. size.

Middle John Day. This fine specimen is here made the type of a new genus and species.

The fact that it came from the John Day region makes it seem probable that it is related to *Archæotherium robustum* (Leidy) and to *Chœrodon calkinsi* (Sinclair). From the former it is distinguished by the greater size and the more prominent cusps, especially those of the lower molars, anterior. There is, on the other hand, a remarkable similarity to *C. calkinsi* in proportions and size, judging from the measurements given by Sinclair. The difference lies in the processes, long and extended far backward, in the presence of anterior mental tubercles, and in the long curved canines.

This difference in the mental tubercles separates the specimens widely, unless we admit the theory that this character is a sexual variation (which might apply also to the jugal processes), or the supposition that they were lost in Sinclair's specimen.

The form of the dependent process from the jugal, large, hanging directly in line with the orbit and swinging strongly backward, and the close arrangement of the teeth distinguish this specimen from all others, but bring it nearest to *Megachœrus zygomaticus* (figs. 15, 16). The end of the dependent lobe is much thickened and widened; anteriorly the edge is thin and is folded inward; this feature and the form of the slender anterior process from the temporal resemble the corresponding parts of *A. crassum.*

The glenoid cavity is very narrow transversely and is formed partly by the posterior process from the jugal. The palate is well arched and the posterior narial opening extends forward to a point even with M^2.

The upper rim of the orbit is exceptionally thick and heavy but smooth. The frontals are smooth, though not flat, and a fossa is seen just in front of the parietals as in *Dinohyus.* Between the right frontal and the lachrymal there is a deep round pit; although the bottom is closed now, it seems probable that there might have been a deep wound, which afterward healed, received from the thrust of an opponent's tusk or horn.

The first incisors are very small, the third are large and strong. The long canines are wide-spreading, slender and unusually recurved. They are so long and so curved that the points extend 50 mm. beyond the area of abrasion and are practically unworn.

A striking feature in this species, in both the upper and the lower jaws, is the short diastemata. These, together with the fact that the premolars are all double-rooted, show the specimen to be very conservative in its evolution.

P^1 is small and is situated postero-internal to the canine. P^2 is somewhat larger, is functional, parallel-sided and recurved; P^3 is large, 42×23 mm., has its sides almost straight and had a roughened heel. P^4 is much broader than long (32.5×29 mm.), has its posterior and external sides straight, but anteriorly has the notch so commonly seen outside of *Megachœrus zygomaticus* and *Entelodon magnus.*

M^1 has a long slope on its inner face, resembling *M. latidens* (fig. 17), giving it the width of 38 mm. compared to its length, 32 mm. This feature is found again in M^2

whose diameters are 42 and 36 mm. Both of these teeth have the strong cingulum around the base of the metacone as in *M. zygomaticus* (fig. 16). Each molar is narrower behind than in front. The very high proto- and metaconules in M^3 are an unusual feature in this tooth.

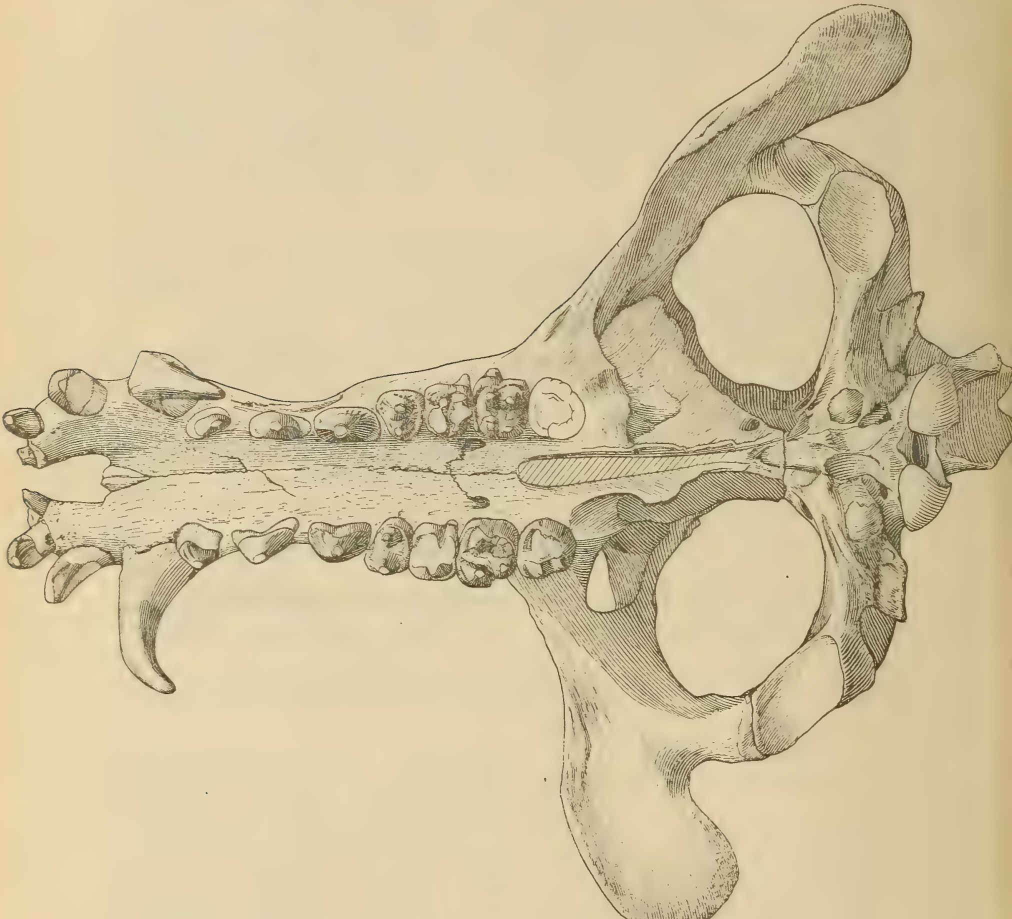


FIG. 20.—*Chœrodon caninus,* gen. et sp. nov. Genoholotype. Cat. No. 11665. Palatal view of skull. One-fifth nat. size.

In the mandible, the heavy tubercles directed downward and outward are located some four centimeters in advance of the beginning of the symphysis. They are long, 35 mm., slightly enlarged on the ends and flat posteriorly. The chin in front of the canines is broad, 110 mm., and convex. Behind the tubercles the body of the ramus is unusually narrow, 60 mm.

The right posterior mental tubercle is hardly more than 20 mm. long. That on the left side (now broken off) was much smaller; but one is led to suppose that the roughened area on the ventral border of the ramus, just anterior, served in its stead for the attachment of the buccinator muscle, as in the carnivores to-day.

The canines in the rami, like those in the upper jaw, are long, slender, and recurved. They curve back so far that the points actually come in contact with the upper canines and therefore wear to sharp edges like those of rodents. P_1 is small and two-rooted and, as previously stated, is situated near the canine and P_2. The other premolars join practically without space. P_3 stands high and its shelf-heel is apparently wide. P_4 has a very broad heel with numerous tubercles on it. Its breadth is 27.5 mm. and its estimated length not more than 36 mm.

M_1, though worn, shows the general proportions of *Archæotherium;* its diameters measure 31 by 26 mm. M_2, 36×30 mm., is wide across the proto- and metaconids which are strong, and there is a definite heel. M_3 is much like M_2 but slightly narrower. On all these molars the cingula are weak, except the anterior one and that around the base of the hypocone. On each the posterior heel is fairly strong.

Summary of Chœrodon caninus Group.

The genoholotype is found in the Middle John Day beds of Oregon. It resembles *Archæotherium* in many generalities, but differs in the long curved canines and dependent processes from the jugal, in the greater size, and in its wide geographical and geological separation. It resembles the genoholotype of *Megachœrus zygomaticus* in the greatly enlarged dependent processes, but it is one fifth smaller, does not have the pitted teeth, has a notch anteriorly in P^4, and very short diastemata. It differs from *M. latidens* in having narrower lower molars, especially behind, high anterior cusps and the much smaller size. It has about the same size, age, and location as *Chœrodon calkinsi,* but is separated specifically in having the larger canines and longer, more recurved dependent processes, and by the presence of strong tubercles on the chin.

Art. XXX.—*The Rhyolites of Lipari*; by Henry S. Washington.

CONTENTS.

Introduction.

The rhyolites of Lipari would seem to have been the earliest of these lavas to be studied chemically, analyses by Abich having been published by him in 1841.[1] Since his time no analyses of the Lipari rocks appear in the literature, until Lagorio[2] published a couple of poor ones in 1887, followed by those of Glaser[3] in 1899. None of the analyses of these Lipari rocks are of first rate quality. In view of their wide-spread occurrence in collections, the typical character of these obsidians, and the well-nigh world-wide use of the pumice of Lipari, this neglect would be somewhat surprising, were it not the common fate of well-known rocks, many of which are so ''well-known' that they are not studied or described.

To make up for this deficiency, I have recently analysed some specimens of the rhyolitic lavas of Lipari, which were collected by Dr. A. L. Day and myself in July, 1914. Brief descriptions of them will be given here, along with the analyses, so that they may be on record.

The characters, occurrence, and sequence of the lavas of the volcanoes of Lipari have been described in some detail by Cortese and Sabatini,[4] and by Bergeat,[5] to whose descriptions the reader may be referred. The sequence of volcanic events would seem to have been about as follows.

Volcanic activity appears to have begun with the formation of the basaltic cones of the ''Timponi'' on the west coast, followed by the basaltic and andesitic cones

[1] Abich, Vulk. Ersch., Braunschweig, 1841, p. 62.
[2] Lagorio, Tsch. Min. Petr. Mitth., 8, 440 and 491, 1887.
[3] Bergeat, Abh. Bayer. Akad. Wiss., 20, 108-118, 1899.
[4] Cortese and Sabatini, Descrizione delle Isole Eolie, Mem. Carta Geol. Ital., VII, 25-45, 98-112, 1892.
[5] Bergeat, Abh. Bayer. Akad. Wiss., 20, 92-141, 1899.

of Monti S. Angelo, Chirica, Rosa, etc., in the central parts of the island. A pause was followed by the eruption of flows of the cordierite andesite of Varesana, and of the rhyolites of Monti Guardia and Giardina in the south end of the island, after which came the eruptions of obsidian and pumice that formed Monte Pelato and the small cones of Forgia Vecchia and Rocche Rosse. These seem to have been the final active phase. The closing of volcanicity is marked by the hot springs of San Calogero and slight fumarolic activity at the present day.

The order of eruptions, regarded chemically, would seem to have been simple and fairly regular, beginning with magmas of about the composition of andose (II.5.3.4), with SiO_2 about 53 per cent, passing to and ending with magmas of the general composition of liparose (I.4.1.3), in which SiO_2 is about 74 per cent. Intermediate magmas are represented by those of the Monte S. Angelo lavas.

Rhyolite Obsidian. Hephaestal[6] Liparose (I.4.1.3).

The chief specimens examined, which are considered as typical, are from the flows of Forgia Vecchia, above Canneto, and from Rocche Rosse, at the north-east corner. These are small, pumice cones, breached by flows of obsidian running down to the sea. Illustrations of them are to be found in several standard works on volcanoes, as those of Judd[7] and Mercalli.[8] Similar obsidians from Monte della Guardia and elsewhere were also studied.

Megascopic characters.—The rock is a typical obsidian, of a jet-black color, highly vitreous luster, and generally perfect conchoidal fracture. On the thin edges of splinters it is transparent, but gradually becomes gray and dusty with inclusions as the splinter thickens, and here and there small black specks are visible.

The density of the specimen from Rocche Rosse (analysed) is 2.370, and of that from Forgia Vecchia is 2.363, both determined at 18° with the balance.

Much of this obsidian is banded with gray in various shades, some of the bands being thin and others thick;

[6] From Hephaestades, one of the Latin names of the island group.
[7] J. W. Judd, Volcanoes, 1890, Fig. 41, p. 124.
[8] G. Mercalli, Vulcani Attivi, 1907, Fig. 20, p. 59.

and some specimens are almost wholly gray. These gray varieties are so common and so distinctive that they might be worthy of being considered as a distinct type, were a detailed study of obsidians being undertaken. Lithophysae and spherulites occur, in some places rather abundantly, though generally they are not common. The fayalite from cavities in these obsidians has been described by Iddings and Penfield.[9]

The refractive indices were determined by Dr. Merwin, who found, for the obsidian of Rocche Rosse, $n = 1.488\text{-}9$, and for that of Forgia Vecchia, $n = 1.490$.

Microscopic characters.—In thin section the black portions of the specimens show a perfectly clear and colorless glass, with no perlitic cracks. In this are sparsely scattered very minute microlites, some of them prismoids and some irregular grains. Under low powers the latter appear black, but higher powers show that they are colorless; both appear to be slightly birefringent. It is assumed that the prisms are of orthoclase and the grains of quartz. It is perhaps worthy of note that these microlites are not as thickly scattered as would be expected from the blackness of the hand specimen. Flow structure is not marked.

In thin section the gray streaks show very many yellowish spherules, which appear white (by reflected light) between crossed nicols. Dr. Merwin suggests that this effect is due to diffraction. The glass in one of the spherulitic streaks (from Forgia Vecchia) is thickly crowded with extremely minute prismoids of a colorless mineral, of low refractive index, which is assumed to be orthoclase.

The pumice of Lipari may be mentioned with the obsidians, as it is but a highly vesicular form of these. Most of this comes from Monti Chirica and Pelato, with some from the Fossa delle Rocche Rosse; the better qualities being found mostly at Monte Pelato. In the store-houses at Canneto it is separated into three main grades. The first quality is the most finely vesicular, the whitest, and the lightest in weight; the lower grades showing more of the non-vesicular glass. The first grade floats readily in water; the second floats, but less readily;

[9] This Journal, (3), 40, 75, 1890. Similar crystals of fayalite from the trachyte of Cuma, in the Phlegrean Fields, have been described by vom Rath (Zs. d. geol. Ges., 18, 609, 1866). The Cuma crystals are tabular parallel to *b* (010), while those of Forgia Vecchia are tabular parallel to *a* (100).

while the third generally sinks slowly, its density as a whole being slightly above 1. No section was made of these pumices, but they seem to show no spherulites and no phenocrysts. The refractive index of the pumice glass was found, by Dr. Merwin, to be 1.499.

Chemical composition.—Analyses were made of three specimens: one a typical, black obsidian, free from gray streaks and spherulites, from Rocche Rosse; another of a black obsidian with gray streaks and showing the yellowish spherulites, from Forgia Vecchia; and one of a "first quality" pumice, taken from the bins at Canneto, but presumably from Monte Pelato. These analyses are given in Table I, along with older analyses by Abich and Glaser of the same rocks. It is interesting to observe how closely those made by Abich, published in 1841, correspond with the most recent ones. They are, as in other cases that I have noted, a striking testimony to his skill as an analyst.

TABLE I.

	1	2	3	4	5	6
SiO_2	74.22	73.86	71.70	74.05	74.37	73.70
Al_2O_3	12.98	12.49	12.60	12.97	12.65	12.27
Fe_2O_3	0.40	0.60	0.48	2.73	2.58	2.31
FeO	1.60	1.40	1.17	n.d.	n.d.	n.d.
MgO	0.04	0.11	0.12	0.28	0.20	0.29
CaO	0.67	0.75	0.79	0.12	1.22	0.65
Na_2O	4.13	4.05	4.15	4.15	3.87	4.52
K_2O	4.97	4.81	5.17	5.11	4.57	4.73
H_2O+	0.27	0.92	3.15		0.22	
				0.22		1.22
H_2O-	0.04	0.09	0.20		0.02	
TiO_2	0.11	0.12	0.11	n.d.	n.d.	n.d.
ZrO_2	0.05	0.06	n.d.	n.d.	n.d.	n.d.
P_2O_5	0.14	trace	trace	n.d.	n.d.	n.d.
SO_3	0.08	0.06	n.d.	n.d.	n.d.	n.d.
Cl	0.03	0.26	0.14	0.31	n.d.	0.31
MnO	0.01	trace	trace	none	n.d.	none
BaO	none	none	n.d.	n.d.	n.d.	n.d.
	99.74	99.58	99.78	100.00	99.70	100.00
Sp. gr.	2.370	2.363		2.370		2.377

1.—Obsidian, Rocche Rosse, Lipari. Washington analyst.
2.—Obsidian, Forgia Vecchia, Lipari. Washington analyst.
3.—Pumice, Monte Pelato, Lipari. Washington analyst.
4.—Obsidian, Rocche Rosse, Lipari. Abich analyst. Abich, Vulkan. Ersch., 1841, Taf. III, p. 62; cf. p. 84.
5.—Obsidian, Forgia Vecchia, Lipari. Glaser analyst. Bergeat, Abh. Bay. Akad. Wiss., 20, 111, 1899.
6.—Pumice, Rocche Rosse, Lipari, Abich analyst. Abich, op. cit., p. 62, Taf. III.

Little need be said here of these analyses; they are quite typical of many rhyolites, and many very similar ones may be found in the same subrang (liparose, I.4.1.3) in the collection of analyses given in Professional Paper No. 99, of the U. S. Geological Survey. The pumice shows considerably less silica, which is compensated for by the higher water. As the pumice belongs to an earlier series of eruptions, while the obsidians represent the last phase of eruptions, the idea naturally suggests itself that much of the contained water was lost from the magma before the last eruptions.

The most interesting feature in all the first three analyses is that, while the total amounts of the iron oxides are about the same, the amount of FeO is largely in excess of that of Fe_2O_3. This seems to be characteristic of the glassy forms of the same magma, as contrasted with the inverse relation in the holocrystalline forms, and will be discussed later.

There are scarcely more than traces of magnesia, a small amount of lime, and but little titanium. The presence of zirconia in quite distinct amounts is of interest; while manganese and phosphorus are almost wholly absent, as is baryta. The presence of very decided amounts of both sulphur trioxide and chlorine is noteworthy. It may be mentioned that, in the determination of water by Penfield's method, in both obsidians and the pumice, a distinct ring of sublimate was formed in the glass tube. This ring gave distinct reactions for chlorine and sulphur trioxide, in all three cases.

Classification.—The norms of the first three specimens analysed are as follows:

	1	2	3
Quartz	28.68	29.58	26.64
Orthoclase	29.47	28.36	30.58
Albite	35.11	34.58	35.11
Anorthite	2.22	1.67	0.56
Diopside	0.99	1.70	none
Hypersthene	1.95	1.26	1.88
Magnetite	0.70	0.93	0.70
Ilmenite	0.15	0.15	0.15

These place all three in liparose, the Rocche Rosse obsidian having the symbol I.4.1.3; that of Forgia Vecchia I.″4.1.3.; and the Monte Pelato pumice I.4.1.3.

LITHOIDAL RHYOLITE. AEOLAL LIPAROSE (I.4.1.3).

At the southern end of the island of Lipari the massif of Monte Guardia (including Monte Giardina), is composed very largely of rhyolites of a type that is very different from the later obsidians and pumices, though obsidians are also met with here. These are what have been called lithoidal rhyolites, the liparite of von Richthofen. They have a dull luster in the hand specimen, that is, are megascopically felsitic, though they may be actually highly vitreous as seen in thin section. For the present it will suffice to describe both the hyaline and the holocrystalline varieties together, since they both show the same, or almost the same, megascopic features. The description is based on two specimens of this type which were analysed, and which appear to be characteristic of these rocks on Lipari. The term *aeolal* is derived from the common name of the island group, the Aeolian Islands, and is applicable especially to the holocrystalline type.

Megascopic characters.—One specimen, from near the southern end of Monte Guardia, is of a pure light ash-gray color, dull luster, and very fine-grained—a typical felsite. There are some small phenocrysts of a greenish black pyroxene, some of them surrounded with very thin zones of white feldspathic material, but there are practically no feldspar phenocrysts. A decided flow structure is shown by very narrow, whitish streaks. The other specimen, from a small quarry on the northwest slope of Monte Giardina (north of Monte Guardia), is also very fine-grained and of a dull luster. Its color is a very light, slightly brownish gray. There are no phenocrysts, but a banded structure similar to that of the Monte Guardia specimen is evident.

Microscopic characters.—In thin section the Monte Guardia specimen shows a quite typically trachytic texture, and appears to be holocrystalline. There are rather numerous small prismoids of almost colorless augite, with very few small phenocrysts of orthoclase, in a finely "felted" groundmass, made up of very small laths of orthoclase, few magnetite grains, and with what appears to be some interstitial quartz. If glass is present, it is in very small amount and is not easy to detect. Flow structure is marked.

The specimen from Monte Giardina is quite different in thin section. It is very largely composed of a colorless glass, thickly crowded, however, with very small orthoclase prisms, augite prismoids, and fewer minute magnetite grains. There are also present, in considerable quantity, small, yellowish spherulites, to which the slightly brownish color of the hand specimen is doubtless due. Flow structure is also well developed.

Chemical characters.—My analyses of these two specimens, with one by Abich of a Monte Guardia lithoidal rhyolite, are given in Table II.

TABLE II.

	1	2	3
SiO_2	74.70	69.64	68.35
Al_2O_3	12.71	13.48	13.92
Fe_2O_3	1.15	1.93	2.28
FeO	0.28	1.37	n.d.
MgO	0.07	1.68	2.20
CaO	0.54	2.80	0.84
Na_2O	3.89	4.05	4.29
K_2O	4.91	4.87	3.24
H_2O+	1.01	0.17	4.64
H_2O-	0.10	0.12	
TiO_2	0.10	0.13	n.d.
P_2O_5	n.d.	0.09	n.d.
MnO	0.04	trace	n.d.
	99.50	100.33	99.76

1.—Lithoidal rhyolite (dohyaline), Monte Giardina, Lipari, Washington analyst.
2.—Lithoidal rhyolite (holocrystalline), Monte Guardia, Lipari, Washington, analyst.
3.—Lithoidal rhyolite, Monte Guardia, Lipari, Abich analyst. Abich, Vulkan. Ersch., 1841, p. 25.

The dohyaline Giardina rhyolite resembles very closely the obsidians described above, the only marked point of difference being in the relative amounts of the iron oxides. Here ferric oxide is present in much greater amount than ferrous. The Guardia rhyolite is decidedly lower in silica, but higher in iron oxides, magnesia, and lime than the obsidians, though the alkalies are about the same. In this holocrystalline rock ferric oxide is present in considerably greater amount than ferrous.

Classification.—The norms of the rhyolites from Giardina and from Guardia, as analysed by me, are calculated to be as follows:

	1	2
Quartz	31.98	20.70
Orthoclase	28.91	28.91
Albite	33.01	34.58
Anorthite	2.78	3.89
Diopside	——	7.23
Hypersthene	0.20	1.46
Magnetite	0.70	2.78
Ilmenite	0.15	0.30
Apatite	——	0.34

From these it appears that both fall in liparose, though No. 2 is almost in dosalane and also is almost domalkalic. The symbols are, for the Giardina rock, I.″4.1″.3, and for that from Guardia, I(II).4.1(2).3.

Hyalo-Dacite.

Although this study was undertaken primarily to ascertain the chemical composition of the Lipari rhyolites, yet it has been pushed a step further to include an analysis of a specimen representing the main rock of the central cone of Monte Sant' Angelo. Judging from the descriptions by Sabatini[10] and by Bergeat[11] the rocks of this cone vary considerably, though the specimens that I collected do not show great variety. For special examination there was selected a specimen from near the church of La Perrera to the north of, and above, the town of Lipari. It was taken where the road of Forgia Vecchia makes a sharp bend to the east (right). This specimen was selected from several that resembled it, because it seemed to correspond best with what Bergeat calls the typical lava of Monte Sant' Angelo.

Megascopic characters.—The rock is dense and compact, and of a very dark gray, almost black color. Small (1-2 mm.) phenocrysts of yellowish white feldspar are scattered quite thickly through the dense, almost black, groundmass, which shows a rather dull luster. There are scarcely any phenocrysts of pyroxene. Specimens obtained from the neighborhood of San Calogero and also from near Santa Margherita, greatly resemble this, both megascopically and microscopically.

Microscopic characters.—In thin section the rock is seen to contain numerous, mostly euhedral, phenocrysts of plagioclase, which is always multiply twinned, and shows extinction angles that indicate a composition of about Ab_2An_3. They are not zonally built. Small inclu-

[10] Sabatini, Mem. Carta Geol. Ital., VII, 104, 1892.
[11] Bergeat, Abh. Bayer. Akad. Wiss., 20, 98, 1899.

sions of brown glass, thickly crowded with microlites, are common in them. There are also a few subhedral phenocrysts of what appears to be a somewhat sodic orthoclase, but no pyroxene phenocrysts are visible in my sections.

The groundmass in which these phenocrysts are imbedded is very glassy, of a general brownish color, and is hyalopilitic or (as Prof. Zirkel used to say) "a glass-saturated microlite felt." The microlites are very small prisms of alkalic feldspar, numerous still smaller grains and prismoids of pyroxene, and still smaller grains of magnetite. No quartz is visible.

Chemical composition.—For an analysis of this type there was chosen the specimen just described. For comparison with it is given an analysis of a cordierite andesite described by Bergeat[12] and Sabatini.[13] This is inserted as being the only published analysis of a rock from Monte Sant' Angelo that I have been able to find; though the presence of cordierite and some of the chemical peculiarities would appear to be caused by assimilation of foreign rocks. Bergeat (page 99) also gives two silica determinations of lavas from the same cone, yielding 58.22 and 56.54 per cent.

TABLE III.

	1	2
SiO_2	60.57	59.31
Al_2O_3	19.47	16.95
Fe_2O_3	0.94	8.07
FeO	2.83	....
MgO	0.94	1.65
CaO	6.10	4.30
Na_2O	3.07	1.59
K_2O	3.71	3.42
H_2O+	0.93	2.64
H_2O-	0.11	2.10
CO_2	none	....
TiO_2	0.71	n.d.
P_2O_5	0.31	0.40
Cl	trace	n.d.
MnO	0.06	n.d.
	99.75	100.43

1.—Hyalodacite, near La Perrera, Monte Sant' Angelo, Lipari. Washington, analyst.

2.—Cordierite andesite, Varesana, Monte Sant' Angelo, Lipari. Glaser, analyst. Bergeat, op. cit., page 102.

[12] Bergeat, Abh. Bayer. Akad. Wiss., 20, 102, 1899; Neues Jahrb., Beil.-Bd. 30, 575, 1910.

[13] Sabatini, in Cortese and Sabatini, Mem. Carta Geol. Ital., VII, 111, 1892.

The typical Sant' Angelo rock is thus decidedly lower in silica than the rhyolites, somewhat lower in alkalies (though their relative proportions are about the same), with but slightly higher iron oxides, (in which the dominance of ferrous over ferric oxide is to be noted), and higher lime and alumina. From the two silica determinations reported by Bergeat, it is clear that the Sant' Angelo lavas are quite variable, and that further study of them is called for.

Classification.—The norm of the Perrera rock is as follows:

Quartz	13.20
Orthoclase	21.68
Albite	26.20
Anorthite	28.63
Hypersthene	5.77
Magnetite	1.39
Ilmenite	1.37
Apatite	0.67

This norm places the rock in amiatose, with the symbol I.4(5).3.3., showing thus that there is a decided excess of silica, even though no quartz is seen in the rock itself.

In the current classifications these lavas have been called andesite by Bergeat and by Sabatini, and this would appear to be justifiable from consideration of the mode, the rock being composed essentially of andesine, pyroxene, magnetite, and glass. The analysis and the norm, however, reveal the fact that, had the magma solidified as a holocrystalline rock, a very notable amount of quartz would have been present, in which case the rock would have to be classed systematically as a dacite. The normative quartz is ''occult' in the glass base, to use Iddings' term.[14]

The choice of a suitable name for such rocks, those in which there is considerable excess silica occult in the glass base, has been a mooted question for many years, especially since the chemical composition of igneous rocks has become a matter of some importance.

The name dacite was applied to them originally, and still denotes, generally, a quartz-bearing andesite, one in which the quartz is present modally. For the modally quartz-free ''andesites'' which, however, contain so much silica that notable amounts of quartz would crystallize were they holocrystalline, Lacroix[15] has recently pro-

[14] J. P. Iddings, Igneous Rocks, Vol. II, p. 19, 1913.
[15] Lacroix, C. R., 168, 298, 1919.

posed the term "dacitoide." Although some such term seems to be highly desirable, yet it is questionable if "dacitoide" is quite the most appropriate. Etymologically, the name implies a rock that resembles a dacite (that is, according to the original definition, one that contains modal quartz), while in reality the rock is one that, while it has the chemical composition of a dacite, resembles modally an andesite. The term hyalodacite was introduced by Rosenbusch long ago, implying that modal quartz is present. Some years ago, in describing the rocks of Pantelleria, I suggested[16] the term "hyalopantellerite" for the very glassy forms of the pantellerites, in which feldspar phenocrysts are abundant, but those of pyroxene are scarce, though the rocks have a chemical composition practically identical with that of the holocrystalline pantellerites. Following the same idea, I would suggest here that the term hyalo-dacite be used for lavas of dacitic chemical composition, that is, which contain a considerable amount of excess silica, though modally they may be free from quartz.

Rhyolite Obsidian. Island of Milos.

Since writing the foregoing pages I have made an analysis of a specimen of the obsidian of Bombarda, on the Island of Milos, which I obtained from Kranz of Bonn many years ago. The analysis shows that it is a sodi-potassic rhyolite, but slightly higher in silica and in lime than the Lipari obsidians. A description of it is given here, for comparison with the Lipari rhyolites, and because no analyses or detailed descriptions of the rocks of Milos have yet been published.[17]

The obsidian is a quite typical one, perfectly glassy, of a grayish black color, not as pure a black as the Lipari obsidians, and with a slightly duller vitreous luster. It shows perfect conchoidal fracture, and also a distinct flow structure. There are no phenocrysts. In thin section it is seen to be an almost pure, colorless glass, without spherulites, but with numerous, extremely minute (about 0.01 mm. long) black, baculitic microlites, which

[16] H. S. Washington, Jour. Geol., 22, 704, 1914. I called highly silicic, glassy but quartz-free, rocks from Asia Minor, dacites many years ago (This Journal, 3, 43 and 47, 1897).

[17] For a description of Milos, see K. Ehrenburg, Die Inselgruppe von Milos, Leipzig, 1889.

show marked fluidal arrangement. No microphenocrysts are to be seen.

The analysis is given in Table IV.

TABLE IV.

	1	2
SiO_2	76.56	76.73
Al_2O	13.47	12.24
Fe_2O	0.20	1.38
FeO	1.01	0.76
MgO	0.08	0.22
CaO	1.47	1.46
Na_2O	3.76	3.32
K_2O	3.51	4.17
H_2O+	0.27	0.49
H_2O-	0.22	
TiO_2	0.10	n.d.
P_2O_5	n.d.	n.d.
SO_3	n.d.	n.d.
Cl	n.d.	n.d.
MnO	0.06	n.d.
	100.71	100.77

1.—Rhyolite obsidian, Bombarda, Milos. 1.3(4).2.3(4). Washington, analyst.

2.—Rhyolite obsidian, Jali, Nisyros. I.3(4).2.3. Martelli, analyst. A. Martelli, Gruppo di Nisiro, p. 69, Rome, 1917.

As compared with the Lipari obsidians, this shows somewhat higher silica, as well as higher lime, somewhat lower alkalies, with a rather higher proportion of soda. These differences are clearly and concisely expressed by the symbols according to the quantitative system. It will be noted that in this highly vitreous obsidian the ferrous oxide is greatly in excess of the ferric, just as we have seen to be the case elsewhere.

My specimens of the other Milos rocks are not available at present, so I am unable to make an analysis now of the holocrystalline varieties. Study of their thin sections indicates, however, that most of those in my possession are rhyolites, with orthoclase or sodi-orthoclase as phenocrysts and groundmass laths, and more or less quartz. But a little plagioclase seems to be also generally present, so that these rocks may be considered as toscanites, rather than purely alkalic rhyolites. This occurrence of plagioclase is in agreement with Ehrenburg's descriptions of many andesites on Milos, though few of these are represented in my small collection of about twenty specimens. It is also quite in harmony with the generally domalkalic characters of the lavas of the Aegina-Methana-Milos-Santorini-Nisyros row of volcanoes, the rocks of which are mainly dacites and andesites, with some basalts.

It is of interest to note the chemical correspondence between the Milos obsidian and one from Nisyros, published by Martelli (No. 2 above). The two are very closely alike, except for the somewhat higher potash in the second and the higher ferric oxide as compared with ferrous. The Nisyros obsidian, it is to be noted, is not a pure glass, but contains phenocrysts of quartz, andesine, orthoclase, and pyroxene; so that here also we find the general rule as to iron oxides and crystallinity observed.

The Relation of Iron Oxides and Glass Content.

Attention has already been called to a feature shown by the rhyolites of Lipari which seems to merit some further discussion, because of its apparently common occurrence elsewhere, and because it may possibly throw some light on the nature of the gases that are present in lavas as they issue from the depths. This is, that in many effusive lavas, ranging from rhyolites to basalts, ferrous oxide dominates very greatly over ferric oxide in the glassy forms, while ferric dominates over ferrous oxide, or at least is in much greater relative amount, in the docrystalline or holocrystalline forms. That is, it would appear that when a lava cools rapidly, other things being equal, the iron is less oxidized than if it cools more slowly. This seems to be true of the lavas of several Italian volcanoes that I have studied chemically, and also seems to be often true of those of other regions. It is a point to which I have already called attention several times,[18] but which has apparently not been noticed otherwise.

To illustrate this relation there are given in Table V data from analyses by me of lavas from various Italian volcanoes, selected so as to eliminate, so far as possible with the data at hand, disturbing factors due to differences in chemical composition. Many other analyses might be cited as well, but it would seem best here to restrict our observation to the lavas of one general region. The analyses given are confined to rhyolites

[18] H. S. Washington, this Journal, 27, 148, 1909; 36, 583, 1913; Jour. Geol., 22, 707, 1914.

and basalts, inasmuch as the lavas of intermediate composition, such as those of trachytes, dacites, and andesites, seem to be somewhat less regular, though they conform in general to the same rule. This lesser regularity may lead to the recognition of other factors in the problem.

For the sake of brevity only the figures for silica, ferric oxide, ferrous oxide, and the molecular ratio FeO/Fe_2O_3 are given here. The complete analyses and the references may be found in Professional Paper No. 99, except for the analyses of the Lipari rhyolites that have been given in the preceding pages. The lavas of the different volcanic centers are distinguished as hyaline (that is, with much glass), or as crystalline (that is, with no or almost no glass). A further study of these relations is to be made, taking into consideration many more data than are given here.

TABLE V.

Relations of the Iron Oxides and Glass in Italian Lavas.

RHYOLITES.

Lipari.

	Hyaline			Crystalline	
SiO_2	74.22	73.86	71.70	74.70	69.64
Fe_2O_3	0.40	0.60	0.48	1.15	1.93
FeO	1.60	1.40	1.17	0.28	1.37
$\frac{FeO}{Fe_2O_3}$	7.33	4.75	5.33	0.57	1.58
Symbol	I.4.1.3	I.4.1.3	I.4.1.3	I.4.1.3	I.4.1.3

Sardinia.

	Hyaline		Crystalline	
SiO_2	74.61	70.50	73.09	72.05
Fe_2O_3	0.09	0.75	1.28	2.93
FeO	1.36	1.22	0.68	0.39
$\frac{FeO}{Fe_2O_3}$	19.00	3.40	1.25	0.33
Symbol	I.4.1.3	I.4.1.3	I.4.1.3	I.4.1.3

PANTELLERITES.

Pantelleria.

	Hyaline				Crystalline		
SiO_2	69.91	69.33	67.85	66.07	72.21	70.21	69.79
Fe_2O_3	1.81	2.65	1.84	2.05	3.26	6.01	5.35
FeO	5.86	5.52	4.54	5.88	1.07	2.73	1.43
$\frac{FeO}{Fe_2O_3}$	7.45	4.46	5.25	6.31	0.75	1.00	0.59
Symbol	II.3.1.3	II.3.1.3	II.4.1.3	II.4.1.3	II.4.1.3	II.3.1.3	II.4.1.3

BASALTS.

Submarine Eruptions and Pantelleria.

	Hyaline			Crystalline	
SiO_2	48.97	44.83	45.72	46.40	46.22
Fe_2O_3	1.33	1.35	1.57	4.09	4.91
FeO	8.56	11.79	12.01	8.22	7.71
$\frac{FeO}{Fe_2O_3}$	14.88	18.22	16.70	4.38	3.45
Symbol	II.5.3.4	III.5.3.4	III.5.3.4	III.5.3.4	III.5.3.4

The figures given in Table V would seem to show quite conclusively that there is a direct relation between the ratios of the iron oxides and the degree of crystallinity in the rhyolites and the basalts of the Italian volcanoes, in the sense that ferrous oxide dominates over ferric in the glassy forms, while the reverse is true in the crystalline forms, of lavas that are otherwise of almost identical composition and are derived from the same magma. The same relation holds good for rhyolites and other such highly silicic lavas at other volcanoes, as in the Auvergne, the Yellowstone Park, at Pelée, and elsewhere, the data for which are not given here. The same relation is also apparent, though possibly not so invariable, among the lavas of intermediate composition, such as dacites, trachytes, and andesites, and is also to be seen among the basaltic lavas, though hyaline forms are less commonly met with among basalts, while analyses of them are still more rare.

An adequate explanation of this state of affairs is somewhat difficult to find, and the subject requires further study. It may reasonably be assumed that the hyaline forms represent more closely than the crystalline the chemical conditions as to the iron oxides that obtain in the liquid magma itself, and the relations may presumably be connected with the reducing or oxidizing characters of the magmatic gases. As to the exact nature of these gases as they exist in solution in the magma we have but little knowledge. The earlier analyses, such as those of Deville, Fouqué, and Brun, cast no light on the problem, partly because the gases were collected after issuing from the lava and thus having been subject to mixture with and oxidation by the air, and also because of the very imperfect methods of analysis that were used in their study. The studies of the gases from the Kilauea lavas by Day and Shepherd[19] are, so far as I know, the only ones that convey any just idea of the conditions of the various gases as they exist in the magma. The possible interreactions between them, at different temperatures and pressures and with different mixtures, are numerous but have been little studied so far. This is a topic into the consideration of which we cannot enter here.

It would seem, however, that although the specimens of gas collected and analysed show a greater or less degree of oxidation, as has been pointed out by Day and Shepherd, yet there still remains in the residual gases a notable percentage of oxidizable, and therefore reducing, gases such as hydrogen, carbon monoxide, and sulphur vapor. It might therefore be suggested that the iron is in the ferrous condition because it has been kept from oxidation by the general reducing effect of the gases. Or one might argue in the other direction, so to speak, and hold that the generally oxidized condition of the gases is to be attributed (apart from possible atmospheric influences), to reduction of original ferric iron. Of the two the former seems to me to be the more plausible because we have reason to believe that there exists, beneath the uppermost "crust" of the earth, a zone of material that is composed in great part of metallic iron or an iron-nickel alloy, analogous to the siderolitic meteorites.

But, assuming either of these alternative hypotheses, it remains to be explained how the ferrous oxide becomes oxidized to ferric during crystallization, as appears to be the case. For the present the matter must be left in abeyance, and the data are presented here so as to call the attention of petrologists and geophysicists to a little-known feature of the chemistry of igneous rocks that may possibly lead to some generalization as to the character of magmatic gases and the true composition of the sub-superficial magma.

Refractive Indices of Rhyolite Glasses.

Dr. Merwin kindly determined the refractive indices of several of the Lipari glasses, as well as those of an obsid-

[19] Day and Shepherd, Bull. Geol. Soc. Amer., 24, 573, 1913; C. R. Acad. Sci., 157, 1027, 1913. E. S. Shepherd, The Composition of the Gases of Kilauea, Bull. Hawaiian Volc. Observatory, 7, No. 7, 1919.

ian from Monte Arci in Sardinia and of one from the island of Milos. As there are very few data on this feature of volcanic glasses, and as Merwin's results show some points of interest, it may be worth while to devote a few words to discussion of the subject. The data[20] are as follows:

Obsidian, Rocche Rosse........	1.488–9
Obsidian, Forgia Vecchia......	1.490
Pumice, Monte Pelato	1.499
Obsidian, Monte Arci.........	1.487–9
Obsidian, Milos	1.490

The refractive indices of the two Lipari obsidians are almost identical, and that of the Monte Arci obsidian is also almost the same; this correspondence being quite in accord with the very similar chemical compositions of the three glasses. But the distinctly higher index of the Lipari pumice glass is remarkable. As this contains about three per cent of water, much more than do the corresponding obsidians, it would be expected that the pumice glass would have a lower refractive index, while the contrary is true. It is difficult to account for this, and the matter must await further study and the accumulation of more data.

Martelli[21] determined the refractive index of the Nisyros obsidian glass as between 1.478 and 1.496. The mean, 1.487, is very close to that of the Lipari obsidian. Taking the difference in chemical composition into account, the close approach in refractive indices may be explained by the effect of the lime in raising and the silica in lowering, the index.

[20] Wülfing gives the refractive index of obsidian glass as 1.484–1.495 (Rosenbusch-Wülfing, Mikros. Physiog., I, (1), Table I, 1905).

[21] A. Martelli, Mem. Soc. Ital. Sci. dei Quaranta, Rome, 20, 66, 1917.

Geophysical Laboratory, Carnegie Institution of Washington,
Washington, D. C., July, 1920.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Desulphurizing Action of Hydrogen on Coke.*—Alfred R. Powell, of the Pittsburgh Experiment Station of the U. S. Bureau of Mines, has made an elaborate study of the reactions of the sulphur in coal during the coking process, and has studied also the effect of hydrogen and gas mixtures containing this element as desulphurizing agents when passed through finished coke at high temperatures or through coal in the process of coking. The effect of hydrogen was found to be very marked upon the removal of sulphur as hydrogen sulphide, and in most cases the greater part of this objectionable element was removed by passing the gas for 3 hours over the coke at a temperature of 1000°C. As the employment of pure hydrogen as a desulphurizing agent would probably not be practical on the large scale on account of the cost, a mixture containing 50% hydrogen together with methane, carbon monoxide, etc. was tried, as it corresponds to the by-product gas of the coking process, which apparently might be employed very cheaply in practice. This mixture was found to give slower and less extensive desulphurization, but the results even in this case were promising. For instance the mixture of gases diminished the sulphur in a coke from 1.20 to 0.34%, while pure hydrogen used for a shorter time brought it down to 0.11%. The work thus far done has been on a small laboratory scale, but the work will be continued, and it is to be hoped that it will lead to the manufacture of low-carbon coke for metallurgical use.—*Jour. Indust. Eng. Chem.* **12**, 1077. H. L. W.

2. *Chemical French*, by Maurice L. Dolt. Second Edition 8vo, pp. 413. Easton, Pa., 1920 (The Chemical Publishing Co.).—This introduction to the study of French chemical literature was very favorably mentioned in this department of the *Journal* when the first edition appeared about three years ago. The appearance so soon of a new edition indicates that the book has been well received and extensively used. About one half of the text is devoted to very satisfactory exercises which give a large amount of chemical information in addition to a knowledge of French, while the remaining part for advanced reading is made up of an excellent selection of important chemical articles copied from the literature. There is a table of irregular verbs; there are special vocabularies in connection with the exercises, as well as a general vocabulary. The new edition has received some corrections, and two very good articles, one by Le Chatelier and the other by Haller, have been added. H. L. W.

3. *A History of Chemistry;* by James Campbell Brown, edited by Henry Hilton Brown. Second Edition. 8vo, pp. 544.

Philadelphia, 1920 (P. Blakiston's Son & Co.).—With the exception of a few slight changes the present edition of the book corresponds to the first one which appeared in 1913. It represents a course of lectures given at Liverpool University by the late Professor Brown, whose notes were revised by the editor for publication. There is a frontispiece portrait of the author and a sketch of his life, and there are more than 100 illustrations, including the portraits of a number of chemists.

The book gives an excellent account of chemical history from the earliest times. The author appears to have been particularly interested in the history preceding the rise of modern chemistry, so that practically one-half of the book deals with those early times previous to about 1775. Probably the book contains more details about the names and writings of the alchemists than most readers will care to follow closely, but there are interesting chapters concerning the aims, methods and symbolism of those searchers for the transmutation of the metals. It is the last half of the book that is of particular interest to students of chemistry since it deals with the development of the modern science. H. L. W.

4. *The Simple Carbohydrates and the Glucosides;* by E. Frankland Armstrong. Third Edition. Royal 8vo, pp. 239. London 1919 (Longmans, Green and Co. Price $4 net).—This is one of the series of monographs on biochemistry. It gives a clear and concise account of the sugars and their compounds, their nomenclature, the theories regarding their moleeular structures, their synthesis, etc. There is a very extensive classified bibliography which adds greatly to the usefulness of the book. It is a very valuable monograph for the use of students who are familiar with the subject so far as it is dealt with in the ordinary text-books and wish to know what has been done in this interesting and important branch of organic chemistry.

H. L. W.

5. *Chemical Reactions, their Theory and Mechanism,* by K. George Falk. 12 mo, pp. 211. New York, 1920 (D. Van Nostrand Co. $2.50 net).—This book gives an interesting discussion of the theories of valence in connection with chemical compounds and of the theoretical mechanism of their reactions. Not many ideas that are fundamentally new are presented, but some striking modifications of previous theories are brought forward. It is attempted to develop a general theory of reactions which will include those of both inorganic and organic substances, by assuming that an addition product is always the first step in both kinds of reactions, but it appears doubtful to the reviewer that this view will be generally accepted for the ionic reactions. The ideas of the connection of the electron with valence are adopted in a very satisfactory way, particularly in connection with water of crystallization and other molecular compounds. Considerable use is made of Thiele's ideas in connection with the

discussion of valence. Friedel and Craft's reaction, Grignard's reaction, the reactions of olefins, as well as reactions of oxidation and reduction are extensively discussed. The book is to be recommended to those who are interested in the recent theories in regard to molecular structure. H. L. W.

6. *Experiments with Mechanically-Played Violins.*—In continuation of his earlier work (see **48**, 74, 1919) C. V. RAMAN has recently designed, constructed, and experimented with a new form of mechanical violin-player. He says: "The principal feature in the player which is worthy of notice is that the conditions obtaining in ordinary musical practice are imitated with all the fidelity possible in mechanical playing, and the results obtained with it may therefore be confidently regarded as applicable under the ordinary conditions of manual playing."

The most important results recorded in the present paper may be summarized as follows:

(1) If the speed of the bow is not too low, the bowing pressure necessary within the ordinary musical range of bowing varies inversely as the *square* of the distance of the bow from the bridge.

(2) For very small bowing speeds, the bowing pressure necessary tends to a finite minimum value, and the increase of bowing pressure with speed is at first rather slow, but later it becomes more rapid.

(3) The graph for the bowing pressure for different frequencies shows a series of maxima which approximately coincide in position with the frequencies of resonance of the instrument.

(4) The mute produces profound alterations in the form of the graph. The bowing pressure necessary is increased in the lower parts of the scale and decreased in the higher parts of the scale. The peaks in the graph shift toward the lower frequencies in consequence of the alteration in the natural frequencies of resonance of the violin produced by the loading, and the change in form of the graph is closely analogous to the change of the intensity of the fundamental tone of the instrument produced by the muting.—*Proc. Indian Assoc. Cult. Sci.,* **6**, 19, 1920.

H. S. U.

7. *Relativity;* by ALBERT EINSTEIN. Translated by ROBERT W. LAWSON. Pp. xiii, 168. New York, 1920 (Henry Holt and Co.).—The present book is intended, as far as possible, to give an exact insight into the theory of relativity to those readers who, from a general scientific and philosophical point of view, are interested in the theory, but who are not conversant with the mathematical apparatus of theoretical physics. The text is divided into three parts which deal respectively with the special theory of relativity, with the general theory of relativity, and with considerations on the universe as a whole.

The attractiveness and value of the English edition are increased by the addition of an autographed portrait of Einstein, of a biographical note, of appendix III on the experimental confirmation of the general theory of relativity, of a short bibliography of English works on the subject, and of an index. Since the original text came from the pen of the highest authority on the subject and since the translation has been done in a very faithful and conscientious manner, the present volume can be highly recommended to all who are interested in the epoch making discoveries of A. Einstein. H. S. U.

8. *The Discovery of Electromagnetism Made in the Year 1820 by H. C. Oersted;* by Absalon Larsen. Pp. 46. Copenhagen, 1920 (F. Hendricksen and H. H. Thiele).—On July the 21st 1820 the Danish physicist Hans Christian Oersted published his first pamphlet on the effect of the electric current on the magnetic needle. In commemoration of the great discovery recorded in this pamphlet the present brochure was issued on the centennial anniversary of the event by the Oersted committee at the expense of the State.

The preface, which is given first in French and then in English, contains a brief account of the life and scientific career of Oersted. This is followed by facsimile reproductions of the Latin pamphlet published by Oersted and of the translations of the original paper which appeared almost immediately in French, Italian, German, English, and Danish scientific journals. The Oersted medal, which is awarded as a prize for scientific work, is reproduced both on the front cover and on the title page of the brochure. The present collection will be welcomed by all who are interested in the precise history of Oersted's epoch making discovery. H. S. U.

9. *Augusto Righi.*—The Italian publication "l'Arduo" has recently dedicated a small volume of eighty pages to the memory of the late Augusto Righi, Professor of Physics at the University of Bologna. The first part of the text comprises six essays each of which deals with special phases of the personality and of the scientific career of Righi. This part of the book was written by prominent Italians in their native language. The second part of the volume consists of about thirty-five short letters of appreciation and of condolence written by noted Dutch, English, French, German, Italian, etc. physicists at the suggestion of the editorial staff of l'Arduo. The value of the book is appreciably increased by the frontispiece, which is an excellent reproduction of an autographed photograph of Righi, and by another full page photograph of the representatives present at the international conference held at Paris in 1912, on which occasion Righi acted as minister plenipotentiary for the Italian Government.

H. S. U.

10. *Smithsonian Physical Tables. Seventh Revised Edition;* prepared by Frederick E. Fowle. (Publication 2539) Pp. xlvi,

450, with 579 tables and an index. Washington, 1920.—The latest edition of this volume involves a considerable enlargement. Besides the incorporation of new data in the older tables, 172 new tables have been added. The scope of the collection has been broadened to include tables on astrophysics, meteorology, geochemistry, atomic and molecular data, colloids, photography, etc. The tables have been radically rearranged so as to effect a more logical order than prevailed in the earlier editions; the present sequence being,—mathematical, mechanical, acoustical, thermal, optical, electrical, etc. Much credit is due to Mr. Fowle and his collaborators for the valuable service which they have rendered to all who are engaged in extending the domain of the physical and allied sciences. H. S. U.

11. *Logarithmic and Trigonometric Tables. Revised Edition;* edited by EARLE RAYMOND HEDRICK. Pp. xxi, 143. New York, 1920 (The Macmillan Co.).—In effecting the revision care has been taken to preserve the page numbers of the principal tables up to page 114, so that older editions may be used in class-work without confusion, and texts which contain the principal tables may be used in the same class. Several tables not contained in the earlier editions have been incorporated in the present volume. Among these may be mentioned: a table of multiples of M and of $1/M$, a table of haversines, a table of factors of composite numbers and logarithms of primes, tables for compound interest and discount, annuity tables, etc. Every effort has been made to maintain the high standard of accuracy which characterized the previous editions of this very useful collection of numerical data. H. S. U.

II. GEOLOGY AND MINERALOGY.

1. *An Introduction to Palaeontology;* by A. MORLEY DAVIES. Pp. xii, 414, 100 text figs., London (Thomas Murby & Co.), 1920.—The title of this book is somewhat misleading, since it is essentially an introduction to the study of fossil invertebrates. It should be most useful for teaching the morphology of the hard parts of the Brachiopoda, Lamellibranchia, Gastropoda, Cephalopoda, Trilobita, and graptolites. The Cystidea, Blastoidea, sponges, and corals, however, are not described as thoroughly as is needed, while the Bryozoa, Insecta, worms, and Arthropoda (other than trilobites) are only briefly defined. It is well that even invertebrate paleontologists should know something of the vertebrates and plants, and thirty-three pages, with a few illustrations, are devoted to these. The chapters on the collection and preservation of fossils, the rules of nomenclature, and the divisions of geological time are good and highly useful. In general, the book is a commendable one, especially because of the easy and interesting way in which the organisms

are described. The author's ideal has been "in treating each great group of fossils, first to describe with some fulness a few common species from which an idea of the general characters and range of variation may be obtained; and then to give a brief systematic account of the group." C. S.

2. *Cretaceous and Cenozoic Echinoidea of the Pacific Coast of North America;* by WILLIAM S. W. KEW. Univ. California, Bull. Dept. Geology, vol. 12, pp. 23-236, pls. 3-42, 5 text figs., 1920.—In this excellent work there are described and illustrated 90 forms (49 new) of echinids in 17 genera. Of these, 7 are Mesozoic in time (2 in the Knoxville, 6 in the Chico), while the great bulk, about 65, are found in the Miocene and Pliocene, and only 4 in the Pleistocene. "In general," the author says, "the echinoids are of limited range, as their evolution proceeds rapidly. The species are easily recognized, the individuals are often abundant, and their state of preservation is commonly better than that of associated invertebrate forms. These factors combined make the group of exceptional interest for biologic studies, and of unusual importance in geologic correlation and age determinations" (p. 26). The geologic time scale for the Pacific coast opposite page 26 is very interesting and brings out clearly no less than eleven unconformities since Jurassic time. C. S.

3. *Type Ammonites;* by S. S. BUCKMAN, with illustrations from photographs mainly by J. W. TUTCHER.—It is well to call the attention of paleontologists to this periodic publication, as it is of a fundamental character. No worker on ammonites can be without it, not only to have the correct names for his fossils, but even more to learn Buckman's principles of classification. The work is replete with new species and genera. There are now published 23 parts, and the number of half-tone plates is upward of 180. The work can be had of William Wesley and Son, London. C. S.

4. *The American Species of Orthophragmina and Lepidocyclina;* by JOSEPH A. CUSHMAN. U. S. Geol. Survey, Prof. Paper **125**-D, pp. 39-108, pls. 7-35, 1 text fig., 1920.—The large colonial orbitoid foraminifers are excellent horizon markers, as the species attain to large size, have short geologic ranges, and in addition are of wide geographic distribution. Here are described 17 forms of *Orthophragmina* (2 new), the genus being restricted to the Eocene; and 35 of the genus *Lepidocyclina* (13 new), which is restricted to the Eocene and Oligocene. The latter are figured on 24 plates. The forms of the first-named genus range in size up to 14 mm., while those of the latter attain to 100 mm. or 4 inches. C. S.

5. *Geology of the non-metallic mineral deposits other than silicates.* Vol. 1, *Principles of salt deposition;* by AMADEUS W. GRABAU. Pp. xvi, 435, 125 text-figs., New York and London, 1920 (McGraw-Hill Book Company).—This well-balanced, exten-

sive, and carefully wrought out work is a treatise on applied stratigraphy as it relates to the salts of geologic deposits, including the nitrates, phosphates, borates, and similar compounds. "The emphasis is laid upon the geological relationships of these deposits, and the chief endeavor has been to set forth our present understanding of the conditions under which such deposits are formed. To this end, the first volume is devoted to a study of deposits now forming or which have but recently been formed, and of the physical conditions which control such deposition" (ix). Among the more interesting of the eighteen chapters are: III, The sea as a source of saline deposits; V, Sea margin deposits of salts; IX, Connate salts, their origin and method of concentration; and XII, Playa deposits of complex salts. C. S.

6. *Text Book of Geology: Part I, Physical Geology;* by the late Professor Louis V. Pirsson. Revised Edition. New York, 1920 (John Wiley and Sons).—The Text Book of Geology by Pirsson and Schuchert first appeared in 1915 and immediately won favor as a class-room text book. It is now used in over fifty-eight colleges. Part I, Physical Geology, because of its subject matter, is obviously more widely used, and over fifteen thousand copies of the first edition have been sold.

In the revised edition of Part I, much of the knowledge contributed to the subject of Physical Geology since the original writing of the book, has been added, and the volume is now up-to-date. Other parts have been thoroughly revised, and some of the text and illustrations eliminated. Alterations in definitions and headings are also noticeable. Many of the changes are the result of the author's experience in using the book as a class-room text; others embody suggestions and criticisms from the author's acquaintances among teachers of Physical Geology.

Among the parts in which revision has produced great improvement, might be mentioned: the work of stream erosion and the resulting topographic forms; structure and form of the earth; structures of sedimentary rocks; fractures and faulting; and the origin and history of mountains. The classification of ore deposits has been entirely revised. The parts dealing with the relation of stream velocity to transportation and the origin of coral reefs still leave a little vagueness in the student's mind.

The unusually even balance of the book and its satisfactory scope have been maintained, and give it a preeminent place as being particularly suitable for a class room text-book.

Alan M. Bateman.

7. *United States Geological Survey;* George Otis Smith, Director.—Recent publications are noted in the following list (see earlier, vol. **49**, pp. 448-450).

Topographic Atlas.—Forty-one sheets.

Professional Papers.—No. 108. J. The Flaxville Gravel; by A. J. Collier and W. T. Thom, Jr. Pp. 16.

No. 111.—The ore deposits of Utah; by B. S. Butler, G. F. Loughlin, V. C. Heikes, and others. Pp. 669.

No. 125-D. The American Species of Orthophragmina and Lepidocyclina; by J. A. Cushman. Pp. 70 pages, 29 pls. See above.

No. 128-A. The fauna of the Cannonball Marine Member of the Lance Formation; by T. W. Stanton and T. W. Vaughan. Pp. 66; 10 pls.

No. 128-B. Lower Miocene Foraminifera Collected in the Alum Bluff Formation of Florida; by J. A. Cushman. Pp. 8, 1 plate.

No. 128-C. The origin of the faults, anticlines, and buried "Granite Ridge" of the northern part of the mid-continent oil and gas fields; by A. E. Fath. Pp. 10, 3 pls., 3 figs.

128-D. The use of geology on the Western Front; by Alfred H. Brooks. Pp. 40, 3 pls., 16 figs.

Mineral Resources.—Preliminary summary for 1919; by G. F. Loughlin and Martha B. Clark. Pp. 128. Also numerous advance chapters of the final report.

Bulletins.—No. 686-X, W. Structure and oil and gas resources of the Osage Reservation, Okla.; by M. I. Goldman.

No. 697. Gypsum deposits of the United States; by R. W. Stone and others. Pp. 326, 37 pls., 57 figs.

No. 701. Geothermal data of the United States; by N. H. Darton. Pp. 96, 1 pl., 3 figs.

No. 712. Mineral resources of Alaska; by G. C. Martin and others. Pp. 204, 6 pls., 10 figs.

No. 715-A, B. Potash deposits; by H. S. Gale. A, in Spain; B, in Alsace. C, D, Manganese ore deposits; by E. L. Jones, Jr., C, in Wyoming; D, in Colorado; E, Yellow Pine Cinnabar-mining District, Idaho; by E. S. Larsen and D. C. Livingston. F, Iron ore near Stamford, Mont.; by L. G. Westgate.

No. 716-A, Geology of Alamosa Valley, N. Mex.; by D. E. Winchester. B, Upton-Thornton oil field, and C, Mule Creek oil field, both Wyoming; by E. T. Hancock.

Water Supply Papers.—Nos. 451, 452, 461, 464. (1917); 472, 474 (1918). Surface water supply of the United States; Nathan C. Grover, Chief Hydraulic Engineer.

No. 450-C. Ground water in Certain Nevada and California Valleys; by Gerald A. Waring.

No. 490-A. Routes to desert watering places in the Salton Sea Region, Calif.; by J. S. Brown. Pp. 86, 7 pls; 2 figs.

8. *U. S. Bureau of Mines;* Frederick G. Cottrell, Director.—Recent Bulletins are as follows: (See earlier, vol. **49**, p. 450).

No. 95. A glossary of the mining and mineral industry; compiled by A. H. Fay. Pp. 753. Bound in cloth, 75 cents.

Contains more than 20,000 terms and nearly 30,000 definitions, covering technical and local usage in mining and metallurgy.

No. 112. Mining and preparing domestic graphite for crucible use; by G. D. DUB and F. G. MOSES. Pp. 90, 5 pls., 20 figs.

No. 173. Manganese: Uses preparation, etc.; by C. M. WELD and others. Pp. 209, 13 figs.

No. 180. Bibliography of petroleum and allied substances, 1917; by E. H. BURROUGHS. Pp. 170.

No. 182. Casing troubles and fishing methods in oil wells; by THOMAS CURTIN. Pp. 48 3 pls., 15 figs.

No. 184. The manufacture of sulphuric acid in the United States; by A. E. WELLS and D. E. FOGG. Pp. 216, 15 pls., 36 figs.

No. 196. Coal mine fatalities in the United States, 1919; by A. H. FAY. Pp. 86, 1 fig., 38 tables.

Numerous Technical Papers have also been issued.

It is announced that H. S. MULLIKEN, of Lexington, Mass., has been appointed metallurgical engineer and has been assigned as an assistant to the Director in special professional work connected with the Bureau.

9. *The Production of Platinum in 1919—The Production of Precious Stones in 1919;* by GEORGE F. KUNZ. Reprinted from Mineral Industry, volume XVIII, pp. 549 to 567, 584 to 613.

Platinum and allied metals in 1919; by JAMES M. HILL. From Part I of Mineral Resources of the United States, pp. 9 to 18. (U. S. Geol. Survey.)—As is well known, the situation with respect to the supply and price of platinum has been unprecedented ever since 1914. The average price in New York for the troy ounce in 1914 was $45, which had increased in December 1919 to more than $151. In 1919, in addition to the production of 54,550 oz., 25,000 oz. were released by our Government, so that upwards of 90,000 oz. were available. The supply is, however, far less than the demand and this is likely to remain true until the resources of Russia are once more made available. It is interesting to note that in the year under consideration, 56% of platinum went into jewelry, 19% was used for electrical purposes, 14% for dental purposes, and the remainder for chemical and miscellaneous objects. In 1902 this country produced only an insignificant amount, but this had increased in 1919 to 824 oz., all from domestic sources. The total amount recovered by refiners was 54,400 oz. in 1918 and 40,220 in 1919, a large part was from scrap material. The imports of platinum and allied metals in 1919 were approximately 20% more than those in the preceding year. In 1918, Columbia furnished 23,000 oz. and Russia in Asia 21,000 oz. In 1919 the production of Columbia had increased somewhat, but the amount available from Asiatic Russia was reduced to 400 oz. In addition, England and France contributed 26,400 oz. in 1919, chiefly of the refined metal. Dr. Kunz gives interesting facts in regard to prospecting for platinum in Alaska, which may yet prove to be an important source of the metal. He also gives valuable digests of the occurrences in Russia and in Spain, as described by Professor Duparc.

With respect to the always interesting subject of precious stones, it is remarkable that the entire world, even stricken and impoverished Vienna, should have found it possible to purchase diamonds and pearls to an almost unprecedented extent. In this country, 1919 saw the importation of 105 million dollars worth of diamonds, pearls and precious stones. Of uncut diamonds alone, more than twenty-one million dollars worth were imported, nearly double the amount for 1916. It is not surprising under these conditions, that the price has greatly increased. It is remarked also that the total product of the South African mines has been under the control of a Syndicate. With respect to the well known mines in the Kimberley region, it is stated that between 1909 and 1919 the value of the product was upwards of two hundred millions. Furthermore, in view of the fact that nearly fifty years ago (1872) these mines were hardly more than scratches on the surface, it is worth noting that the main rock shaft of the Kimberley mine has gone to a depth of 3600 feet. The Premier mine, famous because of the discovery of the great Cullinan diamond in 1905, yielded in October, 1919, a white flawless stone of 1500 carats or about half the weight of the Cullinan. It is suggested that this last stone may perhaps be a fragment of the original Cullinan crystal, which at the time of its discovery was known to be only part of the original. The value of the diamonds produced from the Premier mine since 1903 was over 100 million dollars. It is proposed to carry on work in the diamond field of Arkansas on a considerable scale, but what success this may meet with is still quite uncertain. The diamonds of Southwest Africa formerly belonging to Germany have been taken over by a British Company. New diamond fields have been discovered at Tlaring, Bechuanaland near Nairobi, British East Africa; and on the African Gold Coast.

10. *Zeitschrift für Krystallographie und Mineralogie,* herausgegeben von P. Groth und E. Kaiser. Leipzig (W. Engelmann).—The concluding double number of the fifty-fifth volume of Groth's Zeitschrift has been recently received; it was issued on September 10, 1920. It embraces nine papers, two of them devoted to the new minerals *leifite* and *ultrabasite* (to be noticed later); with also brief original notes and the usual indexes.

As this number goes to press, the announcement is received that, with volume **56**, the editorship has been assumed by Dr. P. Niggli, professor in the Technische Hochschule at Zürich, Switzerland.

III. Miscellaneous Scientific Intelligence.

1. *The National Academy of Sciences.*—The regular autumn meeting of the National Academy was held at Princeton University, Princeton, New Jersey, on Tuesday and Wednesday, November 16 and 17. The meeting was largly attended and upwards of forty papers were presented for reading. In addition to the last-named, a complimentary lecture was delivered by W. M. Davis on the ''Lessons from the Grand Canyon.'' There was also on Tuesday an excursion to the Rockefeller Institute (department of Animal Pathology). The social side of the meeting was well cared for: this included a reception by President and Mrs. Hibben on Tuesday evening and a subscription dinner of the Academy on Wednesday evening.

2. *Publications of Carnegie Institution of Washington.*—Recent publications of the Carnegie Institution are noted in the following list. (See earlier, vol. **49**, pp. 224, 387.)

No. 161. Periodic orbits; by F. R. Moulton, in collaboration with Daniel Buchanan, Thomas Buck, F. L. Griffin, W. R. Longley, and W. D. MacMillan. Quarto, pp. xlii, 524.

No. 219. The Inscriptions at Copan; by S. G. Morley. Quarto, pp. xii, 643; with frontispiece, 33 pls. and 91 figs.

No. 248. The Cactaceæ: Descriptions and illustrations of plants of the Cactus Family; by N. L. Britton and J. N. Rose. Volume II. Quarto, pp. vii, 239, 40 pl. and 305 figs.—To be noticed later; see also vol. **49**, p. 222.

No. 256. History of the theory of numbers. Volume II, Diophantine Analysis; by Leonard E. Dickson. Pp. xxv, 803.

No. 294. Studies in the development of Crinoids; by Th. Mortensen (Copenhagen). Quarto, pp. v, 94; 28 plates. Vol. 16, of papers from the Department of Marine Biology.

No. 296. Heredity and social fitness: A study of differential mating in a Pennsylvania family; by Wilhelmine E. Key. Pp. 101. No. 32 of papers from the Station for Experimental Evolution at Cold Spring Harbor, N. Y.

3. *The National Research Council.*—It is announced that a site for the new building in Washington, which is to serve as a home for the National Academy of Sciences and the National Research Council, has recently been obtained. It comprises the entire block bounded by B and C Streets and Twenty-first and Twenty-second Streets, Northwest, and it faces the Lincoln Memorial in Potomac Park. The Academy and Council have been enabled to secure this admirable site, costing about $200,000, through the generosity of a number of friends and supporters. Funds for the erection of the building have been provided by the Carnegie Corporation of New York.

4. *Recent Publications of the British Museum of Natural History.*—We have recently received the Supplement, volume II,

of the Catalogue of the Lepidoptera Phalænæ in the British Museum. This includes the Lithosiadæ (Arctianæ) and Phalænoididæ, and is by Sir GEORGE F. HAMPSON. Pp. xxiii, 619, with text figures. This volume was in manuscript in early 1915, but owing to the war, publication was postponed. It has now been completed and so far as possible brought up to date. The text is accompanied by a special volume including plates xlii-lxxi. These are beautifully executed in color as has been true of earlier publications of the work.

Another recent publication is the following:

Economic Series No. 11.—Furniture Beetles, their life-history and how to check or prevent the damage caused by the worm; by CHARLES J. GAHAN, Keeper of the Department of Entomology. Pp. 23; 1 plate, 5 text figures.

5. *The Nature of Animal Light;* by E. NEWTON HARVEY. Pp. x, 182, with 35 figures. Philadelphia and London, 1920 (J. B. Lippincott Co.).—This is the fifth volume of the series of monographs on experimental biology by American authors. It consists of a clearly written summary of our present knowledge concerning the physical characteristics of animal light and the chemical processes involved in its production. It may be surprising to learn that while but two groups of plants—the bacteria and the higher fungi—are known to be self-luminescent, this property is possessed by no less than thirty-six different orders of animals, including many forms of protozoa, hydroids, jelly-fish, bryozoa, polychaete and oligochaete worms, brittle stars, crustacea, myriopods, insects, mollusks, primitive chordates, and fishes. Curiously enough, none of the luminous species inhabit fresh water, all being either terrestrial or marine. In some forms the luminosity is exhibited by both larvae and adults, and in a few forms light is produced by the eggs either before or after segmentation. Many other animals appear to be luminescent at times because of the presence of ingested or parasitic luminous organisms.

Following the description of the cellular structures found in the various types of photogenic organs, the author explains from experimental evidence the chemistry and dynamics of light production. He concludes that the light is produced by the action of an enzyme, luciferase, on a proteid, luciferin, in the presence of water and oxygen. These substances can be separately isolated and are luminescent when brought together outside the body. W. R. C.

OBITUARY.

SVEN LEONHARD TÖRNQUIST, the veteran Swedish geologist, died at Lund on September 6.

M. LOUIS DUCOS DU HAURON, a pioneer in the difficult work of color photography, died on August 31 at the age of eighty-two years.

INDEX TO VOLUME L.*

* This Index contains the general heads, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, ROCKS; under each the titles of Articles referring thereto are included.

NEW PRICE-LISTS

No. 220. **Summary of Collections of Rocks and Minerals.** Briefly describes over 200 scientific collections which we put up.

No. 225. **Minerals Sold by Weight.** Gives prices of several hundred minerals for College Laboratories and chemical examination.

No. 224. **Autumnal Announcements 1920.** Briefly mentions eleven collections bought during the past year, summarizes the purchases made by our Mr. English in Europe and many other recent additions to our stock of minerals.

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Foot notes should be numbered consecutively from 1 up.

The following is an example of the system of references employed, the volume being given in heavy faced type:

Am. J. Sci., **44**, 249, 1917. The year should be given in every case; this renders a series number unessential.

Thirty separate copies of each article will be furnished to the author free of cost and without previous notice from him. They will be provided with a plain cover (but with reference to volume and year). If the author orders separate copies, they will be understood to be in *addition* to the thirty mentioned above, and he will receive a bill for the extra expense involved, as also for that of a printed cover (with title, etc.), when this is *specially ordered*.

The charge for reprints will be made as moderate as possibie, consistent with the present high cost of printing, binding, engraving and paper.

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