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SCIENTIFIC INTELLIGENCE.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. I.—*Current Theories of Slaty Cleavage;* by George F. Becker.

The theory that slaty cleavage is due to pressure normal to the cleavage is old and very generally esteemed satisfactory. Sedgwick and others held cleavage to be mainly a phenomenon due to the crystallization or recrystallization of minerals in an appropriate orientation, and this idea with modifications has been advocated of late years by Messrs. Van Hise and Leith. Mr. Leith's recent paper[*] is the most authoritative exposition of it.

This geologist acknowledges that my theory of slaty cleavage[†] applies in certain cases to which he gives the name of fracture cleavage. According to him, such cleavage is mainly characterized by the presence of actual partings within the mass, but sometimes shows flow structure as well. He distinguishes flow cleavage from fracture cleavage, however, attributing to the former a greatly preponderating importance in nature and ascribing it to causes distinct from those which produce fracture cleavage. To this latter he attributes the fissility of those rocks in which a parallel arrangement of mineral constituents is ab-

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[*] Rock Cleavage, U. S. Geol. Surv., Bull. No. 239, 1905.

[†] Like Tyndall and Daubrée, I consider a parallel arrangement of flattened grains unessential to cleavage. Rupture takes place (as Messrs. Van Hise and Leith concede) on planes of maximum slide or maximum tangential strain. Rupture is a gradual process and cohesion is impaired through flow before it is destroyed. Impaired cohesion in my theory is cleavage. Cleavage developes most perfectly when the stress tending to produce it is persistent in direction, because viscous resistance is then small. In a rotational strain there are two sets of mathematical planes on which maximum slide takes

sent throughout,[*] as well as cleavage which is not parallel to the mica plates of phyllites. Fracture cleavage, he says, is present abundantly in the rocks of the lithosphere.[†] It is perhaps desirable for me to comment on his paper as succinctly as possible.

Mr. Leith does not make the theory he supports entirely clear to me. He states, and repeats in his summary,[‡] that the parallel arrangement of component minerals in slates showing flow cleavage is developed by recrystallization "mainly in planes normal to the greatest pressure." By greatest pressure, I understand him to mean resultant stress. Other passages, however, seem to contradict these. In one of them[§] he says that the final position of cleavage "may or may not be inclined to the greater stress depending upon the nature of the strain." Again on another page[‖] he admits that pure or irrotational strains are of rare occurrence in rock masses and concludes from the nature of rotational strain that "the final position of cleavage is usually inclined to the axis of greatest stress.[¶] He maintains, however, that even in such cases cleavage is always tending to develop normal to the greatest principal stress.

In dealing with the strains accompanying the development of cleavage, Mr. Leith is more definite and states[§] that "wherever the directions of shortening of a rock mass can be determined with certainty, any flow cleavage which may be present is normal to the greatest total shortening which the rock has undergone."

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place and both sets are parallel to the axis of rotation. They make with the greatest axis of the strain ellipsoid angles given by

$$\tan \omega = \frac{\pm B}{(ABC)^{\frac{1}{3}}}$$

A being the greatest axis, B the least and C the axis of rotation. The planes of maximum slide contain the circular sections of the ellipsoid only in a limiting case. During the progress of strain these mathematical planes sweep through wedges of the mass, but the two sets of planes sweep at different rates, one set having a relative angular velocity from, say, 20 to an infinite number of times as great as the other. On the planes which sweep rapidly, viscosity reinforces rigidity, there is no time for considerable flow to take place, and, unless actual rupture occurs, so that joints form, the effect will be small. On the other set of planes viscosity is small, the mass has time to yield by flow, cohesion is weakened, and cleavage results. In a word, the theory is that slaty cleavage is due to solid flow attendant upon rotational strains. So much of the energy of the system as is not potentialized is dissipated on the plans of maximum slide, and this may or may not lead to the alteration of mineral constituents, e. g., the transformation of feldspar into biotite. It is discussed in Finite Homogeneous Strain, Flow and Rupture of Rocks, Bull. Geol. Soc. Amer., vol. iv, 1893, p. 13, and in Experiments on Schistosity and Slaty Cleavage, U. S. Geol. Surv., Bull. 241, 1904.

[*] Idem, p. 127.

[†] Idem, p. 134.

[‡] Op. cit., p. 118.

[§] Idem, p. 138.

[‖] Idem, p. 113.

[¶] Idem, p. 106.

This explanation differs from that proposed in the last paragraph more than might be supposed. It is analogous to Sharpe's theory, but is more general; for Sharpe supposed cleavage developed by an external pressure perpendicular to the induced cleavage, or to a pure strain, usually accompanied by lateral constraint; whereas Mr. Leith's second hypothesis is that, whether the strain is pure or not, the cleavage is normal to the least axis of the strain ellipsoid.

I entirely share Mr. Leith's opinion that pure strains are rare in nature. Some idea of their rarity may be gained by a little reflection. The direction of a force with reference to a resisting plane may be regarded as fortuitous. If so, the chance that the direction will be exactly 90° is infinitesimal, but if a variation of plus or minus half a degree is tolerated, the chance will rise to one in 20,626, which is the number of square degrees on a hemisphere of unit radius, or 360 radians. On the other hand, a zone one degree in width on a sphere at a polar distance of 45° has an area of 255 square degrees, so that the chance of a force having an inclination of $45° \pm 30'$ to a fixed plane is 255 times as great as that it should be normal to the plane. The average value of all possible inclinations is an angle of one radian (57° 18′) to the normal. Thus pressures at less than 45° to the plane are more probable than those at higher angles and normal pressure is least probable of all. Hence a pure strain is a highly improbable limiting case of rotational strain. Unmodified scission is also a limiting case, but is 360 times as probable as a pure strain.

It has been assumed in the preceding paragraph that rock masses undergoing deformation may be regarded as resting against a fixed support, and this is only partially true. Any supporting masses must yield by rotation to some extent, though the amount of such yielding must usually be exceedingly small as compared with the amount of deformation. When a dislocation occurs between the Andes and the basin of the Pacific, the trend of the range is not sensibly changed to accommodate the rocks adjacent to the fault system. However, so far as the supporting resistance does rotate, the probability of a pure strain is increased by the diminution of the rotational strain component. I shall assume that the probability rises to one in 10,000, though in my opinion this is a gross exaggeration.

Sharpe's theory is that cleavage is due to pure strain. The many geologists who are content with this theory ought to tell the rest of us what happens in 9999 cases in which the strain is not pure.

In the vast exposures of the Archean and early Paleozoic, millions upon millions of cases of dynamo-metamorphism are exposed to examination and when such numbers of instances are to be dealt with the laws of probability become exact. Again, wherever there are evidences of dynamo-metamorphism, cleavage appears in the rocks, not always good cleavage, but still a fissile structure which should be accounted for. With every possible allowance for yielding of supports, it appears to me conclusively shown above that the average direction of deforming force to the resisting plane cannot have exceeded something like 45°, and hence also that schistosity is brought about as a concomitant of strains in which the rotational element is large. It follows to my mind that Sharpe's theory is inadequate, for if it were a sufficient explanation, not more than a ten thousandth part of the strained rocks ought to show cleavage or foliation.

The hypothesis that crystallization takes place in surfaces perpendicular to the resultant stress is attractive, but it must be tested first of all by determining for the simplest cases what the direction of resultant stress really is. Mr. Leith evidently supposes that in the case of pure or irrotational strain in a homogeneous mass, the resultant stress coincides in direction with the least axis of the strain ellipsoid. Such a coincidence will truly exist between the external stress or surface traction and the axis in question when the strain is pure, but there is no such agreement between the resultant internal stress at an arbitrarily selected point and the local orientation of the strain ellipsoid. In pure strains the resultant stress acting on any material particle is in the direction of the motion due to this action. The paths traced out by the particles are called the lines of displacement or the "lines of flow" and the surfaces which are perpendicular to these lines are the elastic or plastic

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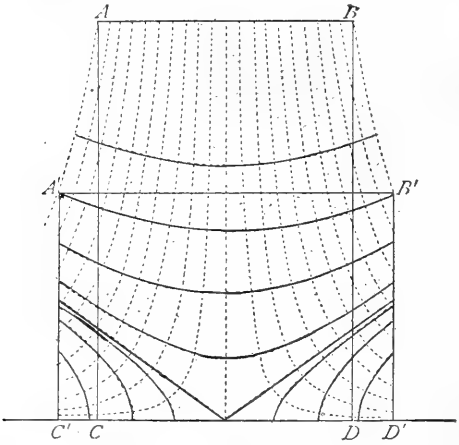

equipotential surfaces. Hence if crystallization takes place on surfaces perpendicular to the resultant stress, these are the equipotential surfaces.

The simplest conceivable deformation is (irrotational) shear. In a shear the lines of flow are rectangular hyperbolas and the equipotential surfaces are rectangular hyperbolic cylinders. Little more complex is the case of two shears at right angles to one another. This corresponds to the axial homogeneous compression of a cube, slab or cylinder of constant volume. In discussing the mechanics of slate formation the cubical compressibility of the mass is of small importance because after the limit of elasticity is reached and flow begins, there is no further change of volume. A cut (fig. 1) showing the lines of flow and the plastic equipotentials is borrowed from W. J. Ibbetson's well-known work on elasticity.* The circular cylinder A, B, C, D is supposed compressed by uniformly distributed pressure to the shorter cylinder A′ B′ C′ D′, and during the process A moves to A′ along the curve connecting the two, B moves to B′, etc. The equipotential surfaces are hyperboloids of revolution represented by the equation given by Ibbetson,

$$2\,y^2 - x^2 - z^2 \pm c^2 = 0$$

where y lies in the vertical and c is a constant. They are represented by full lines in the figure.

Add to the cylinder shown in this figure a second inverted cylinder at the bottom of the first, and suppose the two to represent only the central portion of a slab. Then the entire diagram would show the equipotential surfaces on which mica scales would form if they grew at right angles to the pressure in a mass subjected to pure strain.

In mere translation, or in rotation, no work is done against purely elastic or plastic resistances. Hence in a rotational strain at any given instant the elastic potential is the same as it would be for a pure strain of equal amplitude. There is an important difference between the two cases, however, for in pure strain the system of lines of flow and of equipotentials remains fixed relatively to the mass, so that the motion of the particles, however great, is confined to the lines of flow which pass through them at any instant. On the other hand, in a rotational strain the lines of flow and equipotentials are not fixed relatively to the mass, but only relatively to the axes of the strain ellipsoid, and, like these axes, shift continually with reference to the material particles of the body undergoing strain. At any instant, however, the equipotentials or surfaces normal to resultant stress can be definitely assigned.

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* Mathematical Theory of Perfectly Elastic Solids, etc. London: Macmillan and Company, 1887, p. 172.

In figure 2, I have drawn out the equipotentials for a rotational strain which is identical with that illustrated in figures 3 and 4. The hyperbolas are the traces on the plane of the diagram of the hyperboloids of revolution whose equation is stated above, when the axes of co-ordinates are the principal axes of the strain ellipsoid. The two asymptotes are the traces of a two-sheeted cone of revolution, so that in the whole system of surfaces there is not a plane area. It is upon these surfaces of double curvature that mica should be deposited at the final moment of strain were it true that this mineral crystallizes perpendicularly to resultant stress. If such crystallization occurred during the whole progress of stress, the mica would be found not only on one system of hyperboloids, but upon innumerable intersecting systems of hyperboloids.

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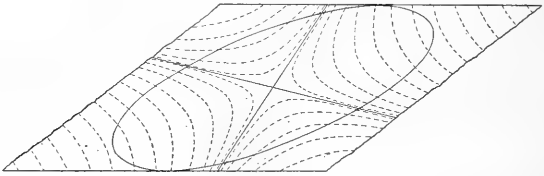

I am not aware of any lithological phenomena of a character corresponding to such equipotentials. Nothing more unlike the structure of a slate belt can be imagined, and I conclude that the hypothesis under discussion is wholly without foundation.* The fallacy, of course, consists in confusing the forces acting on the exterior of the mass with the resultant of these and the internal forces. It is this resultant which is actually exerted on any small group of molecules within the body.

The lines of flow may be considered as representing the absolute motion of particles of the mass. There is also a relative motion of the elements of mass which is rectilinear and takes place along the planes of maximum tangential strain. It is to impairment of cohesion caused by this relative motion that I suppose cleavage and jointing due.

Although the equipotentials are as far as possible from being plane surfaces, yet the mica scales in phyllites are arranged in

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*Mr. F. E. Wright has published a preliminary note on some experiments which would seem to offer some support to the supposition that crystallization in glass is determined by external forces. In these experiments, however, insufficient care was taken to ensure uniformity of temperature, and when they were repeated with more precaution the results were practically negative. This Journal, vol. xxii, p. 224, 1906.

planes and must crystallize there in obedience to some law. Sharpe believed the micas secondary and that they crystallized most rapidly in the direction of least resistance.* I entirely agree with him.

It would appear from Mr. Leith's discussion that as a matter of fact the relation sought to be proved is not that mica scales form normally to local stress, but that they are arranged perpendicularly to the shortest axis of the strain ellipsoid. He offers a variety of evidence that this relation exists in those rocks which have undergone what he designates as flow cleavage, and this evidence is discussed in the fifth chapter of part one. He takes up first the distortion of pebbles in conglomerates, which he alleges are elongated in a direction parallel to the schistosity of the matrix. A schistose conglomerate is not a particularly favorable rock for a discussion of this description, because the schistose lamellæ wind in and out between the pebbles, and it is impossible to assign to them an average direction with any degree of accuracy.† My experience, however, does not coincide with his, so far as observation is concerned. Where conglomerates have been rendered schistose, and the pebbles are not so abundant as to touch one another, it is in some instances possible to break them out with adherent portions of the matrix. I have thus extracted many scores of pebbles from schistose conglomerates where the conditions appeared favorable, and I have found that each pebble came out with an appendage of schist, a sort of beard, which in almost all cases stood at a sensible angle to the major axis of the pebble. Nevertheless, I do not for a moment undertake to deny that there are conglomerates where there is sensible coincidence between these directions. The question is what such a concidence would indicate. I do not think that Mr. Leith has put the correct interpretation upon it. In conglomerates, as everyone knows, there is a strong tendency for the pebbles to arrange themselves with their shortest axes perpendicular to the plane of bedding, though there is usually some imbrication or shingling. If the plane of bedding were parallel to the plane of fixed resistance, and if also a force were to act on the conglomerate at 90° to the plane of bedding, then the elongation of such pebbles as lay quite flat would coincide with the normal to the least axis of the strain ellipsoid. But each of these conditions must be of very rare occurrence, and that both should be fulfilled at once is in the highest degree improbable.

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* Geol. Soc. Journ., vol. v, p. 129, 1849.

† On p. 116, Mr. Leith asserts that in a rock undergoing flow "the general effect of rigid particles is to transmit stresses locally in directions normal to themselves." I know of no such theorem in mechanics, and believe the statement incorrect.

If, on the other hand, either condition fails to be fulfilled, the position of the strain ellipsoid will not be indicated by the elongation of the pebbles and the divergence may amount to any angle. In a general way, this conclusion may be arrived at in a moment, for the ellipticity of the strain ellipsoid will be superposed on that of the pebble and the resultant figure will coincide with neither, either in amount or in attitude.

Specific examples are perhaps more convincing than general principles, and I have therefore computed some cases which are illustrated in figure 3.* In diagram *a* are shown a circle and three ellipses in a square which are to represent the sections of a sphere and three plastic ellipsoids within a cube. In *b* the mass is supposed to be strained by a force acting at 30° to the resistance, and this is assumed to be horizontal. The strain is the same as that represented in two other diagrams in this paper and some further details concerning it will be given presently. The sphere is of course distorted into the strain ellipsoid and the major axis of this figure will stand after strain at an angle of 22° 37′ to the horizontal. The greatest axes of two of the ellipsoids originally coincided with the direction of the resistance, but after strain they make with the horizontal angles 8° 45′ and 6° 5′, showing how the original ellipticity affects the final orientation. One of these elongated pebbles makes an angle of about 14° with the strain ellipsoid and the other about 16½°. No ellipsoid which is originally parallel to the resistance can have a negative inclination after strain, but the third ellipsoid illustrated dips at minus 11° 42′ in the unstrained state and after strain at minus 6° 5′, thus standing at an angle of nearly 29° to the strain ellipsoid. Had either its ellipticity or its attitude in the unstrained mass been different, its final inclination would be more or less than 6° 5′.

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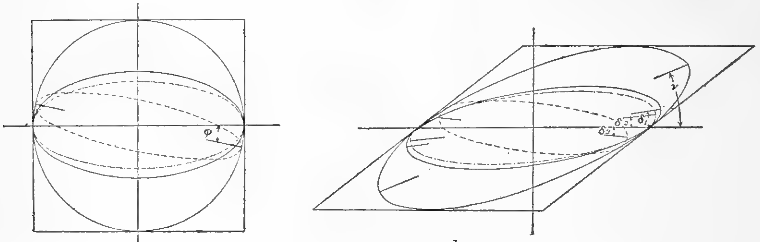

a *b*

This last ellipsoid was computed with a secondary purpose, for, in its final position, it coincides exactly with the direction of the cleavage which, according to my theory, would be developed in the mass by strain. Either of the other pebbles if

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* The angles given in the diagram are $\nu = 22° 37'$, $\delta_1 = 8° 45'$, $\delta_2 = 6° 5'$, $\delta_3 = -6° 5'$, $\phi = -11° 42'$.

broken out of the metamorphosed mass would bring away a "beard" of schist standing at an angle to its axis.

These specific instances merely illustrate the general conclusion that the elongation of pebbles gives no information of any value as to the position of the strain ellipsoid. The same conclusion is immediately applicable to the flattening of angular mineral fragments.

The evidence afforded by fossils is as a rule no better than that derived from pebbles. It is easy to imagine an ellipsoid circumscribed about a trilobite for example, and then infer the apparent distortion in a given strain. The discordant results which have been deduced from the measurements of fossils by various observers are thus easily accounted for.* Nevertheless, with a sufficient amount of work I believe better results could be obtained. In a strained fossil there must be two central sections which are undistorted and possibly these might be found by accurate measurements in some favorable cases. If found, they would determine the position and the ellipticity of the section of the ellipsoid through the greatest and least axes. To determine with accuracy the undistorted sections of a fossil would be a delicate job and has not been attempted so far as I know.

The evidence from volcanic textures, such as the blow holes in pre-Cambrian lavas, is as poor as that from pebbles, since blow holes are substantially always ellipsoidal in unmetamorphosed lavas.

Mr. Leith also attempts to use the distortion of beds and the attitude of folds to prove the position of the minor axes of the strain ellipsoid. In certain cases beds of a composition somewhat different from that of the slate are crenulated in a direction normal to the cleavage, and Mr. Leith considers this a proof that the "greatest shortening" of the mass is also normal to the cleavage. In figure 4, which illustrates my own theory of cleavage, I have drawn a bed before and after distortion, assuming that this bed retains its original length unchanged because of lack of plasticity. The axis of crenulation is exactly

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* A part of the difficulty seems to be due to the fact that even flat organisms are by no means always deposited in strict conformity to the stratification. This is apparent in recent muds and in unaltered sedimentary rocks. Among schistose rocks a good example is afforded by the Ordovician slates of Arvonia, Virginia. They contain Cyclocystoides which were originally circular flattened discs and have been converted into very regular ellipses with axes in the average proportion of 3 to 2 or thereabout. I have examined some specimens of this slate a few square inches in area on which the orientation of the little ellipses varied by at least 45° and in no regular manner, doubtless because of original variation in position. Again, where the plane of cleavage approaches the plane of sedimentation, but does not coincide with it, fossils may undergo a deceptive distortion. Thus in the Arvonia slates there are cases where the ellipses representing Cyclostoides are very regularly oriented, but with their major axes at an angle of some 20° to the grain of the slate.

normal to the plane of cleavage assigned by my theory and marked by broken lines, but it is at an angle of 29° to the minor axis of the strain ellipsoid. The crenulation of a bed merely shows that the axis of folding lies between the minor axis of the strain ellipsoid and the direction of unaltered length; it does not even tend to prove the actual position of the strain ellipsoid. On any theory of slaty cleavage it is easy to construct crenulated beds at any of a wide range of inclinations to the cleavage, and therefore no one angle has any valuable significance.

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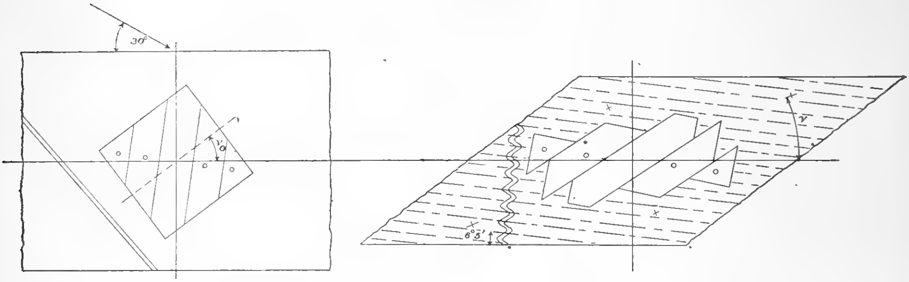

Mr. Leith, furthermore, advances the view that intrusions of great masses of igneous rocks are known to compress adjacent rocks in directions normal to the periphery of the intrusive mass, and that cleavage is developed in the surrounding rocks parallel to the periphery of the intrusive masses. Now, when batholiths invade a region, they unquestionably produce an outward pressure which is commonly manifested by fractures and apophyses in the surrounding rock. The strains set up must be of an enormously complicated kind and the outlines of the batholith itself usually show great irregularity. That anyone should be able adequately to analyze these strains so as to determine the principal axes, or even to establish with any fair degree of approximation the parallelism of the schistosity to the outlines of the batholith, is to me quite inconceivable.

Mr. Leith's last argument on this subject is that crystals and pebbles included in schistose rocks are frequently fractured or sliced, and that this slicing does not take place parallel to the schistosity, but at a considerable angle to it. From this discrepancy, he argues that the cleavage has a different origin from the slicing, and that while the slicing occurs at an angle to the direction of greatest negative normal stress, the schistosity is perpendicular to it. Now, if an included pebble or crystal had precisely the same properties as the surrounding mass, it would of course yield like the surrounding mass, and would show the same schistosity and nothing more. On the other hand, if the included mass were relatively very brittle, it would be cracked at the inception of strain, and would therefore exhibit a behavior of its own. On my theory of cleavage, this behavior can be fairly well followed up. Fig. 4 is a diagram supposed to represent a quadrangular surface of a plastic mass including a cube of a different character. I suppose this cube to be made of some substantially isomorphous material, such as glass or quartzite or some very fine-grained eruptive rock, and that this cube is also brittle. Then at the inception of strain, it will be cracked at angles of 45° to the axes of the initial strain-ellipsoid. It may crack in two directions, or only in one, and I shall suppose that the direction in which it yields is that which, according to my theory, is characteristic of the master joints in slates. Now, these lines of fracture will during continued strain change their inclination, precisely as if they were mere geometrical lines in the plastic mass. The several slices will slip over one another and be rearranged. Doubtless at the edges of these slabs there will be a certain amount of disturbance of the surrounding material, but there appears to be no reason to suppose that these disturbances will not so balance one another that the centers of inertia of the several slabs will behave with simple regularity. If so, these centers of inertia will also remain on a material line which will be deflected precisely as if the cube were absent altogether. It is then possible to compute for certain displacements the position which these centers of inertia will take, and therefore to exhibit the relative position of the slices after deformation is complete, and this is done in the second figure of the diagram.

In constructing this diagram, advantage has been taken of a little problem solved in my former paper on this subject. I have there shown that, provided Hooke's Law holds and Poisson's ratio is assumed at one-fourth, a force inclined to the surface of the mass at an angle of 30° will bring about just this distortion. Now, there are substances for which Poisson's ratio is equal to one-fourth, especially the glasses. Hooke's Law is applicable to small strains with perfect accuracy; for large strains it affords only a first approximation. The diagram may therefore be erroneous to some extent, but the only error which it can contain is in the direction of the applied force, and this error probably does not exceed one or two degrees at most. It is impossible to draw such a diagram without assuming some law between stress and strain.*

It thus appears that my theory of cleavage completely explains the slicing of a pebble and the inclination in the position of the

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*If x, y is the position of a point in the unstrained mass, and x', y' the point to which it is brought by strain, then $x' = 1{\cdot}0577\,x + y$; $y' = 0{\cdot}7691\,y$. It follows that $\nu_0 = 36°\ 58'$, $\nu = 22°\ 37'$.

fractures to the resultant cleavage shown in the cut by broken lines. In fact, if my theory is correct, some further information might possibly be obtained from such pebbles as to the operations to which the mass has been subjected. It may be observed in the diagram that the line of the centers of inertia of the several fragments nearly coincides with the direction of cleavage, but does not do so absolutely. The difference is so slight that it might be attributed to bad drawing, but this is not the case. The difference is only two-thirds of one degree, and the significance of this difference is this: The lines of the center of inertia coincide with the direction of the first fibers to undergo maximum tangential strain, whereas the cleavage represents the final direction of maximum slide. Now, as has been mentioned above, there is another set of planes of maximum tangential strain which, in this particular case, has wandered through a wedge of the mass bounded by planes at 28° from one another; thus the particles lying between the direction of the lines of the center of inertia and the cleavage have been subjected to maximum tangential strain more than forty times as long as the particles in the other direction, and it is to this difference that I attribute the development of the cleavage. If instead of being absolutely brittle the enclosed cube yielded plastically to a minute extent before rupture, the fractured mass would show a trace of cleavability in the direction of the centers of inertia of the slices. If rupture were to take place simultaneously on both sets of planes of maximum slide, double displacements resembling those shown in my paper on Simultaneous Joints,* figure 9, would probably occur. Fig. 5 is borrowed from Mr. Diller's paper on the Taylorsville region of California,† figure 4, and shows a sliced quartzite pebble from a schist. A sliced rock pebble is more instructive than a cleaved feldspar because the cleavage of the mineral will modify the angle of slicing.

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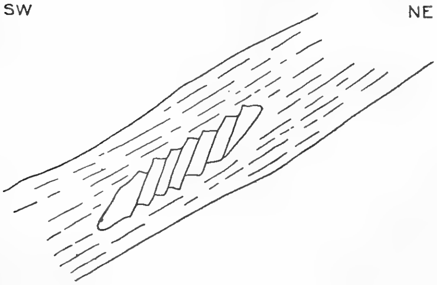

Mr. Leith presents no further argument from observation for his contention that "wherever the directions of shortening and elongation of a rock mass can be determined with certainty, any flow cleavage which may be present is normal to the great-

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* Washington Academy Sci., vol. vii, p. 274, 1905.

† U. S. Geol. Surv. Bull. on Taylorsville Region, not yet in print.

est shortening which the rock has undergone." Certainty seems to me a strange word to apply to conclusions from such evidence. Not one of the methods can be depended upon to determine the position of the strain ellipsoid within many degrees, excepting the untried expedient of seeking the undistorted sections of a fossil.

Mr. Leith discusses at some length the superposition of fracture cleavage on flow cleavage. He interprets many observed cases as indicating that after flow cleavage has been developed, a fracture cleavage has been superimposed upon it, of course under radically different conditions of stress. He borrows from a report by Mr. Dale* an illustration of such a case taken from a thin section, and I shall follow his example in figure 6. When a double structure is developed in rocks the hypothesis that each is due to a separate cause always seems to me very dubious. If parting, or weakness (cleavage), is developed in one direction, a subsequent fortuitously oriented force intense enough to produce rupture at all is almost certain to lead to movements on the old surfaces, and, if this will not suffice to relieve strain, something like granulation usually ensues. Hence I am led to believe that the divisions shown in Mr. Dale's plate have a common origin and were simultaneously developed. Mr. Leith concludes that the diagonal fractures in the cut are developed on my theory. But if I apply my theory *in extenso* to this case, the exact orientation of the strain ellipsoid is at once determined. The major axis should bisect the acute angle between cleavage and the cracks, and therefore stand at an angle of 19° to each. The position of the minor axis follows. Supposing the volume of the rock constant, the minor axis will be proportional to the tangent of 19° or 0·344 $=B$. Hence at once the linear compression in the direction of

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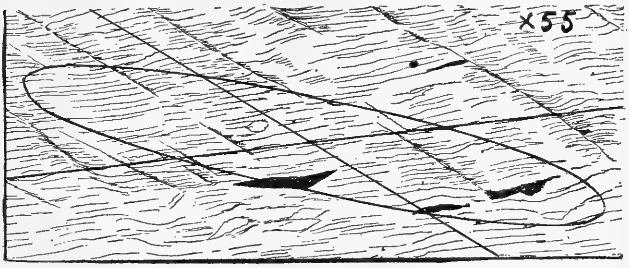

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* U. S. Geol. Surv., 19th Am. Rep., pt. iii, pl. 28, p. 208. From a slide of a Cambrian roofing slate near West Paulet, Vermont. The black spots in the lower part of the cut are pyrite.

B has reduced the unit length to 0·344 unless the strain was attended by diminution of volume, in which case the shrinkage in this direction was somewhat greater. The product of the other two axes is AC=1/B for the case of incompressibility. Some further relation must be exactly known to determine the ratio of A to C. This the cut does not afford, but an approximation can be obtained without difficulty. The fixed plane in the case of pure strain is in the direction of the major axis, while in the case of scission on my theory, it coincides in direction with the cleavage. When pure and rotational strains are combined the resistance lies between the two extremes noted, which in this case differ by 19°. Now, as I shall point out presently, the strain exhibited in the cut bears evidences of a large amount of rotation and the fixed plane was probably nearer the cleavage than the major axis. The assumption that it made an angle of 6 degrees with the cleavage cannot be more than a degree or two out of the way, and if this were the correct value, it easily follows that A = 2·36 and C = 1·23.

I have drawn in to the cut, fig 6, the ellipse with these axes and also shown the two lines representing the traces of the planes of maximum tangential strain. One of them coincides accurately with the cleavage while the other has exactly the same direction as the joints. If this cut is compared with fig. 10 of my former paper, which was issued six years before Mr. Dale's plate, it will be seen that the similarity is very great. According to my theory, cleavage should develop in the acute angle between the direction of the applied force and that of the fixed resistance on one set of planes of maximum slide, while the other set of such planes will be marked, if at all, by joints. That appears to be exactly what has happened in the case under discussion, and it is the great difference between the two structures which lead me to infer that the element of scission in the strain is large.

Having an approximation to the values of the axes, it is a mere matter of detail to compute the component pure strains and scission. The former are due to the vertical force component, the latter to the horizontal component. To combine them to a resultant applied force it would be needful to know or to assume the relations between strain and stress. Hence I merely indicate a pressure which must lie between the minor axis and the cleavage, but an uncertain angle.

It would appear that my theory throws far more light on this occurrence than does Mr. Leith's, and affords a very satisfactory explanation of an interesting occurrence which on a natural scale covers only one square millimeter.

While my theory of cleavage does not necessarily involve the formation of new minerals, such as mica, it affords a means of accounting for the frequent occurrence of mica on at least one set of plane surfaces wherever the rocks affected by cleavage have presented great resistance to deformation. During the progress of a strain in a body which is not ideally brittle, there is at first a cubical compression affecting the whole mass alike and becoming constant at the elastic limit. Thereafter an expenditure of energy takes place and this is confined to the planes of maximum slide, where it is dissipated through the viscosity of the material. It is not needful to prove this statement, which is involved in the very definition of viscosity. The temperature along these surfaces must rise, and, by increasing the mobility of the molecules, the heat liberated will promote chemical recombination in so far as compounds of lower potential are stable at the prevailing temperature and pressure. In rotational strains the energy expended per unit mass along those planes of maximum slide which are nearly fixed relatively to the material particles will be many times as great as along the set of planes which wanders rapidly through the mass, and the chemical effects which may take place will be in some direct proportion to this expenditure. Thus in slates due to rotational strains it is comprehensible that one and only one set of planes should be marked by abundant mica scales. In irrotational strains there may be two or more mica-coated surfaces. On the other hand, there is no liberation of heat during distortion which characterizes planes perpendicular to the least axis of the strain-ellipsoid and none distributed along the equipotential surfaces.

A few pages of the memoir under review are devoted to a discussion of strain and stress, and these call for some comment lest they should mislead. The author states that when the form of a body alone changes, the strain is called distortion, which is in entire accord with usage. A few lines further on he adopts from Van Hise a term "pure shortening" for "any irrotational strain in which all three principal axes are changed in length in such a ratio that the volume remains constant." As is well known, a "pure" distortion is synonymous with an irrotational distortion, so that shortening as here employed is absolutely synonymous with distortion. Why so well-chosen a term as distortion should be replaced by one which does not suggest its definition is not clear. Shortening is indeed absolutely misleading, for its opposite would be elongation, a term frequently used in the discussion of strains, but in a very special sense. It means extension in a single direction *without* change of dimensions at right angles to this direction; so that if the ratio of elongation is 2, the volume of the mass is doubled. Elongation in this technical sense is merely an analytical device. Only such cellular structures as pith, cork and sponge have properties which enable them to be used in approximate illustration of (negative) elongation. Mr. Leith not only defines pure shortening, but illustrates it. The illustration, however, shows a strain in which only two of the axes have undergone change, and which is neither more nor less than a (pure) shear. Perhaps, then, shortening is only a new term for shear.

Mr. Leith says that Thomson and Tait call an irrotational or pure shear a "simple" shear. This is incorrect. They designate by "simple" shear the strain I ventured to rename scission, while they call a pure shear simply a "shear."* It was the confusing similarity between the terms for essentially different strains which led to my innovation. In my nomenclature, *pure* is a qualification of shear which is superfluous excepting when the reader might possibly forget the definition of scission.

Farther on, he states that "scission is equivalent to a pure shortening combined with a rotation of the body as a whole." If the verbal definition is accepted, this is wholly untrue. If the diagram is correct so that shortening = shear, it is true in a sense, because the two processes may each give an equal ellipsoid in the same orientation; but the boundary condition of the two ellipsoids would not be the same, so that if each were elastic their behavior on being set free suddenly would differ fundamentally. The ellipsoid due to scission would not only vibrate about the mean spherical figure, but (because of inertia) spin on its mean axis; while that due to pure deformation followed by rotation would not spin. If the ellipsoid were plastic, that produced by scission would show a fiber or cleavage under proper conditions of rupture or etching. Rolled steel is a case in point; and when blocks of steel are used to test explosives, the substitution of rolled metal (which has undergone scission) for forged metal (in which, so far as possible, scission is avoided) can be detected at a glance.

Mr. Leith states that "stress is the action and reaction between two adjacent parts of a body." This definition defines nothing at all. If stress is action, it cannot be reaction. In fact, the phrase sounds like a confused echo of the theorem as to the equilibrium of different stresses embodied in Newton's third law. Stress is simply the total force measured per unit area which is exerted between contiguous bodies or contiguous parts of a body. It is distinguished from "bodily" forces such as gravity, which are measured per unit volume.

The author further states that "any possible stress may be regarded as equivalent to three normal stresses whose directions

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* See Nat. Phil., paragraphs 172 and 682. Love employs the same terms, which are in accord with the commonly accepted definitions.

are mutually perpendicular." This is true only for a case of static equilibrium. In any authoritative text-book on dynamics will be found Poinsot's theorem, that the forces acting on any point are reducible to a resultant *and a couple.** If Mr. Leith's statement were correct, it would be possible to reduce a couple to a single force. It is, of course, the couple which when resisted gives rise to the rotational strain, just as it is an unresisted or partially resisted couple which gives the rotation of a planet or a rifle ball.

All the arguments which Mr. Leith offers in favor of his views of slaty cleavage and against my theory have now been passed in review; while to his denial of my accuracy in reporting the orientation of bubbles in cakes of ceresin and in stating the directions of cleavage,† I have no reply to make. Messrs. Van Hise and Leith do not seem to me to have improved upon Sharpe's theory, and, so far as I can see, geologists must choose between the pure strain theory of the able Englishman and my rotational strain theory. Sharpe's theory is consistent but leaves much to be explained, both from a molecular and a molar standpoint. When the prevalence of rotational strains is admitted, so that a slate belt becomes tectonically equivalent to a distributed fault, this theory does not apply and cannot be adapted.

It appears to me that Mr. Leith is in duty bound to make public exact reasons for his assertions, to give precise methods for determining the position of the strain ellipsoid or the equipotentials in a slate, to show why there is no cleavage on planes of maximum slide, and to explain thermodynamically how it happens that the planes on which the entire energy of deformation is expended are not those on which feldspar is converted into mica. We are past the stage in which mere opinions or general impressions should be allowed decisive weight.

The distinction which Mr. Leith draws between flow cleavage and fracture cleavage is substantially a real one, which I pointed out 14 years ago. "Flow will tend to take place," I stated, "along one set of planes of maximum slide "because of the inferior viscous resistance." The other set of planes of maximum slide, it was inferred, would be marked by ruptures such as joints. I did not perhaps sufficiently consider that the scale of the whole structure might be microscopic, yet the magnified reproduction of Mr. Dale's slide precisely resembles a reduced photograph of the structure which I had in mind.

Washington, D. C., April, 1907.

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* Cf. e. g., Thomson and Tait, Nat. Phil., section 559 g.

† *Op. cit.*, p. 129.

ART. II.—*On the Origin and Definition of the Geologic Term Laramie*[*]; by A. C. VEATCH. (An Abstract.)

INVESTIGATIONS of the United States Geological Survey during the summer of 1906, covering the larger part of the Laramie exposures on the Laramie Plains, examined by the King and Hayden surveys, have revealed many new and important facts bearing on the Laramie problem.

By detailed areal surveys it was found: (1) That the lignitiferous series which in the Laramie Plains lie between the Montana below and the Fort Union above, and has a maximum thickness of about 12,500 feet, is divided about the middle by an unconformity; (2) that this unconformity is in the same stratigraphic plane and continuous with the unconformity which in the vicinity of Carbon and to the southeast separates all the Laramie beds, studied by the Hayden and King parties, from the underlying Cretaceous; (3) that the beds above the unconformity rest, often with great divergence of dip, on all the underlying beds down to and including the Dakota; (4) that the basal conglomerate, locally well developed at the horizon of the unconformity, while composed largely of material derived from the underlying Cretaceous rocks, notably the Benton, contains pebbles and bowlders from the pre-Cambrian crystallines now exposed in the hearts of the surrounding ranges. This unconformity thus involves the total thickness of the Cretaceous portion of the beds below the unconformity, and probably the whole sedimentary series of this region, or over 20,000 feet of strata.

The Laramie Plains section in brief is as follows:

Generalized section of the rocks of the western part of the Laramie Plains in Carbon County, Wyoming.

			Feet
	North Park Tertiary		4,500 +
	Unconformity		
	Fort Union		800–2,000
	"Upper Laramie"		6,000
	Unconformity		
	"Lower Laramie"		6,500
Montana	Lewis	"Fox Hills" of the early surveys	3,000
	Mesa Verde		3,200
	"Pierre shale"[†]		3,500

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[*] Published by permission of the Director of the United States Geological Survey. This subject is discussed in full in the Journal of Geology, No. 5 (July–August).

[†] It is the belief of Dr. T. W. Stanton that the Mesa Verde and part of the Lewis also belong to the Pierre, as that formation is developed east of the Rocky Mountains. A local name will therefore be applied to this lowest division of the Montana in this section.

		Feet
Colorado	Niobrara	800
	Benton	1,500
	Dakota	150
	Morrison	200
	Marine Jurassic	75
	Red Beds	1,650
	Carboniferous sandstone and limestone with basal conglomeratic quartzite	1,800
	Pre-Cambrian crystallines.	

Since returning to Washington, the author has critically reviewed the writings of the Hayden and King surveys and prepared a discussion on the subject, which is now in course of publication in the Journal of Geology. These investigations have resulted in the following conclusions:

1. The name Laramie is derived from Laramie Plains in eastern Wyoming. As commonly used in the early seventies, this included the plains region extending from the Front Range to and slightly beyond the North Platte River.

2. The most important locality on the Laramie Plains at this time was Carbon. It was not only a noted paleontological locality, but the most important coal mining town on the Union Pacific Railroad at that time. It was the only locality on the Laramie Plains where the King Survey critically examined and distinctly delimited the Laramie beds. The Hayden Survey recognized Laramie strata at another point on the Laramie Plains, Rock Creek, but regarded the Carbon locality, including its southern extension containing the plants labeled from "Medicine Bow stage station," as affording better and more complete exposures.

3. It was the practice of the Hayden and King surveys to name formations and groups from localities where the beds were regarded as typically exposed. While King and Hayden did not always definitely state that the name was derived from a certain locality, the source of the name can in all cases be completely inferred from the context. Thus King used Green River, Bridger, Uinta, Truckee, and other names without saying the name was derived from such and such a locality, while he distinctly states the source of Vermilion Creek, Weber, and other names. King's strong feeling in this matter of a type locality is shown by the fact that he refused to use the prior name Wasatch and adopted the new name Vermilion Creek simply because at what he considered Hayden's type locality the beds were not completely and typically exposed. The state of feeling at this time is further shown by the fact that the name Laramie was proposed and adopted as an exact synonym of Hayden's Lignitic as defined by him in Wyoming and

Colorado. If merely a general term without a type locality had been desired, the term Lignitic, exactly defined for the area involved, would have served all purposes. The change was clearly based on recognition of the necessity of having a geographic type locality. From the above facts it follows irresistibly that the type locality of the Laramie is Carbon, on the Laramie Plains.

4. A critical consideration of investigations of Hayden and King parties in this region shows that the actual Laramie exposures studied by them are separated from the Cretaceous by an unconformity of great magnitude. At Carbon, Hague particularly and minutely included only the beds above the break. Both Hayden and Hague regarded these beds as entirely conformable with those beneath; hence the statement by King that the Laramie beds are those which conformably overlie the Fox Hills, while correct according to the then existing knowledge, is not correct at the type locality and therefore without determinative value in this connection. It but illustrates anew the absolute necessity of a type locality to afford means of finally and conclusively correcting any inaccurate statement or conclusions of the author or authors of a geologic name. Strictly considered, the term Laramie, therefore, can appropriately be applied only to the beds above the great unconformity and—fixing an upper limit in part from our present knowledge—below the Fort Union.*

5. The attempt to redefine the term Laramie from the exposures in the Denver region, some 200 miles from the type locality, is therefore not defensible. It results in the scientific anomaly of applying the term Laramie to a series of beds entirely distinct from those at the type locality on which the name was based. It completely robs the name of all geographical significance and gives to it even less meaning or appropriateness than a mere lithologic term such as Lignitic.

6. While strictly speaking the name Laramie can be applied appropriately only to the upper beds ("Upper Laramie") and it cannot with any propriety be restricted to the lower beds ("Lower Laramie"), the consideration that it was proposed for

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* At Evanston there are several reasons for believing that the base of the Wasatch of Hayden contains representatives of the Fort Union, Puerco, and Terrejon. Between the Laramie and the Coryphodon-bearing Wasatch are some 4000 feet of strata separated from the Coryphodon-bearing beds by an unconformity. At Black Buttes beds now known to be Fort Union (Knowlton, Bull. Geol. Soc. Am., vol. viii, 1896, p. 145) were referred by King to the Vermilion Creek. It therefore seems not only logical but in accord with the original usage to define the upper limit of the Laramie as the Fort Union. The Washakie beds which Hayden regarded as, in this region, limiting the Lignitic above (3d Ann. Rept. U. S. Geol. Survey Col. and New Mex., 1869, p. 90) and which were included by King in his Vermilion Creek, are the beds from which Knowlton reports distinctive Fort Union plants at Black Buttes.

the beds between the Wasatch and the marine Montana Cretaceous and has been most commonly and extensively used in this broad sense, has led to the suggestion that the retention of the name in this original sense will cause the least confusion and that it therefore might be expedient to define the Laramie as that series of beds occurring between the marine Montana Cretaceous and the Fort Union.

In connection with this suggestion of expediency, it should be pointed out that the continued use of this term in the "catch all" sense is wholly at variance with the abundance of strong and wholly logical reasons for the restriction of the term Laramie to the "Upper Laramie" shown by a careful consideration of the historical data. If the point of confusion is regarded as one of great importance, it might be worth while considering the entire abandonment of the term Laramie.

In either case a new name is required for the beds here referred to as "Lower Laramie." Many considerations suggest that this name should come from the region of the Laramie Plains. This would be historically appropriate in many ways, and would result in placing the type localities of the upper and lower portions of the beds which have been called Laramie in the broad sense in the same section. There are reasons for believing that the enormous development of Lower Laramie beds in the western part of the Laramie Plains near the mouth of the Medicine Bow River, or, as it is more commonly called by the local people, "The Bow," where there is relatively very little evidence of a break between the upper and lower beds, more completely represents the Laramie deposition than at any other point. These considerations make the Bow formation or group a very appropriate designation for these lower beds. On the other hand, the fact that the region of Golden has been made classic, in connection with the "Laramie problem," by the studies of Cross, Eldridge, Knowlton, and others, raises the question whether the name Golden formation or group might not be a more appropriate name.

The discovery of this great unconformity at all points that have been critically examined over an area 1,000 miles north and south and 250 miles east and west, the fact that it occurs on both the east and west sides of the Front Range of the Rocky Mountains, and its great magnitude, all make it one of the important mile-posts in the geologic history of western North America. All these considerations suggest anew the first conclusion of Cross in the Denver region that this unconformity marks the dividing line between the Cretaceous and Eocene in this region. On this basis the arrangement of groups immedately above and below the great break would be as follows:

Lower Tertiary or Eocene	Green River	
	Knight of Coryphodon beds[*]	Wasatch
	Fort Union, Puerco and Terrejon[†]	
	Laramie	
	Unconformity	
Upper Cretaceous or Gulf series	"Lower Laramie"	
	Montana	
	Colorado	

[*] The name Knight has been proposed for the upper part of the Wasatch containing Coryphodon remains. It is taken from Knight Station, a point near the locality where fossils belonging to this genus were first found in North America. Further, the typical Upper Wasatch is extremely well developed around Knight Station. Certain considerations suggest that the Knight formation may be an exact synonym of King's Vermilion Creek formation, but as the writer has not had the opportunity to examine King's type section he has proposed the provisional name Knight pending a study of the Vermilion Creek section. See Prof. Paper 56, 1907, pp. 87-89, 92-96.

[†] In the Evanston section, between the beds belonging to the Laramie (Carbon) group and the Coryphodon-bearing Wasatch, are 4,000 feet of strata which have the stratigraphic position of the Fort Union and Puerco. These are here separated from the Coryphodon-bearing portion of the Wasatch by an unconformity of much less magnitude and importance than that of the base of the Laramie (Carbon) beds.

Art. III.—*A New Method for the Determination of the Hardness of Minerals;* by H. Z. Kip.

1. The hardness of minerals is perhaps their most obvious physical characteristic. It was natural, therefore, that no sooner had minerals become an object of scientific inquiry than efforts were made to determine the relative, and later the actual hardness of various species. Simple as the problem would appear at first glance, the results for the mineralogist of more than a century of intermittent investigation, carried on by more than a score of different investigators, are surprisingly meager. Every text-book of mineralogy gives, it is true, a rough statement for the mean relative hardness of each species described, as referred to an empirical scale of ten grades (Mohs's scale), and for ordinary determinative purposes this is valuable, though less so than it might become. We know also in a general way that many minerals show greater hardness on one crystal face than on others, though specific information is lacking for the most part in the manuals. Differences have also been shown to exist on one and the same face according to the direction of the test. The curves obtained by plotting these different values reveal a direct relation to the symmetry of the crystal and form the most important result yet attained in the study of hardness, though comparatively few minerals have been investigated and the curves established by different investigators are far from uniform.

The main problem, however, that has engaged attention, the determination of numerical values for every degree of hardness, has as yet found no satisfactory answer. Several experimenters have, it is true, arrived at values for 8, 9 or even all 10 of the members of Mohs's scale, but these results vary so greatly among themselves that without some method of control or verification it is impossible to place confidence in any of them. Thus Iddings's Rock Minerals, to quote one of the most recent publications, allows us to believe with one authority that the hardness of gypsum as compared with corundum (assumed to be 1000) is ·04, or with another that it is 1·25, more than 30 times as great, or with a third that it is 12·03, 300 times as great.

2. Corresponding to the lack of uniformity of result, and indeed largely responsible for it, we find varying conceptions as to what hardness really is and of the factors upon which it depends, no agreement as to what method, theoretically or practically, would give the most reliable returns, the assumption of various unproved conditions, the confusion of physical with

chemical terms, and finally, no concurrence as to what force or forces should be the measure of hardness or how these forces should be combined.* The problem is indeed so complicated, primarily by inherent conditions (chiefly the difficulty of distinguishing hardness from allied physical properties) and secondarily by the varying methods offered for its solution, that here and there voices are heard pronouncing the problem insolvable. Thus Daniell in his Principles of Physics states that "hardness is a property that cannot be measured" and Miers in his Mineralogy speaks of hardness as a character not capable of absolute measurement (ed. 1902, p. 110). While admitting, and indeed emphasizing the fact that the results hitherto obtained are anything but convincing, I do not at all agree with the views just quoted. The investigations that have been made are not so much failures in themselves (quite the contrary can be maintained of most of them) as they are failures when regarded as solutions of one and the same problem. Viewing the history of these efforts in a general way, one is struck by the fact that too often the investigators appear as devotees of a certain method rather than as seekers for a certain end, employing a given method and moulding it to their purpose. And their effort appears too often as an attempt to refine a method rather than to establish its serviceability. As in the history of many mechanical inventions, one observes an advance from simplicity to complexity but as yet no advance from complexity to refined simplicity. Thus the metal needles of Frankenheim, guided by the hand, make way for the weighted point of Seebeck, under which the mineral is drawn by the hand. Grailich and Pekarek replace the human hand with a pulley and weight. Pfaff substitutes seven diamond points for one and then passes over to the boring method for rapid determination of a mean value. Jaggar carries the boring method to the highest degree of delicacy, and one must add of complexity, yet attained by adding clock-work and the microscope. Static pressure tests have likewise advanced from the simple plan of

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* A good bibliography of the somewhat voluminous literature on the subject of mineral hardness will be found in Professor T. A. Jaggar's article—A Microsclerometer, for determining the Hardness of Minerals, this Journal, Dec. 1897. The article by Franz there referred to (cited incorrectly by Grailich and Pekarek) is to be found in Pogg. Annalen, Bd. lxxx, 37-55, 1850.

To Professor Jaggar's list should now be added: Rosiwal, Quarz als Standard-Material für die Abnützbarkeit; Vienna, Verhandl. Geol. Reichsanst., 1902 (234-246). J. L. C. Schroeder van der Kolk, Over Hardheid in verband met Splijtbaarheid, voornamelijk bij Mineralen; Verhandel. der K. Akad, Wet., 2 Sect., viii, No. 2, Amsterdam, 1902. Egon Müller, Über Härtebestimmung; Inaug. Diss., Jena 1906. A fairly complete survey of the whole field may be obtained by consulting the article by Grailich and Pekarek (Sitzungsber. k. k. Akad., Vienna 1854, xiii) for the earlier period and the dissertation of Egon Müller for the more important recent contributions.

noting the weight required to force a point a given depth into a surface to the laborious method of Auerbach, who regards hardness as "the limiting elastic resistance (tenacity) of a body, in case of contact of one of its plane surfaces with the spherical surface of another body," and who would obtain a value for hardness by multiplying the least value of the (central) pressure per unit of area necessary to produce permanent set or rupture at the center of the impressed surface by the cube root of the radius of the sphere.

3. In taking up the problem once more I have a threefold object in view. 1. To invite general acceptance of a single definition of hardness, based upon the actual constitution of minerals rather than upon abstract physical conceptions, which will serve as a working hypothesis in determining its value. 2. To establish theoretically in conformity with the definition the best method of investigation. 3. To put this method in practice by means of suitable apparatus and adequate mathematical calculation.

It is self-evident that we cannot expect uniformity of result until we secure uniformity of aim, i. e. an agreement as to what hardness is. By this is not meant an explanation of the factors that combine to produce the quality (that is a problem for pure physics), but merely an agreement as to what force or forces must be used to overcome hardness. This, it will be observed, is a simpler task than the measurement of the forces upon which hardness depends. With these we cannot as yet deal directly, or more properly singly. Fortunately there is already a high degree of unanimity along mineralogists as to what hardness means for them. This conception has been crystallized in the brief but admirable definition given by Dana: "Hardness is the resistance offered by a smooth surface to abrasion," and with a slight improvement by the Century Dictionary, as "the quality of bodies which enables them to resist abrasion of their surfaces." To this conception of the quality, which is not an off-hand generalization but a well-considered and well-tested definition I hold, not loosely and vaguely but with all strictness. Other definitions are conceivable and others have been given, but none defines so accurately what the mineralogist understands by hardness and none adapts itself better to the physical constitution of minerals as we conceive it to be. To a person not familiar with the history of sclerometry this insistence upon a single clear-cut definition, in view of the fact that others are possible, may seem superfluous if not pedantic. Yet the lack of one or the failure to hold firmly to one accepted in theory is accountable for much of the confusion of conception and diversity of aim on the part of those who have believed themselves to be working on the same problem.

Thus Jaggar, while accepting Dàna's definition in theory and repudiating static pressure tests, reverses this in practice and actually employs a method which, as Auerbach has pointed out, is fundamentally only a modification of the method he condemns. Pfaff likewise passes from abrasion tests, or what are certainly intended as such, to the boring method, apparently without realizing that he is implying thereby a very considerable modification of his definition of hardness.

4. Abrasion being a mechanical process, the question at once arises what force or forces produce it and how are these forces to be measured and combined. In fig. 1 let CD represent a tool producing abrasion upon the surface AB, and let it represent by its length the least force adequate for this purpose. The value of CD is evidently $\sqrt{\overline{EC}^2+\overline{CF}^2}$. Or, expressed in words, the force that produces abrasion is resolvable into two forces, one perpendicular to and the other in the plane of the surface. Calling the former the pressure and the latter the pull, the force producing abrasion is equal to the square root of the square of the pressure plus the square of the pull. In practice the two components are generally applied as separate forces. It should be noted further that the lateral component may also be a complex force, though not necessarily so. Thus in a mineral with striations running at an angle between 0° and 90° to the direction of CF, this force will again be resolvable into two forces acting at right angles in the plane of the surface, and its value will have to be determined before it can be combined with EC.

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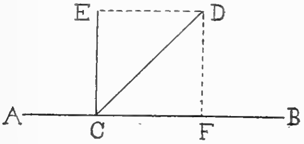

Investigators have hitherto assumed that a sufficient measure for abrasion could be found in pressure alone or in pull alone. This assumption would be true only when the one force was a direct function of the other, a condition which may obtain among amorphous substances but which nowhere else can be assumed as true, or even probable, without proof. Imagine a mineral with the molecular structure suggested in fig. 2. A tool passing in the direction AB will produce abrasion, let us say, with a pressure of x grams and a pull of $2x$ grams. Proceeding in the direction BA it is quite conceivable that a pull of x grams would be sufficient but that a pressure of $2x$ grams would be required. In both directions the resistance to abrasion would be the same, though the factors that combine to produce this resistance might differ according to the direction of the test,

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the lesser pull required in the direction BA being offset by the greater pressure required to overcome the tendency of the molecules to "shed" the pressure, and conversely in the direction AB. It is evident at once what untrustworthy values will be obtained if either component alone be taken as the measure of hardness. It also becomes clear how futile it is to compare results obtained from abrasion tests with those obtained from static pressure tests, since the two forces required to produce abrasion are in no sense a function of the force required to produce penetration. It should be remarked in passing that the force EC in fig. 1 is not necessarily the same in value as the corresponding force in a static pressure test on the same specimen. EC in itself may produce no appreciable effect upon the surface, molecular dislocation taking place only when it acts in union with the force CF.

5. A fallacy into which some investigators seem to have fallen is the substitution of rate for pull, in cases where the abrading instrument passes over the same portion of the surface repeatedly, in a single direction or with a rotary movement. Thus Jaggar speaks of four variables: rate, weight, depth and duration, and states that any one of them may be made a measure of hardness provided the other three be kept constant. The value of the lateral component in the abrading force is not taken into account, although care is taken to specify that it must operate at a known rate. Thus, it is argued, if with a given weight and a given rate 50 revolutions of the diamond point be required to attain a given depth in the case of calcite and 143 revolutions be required to reach the same depth in fluorite, then 50 and 143 represent the respective hardness of these minerals in relation to the abrading agent. This statement, however, would be true only on the theory that the work done by the 50 revolutions was exactly 50/143 of the work done by the 143 revolutions, or in other words, that the resistance overcome by the average revolution on the specimen of calcite was exactly the same as that accomplished by the average revolution in the case of fluorite. The mere fact that the rate was maintained constant in both cases is, of course, no proof that this assumption is correct. The discrepancy involved becomes still more apparent when we consider the results obtained by this method for No. 2 and No. 9 of the Mohs's scale, the hardest and least hard of the minerals tested. Doubtless scores of the 188,808 revolutions required to reach a depth of 10μ in the case of corundum were entirely or practically ineffective in producing abrasion, and probably no one of them represents as great an expenditure of abrasive force as is represented by the average of the 8.3 revolutions that sufficed

to reach the same depth in gypsum.* The number of abrading movements is no true test of hardness unless the effective force of the average movement is the same in all cases.

6. While bringing in one factor which has hitherto been generally disregarded, I attach, on the other hand, much less importance to another variable which Pfaff, Jaggar and others have been careful to maintain constant or to submit to careful measurement, namely, depth. It is not too much to say that instead of keeping depth constant it ought to be left to shift for itself. Imagine two minerals the dimensions of whose molecular unit spaces stand in the ratio of 1:3 but which are alike in respect to intermolecular attraction and molecular form and arrangement. Evidently the resistance to abrasion will be the same in both. If, however, we should make depth a constant, the hardness of the mineral with the lesser molecular volume would appear three times as great as that of the other. Pfaff's substitution of equal volumes of abraded substance for equal depth of abrasion is, of course, merely a device for measuring depth, the length and breadth of the abraded surface being kept constant. In determining hardness we are concerned with a molecular phenomenon. Therefore depth and volume, as used by the authors quoted (as well as by Rosiwal, Müller, Bottone and others), involving as they do arbitrary spacial units of measurement, have here as little significance as the size of crystal faces in crystallographic determinations. A further objection to the method in which weight and rate are kept constant and hardness determined by the number of abrading movements necessary to reach a given depth is the fact that a point weighted sufficiently to procure molecular dislocation when drawn over or revolved upon a given mineral will almost certainly produce mass dislocation when applied to any mineral softer than the first. Hence by this method the actual differences between the harder and the softer minerals will be invariably exaggerated. The weight, therefore, in all cases should be great enough when put in motion to produce molecular displacement, but no greater.

7. It follows from the above that hardness must be determined either:

(1.) By observing the least force (whose components for a given mineral may be designated as the critical pressure and the critical pull for that mineral) sufficient to produce abrasion, or

(2.) By noting the total force required to produce a given amount of molecular dislocation.

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* In justice to Professor Jaggar it should be stated that he attaches himself no great value to the numerical results obtained in the series of experiments described in his article; a fact which those who quote him would do well to mention.

The two methods are, of course, the same in principle and one may be used to control and verify the other.

Given any two minerals, to determine the relative amounts by weight that must be abraded from each to produce equal molecular dislocation, the following method is suggested:

Multiply the specific gravity of the first over the specific gravity of the second by the density of the second over the density of the first. The result will be the weight of n molecules of the first over the weight of n molecules of the second. Thus if the specific gravity of fluorite be 3·183 and its density ·123, and the specific gravity of quartz be 2·65 and its density ·132,* then

$$\frac{3{\cdot}183}{2{\cdot}65} \times \frac{{\cdot}132}{{\cdot}123} = \frac{{\cdot}420156}{{\cdot}32595}$$

that is, a mass of fluorite that contains as many molecules as a given mass of quartz will weigh 1·3 of the weight of the quartz.

Omitting the conception of mass or volume, we can arrive at the same result more simply by making the weight of the material abraded from each mineral proportional to the molecular weight of each. It is evident that if the molecular weight of fluorite be 78 and of quartz 60 the weight of n molecules of each will stand in the same ratio. If, now, we determine the total amount of force required to abrade 1 mg. of quartz and then the total force required for 1·3 mg. of fluorite, we shall have the respective hardness of the two minerals. These values should be exactly proportionate to those obtained by Method 1, provided both are carried out with sufficient accuracy.

This plan, however, is open to some objection in practice. It would necessitate constant weighing of the fluorite lest the amount abraded should exceed 1·3 of the weight of the quartz. Furthermore in view of the unequal density of the two minerals we evidently could not multiply the force employed by the distance traversed in determining the total force, nor yet by the time during which the force operated, except on the assumption that the time of passage of the point over the surface was determined by molecular resistance alone. This assumption is generally made, but it evidently only approximates the truth.

8. A more feasible plan for amorphous and isometric minerals, and one which could be adapted to minerals of lesser symmetry as our knowledge of molecular structure increases, is the following: It is clear that if we would dislocate the same number of molecules in two minerals, A and B, of which B is the denser, we must cause the abrading agent to traverse a greater distance on A than on B. In general the distance to

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* These values according to Schroeder van der Kolk, loc. cit.

be traversed on the denser mineral, B, is to the distance to be traversed on the less dense mineral, A, as $\sqrt[3]{\text{den. A}}$ is to $\sqrt[3]{\text{den. B}}$.

In practice, then, we should proceed as follows:

Determine the critical pressure, x, and the critical pull, y, for a given mineral by direct observation and measurement. Hardness, then, $= \sqrt{x^2+y^2}$. This is Method 1. Establish in this way the hardness of a series of minerals, a, b, c, d. To verify the results. Pass the point over the surface of mineral a, with the critical pressure previously determined, at a constant rate* until a distance p has been traversed. Determine weight of material abraded. Pass the point over the surface of mineral b, with the critical pressure already established for b, at the same rate as on a, a distance

$$p \times \frac{\sqrt[3]{\text{den. } a}}{\sqrt[3]{\text{den. } b}}$$

Weigh the abraded material. This weight should bear the same relation to the weight of substance abraded from a as the molecular weight of b bears to the molecular weight of a. Thus if the molecular weight of a be 75·6 and of b 50·4 the amount of matter by weight removed from a by 40 movements or trips of the abrader should be 1·5 times the weight of that removed from b in 20 trips, assuming the trips to be all of equal length and assuming the density of a to be 8 and of b to be 64. If the substance to be abraded from a should weigh, let us say, 1·6 times that removed from b, it is evident that the critical pressure on a as determined by Method 1 has been too great, or that on b too small. These tests should be carried on until the critical pressure for all the minerals under consideration has been established. The critical pull can then be easily determined by direct measurement, and hardness then calculated as in Method 1.

The fact should not be concealed that in view of our inability to determine in most cases the weight of the physical molecule as opposed to the chemical molecule, our chief reliance at present will have to be placed on Method 1.

9. These theoretical considerations make it necessary that an apparatus designed to measure hardness should meet the following requirements: 1. It must produce abrasion, not merely penetration. 2. It must provide a means of measurement for pull as well as for pressure. 3. It should allow for regulation of rate. 4. The forces producing abrasion should be used solely for that purpose, or if employed otherwise the amount so used should be easily ascertainable.

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* It is desirable that a low rate be adopted, yet not so low as to cause molecular gliding instead of dislocation.

Static pressure tests, producing as they do penetration or fracture but not abrasion, are excluded from the outset.

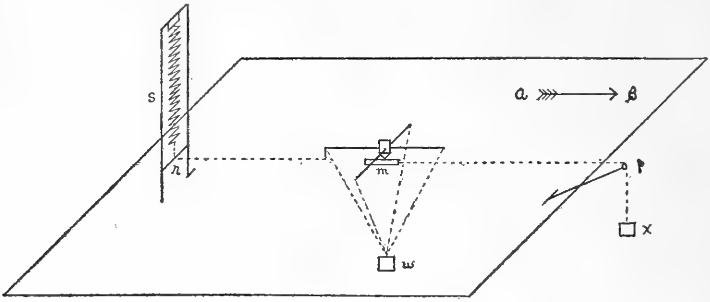
The rotary method under which are included the Rotationssklerometer of Müller and the rotating discs of Jannettaz and Goldberg as well as the Mesosklerometer of Pfaff and Jaggar's Microsklerometer, is likewise inadmissible, certainly in the form in which it has been employed hitherto. For when pressure alone is measured it becomes at once merely a modified form of static pressure test. And the practical difficulties that would confront us if we were to attempt to measure the force of rotation, involving friction at so many points, to calculate the increment of resistance as depth increased and to maintain molecular dislocation as opposed to mass dislocation, on the one hand and polishing of the surface on the other, would be exceedingly great if not insurmountable. Grinding a surface with a standard sand is open to the objection that no means is offered of guarding against mass dislocation, the sand becomes at once adulterated with particules of the abraded substance, there is no certainly that the sand itself has the same force of attack in any two tests and there is no means of determining definitely when the sand is "dead."

We are led by a process of elimination to the abrading method par excellence, at once the simplest and most delicate, which for want of a better name is known as the scratch method. This fulfills, or can be made to fulfill, all the requirements enumerated at the head of this paragraph, and permits, furthermore, of distinction between molecular and mass displacement, in so far as we can deal at all with submicroscopic divisions of matter. In reviewing the devices hitherto employed we find that none satisfies entirely the requirements that may justly be made of such an instrument. Several fail to provide any means of measuring pull as well as pressure, none of them has been actually used so as to measure both forces at the same time, and those that might have been so used afford no means of distinguishing between the forces actually producing abrasion and those expended in other ways or for other purposes.

10. To meet the demands imposed by our definition of hardness and by our conception of the physical structure of minerals the apparatus described below has been designed.

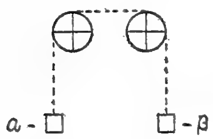
The diamond point resting on the surface of the mineral is balanced by a weight hanging directly beneath it and suspended from four arms running out from the short brass cylinder into which the diamond point and its holder are screwed. Pressure on the point is regulated by the amount of the weight w (fig. 3). The mineral m is drawn in the direction ab by means of a thread passing over a pulley p and ending in a weight x. A thread attached to one of the above mentioned arms at just the level of the diamond point runs in the direction *ba* and joins a spring balance *s*, which is suspended between two uprights. As the mineral is drawn in the direction *ab* the diamond point rides with it until the tension in *s* is so great as to cause the point to become stationary. A scratch will now be produced on *m* provided the weight *w* (including the weight of the diamond point and arms) be not less than the critical pressure for the mineral. The critical pull will be shown at once by the spring balance *s*.

3



It will be observed that the two forces producing abrasion are used for that purpose alone, with the exception of what force is absorbed by friction at the point *n*. The friction at this point can be calculated in advance for all weights or tensions likely to occur by the method suggested in fig. 4. Two weights of *x* mg. each are attached to the ends of a thread running over two pulleys, one of which is the same as used at the point *n* in fig. 3 and the other identical in construction. The weight which it is necessary to add to either *a* or *b* in order to destroy their balance is evidently the measure of friction in the two pulleys, and one half of this will be the amount of friction at the point *n* for a tension of *x* mg.

4



All minor details of the apparatus are omitted in order that its main principles may come the more clearly into view. The carriage upon which the mineral rests, the graduated disc by means of which it can be turned at any angle, the tracks upon which the carriage runs, screws for levelling the surface of the mineral, a device for regulating rate and other details can be easily supplied by the imagination.

Results obtained experimentally by means of this apparatus will be published later. Meanwhile the writer would be glad to have anyone interested in the problem of mineral hardness avail himself of the contents of the present paper.

Vanderbilt University, Nashville, Tenn.

ART. IV.—*The Cretaceous Stratigraphy of the Santa Clara Valley Region in California;* by RODERIC CRANDALL.

INTRODUCTION.

IN this paper are recorded the various collections of fossils, from the Cretaceous, that have been found in the vicinity of Santa Clara Valley, and at Mt. Diablo, which is east of this immediate region. The distribution of the three horizons of the Cretaceous in this region are discussed, with reference to their relations elsewhere.

Localities and Faunas.

In the vicinity of the Santa Clara Valley, there are many localities where Cretaceous fossils have been found. These places are given below in geographical order.

1. North Berkeley.
2. Mt. Diablo.
3. Haywards.
4. East of Decoto.
5. Pleasanton region.
6. Jordan's Ranch, Arroyo del Valle.
7. Crossby Ranch, Arroyo del Valle.
8. Milpitas.
9. Beryessa Canyon.
10. Alum Rock Canyon.
11. Evergreen.
12. Dry Creek, five miles southeast of Evergreen.
13. Whitney Ranch near Gilroy.
14. New Almaden.
15. Pigeon Point.
16. Stevens Creek.
17. Stanford University.
18. Belmont.

The accompanying outline map shows the position of these localities in the central portion of California.

North Berkeley.—One mile north of Berkeley, in a locality which comprises less than a square mile, the following Cretaceous fossils have been collected.

Knoxville horizon :

Aucella Piochi Gabb
Belemnites, sp. indet.
Modiola major Gabb
Lucina colusaensis Stanton
Pecten complexicosta Gabb
Cardinia ?
Myoconcha ?
Turbo
Atresius liratus Gabb

Horsetown horizon :

Phylloceras onoënse Stanton

Chico horizon :

Hoplites, sp. indet.
Inoceramus, sp. indet.

Most of the fossils were found in bowlders of limestone lying upon shale beds, but some of the *Aucellae* were found in a fine conglomerate. With the forms listed above are thick, Venus-like shells which cannot be separated from the matrix for identification, but are considered by Dr. Merriam to resemble Paskenta species. It should be noted here that *Phylloceras onoënse* is a Horsetown form, and does not belong with the fossils from the Knoxville.

Fragments of *Hoplites* and an *Inoceramus*, which are the basis of the identification of the Chico horizon, have been found in sandstone beds in the hills directly east of the buildings of the University of California. Little is known of the beds in between the Chico and the *Aucella*-bearing horizons, but it seems probable that there could be only a very small thickness of rocks intervening. The whole series of Cretaceous here is overlain by Tertiary, and in the hills east of Berkeley disappears under the later formations. It reappears in the vicinity of Haywards, about eighteen miles southeast of Berkeley.

Mt. Diablo.—The Knoxville at Mt. Diablo has furnished the following characteristic forms :

Aucella Piochi * Gabb
Belemnites
Inoceramus
Gastropodas

The slightly altered Knoxville beds, with a high and variable angle of dips, rest directly upon the older Franciscan rocks, and are intruded by dikes of peridotite. The unconformity between the Cretaceous and the Franciscan is plainly marked.

The Knoxville series at this place is composed of dark shales, with occasional sandy layers, and small lenticular masses of

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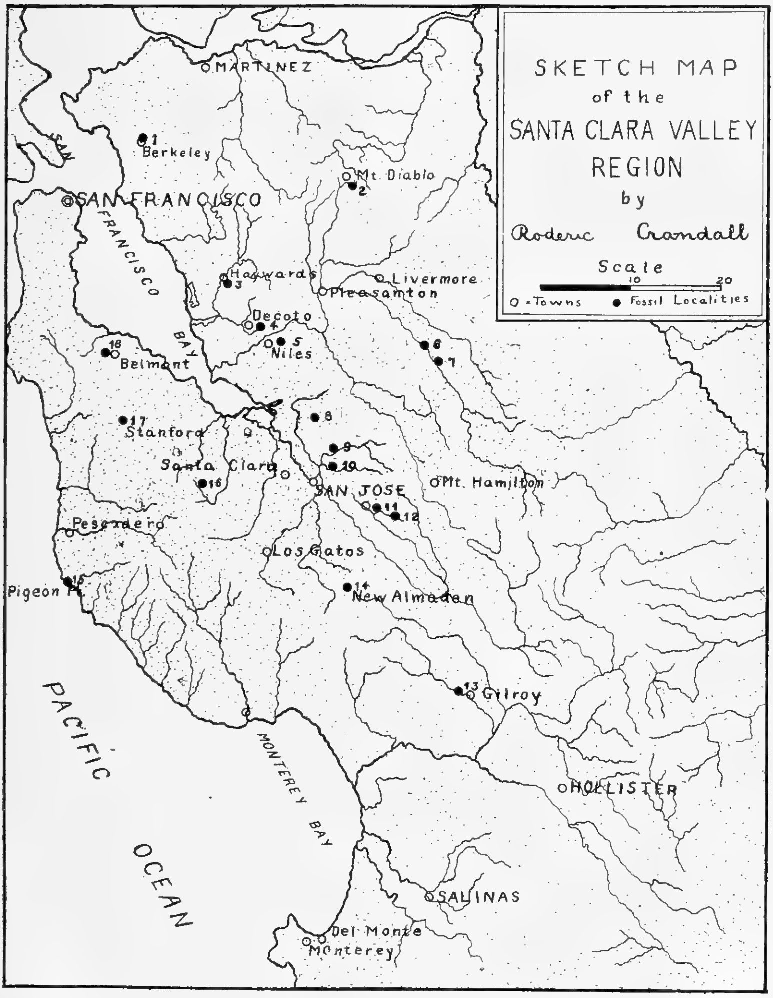
* Given as *Aucella mosquensis*, H. W. Turner, Bull. Geol. Soc. Am., ii, 399.

limestone. Shark's teeth, spines and small silicified foraminifera are present as well as the fossils given above.

The localities where the *Aucellae* were found are Bagley's canyon, two miles north of the main peak, and four-fifths of a mile northeast of Eagle Point in the neighborhood of a large peridotite dike.

1



The Belemnites were found near the northern end of the peridotite dike in limestone and also in a coarse sandstone near by.

The Gastropods, *Aucella* and *Inoceramus* came from a calcareous nodule, one-third of a mile north of the locality where the Belemnites were found.

There was found, just north of the serpentine, a fragment of wood of the genus *Cupressinoxylon*, the ancestor of the sequoias. Near this locality an *Aucella* was collected.*

From the Cretaceous above the *Aucella Piochi* beds of Mt. Diablo there have been collected the following forms, at a locality southwest of the mountain:

LIST OF HORSETOWN FOSSILS.

Chione varians Gabb
Cucullaea truncata Gabb
Trigonia aequicostata Gabb
Lytoceras Batesi Trask

LIST OF CHICO FOSSILS.

Ancanthoceras Turneri White
Anchura californica Gabb
Baculites chicoensis Trask
Dentalium Cooperi Gabb
Dentalium stramineum Gabb
Eriphyla umbonata Gabb
Mactra tenuissima Gabb
Meretrix nitida Gabb
Nautilus sp.
Pachydiscus suciäensis Meek
Pecten operculiformis Gabb
Pinna Breweri Gabb
Schluteria diablöensis Anderson
Scobinella Dilleri White
Trigonia evansana Meek
Cardium annulatum Gabb

The range of the following species is through Horsetown and Chico epochs:

Chione varians
Cucullaea truncata
Eriphyla umbonata
Pecten operculiformis
Trigonia evansana

These five forms are known to have been found in the Horsetown at other places. One of the species, *Lytoceras Batesi*, is a characteristic Horsetown form. This is hardly enough faunal evidence to prove the presence of Horsetown beds at Mt. Diablo, but argument will be offered later to show the probability of the presence of this horizon at this place.

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* H. W. Turner, Geology of Mt. Diablo, Bull. Geol. Soc. Am., ii, 394.

The following are characteristic Chico forms:

Anchura californica
Baculites chicoensis
Nautilus sp.
Pinna Breweri

The Chico series is composed of dark shales, like those of the Knoxville, with sandy and calcareous layers. These cannlo be distinguished from the lower series except by the fossist. The fossils occur sparingly through the beds, northeast, east, southeast, and south of Diablo; but the only place where they are abundant is at Curry's Creek. Besides the shales, at Curry's there are conglomerates, the pebbles of which are fragments of metamorphic rocks and quartz porphyry.

In a geologic section, Mr. Turner shows the Chico resting unconformably upon the Franciscan, but at a very high angle, and overlain at this place by Eocene beds. In another section the Chico rests upon the Knoxville, with dips apparently conformable; but he says that there is no doubt that a considerable time elapsed between the close of the Knoxville epoch and the opening of the Chico epoch. The probable thickness of the Chico, Mr. Turner gives as about six thousand feet.*

Haywards.—A specimen of *Crioceras percostatum* Gabb is given by Anderson† as having been found near Haywards, but from a locality that is unknown. It is considered by him as probably representing the Knoxville at this place. In the first part of his paper he has given this form as a typical Horsetown form.‡ Gabb has classed it as belonging to division "A," which does not place it definitely.§ In connection with other forms at nearby localities, it will be considered here as a Horsetown form.

East of Decoto.—In the collection of the University of California there are two specimens of *Aucella Piochi* Gabb, marked: "east of Decoto." The exact locality is not known, but it probably is in the southeast corner of the Concord sheet, northwest of and adjoining the Pleasanton region.

Pleasanton region.—The Cretaceous of the Pleasanton region covers a large area, which includes about one-sixth of the topographic sheet of this name. Sunol, Pleasanton, and Walpert ridges are for the most part composed of Cretaceous beds. From these beds there has been collected a specimen of *Venus varians* Gabb, of the Horsetown, and several Knoxville forms; *Aucella crassicollis* Keyserling, *Aucella Piochi* Gabb, and Ammonites 3 sp. indet. The Tertiary overlies the Cretaceous on the west

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* H. W. Turner, Geology of Mt. Diablo, Bull. Geol. Soc. Am., ii, 395.

† Cretaceous Deposits, Proc. Cal. Acad. Sci., 3d series, ii, No. 1, 45.

‡ Loc. cit. p. 42.

§ Pal. Cal., i, 77.

and northwest edge of the Pleasanton Quadrangle. South of Niles canyon the Cretaceous appears where the Tertiary has been eroded from the hill tops, east of Niles, and it is also exposed on the west side of Sunol canyon, extending southwestward to form the underlying part of the hills rising between the Calaveras and Santa Clara valleys.

Cretaceous shales are exposed in Niles canyon, showing numerous folds. The Cretaceous of this region consists of three series of beds. North of Niles canyon and south of Haywards pass there are large areas that are covered with massive conglomerates, the main constituents of which are bowlders of quartz porphyry and biotite granite. The conglomerates are probably the same that Mr. Turner described from Mt. Diablo.

South of these conglomerates is a thick series of hard, thinly bedded black shales with occasional sandy layers. From these shales on the north bank of Stony Brook Creek, about three miles north of Farwell station in Niles canyon, was collected an indeterminable Ammonite. Another Ammonite came from these same black shales on the west bank of Sunol canyon, at the point where the Mission Peak road enters the canyon from the west.

The third locality where fossils were collected is on the south bank of Niles canyon about one and a quarter miles northeast of Niles. and about due south of the station of Meriendo. A small fossiliferous concretion of hard flinty limestone was found here, but it was possible to get only one good specimen. This specimen was identified as *Venus varians.* Several hundred yards east, up the canyon, *Aucella Piochi* was found in black shale.

Aucella crassicollis was found on the north side of Mission Creek, along the Mission Peak road, about three miles slightly northeast of the town of Irvington. With it were fragments of Venus-like shells. At this place the Tertiary rests unconformably upon the Cretaceous.

The beds in Niles canyon, in which *Venus varians* was found, are several hundred feet higher in the section than those from which *Aucella crassicollis* were obtained. In the general levelling of the Cretaceous sediments, before the deposition of Tertiary, uneven erosion must have left caps of Horsetown upon the Knoxville. The beds from which *Venus varians* was taken are conformable with the Knoxville beds in which *Aucella Piochi* are found. No specimens of *A. crassicollis* were found in the Niles canyon section, but there are several hundred feet of sandstone between the two horizons determined by the fossils found. These intervening beds may represent the horizon of *Aucella crassicollis.*

Jordan's Ranch, Arroyo del Valle. — From Jordan's ranch in Arroyo del Valle, eight miles southeast of Livermore, the

Cretaceous fauna given here has been collected by Dr. J. P. Smith and Dr. L. G. Yates.

HORSETOWN FOSSILS.

Lytoceras alamedense Smith
Phylloceras onöense Stanton
Lytoceras Batesi Trask
Hoplites Remondi Gabb
Lytoceras cf. *timotheanum* Mayor
Belemnites sp.

CHICO FOSSILS

Desmoceras Hoffmanni. Gabb
Haploceras Breweri Gabb
Baculites chicoensis Trask
Baculites occidentalis Meek
Placenticeras californicum Anderson
Placenticeras pacificum Smith
Desmoceras cf. *selwynianum* Whiteaves
Holcostephanus suciäensis Meek
Lytoceras cf. *cala* Stoliczka
Phylloceras ramosum Meek
Cinulia obliqua Gabb
Inoceramus cf. *vancouverensis* Shumard
Trigonia evansana Meek
Pectunculus Veatchi Gabb
Pachydiscus suciäensis Meek
Pachydiscus newberryanus Meek

Of this fauna the following forms are characteristic of the Chico:

Desmoceras Hoffmanni Gabb
Baculites chicoensis Trask
Placenticeras californicum Anderson
Placenticeras pacificum Smith
Cinulia obliqua Gabb
Pachydiscus newberryanus Meek
Trigonia evansana Meek

The Horsetown is represented by the characteristic forms below:

Hoplites Remondi Gabb
Phylloceras onöense Stanton
Lytoceras timotheanum Mayor
Lytoceras Batesi Trask

In the general list there is a strong mingling of Chico and Horsetown forms, but the total fauna shows more affinity with the Horsetown than with the Chico.

Crossby Ranch, Arroyo del Valle.—Interest in the Arroyo del Valle beds led to a measurement of the Cretaceous section at that place. The Jordan ranch beds were taken as a standard horizon, and the thickness of the series determined on both sides of these beds. Southwest of the Jordan ranch beds, there are black shales and hard sandstones. On the ridge due west of Jordan ranch, there is a massive conglomerate, the pebbles of which consist of granite, quartz porphyry, and similar rocks. This conglomerate in places is very hard and quartzitic. The shales, sandstones, and conglomerates are very similar, lithologically, to the Knoxville beds in the adjoining Pleasanton region. Search for fossils brought no results, but at a ranch in the canyon the writer was shown a collection of shells from the surrounding hills. One of these rock specimens contained gastropods and Venus-like shells which were in rock that resembled the yellow sandstone at the Jordan ranch. Another piece of hard black shale contained *Aucella Piochi* Gabb. The exact location is unknown, but it came from beds already classified, in field work with the Knoxville, because of its distinctive tilhologic character and its dissimilarity to the overlying Upper Cretaceous. In no place was an actual contact found between the Upper Cretaceous and the Knoxville, but wherever the line was crossed the dips and structure indicated conformable deposition. The Knoxville beds rest directly upon the older Franciscan rocks, containing schists, jaspers, serpentines and igneous intrusives. In no place was any actual contact observed between the Knoxville and the Franciscan. Here, as in other places, the change from massive Cretaceous beds with good dips everywhere, to crushed sandstones, schists, serpentines, and intruded igneous rocks, is marked.

A number of sections were run across the Knoxville and Upper Cretaceous beds. The conditions for determining sections are not good, because the Knoxville is covered in most of the area by Upper Cretaceous and the Upper Cretaceous is in turn overlain by Pliocene or Pleistocene gravels. The thickness of the Knoxville was found to be about four thousand feet, the line between this horizon and the Upper Cretaceous being determined arbitrarily by lithological differences in sandstones and shales.

With the Jordan ranch beds as a fixed horizon, the thickness of Upper Cretaceous was found to be about four thousand feet. The bed from which the fauna was collected by Dr. L. G. Yates and Dr. J. P. Smith is in the middle of this section. The fauna given here shows more affinity with the Horsetown than with the Chico, and still there are two thousand feet of sandstone below these beds and above the Knoxville.

As far as evidence of structure goes, the beds assigned to the

Horsetown are entirely conformable in dip with those of the Knoxville, indicating continuous deposition as proven by Diller and Stanton through the Shasta-Chico series in northern California. The upper part of this four thousand feet may be considered Chico, on the evidence of the Chico fauna. Northwest of Jordan's ranch, down Arroyo del Valle, the Chico is overlain by massive, light yellow, cavernous weathering sandstones, conformable in dip. No fossils were found, but the beds resemble the Eocene as found in other places in middle California, and are similar to the series described by Mr. Turner as overlying the Chico at Mt. Diablo. At the latter place they have been identified by the presence of *Turritella uvasana* and other characteristic Eocene fossils.

Milpitas.—The Milpitas locality is southwest of and is practically a continuation of the Pleasanton region. The fauna is typically Knoxville in character.

Aucella Piochi Gabb
Hoplites (fragment)
Belemnites (fragment)
Pecten complexicosta Gabb

The exact locality from which these fossils come is on the west side of the range separating Santa Clara and Calaveras valleys, and is about 2½ miles northeast of Milpitas. *Aucellae* were found in several other localities southeast of this place along the foot of the Monument Peak ridge. The locality, at which fossils are most plentiful, is on the road from Milpitas to Calaveras Valley, about a quarter of a mile east up the grade from the valley floor. All the fossils in this locality come from a hard compact sandstone that weathers with a brown concentric stain, which makes a lithologic character that is very constant. Above the Cretaceous there is a blue shale, probably middle or lower Miocene, which is apparently conformable in dip, but not so in reality. The unconformity is shown by the lack of Eocene sandstone which is present in Arroyo del Valle, Mt. Diablo section, several miles east of this place, and by a variation in the level to which the Cretaceous floor was reduced by erosion, previous to the depositions of Miocene. In the Milpitas locality, the Miocene overlies beds containing *Aucella Piochi* of the lower Knoxville, and in the Pleasanton region it overlies beds containing *Aucella crassicollis* of the Upper Knoxville in one place, and *Venus varians* of the Horsetown in another.

Beryessa Canyon.—In Beryessa canyon the fossils given here have been found in a coarse conglomerate that is composed of hard flinty shale nodules.

Aucella Piochi Gabb
Phylloceras knoxvillense Stanton

The *Aucellae* here are found both in the pebbles and in the matrix of this conglomerate. This indicates an elevation of the land mass in this vicinity during Knoxville times, with rapid erosion following the uplift. This may mean no more than a local unconformity, in this place, and is representative of near shore conditions. There is a considerable thickness of barren shales, sandstones, and conglomerates interbedded, underlying this fossiliferous conglomerate, which must belong to the Knoxville. Serpentine is intruded into the Knoxville sandstones at this place. As was found further north near Milpitas, the Tertiary overlies the Cretaceous unconformably. In Alum Rock canyon, several miles south of this place, there is a similar conglomerate, apparently continuous with the Beryessa conglomerate, but in the pebbles of which no *Aucellae* have as yet been found.

Alum Rock Canyon.—The Cretaceous conglomerate of Alum Rock, exposed near the mouth of the canyon, has furnished no fossils, but a fine-grained conglomerate further up the canyon has yielded the following Knoxville forms:

Belemnites, sp.
Aucella Piochi Gabb *

There are also beds of a heavy massive sandstone which have yielded no fossils.

The sedimentary beds continue southeast along the base of the Monument Peak range for several miles and then disappear.

Evergreen.—The main mass of the Cretaceous sediments in the ridge between Hall's valley and the Santa Clara Valley are massive conglomerates with large bowlders of quartz porpyhry, and other siliceous igneous rocks. Above this conglomerate there are a few hundred feet of Cretaceous sandstone upon which the Tertiary lies unconformably. Below the conglomerate is a hard black shale from which *Aucella Piochi* Gabb was obtained. The exact locality is a small hill that juts out from the Monument Peak ridge, about one and a half miles southeast of the town of Evergreen.

Dry Creek.—The Dry Creek locality is five miles southeast of Evergreen P. O. The Cretaceous at this place is represented by black sandy shales which are badly crushed near the serpentine of the Silver hills. These fossils were found near the Dry Creek road that goes from Evergreen to San Felipe Valley.

Aucella Piochi Gabb
Aucella crassicollis Keyserling

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* This was termed *Aucella mosquensis* by Dr. J. P. Smith in his paper on the Age of the Auriferous Slates of the Sierra Nevada, Bull. Geol. Soc. Am., v, 256. *Aucella trigonoides* was also mentioned from Stevens creek canyon, west of San José. Both of these species of *Aucella*, Dr. Smith has since recognized as being the common *Aucella Piochi* of the Pacific Coast.

Near Silver Creek, in the southwest corner of the Mt. Hamilton sheet, the Franciscan rocks are present, but whether the Cretaceous lies upon them or is faulted against them is not known, as intruded serpentine has obscured the relations.

Gilroy.—Gilroy is the next known locality of Cretaceous in the Santa Clara Valley region and is the furthest south of those under consideration. In a road cut on the Whitney ranch, about four miles west of Gilroy, Dr. J. P. Smith found the following fossils:

Aucella crassicollis Keyserling
Olcostephanus cf. *mutabilis* Stanton

These were in a hard black shale similar to the Knoxville shale elsewhere. Near where the fossils were found, the serpentine has been intruded into the shales but there has been no appreciable metamorphism.

New Almaden.—Gabb mentions *Aucella Piochi* from near the New Almaden mine southwest of San José, but does not give the exact locality.* Dr. Becker † states that the greater part of the surface at this place is occupied by the metamorphic rocks, pseudodiorites, pseudodiabases, phthanites, limestones and serpentines. The age of these he gives as Cretaceous because of the *Aucella* found by Mr. Gabb. It is known now that some of the rocks classified by Becker as Cretaceous are pre-Cretaceous. We may assume, then, that there is an area of Cretaceous or Knoxville age near New Almaden, resting upon the metamorphic rocks of the Franciscan series, which have not been properly differentiated from them.

Pigeon Point.—Cretaceous beds exposed along the coast, in a section from ½ to 2½ miles wide, and 12 miles long, starting from near the mouth of Pescadero Creek and extending southward to Año Nuevo Bay, have furnished the following Chico fossils:

One and a half miles southeast of Pigeon Point on coast.

Turritella chicoënsis Gabb
Trigonia evansana Meek
Panopaea concentrica Gabb
Arca breweriana Gabb
Tellina, sp. indet.
Nucula truncata Gabb
Cucullaea bowersiana Cooper
Ostrea, sp.

One mile north of Pigeon Point on coast.

Trigonia leana Gabb
Mactra, sp. indet.
Glycymeris Veatchi Gabb

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* Pal. Cal., ii, 247.

† Mon. xiii, U. S. Geological Survey, p. 310.

Pholadomya subelongata Meek
Pinna Breweri Gabb
Inoceramus subundatus (?)
Cinulia obliqua Gabb
Perissolax brevirostris Gabb
Lunatia, sp.

Two and three-quarter miles north of Pigeon Point on coast, in conglomerate.

Turritella chicoënsis Gabb

Half a mile south of mouth of Pescadero Creek.

Mactra, n. sp. (?)

Fragment of coral, unidentifiable.

Bolsa Point, one mile north of Pigeon Point.

Glycymeris Veatchi Gabb
Mactra-like shell

The beds are of hard shales, sandstone and massive conglomerates. The conglomerates forming the top of the series are much disturbed; the shales are apparently the bottom.

Sand dunes and gravels overlie these Upper Cretaceous beds along the coast, exposing the Chico only in the cliffs in places. The relations of Cretaceous to Tertiary are not plainly shown here, but the two series of beds are supposed to be unconformable.

Stevens Creek.—The Cretaceous beds at Stevens Creek consist of interbedded conglomerates and hard black shales, which have furnished these Knoxville fossils.

Aucella Piochi Gabb
Belemnites

The fossils were found both in the shale and conglomerate. The shale has broken off in large blocks from the steep walls of the canyon and in these the *Aucellae* and *Belemnites* were obtained as well as from rock in place near by. The shale fragments are large and angular, so they must be from the walls of the canyon. Besides the fossils given above an unidentifiable bivalve was found.

Stanford University.—Two specimens of *Baculites chicoënsis* Trask have been found near Stanford University. One came from a hard yellow sandstone, apparently in place, at the north end of a quarry about a quarter of a mile south of the University buildings. The other specimen was found inside of a block of sandstone that was brought up by an intrusion of basalt. The basalt cuts rocks of Miocene age, and this specimen of *Baculites* may be considered as proof of the presence of Chico underlying the Tertiary deposits in this neighborhood.

Belmont Hill.—From Belmont Hill, west of the town of that name, these four Knoxville forms have been collected.

Aucella Piochi Gabb
Gastropods, sp. indet.
Aucella crassicollis Keyserling
Hoplites fragment

There are two different places where the fossils were found in this general locality. A little west of Belmont Hill, the *Hoplites*, gastropods and a fragment of an imprint that might be either an *Aucella* or an *Inoceramus* were found by Dr. J. C. Branner.

About one-half mile southwest from this place, in the main creek bed, Dr. Branner and Mr. R. Anderson found a bowlder that contained *Aucella Piochi.* The material of the bowlder seemed the same as the rock exposed in the creek bed, although no fossils have yet been found in the rock in place.

The bowlder containing the *Aucellae* is a fine-grained conglomerate, made up of small pebbles of jasper.

On Belmont Hill these fine-grained conglomerates rest upon the jaspers of the Franciscan series. These pebbles of jasper in the conglomerate here are proof of the unconformity between the Franciscan rocks and the Knoxville.

A table is given below which shows the distribution of species from the various Cretaceous horizons of this region.

The Horsetown Horizon.

In the first work done upon the Cretaceous of California, two divisions of the Cretaceous were recognized—the Shasta and the Chico groups. The Shasta group was subdivided into two horizons by Dr. White and the upper part was called Horsetown, and was considered to have a distinctive fauna.*

The tendency of other geologists has been to class this horizon with either the Upper or Lower Cretaceous rather† than consider it as independent.

Mr. Anderson is of the opinion that the Horsetown is a separate horizon.‡

Diller and Stanton have shown that there was continuous sedimentation throughout the Cretaceous in northern California; that the fauna of Knoxville, Horsetown, and Chico intergrade, but still the three horizons are considered to have sufficiently distinctive faunas to be separated.§

*Correlation paper, Bull. 82, U. S. Geol. Survey, p. 184.

†G. F. Becker, Early Cretaceous of Calif., Bull. Geol. Soc. Am., ii, 204; J. S. Diller, Geology of Calif. and Oregon, Bull. Geol. Soc. Am., iv, 212.

‡Cretaceous of Pacific Coast, Proc. Cal. Acad. Sci., 3d series, ii, 1, p. 47.

§The Shasta-Chico series, Bull. Geol. Soc. Am., v, 464.

TABLE SHOWING THE GEOGRAPHICAL DISTRIBUTION OF THE FAUNA.

KNOXVILLE FAUNA	1 Berkeley	2 Mt. Diablo	3 Haywards	4 East of Decoto	5 Pleasanton region	6 Jordan Ranch Arroyo Valle	7 Crossby Ranch Arroyo Valle	8 Milpitas	9 Beryessa	10 Alum Rock Canyon	11 Evergreen	12 Dry Creek (5 mi. S. Evergreen)	13 Gilroy	14 New Almaden	15 Pigeon Point	16 Stevens Creek	17 Stanford Univ.	18 Belmont
Aucella Piochi Gabb	×	×		×			×	×	×	×	×			×		×		×
Belemnites	×	×						×		×						×		
Modiola major Gabb	×																	
Lucina colusaensis Stanton	×																	
Pecten complexicosta Gabb	×							×										
Cardinia (?)	×																	
Myochoncha (?)	×																	
Turbo	×																	
Atresius liratus Gabb	×																	
Inoceramus		×																
Gasteropods		×																×
Aucella crassicollis Keyserling					×							×	×					
Ammonites indet.					×													
Hoplites								×					×					×
Phylloceras knoxvillense Stanton									×									
HORSETOWN FAUNA																		
Phylloceras onöense Stanton	×					×												
Chione varians Gabb		×			×													

HORSETOWN FAUNA (cont.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Cucullaea truncata Gabb		×																
Eriphyla umbonata Gabb		×																
Lytoceras Batesi Trask		×				×												
Trigonia aequicostata Gabb		×																
Cricoceras percostatum Gabb			×															
Lytoceras alamedense Smith																		
Hoplites Remondi Gabb						×												
Lytoceras timotheanum Mayor						×												
Belemnite sp.						×												
CHICO FAUNA																		
Hoplites fragment	×																	
Inoceramus "	×																	
Anchura californica Gabb		×																
Baculites chicoensis Trask		×				×									×	×		
Chione varians Gabb		×																
Cucullaea truncata Gabb		×																
Dentalium Cooperi Gabb		×																
" *stramineum* Gabb		×																
Eriphyla umbonata Gabb		×																
Mactra tenuissima Gabb		×																
Meretrix nitida Gabb		×																
Nautilus sp.		×																
Pachydiscus suciaensis Meek		×																
Pecten operculiformis Gabb		×																
Pinna Breweri Gabb		×													×			
Schlutheria diabloensis Anderson		×																
Scobinella Dilleri White		×																
Trigonia evansana Meek		×				×								×				

CHICO FAUNA (cont.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Cardium annulatum Gabb		×																
Trigonia aequicostata Gabb		×																
Desmoceras Hoffmanni Gabb						×												
Haploceras Breweri Gabb						×												
Baculites occidentalis						×												
Placenticeras californicum Anderson						×												
Desmoceras cf. *selwynianum* Whiteaves						×												
Lytoceras cf. *cala* Stoliczka						×												
Placenticeras pacificum Smith						×												
Holcostephanus suciaënsis Meek						×												
Phylloceras ramosum Meek						×												
Cinulia obliqua Gabb						×									×			
Inoceramus cf. *vancouverensis* Shumard						×												
Pectunculus Veatchi Gabb						×												
Pachydiscus newberryanus Meek						×												
Ammonites Turneri White		×																
Turritella chicoensis Gabb															×			
Panopœa concentrica Gabb															×			
Arca breweriana Gabb															×			
Tellina sp. indet.															×			
Nucula truncata Gabb															×			
Cucullaea bowersiana Cooper															×			
Ostrea sp.															×			
Trigonia leana Gabb															×			
Mactra sp. indet.															×			
Glycymeris Veatchi Gabb															×			
Pholadomya subelongata Meek															×			
Inoceramus subundatus (?)															×			
Perissolax brevirostris Gabb															×			
Lunatia sp.															×			

The type section of Horsetown, near the place of that name, is considered by Mr. Diller to represent only the upper part of the horizon.*

Dr. L. F. Ward has lately identified plant remains from Horsetown, which he has pronounced Lower Cretaceous in age.†

It is evident that the Horsetown is an independent horizon.

Distribution of the Horsetown Horizon.—The Horsetown has long been known in northern California, but has not been recognized in central or southern California. A few species representative of this horizon which have been found in the vicinity of Mt. Diablo, have been referred to the Chico. ‡ Dr. Becker has expressed the opinion that there was an unconformity between Chico and Knoxville at Mt. Diablo, § and Dr. Fairbanks ‖ has described these formations as unconformable in southern California.

Mr. Turner has found a conformable series of 10,000 feet of Cretaceous at Mt. Diablo with *Aucella Piochi* at the bottom and lower Chico forms near the top.¶ There are five thousaud feet of unfossiliferous beds in between these two places, which Mr. Stanton thinks must represent Upper Knoxville and the Horsetown. Sedimentation was slower at Mt. Diablo than in northern California, or else Mt. Diablo was out of water during the Horsetown period.**

All of these statements have tended to the general opinion that the Horsetown was absent in the Mt. Diablo region and that Knoxville and Chico are unconformable.

From the Santa Clara Valley region there are forms which show the probable presence of Horsetown at certain localities.

The fauna, given in the table, shows the possible presence of Horsetown at Pleasanton, Arroyo del Valle, Haywards, Berkeley, Benicia and Mt. Diablo. Further proof of the presence of this horizon at the last-named place is, that there are five thousand feet of beds between lower Knoxville and lower Chico, and field work has shown the whole Cretaceous series to be conformable here, as is true at Arroyo del Valle and Pleasanton. The thickness of Chico Turner gives as six

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* Geol. Cal. and Oregon, Bull. Geol. Soc. Am., iv, 213.

† Mesozoic Flora of the U. S. Monog. xlviii, U. S. Geol. Sur., Pt. I, p. 227.

‡ T. W. Stanton, Fauna of the Knoxville Beds, Bull. 133, U. S. Geol. Survey, p. 21.

§ Stratigraphy of Cal., Bull. 19, U. S. G. S., p. 16.

‖ H. W. Fairbanks, Pre-Cretaceous Age of Metamorphic Rocks of the Coast Ranges, Am. Geol., ix, 165; also Stratigraphy of Calif. Coast Ranges, Jour. Geol., iii, 426.

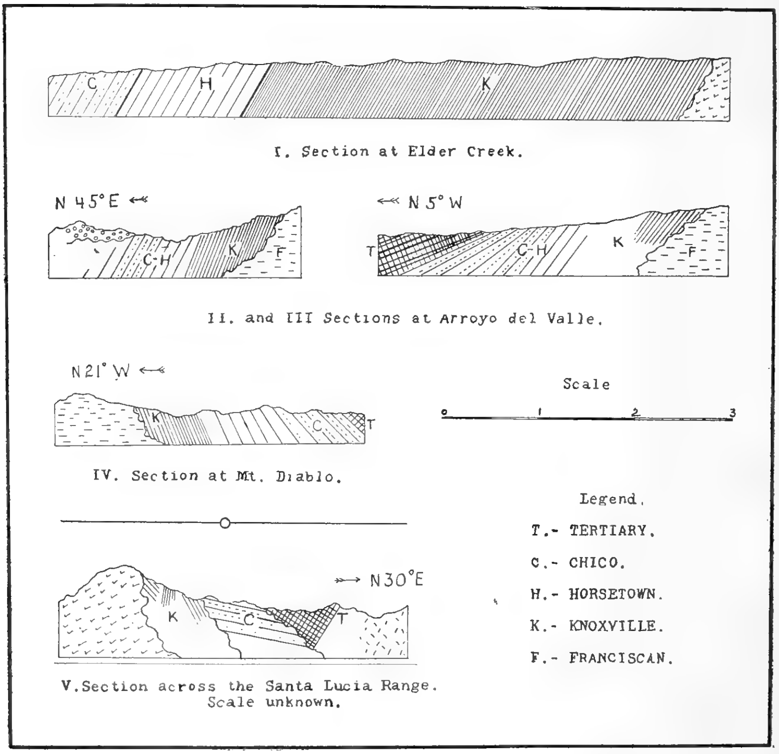
¶ Geol. of Mt. Diablo, Bull. Geol. Soc. Am., ii, 401.

** T. W. Stanton, Fauna of the Knoxville Beds, Bull. No. 133, U. S. G. S., p. 21.

thousand feet; but in the thickest known section of Cretaceous on Elder Creek the Chico is only four thousand feet; and south of Mt. Diablo at Arroyo del Valle four thousand feet is the thickness of combined Horsetown and Chico, with the same amount for Knoxville. Thus, at Mt. Diablo, the six thousand feet must represent more than the Chico and some of it may be considered Horsetown. The series seems to be conformable and sedimentation was probably slower at this place than in northern California.

South of Arroyo del Valle, the Horsetown has not been recognized* and the Chico is found resting unconformably upon Knoxville shales and sandstones, into which serpentine has been intruded in pre-Chico times.

2



Comparative sections showing the relations of the Cretaceous in California.

Cause of Absence of Horsetown in Southern California.—The lack of Horsetown in Southern California shows that at

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[*] A specimen of *Hoplites Remondi* has been picked up in the hills near Del Monte, but nothing definite is known about its occurrence.

the end of Knoxville time a movement took place which lifted southern California out of water, and submerged a greater area of northern California, allowing the transgression of Horsetown beyond the eastern limits of the Knoxville sea. The sections given here (fig. 2) show the relations of the three Cretaceous horizons in northern, central and southern California.

Section I is plotted with uniform dips from Dr. Diller section on Elder Creek.*

Section II is from Mr. Turner's work at Mt. Diablo, and shows a conformable series.†

Sections III and IV are from field work at Arroyo del Valle, and show the conformable relations of the Cretaceous series, and the position of the Jordan ranch beds, from which the mingled Horsetown and Chico fauna was taken.

Section V is from work done by Dr. Fairbanks in southern California.‡

An outline map is given below to show, diagrammatically, the relations between the various Cretaceous horizons in California.

The Chico shore line is taken from a map of Diller and Stanton.§ The Horsetown shore line is partly from this same map, and partly from the known distribution of that horizon in this immediate region.

The Knoxville shore line is drawn in from the localities at which this horizon is recognized in the region under discussion, and the occurrence of the same horizon further south at Mt. Pinos,‖ and further north of this immediate region or Napa County.

The overlap of Horsetown upon Knoxville, and Chico upon Horsetown in northern California, as demonstrated by Diller and Stanton, is shown here.¶ The lack of Horsetown, and unconformity of Chico upon Knoxville in southern California, is also shown. The point where Horsetown deposits stop, or the approximate location of the axis of differential movement of Horsetown times, which raised southern California and submerged a greater area of northern California, is indicated.

Movements during the Cretaceous.—At the beginning of Knoxville there was an epeirogenic movement that extended from Alaska to southern California, which was a non-uniform

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* Diller and Stanton, The Shasta-Chico Series, Bull. Geol. Soc. Am., v, 438.

† Geol. of Mt. Diablo, Bull. Geol. Soc. Am., ii, 400.

‡ H. W. Fairbanks, Geology of Northern Ventura Co., Santa Barbara Co. etc., Reprint 12th Ann. Rep. State Mineralogist, 1894, p. 2.

§ The Shasta-Chico Series, Bull. Geol. Soc. Am., v, 454.

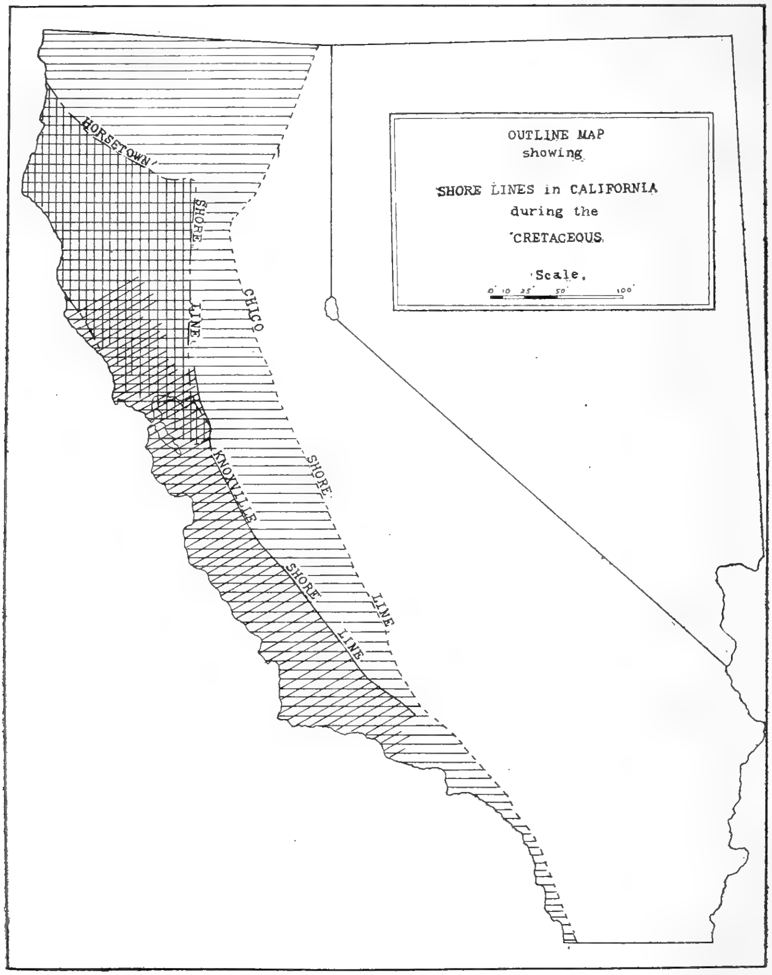
‖ H. W. Fairbanks, Geol. of Northern Ventura Co., etc., 12th Ann. Rep. State Mineralogist, 1894, Reprint, p. 20.

¶ Diller and Stanton, The Shasta-Chico Series, Bull. Geol. Soc. Am., v, 450.

sinking of the western part of the continent. Deposits of Knoxville age are known to occur from Alaska to Mexico.*

At the end of the Knoxville, or the beginning of the Horsetown period, there must have been another large movement. The extent of this cannot be determined now, but appears to have affected mainly the southern portion of the Pacific Coast by uplifting it above the Knoxville sea.

3



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* Diller and Stanton, Shasta-Chico Series, Bull. Geol. Soc. Am., v, 456.

In northern California, the Horsetown overlaps the Knoxville and the Chico overlaps the Horsetown, but in the vicinity of Mt. Diablo the Horsetown cannot be considered to overlap the Knoxville. At the time of the movement or some time during the Horsetown epoch, the large intrusions of serpentine through the Coast Ranges must have taken place, as they are found in numerous localities intruded into the Knoxville, but not into the Chico beds.*

At the end of the Horsetown period there was a gradual submergence of the whole coast, which allowed the transgression of the Chico to the foot of the Sierras, in northern California, and permitted the Chico sea to cover the present Sacramento Valley. In southern California, the Chico shore line, as given by the authorities previously quoted, is close to the present shore line, indicating a fairly uniform subsidence of the coast, but with the southern end of California relatively higher than the northern, as were the conditions during Horsetown time. In northern California, the Chico has transgressed nearly to the Nevada State line, but in southern California the shore line, from the present evidence, could only have been about as far east as the base of the present San Jacinto range.

Résumé and conclusions.—In the Santa Clara Valley region there are scattered localities where the Cretaceous is present.

The three horizons of the Cretaceous are represented among these various localities.

The Knoxville is present at fourteen, the Horsetown at five and Chico at five. At three of the five localities where Horsetown is present Chico is present also.

The Knoxville and Chico are both on the east and west sides of the Santa Clara Valley. The Horsetown is found only upon the east side in the vicinity of Mt. Diablo.

The Knoxville and Chico extend farther south than the most southerly of the localities considered in this paper. The Horsetown is not known in any place farther south than the Arroyo del Valle.

The Cretaceous is represented at Mt. Diablo and Arroyo del Valle by about one-half the thickness of the maximum section on Elder Creek.

There is no unconformity between Horsetown and Knoxville or Horsetown and Chico in this immediate region.

There is nothing to show interrupted sedimentation at the last mentioned localities.

The continuity deposition of the Cretaceous series in northern California, as advocated by Diller and Stanton, is accepted. Continuity of deposition is considered true of the series at Mt. Diablo and Arroyo del Valle.

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* F. M. Anderson, Cretaceous Deposits of the Pacific Coast, Proc. Cal. Acad. Sci., 3d series, ii, 1, p. 54.

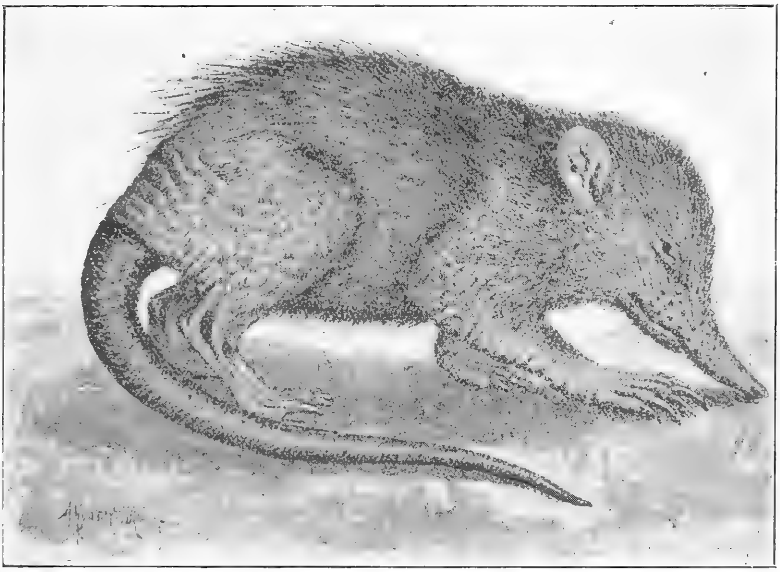
The Horsetown sea transgressed over northern California beyond the Knoxville shore line; at Mt. Diablo it almost coincided with the Knoxville shore line, and in southern California appears to be absent.

The shore line of the Chico sea shows that when subsidence took place that the southern end of California was relatively higher than northern California, as was the condition of affairs during the Horsetown period.

Stanford University, California, Dec. 16, 1906.

Art. V.—*Notes on the Habits and External Characters of the Solenodon of San Domingo* (*Solenodon paradoxus*); by A. Hyatt Verrill.

Although *Solenodon paradoxus* of San Domingo and Haiti was discovered and imperfectly described as early as 1839, several years before the Cuban species (*Solenodon cubanus*) was known to science, it is still practically unknown to recent zoologists. The published descriptions of this rare and interesting mammal are vague and unsatisfactory. For many years it has been commonly considered extinct, and when, in December, 1906, I undertook a collecting trip to San Domingo with the avowed intention of obtaining the *Solenodon*, prominent zoologists stated that the quest was hopeless, one of them saying that I would be as likely to secure specimens of ghosts as of *Solenodon paradoxus*.



San Domingo Solenodon (*Solenodon paradoxus*).

During the five months spent on the island, I devoted a great deal of time to hunting for the Solenodon, and in interviewing natives from the remote and little-known parts of the island.

I soon found that the animal was well known to the natives in certain isolated localities, but that over the greater portion of the Republic it was absolutely unknown.

This is readily accounted for by the presence of the mongoose in most parts of the country, and it is only a question of time when this pest will overrun the entire island and the Solenodon will become actually exterminated.

The natives have several names for the Solenodon, calling it "Orso", "Milqui", "Homigero", and "Juron", while the English-speaking negroes from the British West Indies know it as "Ground Hog". The name "Juron" (ferret) is also applied to the mongoose, and for some time I was misled by this confusion of the two animals. In its habits the Solenodon resembles a hog, rooting in the earth and cultivated grounds, tearing rotten logs and trees to pieces with its powerful front claws, and feeding on ants, grubs, insects, vegetables, reptiles, and fruit, and at times proving destructive to poultry. On several occasions it has been known to enter the houses in search of roaches and other vermin, and has been captured in rat-traps.

It is strictly nocturnal, and spends the day in caves, holes in the coral limestone rocks and in hollow trees and logs. It is a slow, stupid creature. It is unable to run rapidly, but shambles along with the zigzag, sidewise motions of a plantigrade. It is doubtless owing to this that it obtained the native name of "Orso" (bear).

Its long snout and stout front feet, with their curved claws, and its thick, short neck, prove impediments to forward progress. According to the natives it is incapable of running straight. They also claim that when pursued it frequently trips itself and tumbles heels over head. When hunted with dogs it thrusts its head into the nearest hole or shelter and allows itself to be captured without resistance.

The only specimen that I obtained was a female which was captured alive and uninjured. A few days after its capture it gave birth to three naked young. These the mother promptly devoured, and she died three days later.

This specimen (see figure), as preserved in formol, is 14 inches in length, exclusive of the tail, which measures about 13 inches in length.

The body and head are covered with sparse, coarse hair, which is reddish ferruginous from the eyes to the shoulders, and dusky brown on the rest of the body.

The hair becomes very thin and scattered on the hind quarters, which for some distance on the back and sides are naked, roughly corrugated, and warty, with a sparse, short, wooly growth between the excrescences.

The legs, snout, and eyelids are naked and with the bare skin of the rump are pinkish white. The ears are short, thin, rounded, and are bluish gray with light edges. The heavy, rat-like tail is dark brown and naked. The claws are horn-color. The front feet and claws are large, heavy, and mole-like and well adapted to digging and tearing asunder rotten wood, etc. They are much smaller in proportion than in the Cuban species, however. The snout is also more flexible than in *S. cubanus*, from which it also differs in the naked skin of the rump, the color, size, and other characters.

Art. VI.—*Mississippian (Lower Carboniferous) Formations in the Rio Grande Valley, New Mexico;*[*] by C. H. Gordon.

Introduction.

The observations upon which the following notes are based were made during the summer of 1905 in connection with an investigation by the U. S. Geological Survey of the mines and mining districts of New Mexico under the direction of Mr. Waldemar Lindgren, the results of which are to appear in a forthcoming report by the Survey. For the identification of the fossils collected, the writer is indebted to Mr. George H. Girty.[†]

Exposures of rocks belonging to the Mississippian series occur at a number of places in New Mexico. They have long been known to occur at Lake Valley, from which circumstance they early received the name of the Lake Valley Limestone.[‡] The observations of the writer show that exposures of the Lake Valley limestone occur in many places in the region about the southern extension of the Black and Mimbres ranges, and rocks apparently identical were observed in the Caballos Mountains but fossil evidence of the age of these beds is not at hand. In Socorro County there are but two small areas in which outcrops of Lower Carboniferous rocks are known to occur, one in the Magdalena Mountains, where they constitute the principal ore-bearing formation of the lead and zinc mines at Kelly, and another on the Arroyo Salado at the base of the Sierra Ladrones, discovered in 1905 by W. T. Lee,[§] of the U. S. Geological Survey.

The limestones at Kelly are seemingly unfossiliferous, though Lower Carboniferous crinoids are reported [‖] to have been found in them. The evidence on which this announcement is based, however, is lacking, and in the absence of satisfactory data these beds can not well be correlated with the Lake Valley limestone. Herrick[¶] gave to these beds the name Graphic-Kelly limestone. A hyphenated name of this kind is objectionable and they will be here referred to as the Kelly limestone, from the town in the vicinity of which they occur.

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[*] Published by permission of the Director of the U. S. Geological Survey.

[†] A bulletin of the U. S. Geological Survey treating of the fauna of the Lake Valley formations is now in preparation by Dr. Girty.

[‡] Cope, E. D., Eng. and Mining Jour., vol. xxxiv, p. 214, 1882.

[§] Personal communication.

[‖] Herrick, C. L., Am. Geol., vol. xxviii, p. 310, 1904; Jour. Geol., vol. xii, p. 138, 1904. Keyes, C. R., Proc. Iowa Acad. Sci., vol. xii, p. 169, 1904.

[¶] Loc. cit.

North of Socorro County the Lower Carboniferous formations disappear by overlap, the rocks of the Pennsylvanian series resting directly upon those of pre-Cambrian age.

Lake Valley Limestone.—Above the Percha shale (Devonian) in western Sierra County is a series of limestones with some shales, the upper beds of which at Lake Valley and Hillsboro are filled with fossils. The Carboniferous age of these beds was first recognized by E. D. Cope,* who, on the authority of Dr. C. A. White, referred them to the Middle Carboniferous (August, 1881).

S. A. Miller, to whom Cope submitted the fossils collected by him at Lake Valley, published† a description of them, in which he announces their Lower Carboniferous age and describes several species new to science.

A little later (January, 1882), B. S. Silliman,‡ on the authority of Mr. Arnold Hague and Mr. C. D. Walcott, likewise assigned these beds to the Lower Carboniferous. This conclusion was strengthened by the investigations of F. M. Endlich § in 1883, whose excellent section of the formations at Lake Valley is reproduced on page 61. In a paper published in 1884, F. M. Springer ‖ described the Lake Valley beds, and gives a list of the fossils obtained from them.

Ten years later Ellis Clark, at that time manager of the Lake Valley mines, published a paper,¶ illustrated by map and sections, in which the stratigraphy and ore deposits are described with considerable detail.

Following is a section of these beds obtained by the writer at this locality:

9. Capping of andesite.

Lake Valley Limestone. (Mississippian.)

8. Coarse, subcrystalline, yellowish-white limestone in moderately thick beds, more shaly below. Abounds in crinoids and other fossil forms. Some beds cherty. Full thickness not shown .... 60′
7. Blue shale including thin beds of bluish limestone containing the same fossils as No. 9, but crinoids not so abundant .... 75′
6. Grayish blue hard, compact limestone, more or less siliceous at top. This is called the Blue limestone, and locally is known as the "Footwall Lime" from the fact that it

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* Cope, E. D., Am. Naturalist, vol. xv, pp. 831-832, 1881.

† Miller, S. A., Journ. Am. Soc. Nat. Hist., vol. iv, pp. 306-315. 1881.

‡ Silliman, B. S., Trans. Am. Inst. Mng. Engrs., vol. x, pp. 424-444, 1882.

§ Endlich, F. M., Am. Nat., vol. xvii, pp. 149-157, 1883.

‖ Springer, F. M., this Journal (3), vol. xxvi, pp. 97-103, 1884.

¶ Clark, Ellis, Amer. Inst. Mng. Engrs., Trans., vol. xxiv, pp. 138-169, 1884.

underlies the ore deposits. The upper portion in places consists of flint breccia. The flint fragments, sometimes carrying silver, are gray, brown, chocolate, pearl and green, the green yielding a higher grade of ore than the other colors. At the base is a bed 5 feet thick of coarsely crystallized yellowish-white limestone 25'

5. Compact grayish limestone filled with nodular chert. Shale partings usually rather thick 50'

Percha Shale. (Devonian.)

4. Grayish yellow and blue shales 60'
3. Black fissile shale 100'

Mimbres Limestone. (Siluro-Ordovician.)

2. Pink limestone upper beds siliceous with drusy cavities; contains Silurian fossils 12'
1. Quartzite and limestone below.

By Clark, beds 7 and 8 were called "crinoidal limestones," No. 6 "blue limestones," and No. 5 "nodular limestones."

The recognition of the Lower Carboniferous (Mississippian) facies of the fossils obtained from beds 7 and 8 is confirmed by Dr. Girty. In the collection from the blue shaly beds (No. 7), Dr. Girty identified the following species:—

Fossils from Lake Valley.

Zaphrentis, sp.
Favosites, sp.
Platyceras pileiforme
Megistocrinus evansii ?
Physetocrinus planus
Trematopora vesiculosa
Fenestella, sp.
Pinnatopora, sp.
Crania, sp.
Leptaena rhomboidalis
Rhipidomella ? sp.
Productus semireticulatus
Productus burlingtonensis ?
Productus aff. *scabriculus*
Productus aff. *arcuatus*
Productus, sp. *a*
Productus, sp. *b*
Spirifer imbrex ?
Spirifer aff. *grimesi.*
Spirifer aff. *peculiaris*
Delthyris nova-mexicana
Syringothyris, sp.
Reticularia temeraria
Athyris lemellosa
Athyris aff. *incrassata*
Cleiothyris roissyi
Retzia, sp.
Camarotoechia occidentalis
Rhynchopora aff. *pustulosa.*
Platyceras, sp.
Orthoceras, sp.
Goniatites ? sp.
Phillipsia peroccidens ?

The following were obtained from the overlying beds (No. 8):

Zaphrentis, sp.
Crinoid stems
Megistocrinus evansii ?
Platyceras, sp.
Trematopora americana
Rhombopora, sp.
Leptaena rhomboidalis
Schizophoria swallowi ?

Platyceras peculiare
Platycrinus parvinodus
Dorycrinus unicornis
Stegonocrinus sculptus
Physetocrinus lobatus
Periechocrinus whitei
Fenestella sp.
Productus aff. *arcuatus*
Spirifer aff. *grimesi*
Spirifer imbrex ?
Reticularia cooperensis
Athyris lamellosa
Athyris ? sp.

Crinoids are more abundant in this bed both in species and individuals than in the shaly beds below. Concerning the relations of this fauna, Dr. Girty says*:—"The crinoid-bearing beds at Lake Valley have long been known to paleontologists, and they are generally regarded as of lower Burlington age." Beds 5 and 6 contain corals, crinoid plates and stems, but good specimens are difficult to obtain.

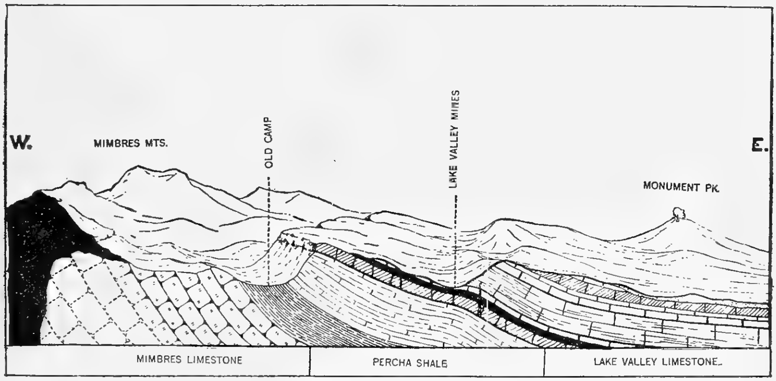

FIG. 1. Sketch profile section at Lake Valley, New Mexico, showing the stratigraphic relations of the formations and the position of ore deposits (represented by the heavy black line) within the Lake Valley limestone. After F. M. Endlich.

Two miles east of Hillsboro a good exposure of the Lake Valley formation shows the lower beds 5 and 6 to be wanting, and the upper crinoidal beds 7 and 8 are seen resting upon the eroded surface of bluish gray calcareous shales carrying an abundant Devonian fauna. Following is a list of fossils obtained from the crinoidal beds at this locality:—

Fossils from Hillsboro.

Michelinia ? sp.
Zaphrentis sp.
Amplexus sp.
Periechocrinus whitei
Rhodocrinus wortheni var. *urceolatus*
Rhipidomella dalyana
Productus semireticulatus
Productus aff. *scabriculus*
Spirifer imbrex ?
Spirifer aff. *peculiaris.*
Delthyris nova-mexicana

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* Personal letter.

Cacocrinus multibrachiatus
Cactocrinus proboscidialis
Steganocrinus pentagonus
Platycrinus sp.
Platycrinus subspinosa
Physetocrinus lobatus
Physetocrinus copei
Trematopora vesiculosa
Leptaena rhomboidalis
Spirifer aff. *S. forbesi*
Spirifer aff. *S. grimesi*
Spiriferina sp.
Athyris lamellosa
Cleiothyris sp.
Platyceras 3 sp.
Phillipsia aff. *peroccidens*
Phillipsia aff. *loganensis*

At Kingston nine miles west of Hillsboro, the Devonian shales (Percha formation) are overlaid by thick-bedded blue limestone, nodular cherty beds and shaly thin-bedded limestone, the total thickness of the formation being about 100 to 125 feet. From these beds were obtained the following representatives of the Lake Valley fauna:—

Fossils from Kingston.

Zaphrentis sp.
Crinoid indet.
Fenestella sp.
Rhombopora ? sp.
Spirifer aff. *peculiaris*
Syringothyris sp.
Athyris lamellosa
Leptaena rhomboidalis
Schizophoria swallowi ?
Productus aff. *scabriculus*
Spirifer imbrex ?
Athyris aff. *incrassata*
Cleiothyris roissyi
Orthoceras sp.

Near Cooks on the north side of Cook's Peak, at the south end of the Mimbres Mountains, the Lake Valley beds have a thickness of 275 to 300 feet and show the same lithological characteristics as at Lake Valley. The following fossils were obtained from them at this locality:—

Fossils from Cooks Range.

Zaphrentis sp.
Crinoid stems
Schizophoris swallowi ?
Productus semireticulatus
Productus sp.
Spirifer centronatus
Athyris lamellosa
Cleiothyris sp.

Kelly Limestone.—Resting upon the eroded surface of granites and schists at Kelly in the Magdalena district at the north end of the Magdalena range, occur 120 to 125 feet of massively-bedded, coarsely crystalline limestone, which, on the evidence above referred to, is usually regarded as Lower Carboniferous in age. This reference receives support also in the general lithologic and stratigraphic relations of the beds. For the most part the bedding is massive and devoid of shale partings. Near the middle of the formation is a dark bluish, weathering to yellowish drab non-crystalline or compact stratum five feet thick which by the miners is known as the "Silver Pipe Limestone." Just below this bed in the Graphic and Kelly mines are located the most important ore bodies, in following which the stratum furnishes a convenient guide. The beds dip from 30° to 40° south 65° west, and have been affected to a notable degree by faulting. The areal extent of the Kelly limestone is limited, being confined so far as demonstrated to the Magdalena region.

Ore deposits in the Lake Valley Limestone.—The discovery of ore at Lake Valley was made by a cowboy in 1878 While tightening the girth of his saddle his attention was attracted by a peculiar piece of stone whose weight surprised him. On having it assayed it proved rich in silver. The fame of the discovery soon spread and the district quickly became noted as a producer of silver. At present no ore is being mined, operations having practically ceased in 1894.

The best description published of the nature and occurrence of the silver ores of Lake Valley is that of Clark in the paper above cited. He classes the ores as (1) siliceous, (2) neutral, and (3) more or less basic. They occur chiefly along the bedding plane between the blue limestones and the overlying shaly beds at the base of the crinoidal limestone formation.

The ores consist principally of gray, brown, chocolate, pearl, and green flints, the last named usually yielding a grade of ore higher in silver than the other colors. The richest ore bodies occur in cavities of varying size containing galena with massive crystalline structure, and sometimes in the form of a pulverulent mass known locally as "grey metal." The largest of these ore cavities, called the Bridal Chamber, produced about 2,500,000 ounces of silver. Manganese and iron oxide have a variable but usually prominent development as accessory minerals, while the silica content ranges from 5 to 60 per cent.

The form and relations of the deposits and their occurrence in pockets and as a siliceous replacement of the limestone along the contact with overlying shales strongly suggests their origin from ascending hot solutions. From the nature of the region the presence at no great distance of an intrusive igneous body from which the solutions come may be safely predicated.

The region is one of extensive volcanic flows, to the erosion of which is due the limited areas of sedimentary rocks exposed in the vicinity of Lake Valley and northward along the slopes of the range. The earliest of these eruptions consisted of andesite, which occurs resting upon the eroded surface of the sedimentary formations.

Ores in the Kelly Limestone—At Kelly the ores occur at several horizons along the bedding planes of the Carboniferous formations, the principal deposits, however, being found within the Kelly beds just below the "Silver

Pipe" stratum above mentioned. The chief ore values in this district consist of lead and zinc, with little or no silver. With the exhaustion of the oxidized ores near the surface, large bodies of sulphide are coming to light below, with which is associated a considerable amount of copper. The association with the ores of certain minerals, such as pyroxene, magnetite, and specularite, intergrown with quartz and calcite, suggests the derivation of these deposits likewise from ascending hot solutions. The region is one of marked igneous activity, as shown by the presence in the immediate vicinity of several bodies of intrusive rocks, chiefly monzonite-porphyries, while extensive flows of andesite and rhyolite cover the range as a whole.

April 20, 1907.

Art. VII.—*The Iodometric Determination of Copper;* by F. A. Gooch and F. H. Heath.

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

When potassium iodide is added to a suitable solution of a cupric salt, cuprous iodide is precipitated while iodine equivalent to the amount of iodine fixed in the cuprous iodide is liberated. This reaction has been made the basis of an iodometric method for the determination of copper. The first suggestion of such a method appears to have been made by De Haen in 1854. In this process cupric sulphate was treated in solution with potassium iodide and the free iodine determined by sulphurous acid according to Bunsen. From the amount of iodine thus found the copper was calculated, according to the equation

$$2CuSO_4 + 4KI \longrightarrow 2K_2SO_4 + Cu_2I_2 + I_2.$$

This method was mentioned in the following year by Mohr,[*] with the modification suggested by Schwarz that the free iodine be determined by sodium thiosulphate instead of by sulphurous acid. E. O. Brown,[†] apparently without knowledge of De Haen's previous work, proposed, in 1857, similar procedure, and in 1868 the method with slight modification was presented again by Rümpler.[‡] Concerning the utility of the method opinions have varied. Mohr never favored it. So late as 1877 Mohr,[§] after quoting Meidinger to the effect that cuprous iodide freshly precipitated and washed is capable of taking up iodine, and Carl Mohr's criticism that potassium iodide acts upon cuprous iodide according to the concentration, states that the method is not exact and has nowhere found practical application. On the other hand, Fresenius[‖] recommended the method for the determination of small amounts of copper, noting that ferric salts and other substances capable of setting free iodine from an acidified solution of potassium iodide must not be present, and indicated the most favorable procedure. The copper salt treated, he says, should be the sulphate, preferably in neutral solution, though a moderate amount of sulphuric acid is not objectionable. Much free sulphuric acid and any free nitric acid should be neutralized by sodium carbonate, and the precipitate dissolved in acetic acid, an excess of which does no harm in the iodometric process.

Of recent writers some have favored the method while others have commented upon it unfavorably. Low[¶] has been

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[*] Titrirmethode, p. 387.

[†] Journ. Chem. Soc., x, 65.

[‡] Journ. prakt. Chem., cv, 193.

[§] Titrirmethode, 5 Aufl., 288.

[‖] Quant. Anal., 6te Aufl., 335, 1875.

[¶] Journ. Amer. Chem. Soc., 18, 468; 24, 1083.

outspoken in praise, to the extent of declaring a preference for this method in the most accurate technical work over all other methods, even the electrolytic method.

According to Low's earlier modification, metallic copper is dissolved in nitric acid, the solution is freed from nitrogen oxides by boiling, a considerable amount of zinc acetate is added, and in the solution having a volume of 50^{cm^3} an excess of solid potassium iodide is dissolved. Zinc acetate is preferred to sodium acetate to take up the free nitric acid. It is said that an excess of potassium iodide is necessary to insure rapidity of action and is harmless. According to the later modification of this method Low prepares the cupric salt by dissolving the metal in nitric acid (sp. g. about 1·20), boils the solution, adds bromine water to destroy the nitrogen oxides, boils to expel the bromine, treats with ammonium hydroxide in excess, adds acetic acid and boils again if necessary to get a clear solution. The advantage of using an excess of potassium iodide is emphasized, and the statement is made that unless an excess of this reagent is present the reaction does not proceed to completion until the titration of the free iodine takes place. Low recommends the use of 1 gm. of potassium iodide, an excess of 0·6 grm., for every 0·075 grm. of copper.

Various criticisms have also been made of the reaction when employed in gravimetric estimations of the cuprous iodide precipitated. Pisani[*] notes that potassium iodide can be used to effect the precipitation of cuprous iodide and that satisfactory separations may thus be brought about.

Flajolot[†] states that potassium iodide cannot be used as the precipitant since it dissolves cuprous iodide, and recommends the precipitation of cuprous iodide from the solution of copper sulphate slightly acidified with sulphuric acid, by treatment with sulphurous acid and hydriodic acid. Kohner[‡] affirms that cuprous iodide is soluble both in hydriodic acid and in potassium iodide.

Browning[§] has shown that cuprous iodide may be satisfactorily precipitated and separated from a cadmium salt by adding to a solution of cupric sulphate a moderate excess of potassium iodide (1 grm. to 4 grm. in all), expelling iodine and hydriodic acid by evaporating the solution to dryness, and treating the residue with water, filtering off the precipitate and weighing upon asbestos in the perforated crucible.

As a result of elaborate study Moser[‖] has reached the conclusion that the reaction by which cuprous iodide is formed

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[*] Compt. rend., xlvii, 294.

[†] Journ. prakt. Chem., xi, 105.

[‡] Ztschr. anal. Chem., xxvii, 213.

[§] This Journal [4], xlvi, 280, 1893.

[‖] Zeitschr. anal. Chem., xliii, 597, 1904.

from potassium iodide and cupric sulphate in neutral solution is complete at very high concentration of the solution; that the completeness of the reaction is greatly affected by the volume of liquid; that the amount of potassium iodide employed is almost without influence either in neutral solution or in acid solution; and that the presence of free sulphuric acid even in large amounts or of hydrochloric acid present in amount equivalent to the cupric sulphate is advantageous. Moser recommends, therefore, the addition of sulphuric acid for the purpose of bringing the reaction to completion. To the cupric sulphate (about 0·6 gm.) dissolved in 50^{cm^3} of water contained in a 300^{cm^3} stoppered flask are added 5^{cm^3} of $\frac{10N}{1}H_2SO_4$, and 2 gm. of solid potassium iodide, the mixture is shaken frequently for two minutes, and the free iodine is titrated by sodium thiosulphate, with stirring, to the end-reaction of the starch indicator.

According to Fernekes and Koch,* an excess of acetic acid does not influence titrations, while a certain amount of potassium iodide—1·5 grm. to 2 grm. for 0·0038 grm. of copper, and 2·5 grm. for 0·0939 grm. of copper—must be added to bring about complete action in a volume of 100^{cm^3}.

Quite recently Cantoni and Rosenstein† have tested the reaction between potassium iodide and a cupric salt under various conditions; but these investigators do not give the absolute values of the amounts of copper taken and found, merely recording the relative effects of varying conditions. From the record of their results it would appear that a five-fold increase of the minimum amount of potassium iodide added to portions of 100^{cm^3} of solution containing the same amount of copper salt is without influence upon the result; that increase of volume from 100^{cm^3} to 350^{cm^3}, other conditions being the same, may affect the results by as much as 5 per cent of their value. The authors conclude that the method gives good results under properly controlled conditions.

So evidence and opinions as to the effects of various conditions in the process are contradictory.

The chief matters of difference concern the influence of an excess of potassium iodide used as the precipitant, the dilution at which the precipitation should take place, and the effects of acids upon the formation of the cuprous iodide. We have thought it desirable, therefore, to again study these points experimentally.

In the experiments detailed in Table I, small amounts of a solution of pure copper sulphate, standardized by the electrolytic

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* Jour. Amer. Chem. Soc., xxvii, 1229.

† Bull. Soc. Chim. [3], xxxv, 1067–73 (1906).

method and containing 0·0020 grm. to 1$^{cm^3}$, were drawn from a burette and treated with potassium iodide in solution. In some of the experiments the iodine set free was titrated without previous dilution, while in others the mixture was diluted previous to the titration. The volumes at precipitation and at the end of the titration are noted. In Series A is shown the effect of twice the amount of potassium iodide theoretically required, at volumes varying from 30$^{cm^3}$ to 80$^{cm^3}$ at precipitation and from 36$^{cm^3}$ to 86$^{cm^3}$ at the end of the titration.

In the experiments of Series B the effect of increasing the amount of potassium iodide under conditions otherwise similar is studied. In Series C is shown the effect of large dilution of the solution containing the amount of potassium iodide used in the experiments of Series A.

TABLE I.

Effects of Volume of Solution and Concentration of Potassium Iodide.

	Volume				
Copper taken as $CuSO_4$ grm.	At precipitation cm^3	At end of titration cm^3	KI used grm.	Copper equivalent to I found by $Na_2S_2O_3$ grm.	Error in terms of copper grm.
			A		
0·0400	30	36	·4	0·0391	—0·0009
0·0400	40	46	·4	0·0387	—0·0013
0·0400	50	56	·4	0·0388	—0·0012
0·0400	60	66	·4	0·0391	—0·0009
0·0400	80	86	·4	0·0391	—0·0009[*]
			B		
0·0400	40	46	0·8	0·0400	0·0000
0·0400	30	36	8·0	0·0399	—0·0001[†]
0·0600	45	54	13·0	0·0599	—0·0001[†]
			C		
0·0400	30	200	·4	0·0033	—0·0367[‡]
0·0400	30	300	·4	0·0004	—0·0396[‡]
0·0400	30	500	·4	0·0004	—0·0395[‡]
0·0400	30	1000	·4	0·0005	—0·0395[‡]

From the results recorded in A it appears that, though the excess of potassium iodide is about 0·2 grm., the amount used being approximately twice that required by the theory, the reaction resulting in the formation of cuprous iodide and liberation of iodine is not quite complete. On the other hand, the results recorded in B show plainly that at similar dilution the

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[*] End-point slow in coming.

[†] The Cu_2I_2 was completely dissolved in KI before titrating.

[‡] Visible precipitation of Cu_3I_2 took place on titrating the free iodine.

reaction yields excellent indications of the amount of copper handled when the amount of potassium iodide is considerably more than the theoretical amount, varying from four to sixty times the amount required by theory, the absolute excess varying from 0·6 grm. to 12·7 grm.; and this is true even though the amount of potassium iodide is sufficient to dissolve completely the cuprous iodide formed.

So it is plain that the amount of potassium iodide used has within limits an influence upon the result. In a volume of about 50^{cm^3} an excess of 0·2 grm. of potassium iodide is not enough, while an excess of 0·6 grm. appears to be sufficient. Beyond this limit the addition of potassium iodide has no appreciable effect. It is natural to suppose that at high dilutions a larger excess of potassium iodide would be needed to complete the reaction than is required at lower dilutions. Table II contains the results of experiments made to test the efficiency of potassium iodide in precipating 0·0010 grm. of copper, taken as sulphate, in a volume of 100^{cm^3}.

TABLE II.

Effect of Potassium Iodide in Neutral Solutions at a Fixed Volume of 100^{cm^3}.

Copper taken as $CuSO_4$ grm.	KI used grm.	Acid added cm^3	Volume cm^3	Copper found grm.	Error grm.
0·0010	1	none	100	0·0003	−0·0007
"	2	"	"	0·0006	−0·0004
"	3	"	"	0·0009	−0·0001
"	4	"	"	0·0009	−0·0001
"	3	"	"	0·0013	+0·0003

From the results of these experiments it appears that while the action upon a milligram of copper, taken as the sulphate in 100^{cm^3} of solution containing no free acid, is not completed by 1 grm. or 2 grm. of potassium iodide, it is practically complete when an excess of 3 to 5 grm. of potassium iodide is present. The fact is again emphasized that up to a certain proportion, increasing with the dilution, the amount of potassium iodide influences the completeness of the reaction in neutral solution. An excess of potassium iodide amounting to 0·6 grm. to 1 grm. in a volume of 50^{cm^3}, and to from 3 gr. to 5 grm. in a volume of 100^{cm^3}, will precipitate completely 0·0020 grm. of copper. In the practical application of these facts it must be borne in mind that it is the excess of potassium iodide and not the full amount added which is important.

So we may very properly fix upon 2 grm. as the uniform amount of potassium iodide suitable for the precipitation of cuprous iodide in a volume of 50^{cm^3} of a neutral solution containing 0·2 grm. of copper; and upon 5 grm. as the amount of potassium iodide suitable in neutral solutions having a volume of 100^{cm^3}.

We have now to study the effect of free acid upon potassium iodide.

TABLE III.

Effect of Acids upon Potassium Iodide.

KI grm.	Acid cm³	Volume cm³	Copper equivalent to I set free grm.
	H_2SO_4 conc.		
2	1	50	0·0002
2	2	50	0·0005
2	3	50	0·0007
2	5	50	0·0019
5	1	100	0·0002
5	2	100	0·0002
5	3	100	0·0002
5	5	100	0·0014
	HCl conc.		
2	1	50	0·0002
2	2	50	0·0003
2	3	50	0·0006
2	5	50	0·0016
5	1	100	0·0002
5	2	100	0·0002
5	3	100	0·0002
5	5	100	0·0008
	HNO_3 conc. purified		
2	1	50	0·0025
2	2	50	0·0094
2	3	50	0·0230
5	1	100	0·0002
5	2	100	0·0002
5	3	100	0·0002
5	5	100	0·0294
	$HC_2H_3O_2$ 50%		
2	25	50	0·0002
5	25	100	0·0002
5	50	100	0·0003

So it appears that a trifling amount of iodine is in every case set free, due no doubt to presence of traces of iodate. It appears also that no more than 2^{cm^3} of concentrated sulphuric acid or hydrochloric acid may safely be present with 2 grms. of potassium iodide in 50^{cm^3} of solution, and the presence of 1^{cm^3} of pure nitric acid makes error. The tendency to liberate iodine is manifestly less at the higher dilution, and it appears that in a volume of 100^{cm^3} of solution containing 5 grms. of potassium iodide 3^{cm^3} of concentrated sulphuric acid, hydrochloric acid or nitric acid free from nitrogen oxides may safely be present. Acetic acid of 50 per cent strength may apparently make up half the solution at either dilution. When either sulphuric acid, hydrochloric acid or nitric acid is present, obviously the higher dilution is preferable.

Following are the results of experiments in which various amounts of copper were determined by titration of the iodine set free in a volume of 100^{cm^3} in presence of 5 grms. of potassium iodide and free acid.

TABLE IV.

Effects of Acids upon the Determination of Small Amounts of Copper.

Copper taken as $Cu(NO_3)_2$ grm.	KI grm.	Acid cm^3.	Total volume cm^3.	Copper found grm.	Error grm.
		H_3SO_4 conc.			
0·0010	5	1	100	0·0016	+0·0006
0·0010	5	2	100	0·0014	+0·0004
0·0010	5	3	100	0·0019	+0·0009
		HCl conc.			
0·0010	5	1	100	0.0014	+0·0004
0·0010	5	2	100	0·0014	+0·0004
0·0010	5	3	100	0·0015	+0·0005
		HNO_3 conc. purified			
0·0010	5	1	100	0·0014	+0·0004
0·0010	5	2	100	0·0015	+0·0005
0·0010	5	3	100	0·0015	+0·0005
		$HC_2H_3O_2$. 50 per cent			
0·0010	5	10	100	0.0012	+0·0002
0·0010	5	20	100	0·0012	+0·0002
6·0010	5	30	100	0·0010	±0·0000
0·0010	5	40	100	0.0010	±0·0000
0·0010	5	50	100	0·0010	±0·0000

It appears that so much as 50^{cm^3} of 50 per cent acetic acid may be present with 5 grms. of potassium iodide in 100^{cm^3} of solution without interfering appreciably with the estimation of 0·0010 grm. of copper and that the error introduced by the presence of 1^{cm^3}, 2^{cm^3} and 3^{cm^3} of sulphuric acid, hydrochloric acid and nitric acid (free from nitrogen oxides) in 100^{cm^3} of solution is scarcely appreciable.

In Table V are given the results of similar procedure applied to larger amounts of copper.

In the experiments of Series B and C the material for each test was metallic copper standardized electrolytically. Portions of this material were weighed and converted to the nitrate by acting with nitric acid. The solution of the nitrate was evaporated nearly to dryness and the residue dissolved and titrated in the manner indicated.

TABLE V.

Effects of Acids upon the Determination of Larger Amounts of Copper.

Copper taken as $Cu(NO_3)_2$ grm.	KI Present grm.	KI Approximate excess grm.	Acid cm³.	Volume at beginning of titration cm³.	Volume at end of titration cm³.	Copper found grm.	Error grm.
				A			
			Final volume between 110^{cm^3} and 120^{cm^3}.				
			H_2SO_4 conc.				
0·1200	5·0	4·5	2·5	100	119	0·1200	±0·0000
0·0900	5·0	4·5	3·0	100	114	0·0903	+0·0003
0·0900	5·0	4·5	3·5	100	114	0·0905	+0·0005
			HCl conc.				
0·0900	5·0	4·5	2·0	100	117	0·0897	—0·0003
0·1200	5·0	4·5	2·0	100	119	0·1195	—0·0005
0·0900	5·0	4·5	3·0	100	114	0·0901	+0·0001
0·1200	5·0	4·5	3·0	100	119	0·1200	±0·0000
0·1200	5·0	4·5	3·5	100	119	0·1197	—0·0003
0·0900	5·0	4·5	4·0	100	114	0·0903	+0·0003
			HNO_3 conc.				
0·0900	5·0	4·5	1·0	100	114	0·0900	±0·0000
0·1050	5·0	4·5	1·5	100	117	0·1051	+0·0001
0·0900	5·0	4·5	2·5	100	114	0·0901	+0·0001
			50 per cent $HC_2H_3O_2$				
0·1200	5·0	4·5	3·0	100	119	0·1195	—0·0005
0·0900	5·0	4·5	5·0	100	114	0·0898	—0·0002
0·1050	5·0	4·5	10·0	100	117	0·1048	—0·0002

TABLE V (continued).

Copper taken as $Cu(NO_3)_2$ grm.	KI Present grm.	KI Approximate excess grm.	Acid cm^3.	Volume at beginning of titration cm^3.	Volume at end of titration cm^3.	Copper found grm.	Error grm.
			B				
		Final volume between 140^{cm^3} and 155^{cm^3} without increase of KI.					
0·3336	5·0	3·5	H_2SO_4 3	100	153	0·3315	—0·0021
0·2818	5·0	4·0	HCl 2	100	144	0·2797	—0·0021
0·3320	5·0	3·5	HNO_3 3	100	152	0·3290	—0·0030
0·2541	5·0	3·5	$HC_2H_3O_2$ 6	100	140	0·2523	—0·0018
			C				
		Final volume increased to 132^{cm^3} and 150^{cm^3}, with corresponding increase of KI.					
			H_2SO_4 conc.				
0·2218	7·0	6·0	2	100	135	0·2214	—0·0004
0·3231	8·0	6·4	3	100	150	0·3226	—0·0005
			HCl conc.				
0·2023	7·0	6·0	2	100	132	0·2016	—0·0007
0·2581	7·8	6·7	3	100	141	0·2574	—0·0007
			HNO_3 conc. purified				
0·2023	8·0	7·0	1	100	132	0·2017	—0·0006
0·2520	10·0	8·5	3	100	148	0·2512	—0·0008
			$HC_2H_3O_2$ 50 per cent				
0·2125	7·5	..	5	100	133	0·2119	—0·0006
0·2064	8·0	..	8	100	132	0·2058	—0·0009

The N/10 sodium thiosulphate used in estimating the iodine liberated added appreciably to the initial volume, 100^{cm^3}, of the solution. In series A the increase of volume, less than 20^{cm^3}, did not affect appreciably the accuracy of the determinations. In series B the increase of volume to 140^{cm^3}, without corresponding increase in the amount of potassium iodide present, did affect the indications unfavorably.

In series C, however, the unfavorable effect of similar dilution was overcome by the addition of more potassium iodide.

It is apparent that at any volume a very considerable excess of potassium iodide above the theoretical equivalent involved in the reaction is necessary, and that the necessary excess increases very materially with the dilution of the solution. It appears also that the noted small amounts of sulphuric acid, hydrochloric acid, and nitric acid (free from nitrogen oxides) exert no appreciable influence upon the indications of the process carried out at a volume approximately 100^{cm^3}; and that acetic acid may be present in amount equivalent to at least 25 per cent of the absolute acid.

We find no ground for the inference of Moser* that the presence of acid, best sulphuric acid, is necessary to the attainment of good results at all volumes excepting the most concentrated: and there appears to be no reason why the addition of small amounts of acid should increase the amount of iodine liberated if the potassium iodide is free from iodate or other oxidizer. We are wholly unable to offer any explanation for Moser's extraordinary observation, quite contrary to our own, that variation in the amounts of $\frac{10N}{1} H_2SO_4$, from 1^{cm^3} to 100^{cm^3} (0·49 grm. to 49 grm.) for 50^{cm^3} of a solution of copper sulphate, is practically without effect in the treatment by potassium iodide.

The best general procedure in determining by the iodometric method amounts of copper not exceeding about 0·3 grm. seems to us to be covered by the following directions:—The solution of the cupric salt, containing no more than 3^{cm^3} of concentrated sulphuric acid, hydrochloric acid or nitric acid (free from nitrogen oxides), or 25^{cm^3} of 50 per cent acetic acid, is to be made up to a volume of 100^{cm^3}, 5 grm. of iodate-free potassium iodide are to be added, and the titration of the free iodine is to be made by sodium thiosulphate in the usual manner with the use of the starch indicator at the end. In case the end reaction has not appeared when 25^{cm^3} of the thiosulphate have been added, 2 grm. to 3 grm. more of potassium iodide are to be added before continuing the titration.

The error of the process, properly conducted, should not exceed a few tenths of a milligram in terms of copper.

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* Zeitschr. anal. Chem., xliii, 597, 1904.

ART. VIII.—*The Strength and Elasticity of Spider Thread;*
by J. R. BENTON, PH.D.

THE writer of this note happened to notice a spider thread of such extraordinary thickness and length ($0 \cdot 01^{cm}$ in diameter; $2 \cdot 5^{m}$ long) as to suggest the idea of measuring its physical properties, since this could easily be done with the thread in question, though it would be exceedingly difficult with spider threads of the usual size.

The results may be of interest for the following reasons: (1) as furnishing a test of the popular idea that spider threads are composed of a substance of extraordinarily great strength; (2) on account of the occasional technical application of spider threads in the reticules of scientific instruments; and (3) because the material of the thread, in its chemical nature, is placed among the proteids, which usually have peculiar mechanical properties. On account of the great complexity of chemical structure of the proteids, their physical properties may be especially useful in determining their relationships with one another. In the present instance, the mechanical properties of spider thread may furnish ground for deciding whether or not its material is identical with silk, as is sometimes asserted.

A spider thread, as is well known, is not usually composed of a single fiber, but of a number of fibers adhering together more or less closely. In the thread used for the present study, the number of component fibers was very large. It was not feasible to count them directly; but single fibers, when separated from the main thread, could be seen to have a diameter less than one-twentieth of that of the main thread. This would indicate several hundred fibers in the main thread, if it can be assumed that all of the component fibers have the same size. The component fibers appeared to adhere together only very loosely; at some places bundles of them were distinctly separate from the rest of the thread. Under such circumstances the apparent cross-section of the thread varied greatly from point to point. The true cross-section must be known in order to determine the mechanical properties of the material; and as it was not feasible under these circumstances to ascertain the true cross-section, the thread was twisted, so as to bring all of the component fibers into one compact mass. The twist applied amounted to three revolutions for each centimeter of length, and it resulted in bringing the fibers together into a cross-section of fairly perfect circularity. The diameter, as measured by a micrometer microscope, varied from point to point between the limits $\cdot 0076^{cm}$ and $\cdot 0103^{cm}$.

Tensile Strength.—The following results were obtained for the tensile strength, or stress to produce rupture, the thread having been twisted as described:

Number of trial	Load at rupture in grams weight	Cross-section at point of rupture	Stress at rupture Dynes per cm^2	Stress at rupture Pounds per sq. in.
1	40	$5{\cdot}28 \times 10^{-5} cm^2$	$7{\cdot}4 \times 10^8$	11000
2	82	5·28	15·2	22000
3	85	4·55	18·3	27000
4	85	4·55	18·3	27000
5	88	4·55	18·9	28000
6	98	4·95	19·4	28000
Final value: (Mean of trials 2, 3, 4, 5, and 6)			$18{\cdot}0 \times 10^8$	26200

It would seem justifiable to assume that the first trial, giving a value less than half the mean of the other, represents some anomalous condition (such as a flaw in the material). It is accordingly rejected.

It appears then that the material of this thread possesses quite a high tensile strength, about double that of most kinds of wood (the value for pine being about 10,000 and for other woods ranging between 6,000 and 23,000 pounds per square inch).

Variations in Length.—The length of the thread was found to vary irregularly from day to day, the stretching force being constant. This was probably due to absorption of moisture, but was not definitely investigated.

Elastic After-effect.—If the stretching force was changed, the thread stretched (or contracted); but the strain so produced did not at once assume a constant value, but gradually varied. Thus in one set of experiments, the stress was increased by 5×10^7 dynes per cm^2 (730 pounds per square inch) or 1/36 of the mean breaking strength, and readings taken at intervals of 30 seconds after applying the load gave the following values for the strain (mean of three trials):

·00200
·00203
·00207
·00210
·00218

Upon removing the load as soon as these readings were taken, the following values of the strain were observed at intervals of 30 seconds:

·00048
·00040
·00037
·00034
·00029

Similar, but much less distinct, effects were observed when the change in stress was only half as great.

On account of the hygroscopic properties of the substance it was not feasible to follow these changes over any great length of time.

Young's Modulus.—In view of the variations of strain just described, it is clear that any value obtained for Young's modulus, or the ratio of stress to the corresponding strain, must involve some arbitrariness depending upon the time when the strain is observed. A similar situation exists for most other substances, however, though it is not usually emphasized in publications as much as, in the writer's opinion, it ought to be. Most (if not all) substances exhibit some elastic after-effect after any change of stress, even when the change of stress is very small. It is customary, in computing the modulus of elasticity, to use the value of the strain observed immediately after changing the stress. The result obtained in this way will be approximately the same as if any later value of the strain were used, the approximation being more or less good according as the elastic after-effect is more or less small.

In the present experiments a load was applied long enough (about three minutes) to obtain five readings for the increase in length; then the load was removed, and five readings were immediately taken. The change in length, as determined from the mean of the five readings with the load, and the mean of the five readings after removing the load, was made the basis of computation for Young's modulus.

The first experiments were made with a thread $6{\cdot}2^{\mathrm{cm}}$ long and $6{\cdot}19 \times 10^{-5}$ cm^2 in mean cross-section. The mean of ten experiments gave for Young's modulus $3{\cdot}27 \times 10^{10}$ dynes per cm^2 (480,000 pounds per square inch), the different determinations varying from $2{\cdot}98$ to $3{\cdot}62 \times 10^{10}$ dynes per cm^2. The change in stress employed was $2{\cdot}5 \times 10^7$ dynes per cm^2. With larger change in stress the after-effects were so great as to prevent proper determination of the modulus.

Ten experiments were also made with another piece of the thread, $16{\cdot}5^{\mathrm{cm}}$ long, and $5{\cdot}30 \times 10^{-5}$ cm^2 in mean cross-section, twisted with a specific twist of three revolutions per centimeter of length, the same range of stress being used. They gave a mean value for Young's modulus of $2{\cdot}70 \times 10^{10}$ dynes per cm^2 (390,000 pounds per square inch), the extremes being $2{\cdot}10$ and $3{\cdot}29 \times 10^{10}$ dynes per cm^2.

Adopting as the final value for Young's modulus $3{\cdot}0 \times 10^{10}$ dynes per cm^2, it appears that the material of the spider thread is, like most organic materials, much more stretchy than the metals (modulus about 10^{12}), but does not at all approach such a substance as rubber (modulus about 10^9 dynes per cm^2).

Elongation at rupture amounted to about 20 per cent of the original length of the thread.

The thread showed a distinct elasticity of torsion; but in view of its complex structure, data on torsion can not have any very definite significance, and accordingly are not presented.

Specific Gravity.—A 10^{cm} length of the thread, of mean cross-section 5×10^{-5} cm^2, weighed $0{\cdot}33^{mg}$, which gives for the specific gravity, 0·66.

Comparison with Silk Fibers.—The mechanical properties of silk fibers have been studied by Beaulard,* who found for the tensile strength $2{\cdot}85 \times 10^8$ dynes per cm^2, and for Young's modulus $6{\cdot}50 \times 10^{10}$ dynes per cm^2. As these values differ from those for the spider thread by amounts greater than would be accounted for by experimental errors, it seems probable that the material of the spider thread is different from silk.

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*F. Beaulard: Comptes rendus, cxxxv, pp. 623–626, 1902; Journal de physique, ii, 785–795, 1903; quoted in Science Abstracts, 1903, p. 129, and 1904, p. 137.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *A New Intermediate Product in Thorium.*—It is well known that the radio-activity of ordinary thorium has been attributed by HAHN to radio-thorium, an element so closely related chemically to inactive thorium that the separation of the two presents the greatest difficulties. Boltwood and Dadourian of Yale University both found that the activity of thorium minerals depends directly upon the amount of thorium in them, from which it follows that radio-thorium must be a product derived from ordinary thorium. The same investigators found, however, that commercial thorium nitrate possessed an activity less than one-half as great as it should have, according to the activity of the minerals. This striking result led at first to the belief that radio-thorium must have been separated to a large extent in the process of manufacturing the salt, in spite of the fact of the well-known difficulty of this separation. Hahn has now explained the cause of the low radio-activity of the artificial salt in a very ingenious and satisfactory manner. Upon examining samples of thorium nitrate, which had been kept for various lengths of time, he found that products recently made from monazite gave the activity to be expected according to the amounts of thorium in them, while older preparations gave a much diminished activity. The activity appears to diminish for about three years, then to remain nearly constant for a considerable period, and finally to increase gradually. Hahn explains this behavior by supposing that a product intermediate between thorium and radio-thorium, which emits no α-particles, is separated in the technical production of thorium nitrate ; the radio-thorium, which appears to have a period of decay of about two years, gradually disappears until a sufficient amount of the more slowly formed and more slowly decomposing intermediate substance has been formed to cause the radio-thorium to increase towards equilibrium. At present the data are uncertain, but Hahn estimates that the period of existence of the intermediate product is about 7 years, and that equilibrium would be reached in about forty years. Hahn believes that he has positive proof of the existence of the intermediate product in some preparations which, while containing no appreciable quantity of thorium, are increasing in activity and are producing radio-thorium. Mesothorium is the name suggested for the intermediate body.—*Berichte*, xl, 1462. H. L. W.

2. *The Interference of Fluorides with the Precipitation of Alumina.*—For the determination of the bases in silicates, the method sometimes used is the treatment of the substance with hydrofluoric and sulphuric acids, followed by evaporation and heating until fumes of sulphuric acid come off, in order to remove

the silica and get a solution of the bases. Following this method, Hinrichsen observed that the results obtained in determining alumina were sometimes very much too low, even as much as 30 per cent of the whole amount. He traced the difficulty to the circumstance that the fluorine is often removed very incompletely by evaporation with sulphuric acid in such cases, and to the very surprising fact, apparently hitherto unknown, that ammonium fluoride interferes with the precipitation of aluminium hydroxide by means of ammonia. In fact, when ammonia was added to a solution of aluminium sulphate, which had been acidified with hydrofluoric acid, no precipitate came down while the liquid was hot, but upon cooling a crystalline deposit of ammonium aluminium fluoride, $(NH_4)_3AlF_6$, analogous to cryolite, Na_3AlF_6, was obtained. Hinrichsen has made a quantitative study of this solvent effect of ammonium fluoride and found that 0.6 g. of NH_4F was sufficient to keep in solution 0.14 g. of Al_2O_3. He recommends avoiding the decomposition of silicates for analysis by means of sulphuric and hydrofluoric acids except in cases where the presence of alkalies makes it "unavoidable." (Like most of the German chemists, he is evidently unfamiliar with the excellent method of J. Lawrence Smith for the determination of the alkalies.) When the method is used he advises evaporating off the sulphuric acid completely and gently igniting the residue, in order that the fluorine may be completely removed.

The interesting and important fact disclosed by Hinrichsen's work led the writer of this notice to confirm it by qualitative experiments. It was found that while ammonium fluoride readily prevents the precipitation of aluminium hydroxide by ammonia, this is not the case with ferric hydroxide, and further that the addition of a soluble phosphate to such a solution causes the precipitation of aluminium phosphate. It appears possible that a method for the separation of iron and aluminium might be based upon this behavior, the aluminium to be precipitated as phosphate and weighed as such.—*Berichte*, xl, 1497. H. L. W.

3. *Magnetic Compounds of Manganese with Boron, Antimony and Phosphorus.*—Until a few years ago the only magnetic metallic substances known were iron, nickel and cobalt. Then several alloys of non-magnetic constituents were found to be strongly magnetic, all of which contained manganese, viz., manganese-tin, manganese-aluminium and manganese-aluminium-copper. It appears, however, that Wöhler had noticed nearly 50 years ago the first case of a magnetic compound of non-magnetic elements in the oxide of chromium Cr_5O_9. Wadekind has recently found that the boride of manganese, MnB, has remarkably strong magnetic properties, probably one-quarter to one-half as great as soft iron, while the compound MnB_2 does not appear to be magnetic at all. The antimonide, MnSb, seems to be about twice as strongly magnetic as the boride, while the phosphide Mn_3P_2 shows this property to a much slighter extent.—*Berichte*, xl, 1259. H. L. W.

4. *A New Variety of Chromium.*—It has been observed by JASSONNEIX that metallic chromium, or also this metal containing boron or carbon, when heated in the electric furnace in contact with much copper, gives a solution containing about 1·6 per cent of chromium. Upon cooling, the chromium separates in a mossy, crystalline condition, and this can be separated from the matrix of copper by dissolving the latter in nitric acid. The product is almost pure chromium in a very fine state of division. It is stable in the air at ordinary temperatures, but it burns like tinder in contact with a flame, and ignites in oxygen at about 300°, giving a very brilliant incandescence.—*Comptes Rendus*, cxliv, 915.

H. L. W.

5. *Memoir and Scientific Correspondence of the late Sir George Gabriel Stokes.* Selected and arranged by JOSEPH LARMOR. In two volumes, Vol. I, pp. xii + 475; Vol. II, pp. vi + 507. Cambridge, 1907 (The University Press).—From 1854 to 1885 Sir George Stokes was Secretary of the Royal Society and had much to do with the scrutiny to which that society subjects papers which are offered for publication in its transactions. He performed these duties so carefully, with so much kindness and critical acumen, and offered so many helpful suggestions to the authors of papers that he gradually came to occupy the place of adviser and friendly critic to most of the British physicists of his own and of the younger generation. His correspondence was thus very large and he saved all letters which came to him, so that at his death more than ten thousand letters were found. Out of this great number Professor Larmor has made a careful selection and, in many cases, has been able to obtain Stokes's replies, which are inserted in their proper places. We have the result in the two volumes under review, which no student of physics can read without keen delight and very great profit. Stokes's life-time covered that great era of physical discovery which (if second to any other) is second only to the time of Newton; he, and some of his correspondents, contributed more, probably, to these great results than any other group of men in any country. And in these volumes we find the intimate, contemporary history of this active time; we read the first informal accounts of important discoveries, or of tentative and hesitating speculations which have since become the classical theories of physical science. One gets thus a feeling for historical perspective and an appreciation of how discoveries are made which could hardly be obtained in any other way. Another thing which comes out quite clearly, is the effect which Stokes's activity had upon the progress of his science indirectly, through his advice and assistance to others, and quite independently of his published contributions. Many investigators have gratefully acknowledged their indebtedness to him, and these letters show very clearly that the gratitude was well-deserved. Lord Kelvin, in particu-

lar, has more than once insisted upon his own obligations to his friend for advice and suggestions; and though the correspondence between these two great men is not included in the present volumes, one is glad to learn from the preface that the letters on both sides have been preserved and will be published separately as "a memorial of the life-long friendship and collaboration of the authors."

Besides the scientific correspondence there are letters of biographical interest, and the first volume begins with an admirable chapter of personal "Notes and Recollections" of Sir George Stokes by his daughter, Mrs. Humphry. A useful index is appended to each volume. H. A. B.

6. *Elektrische Fernphotographie und Ähnliches;* von ARTHUR KORN. Pp. 87, with 21 figures and 1 table. Zweite Auflage. Leipzig, 1907 (S. Hirzel).—This second edition follows the first issue after an interval of some three years. The subject with which it deals is one in which so much active work has been and is still being done that in many respects, especially from the practical side, the situation is materially changed. The author, who has already presented the prominent advances in wireless telegraphy in recent numbers of the *Physikalische Zeitschrift*, now gives them to a wider public in this volume. Although brief in extent, the subject is clearly and adequately presented.

II. GEOLOGY.

1. *United States Geological Survey.*—Recent publications of the U. S. Geological Survey are included in the following list (continued from vol. xxiii, p. 226):

TOPOGRAPHIC ATLAS. One hundred and forty folio sheets.

MINERAL RESOURCES of the United States: Calendar Year 1905. DAVID T. DAY, Chief of Division of Mining and Mineral Resources. Pp. 1403, with one figure.—This is the twenty-second volume of this valuable series; many of the chapters have already been placed in the hands of the public as separate pamphlets.

PROFESSIONAL PAPERS, No. 57. Geology of Marysville Mining District, Montana: A Study of Igneous Intrusion and Contact Metamorphism; by JOSEPH BARRELL. Pp. x, 178, with 16 plates (two in cover) and 9 figures.—See p. 85.

BULLETINS, No. 279. Economic Geology of the Kittanning and Rural Valley Quadrangles, Pennsylvania; by CHARLES BUTTS. Pp. 198, with 11 plates and 14 figures.

No. 286. Economic Geology of the Beaver Quadrangle, Pennsylvania (Southern Beaver and Northwestern Allegheny Counties); by LESTER H. WOOLSEY. Pp. 132, with 8 plates and 35 figures.

No. 287. The Juneau Gold Belt, Alaska; by ARTHUR C. SPENCER: and A Reconnaissance of Admiralty Island, Alaska, by CHARLES WILL WRIGHT. Pp. xii, 161, with 37 plates and 41 figures.

No. 294. Zinc and Lead Deposits of the Upper Mississippi Valley; by H. FOSTER BAIN. Pp. xi, 155, with 16 plates and 45 figures.

No. 296. Economic Geology of the Independence Quadrangle, Kansas; by FRANK C. SHRADER and ERASMUS HAWORTH. Pp. 74, with 6 plates and 3 figures.

No. 297. The Yampa Coal Field, Routt County, Colorado; by N. M. FENNEMAN and HOYT S. GALE: with a chapter on the Character and Use of the Yampa Coals by MARIUS R. CAMPBELL. Pp. 97, with 9 plates and 2 figures.

No. 303. Preliminary Account of Goldfield, Bullfrog, and other Mining Districts in Southern Nevada; by FREDERICK LESLIE RANSOME; with Notes on the Manhattan District by G. H. GARREY and W. H. EMMONS. Pp. 98, with 5 plates and 15 figures.

No. 305. The Analysis of Silicate and Carbonate Rocks; by W. F. HILLEBRAND. Pp. 200, with 24 figures.

No. 314. Report on Progress of Investigations of Mineral Resources of Alaska in 1906; by ALFRED H. BROOKS and others. Pp. 235, with 4 plates and 9 figures.

No. 315. Contributions to Economic Geology 1906. Part I—Metals and Non-metals, except Fuels. S. F. EMMONS, E. C. ECKEL, Geologists in Charge. Pp. 505, with 4 plates and 20 figures.

WATER SUPPLY and IRRIGATION PAPERS, No. 182. Flowing Wells and Municipal Water Supplies in the Middle and Northern Portions of the Southern Peninsula of Michigan; by FRANK LEVERETT and others. Pp. xl, 292, with 5 plates and 69 figures.

No. 187. Determination of Stream Flow during the Frozen Season; by H. K. BARROWS and ROBERT E. HORTON. Pp. 99, with 1 plate and 14 figures.

No. 188. Water Resources of the Rio Grande Valley in New Mexico and their Development; by WILLIS T. LEE. Pp. 59, with 10 plates and 2 figures.

No. 191. The Geology and Water Resources of the Western Portion of the Panhandle of Texas; by CHARLES N. GOULD. Pp. 70, with 7 plates and 3 figures.

No. 192. The Potomac River Basin; by HORATIO N. PARKER, BAILEY WILLIS, R. H. BOLSTER, W. W. ASHE, and M. C. MARSH. Pp. vi, 364, with 10 plates and 2 figures.

No. 193. The Quality of Surface Waters in Minnesota; by R. B. DOLE and F. F. WESBROOK. Pp. 171, with 7 plates and 4 figures.

No. 194. Pollution of Illinois and Mississippi Rivers by Chicago Sewage; by MARSHALL O. LEIGHTON. Pp. 369, with 2 plates and 5 figures.

No. 196. Water Supply of Nome Region, Seward Peninsula, Alaska, 1906; by JOHN C. HOYT and FRED F. HENSHAW. Pp. 52, with 6 plates and 1 figure.

No. 200. Weir Experiments, Coefficients, and Formulas (Revision of Paper No. 150); by ROBERT E. HORTON. Pp. 195, with 38 plates and 17 figures.

2. *Wisconsin Geological and Natural History Survey.* Bulletin No. xv. Economic Series No. 10. *The Clays of Wisconsin and their Uses,* by HEINRICH RIES; with a *Report on Molding*

Sands, by H. RIES and F. L. GALLUP. Pp. xii, 259, with 30 plates and 7 figures. Madison, Wis., 1906.—The geological and chemical relations of the clays of Wisconsin were described in a Bulletin of the State Survey by Dr. E. R. Buckley, issued in 1900. A second part dealing with physical and other tests of the bricks made from the clays was projected but not completed. The present Bulletin by Dr. Ries takes up this latter aspect of the matter, as well as dealing independently with the whole subject of the clay industry. The observations upon which the report is based have been accumulated by the writer with the assistance of Mr. F. L. Gallup. It may be noted that the value of the products of the clay-working industries of the State in 1905 was $1,382,000, of which more than 90 per cent was in common brick. The author discusses the probable future of the industry and concludes that there is likely to be a steady increase in the annual production of clay products and raw clays in the State. The second part of the volume is devoted to a report on the molding sands by the two gentlemen already named.

3. *Geological Survey of Alabama. The Underground Water Resources of Alabama;* by EUGENE A. SMITH. Prepared in coöperation with the United States Geological Survey. Pp. xvi, 388, with 30 plates and 23 figures. Montgomery, 1907 (The Brown Printing Co).—The material of the present volume was largely developed by work carried on jointly by the State Survey and that of the general Government. Water Supply Papers Nos. 102 and 114 (U. S. G. S.) contain most of the well records here given, as also a sketch map of the Artesian Water System. The subject has been further investigated, however, and the results are now published under the auspices of the Alabama Survey. A somewhat full account of the geology of the State bearing upon this subject is given, and the subject of Underground Waters and Artesian Wells in general is also discussed. Then follows an account by counties of the wells of the State, followed by data in regard to their chemical character. It is interesting to note that of the 1414 wells described, 86 per cent are in the Cretaceous, about 10 per cent in the Tertiary, and the remainder, 4 per cent, in the older forms of the Appalachian division. The larger part of the wells are in the outcrop of the Selma chalk and obtain their supply mainly from the Eutaw sands, although some penetrate as low as the Tuscaloosa strata. A series of maps shows the geological and geographical relations of these underground waters.

4. *Geological Survey of Western Australia, Mt. Margaret Goldfield;* by CHAS. G. GIBSON, Assistant Geologist. Bulletin No. 24. 77 pp., 7 figs., 26 pls., with 13 geological and mining maps. Perth, 1906 (Fred. Wm. Simpson, Government Printer).—This report is the most recently issued of the series of special bulletins dealing with the mineral fields of Western Australia. The bed-rock throughout the region is granite, which occurs in dikes and bosses, and greenstone,—both massive and foliated

varieties. The weathering of the granite rocks to a great depth is one of the marked features of the area. In the Laverton belt the ore occurs as hematite-quartz lodes and as reefs; the Burtville mines are in small quartz reefs of exceptional richness, and the Erlistoun belt contains ore in veins and mingled with hematite-bearing quartz lodes.

5. *Geology of the Marysville Mining District, Montana;* by JOSEPH BARRELL. Prof. Paper No. 57, U. S. Geol. Surv., pp. x, 178, with 16 plates and 9 figures, including maps in cover. As stated in the sub-title, this is chiefly "a study of igneous intrusion and contact metamorphism." The Marysville region lies 17 miles northwest of Helena, and its importance as a mining district is due to the deposition of ores in the contact-zone of a small bathylith or stock of quartz diorite about 2½ miles long by 1½ broad at its widest part. The map which accompanies the work, on a scale of ½ mile to the inch, presents the detailed geology of an area about 5½ by 8 miles in length and breadth. The sedimentary rocks are upturned limestones and shales of Algonkian age, through which the igneous mass has been intruded with peripheral sheets and dikes of aplite, microdiorite and diorite-porphyry, with some small intrusions of gabbro in another place. All of these varied features receive adequate treatment, but the special character of the work lies in the detailed investigation of the bathylithic body, of the method of its intrusion, of its form and of its relations to the surrounding rock masses both past and present. Added to this is a study of the contact phenomena produced, from various points of view, all of which are treated in detail. The presentation of the geological facts shown by the very careful and complete study of the district is accompanied by a very full discussion of them on the theoretical side, so far as they have a bearing on the main problems of the area.

In regard to the manner of intrusion, Professor Barrell believes this was accomplished, not by the filling of a predetermined chamber, nor by marginal assimilation and melting of the walls, nor by laccolithic invasion, but by magmatic stoping, that is by a process of passive invasion of the sediments, by the breaking off of blocks from the roof and their subsidence into the body of the magma, the latter thus eating its way upward. He is led to this view by the insufficiency of other hypotheses and by certain positive facts which are presented. This view, as a method of explanation for the "*mise en place*" of many bathylithic bodies of granite, has been advanced by other geologists, but this is the most complete and adequate presentation of it, founded upon details of actual occurrence carefully worked out, that has yet appeared. Thus the work, though devoted to the local geology of a small area, is of wide interest since the problems treated are of great general importance.

L. V. P.

6. *Invertebrate Paleontology of the Upper Permian Red Beds of Oklahoma and the Panhandle of Texas;* by J. W. Beede. Kansas Univ. Science Bull., vol. iv, 1907, pp. 115–171, pls. v–viii. —Here is presented a long and detailed historical review of the Permian in the area named in the title. The author concludes that "the Wichita (including the Albany) and Clear Fork beds of Texas are unmistakably Permian. * * * The light-colored Permian rocks of Kansas and Texas have their equivalents in the red strata of Oklahoma."

The fauna described is from the Red-Bed series at Whitehorse spring, west of Alva, Oklahoma, and near Dozier, Texas. "Some of the species seem directly derived from the Kansas Permian or Pennsylvanian, while others * * * are derived from the European Permian, especially that of Russia. There seems to be comparatively little resemblance to the Indian or Chinese forms." These latter faunas are of the normal type, while those of Russia and this American region are of a very salty sea yielding Red Beds, gypsum, and salt. It is therefore probable that the physical condition rather than faunal migration has in the main caused the resemblance pointed out. Further, as "the preservation of the specimens is such as to obliterate many of the critical characters," it seems, at least for the present, safer to assume that the invertebrates of the Red Beds are a direct outgrowth of the previous Pennsylvanian species of the same region.

The named species number 28, of which 23 are new. It is almost entirely a molluscan assemblage, there being 13 Pelecypoda, 14 Gastropoda and 1 brachiopod. The difference between this assemblage and that described many years ago by White, from the Wichita, is very striking, as the latter is a biota of decidedly Pennsylvanian character plus 4 ammonites with Mediterranean affinities. These differences are hardly satisfactorily explained by differences in facies alone, as "the Wichita material is a limestone fauna, while the fauna [here described] * * * is a sandstone fauna." All in all, paleontologists are thankful for this contribution, but it is evident that much yet remains to be done in the field before a complete unraveling of the physical and faunal conditions during the Pennsylvanian and Permian of the Southwest, now bound up in the Red-Beds formations, is at hand. C. S.

7. *The Stromatoporoids of the Guelph Formation in Ontario;* by W. A. Parks. Univ. Toronto Studies, Geol. Ser., No. 4, 1907, pp. 137–172, pls. 1–6.—This is the first of a much-desired proposed work on the American Stromatoporoids, and treats of all the recognizable species in the higher Silurian, the Guelph of Ontario. The illustrations are heliotype reproductions of good drawings by the author, showing the microscopic structure. There are, of *Actinostroma*, 1 new species; of *Clathrodictyum*, 3 species; *Labechia*, 2 new; *Rosenella*, 1 new; *Stromatopora*, 1; *Stromatoporella*, 2 new; *Hermatostroma*, 1 new species. C. S.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Bulletin of the Bureau of Standards.* S. W. STRATTON, Director. Vol. ii, No. 3, pp. 319–483; vol. iii, No. 1, pp. 1–161.—The two numbers above noted complete the second volume of the Bulletin of the Bureau of Standards and begin the third volume. This Bureau, since it was established by Act of Congress in 1901, has not only accomplished its organization on a practical basis, carried on the regular routine work of the office, and issued a series of twelve Bureau circulars, but it has also completed a large number of investigations in various related lines in physics and chemistry. The papers which have thus far appeared in the Bulletin number fifty-four. A considerable number of these deal with electrical problems, including theoretical discussions, as for example that by Dr. E. B. Rosa (vol. ii, No. 3) on the formulæ for the mutual inductance of coaxial coils; also measurements of inductance, capacity, electromotive force; descriptions of instruments, as the electrodynamometer and potentiometer, etc. The different aspects of photometry are repeatedly presented, with also the problems of radiation, absorption and spectroscopy, the phenomena of incandescent lamps, etc. Still other papers deal with subjects under heat, the testing of thermometers, and so on.

A large number of workers have contributed to the list of papers referred to; among these the following names are often repeated: E. B. Rosa, E. P. Hyde, P. G. Nutting, K. E. Guthe, G. K. Burgess, C. W. Waidner. W. W. Coblentz has an article in vol. ii, No. 3, on a vacuum radiomicrometer, and another on the investigation of infra-red absorption and reflection spectra. This last is a somewhat novel method of investigating the chemical constitution of various compounds, chiefly minerals. The fact is brought out that minerals containing water of crystallization show quite uniformly water bands, while those containing hydroxyl groups generally have a marked band at 3μ; further, sulphates have a strong band at $4{\cdot}55\mu$, one less constantly shown at $9{\cdot}1\mu$, while silicates lack such definite bands, thus suggesting a lack of uniformity in the structure of the silicate radical. The fact that the 3μ band is absent with talc, while it is given by serpentine, confirms the general view that hydroxyl is present in the latter but not in the former species.

2. *Carnegie Institution of Washington.*—Recent publications from the Carnegie Institution are included in the following list:

Variation and Differentiation in Ceratophyllum; by RAYMOND PEARL with the assistance of OLIVE M. PEPPER and FLORENCE J. HAGLE. Pp. 136, with 26 figures and 67 tables.—The immediate purpose of this investigation is stated to be an "attempt to work out as exactly and completely as possible for a particular organism the laws according to which post-embryonic differentiation and growth occur."

The Collected Mathematical Works of GEORGE WILLIAM HILL. Volume Four. Pp. 460, 4to.—This volume contains memoirs No. 51 to No. 84.

Research in China. In three volumes and Atlas. Volume I in two parts. Part I: Descriptive Topography and Geology; by BAILEY WILLIS, ELIOT BLACKWELDER, and R. H. SARGENT. Pp. xiv, 353, xvi, with 51 plates and 65 figures. Accompanied by a folio Atlas embracing 41 pages of Geographical and Geological Maps, largely colored.—A notice of this highly important work will appear later.

Selection and Cross-breeding in Relation to the Inheritance of Coat-pigments and Coat-patterns in Rats and Guinea-pigs; by HANSFORD MACCURDY and W. E. CASTLE. Pp. 50, with 2 plates and 31 tables.

Further Researches Concerning Atomic Weights of Potassium, Silver, Chlorine, Bromine, Nitrogen, and Sulphur; by T. W. RICHARDS in collaboration with ARTHUR STAEHLER, GEORGE S. FORBES, EDWARD MUELLER, and GRINNELL JONES. Pp. 88.

The Compressibilities of the Elements and Their Periodic Relations; by THEODORE W. RICHARDS, in collaboration with W. N. STULL, F. N. BRINK, and F. BONNET, JR. Pp. 67, with 7 figures.

3. *Field Museum of Natural History.*—The official title of the Field Columbian Museum, as it was formerly known, has recently been changed to the form here given. The Annual Report of the Director, Dr. Frederick J. V. Skiff, to the Board of Trustees for 1906, contains besides general administrative matter of particular importance to those engaged in museum work, a portrait of the late Mr. Marshall Field, the founder of the Museum, and some remarks about him and his work. Other publications of the Museum recently issued include the following:—

Botanical Series. Vol. II, No. 4, Publication 117. Studies in the Genus Citharexylum; by JESSE MORE GREENMAN. Pp. 185–190. Vol. II, No. 5. (No. 118.)

Flora of the Sand Keys of Florida; by CHARLES FREDERICK MILLSPAUGH. Pp. 191–243.

Geological Series, Vol. III, No. 5. (No. 120.) Analyses of Iron Meteorites; compiled and classified by OLIVER CUMMINGS FARRINGTON. Pp. 59–110.—The author has here brought together all reliable analyses of iron meteorites classified according to the physical structure of the specimens, the classification being that ordinarily in use as developed particularly by Brezina and Cohen. This compilation is not only of very great interest and value in itself, but it serves to bring out clearly the relation between chemical composition and structure. In regard to this the author states:—

"The most striking feature brought out by the analyses is the relation shown between chemical composition and structure. This seems to be definite and general. All the meteorites of a hexahedral structure have a nearly uniform composition, while among the octahedral meteorites, fineness of structure increases with increase of nickel. This conclusion can best be shown by obtaining the averages from the analyses of the different groups, omitting all obviously faulty analyses. The results thus obtained are as follows :—

Class.	No. of analyses.	Width of lamellæ in millimeters.	Per cent Fe.
Hexahedrites	29	------	94·12
Coarsest oxtrahedrites	12	+ 2·5	93·18
Coarse "	22	2·0–1·5	92·28
Medium "	88	1·0–0·5	90·64
Fine "	41	0·4–0·2	90·18
Finest "	13	0·2– —	88·51

"It is worthy of note that these averages are not means between wide limits, but are derived from nearly uniform values. Practically all of the members of the classes conform in composition to the average. Were all the groups equally well known, it is probable, too, that the gradation of percentage of Fe would be even more uniform than here shown. The medium octahedrites, for example, while numerous, have been as a whole imperfectly analyzed. Moreover, some of the meteorites classed as medium octahedrites, which are characterized by low percentage of iron, such as Algoma and Glorieta Mountain, have width of lamellæ such as to place them near if not in the fine octahedrites.

"The apparent conclusion from the above results is, that the content of nickel influences the structure. It may also account for the change from a hexahedral to an octahedral structure, since the irons with a hexahedral structure have the lowest per cent of nickel. So constant and definite does this relation hold, that given a certain structure the per cent of nickel can probably be stated more accurately by this principle than it has been determined in some analyses."

4. *Twenty-fourth Annual Report of the Bureau of American Ethnology to the Secretary of the Smithsonian Institution, 1902-1903 ;* by W. H. Holmes, Chief. Pp. xl, 846, with 21 plates and 1112 figures. Washington, 1907.—The opening pages (i–xl) of this volume are given to details of the administration and work of the Bureau. Following this report is an exhaustive and most interesting paper (pp. 1–846) by Mr. Stewart Culin upon the games of the American Indian. The amount of material collected by the author (in his early work, associated with the late Mr. F. H Cushing) is surprisingly large and varied, and it is presented with admirable fullness of description and illustration; his studies thus throw new light upon the mental characteristics and life of the Indian. The games are either games of chance or of dexterity, those involving pure skill and calculation being absent. Further, the games are found to be essentially identical among all the tribes. It is shown also that they are either connected with definite rites or have come from ceremonial religious observances.

5. *Bulletin of the Imperial Earthquake Investigation Committee.*—Vol. I, No. 2. March, 1907, Tokyo, Japan.—This second number of the Bulletin, the inauguration of which has already been announced (xxiii, 322), is devoted to a series of earthquake papers by Professor F. Omori. One of these discusses the Valparaiso and Aleutian earthquakes of August 17th, 1906, remarkable as occurring almost simultaneously, although their centers were separated by a little more than two-thirds of the earth's seismic circumference. These disturbances were doubtless not independent, but are to be regarded as manifestations of seismic force at the extremities of the earthquake zone which extends along the entire Pacific coast of North and South America. Another article of more than local interest is devoted to the distribution of recent Japan earthquakes; among other points it is shown that the most active seismic zone of Japan forms a connecting link between the Mediterranean-Himalaya zone and the great American zone before alluded to.

6. *Studies in Plant Chemistry and Literary Papers;* by Helen Abbott Michael, with a Biographical Sketch. Pp. 416. Cambridge, Mass., 1907 (The Riverside Press).—Dr. Michael (Helen C. DeS. Abbott) has left a noteworthy record as the result of a brief scientific career, aside from her endeavors in other fields of activity. As a chemist she was, as Dr. Wiley has pointed out in an appreciative introduction, among the very first investigators of this country who began in a systematic way to study the relations of chemical composition to species of plants and plant growth. The relations which she endeavored to establish between morphological and chemical features in plants are pointed out in some of the papers reprinted in this volume. There are also included certain more popular addresses which indicate the advances in the biochemical study of plants and their constituents, especially the influence of environment upon plant composition.

The biographical sketch of 100 pages, by Nathan Haskell Dole, deserves particular notice. In it are reproduced Miss Abbott's detailed impressions of the great teachers whom she met during her travels abroad. One finds most delightful sketches of many of the distinguished chemists and botanists of twenty years ago. The reminiscences of Hoffmann, Liebermann, Ladenburg, Pringsheim, Wislicenus, Pfeffer, E. von Meyer, Bunsen, Kekulé, Crookes and many others make one wish that more of these entertaining impressions were available. They also serve to indicate the difficulties which woman has encountered in gaining scientific recognition, and recall Dr. Michael's pioneer efforts in overcoming current prejudices.

The volume is primarily attractive as the record of the scientific and literary endeavors of a woman "emancipated from the shackles of conservatism." A series of literary papers are appended to the scientific reprints. L. B. M.

7 *Beiträge zur chemischen Physiologie*, herausgegeben von F. Hofmeister. IX. Band. 1906–1907. Braunschweig (Fr. Vieweg und Sohn).—Among the papers which deserve special notice in this volume are the studies of Wiechowski and Wiener on the fermentative destruction of uric acid and the products arising therefrom. New methods of preparing organs for the investigation of the purine enzymes are described and allantoïn was isolated as an enzymatic product resulting from the metabolism of uric acid. Papers from Prof. Hofmeister's laboratory (by Sasaki and Savarè) deal with the non-diffusible substances in the urine and indicate that the compounds included in this group may have significance through the quantitative alterations found in pathological conditions. An elaborate investigation of the debated specific-dynamic action of proteins in nutrition is presented by Falta, Grote and Staehlin. Almost every important department of physiological chemistry is represented in the present volume; e. g. the chemistry of the liver (Bang, Türkel, Goodman), muscle (Saxl, Urano, Comessatti), digestion (Slowtzoff, Schröder, von Fürth), the blood (Loeb, Lefmann), etc.

L. B. M.

8. *The Common Bacterial Infections of the Digestive Tract and the Intoxications arising from them;* by C. A. Herter, M.D. Pp. vi, 360, New York, 1907 (The Macmillan Company).—This book of 357 pages is of special interest to the student and practitioner of medicine. It gives a clear and concise résumé of recent investigations on the pathological conditions of the gastro-intestinal tract. The bacteria of the digestive tract in health and disease are widely discussed, but most of the emphasis is placed on the relation of the bacterial products to various kinds of intestinal diseases. Excessive putrefactive and fermentative processes, and methods of studying and controlling them form a large part of the discussion. The book embodies the views recently presented in a lecture before the Harvey Society for the Diffusion of Medical Knowledge. L. F. R.

9. *Handbook of American Indians North of Mexico.* Edited by Frederick Webb Hodge. Part I. Pp. ix, 972, with one colored map. Washington, 1907. Bulletin 30 of the Bureau of American Ethnology, Smithsonian Institution.—This is the first part of an encyclopedic work on the American Indian. It is arranged alphabetically and the topics give descriptions not only of the various stocks and tribes and other divisions of the aborigines, with the origin and derivation of their names, but it also includes a host of other terms, both general and special, covering all the subjects connected with Indian life and history. A large number of illustrations are introduced, so that the compendium is one of more than usual completeness. The colored chart, due to the late J. W. Powell, shows the distribution of the linguistic families of American Indians.

10. *A University Text-Book of Botany;* by Douglas Houghton Campbell. Second Edition. Pp. xv, 579, with 15 plates

and 493 figures. New York, 1907 (The Macmillan Company).—This is a new edition of a work which has been before the public for some time; the changes introduced are in general unessential in character.

11. *The Birds of the Chicago Area;* by FRANK M. WOODRUFF. The Chicago Academy of Sciences. Bulletin No. VI of the Natural History Survey. Pp. 221, with 10 plates. Issued April 15, 1907.—The area embraced in this catalogue is about fifty miles square and includes all of Cook and Du Page counties with the nine north townships of Will County and a portion of Lake County, Indiana. It is of varied character and is particularly notable for its birds, since it lies on the border between the eastern ranges of many species as well as being in the path of the Mississippi Valley migration. It is not surprising, therefore, that the list of birds here included is unusually large for a single district.

12. *The Seventh International Zoological Congress.*—The International Zoological Congress will meet at Boston on Aug. 19–23. The meetings of sections will be held at the Harvard Medical School on the successive days named. Saturday, August 24, will be devoted to an excursion to Harvard University, and on the succeeding days arrangements have been made for visits to Woods Hole, Columbia University, and the American Museum, to Yale and Princeton Universities, with excursions also to Philadelphia, Washington and Mt. Vernon, and other points; these will occupy the time from Aug. 25 to Sept. 6. In addition there will be a trip to Niagara Falls, across Lake Ontario to Toronto, Sept. 7–9. Finally, an excursion to Bermuda is planned, in case fifty members enroll themselves for it. This last extends the meeting of the Congress until September 22d. Information may be obtained from Charles H. Townsend, Director of the New York Aquarium, Battery Park, N. Y.

13. *Centenary of the Geological Society of London.*—The Geological Society of London, the oldest geological society in existence, was founded in 1807. It is now to celebrate its Centenary, on the 26–28th of September next, and the occasion promises to be one of very great interest. The Society had its beginning when geology was in its infancy, and during the past one hundred years it has been always in close connection with the development of the science and by its active work has contributed very largely to its advancement.

14. *Neues Jahrbuch für Mineralogie, Geologie, und Paläontologie.*—The honored *Jahrbuch*, which for a century has been one of the chief supports of working mineralogists and geologists, is now in its one hundredth year. This notable event is to be celebrated by the publication of a Festband, which will soon be presented to all its subscribers.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART IX.—*On the Radio-Activity of Thorium Salts;* by BERTRAM B. BOLTWOOD.

MEASUREMENTS of the α-ray activities of a number of minerals containing thorium have been described in an earlier paper.* A measure of the ionization produced by known weights of the finely-powdered minerals in the form of thin films was obtained by introducing the films into an electroscope and determining the rate of leak of the charge in terms of the fall of the gold-leaf in scale divisions per minute. On dividing the rate of leak by the weight in grams of the mineral in the film a number was obtained expressing the specific activity (activity per gram) of the given mineral. The minerals examined contained uranium as well as thorium. The activity of one gram of uranium with its equilibrium amounts of disintegration products (actinium, radium, etc.) has been found to be a constant† which will be called the normal specific activity of the uranium-radium series. The value of this constant for the particular electroscope used was determined by measurements of the activity of certain minerals containing uranium and no thorium. Knowing the content of uranium and the constant for the normal specific activity of the uranium-radium series, it was possible to calculate for each of the thorium minerals that portion of the specific activity of the mineral which was due to the thorium and thorium products which it contained. Dividing this by the weight (in grams) of thorium contained in one gram of mineral, a number representing the activity per gram of thorium was

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* This Journal, xxi, 415, 1906.

† McCoy, Phil. Mag., ix, 176, 1906; Boltwood, loc. cit.

obtained. It was found that, within the limits of experimental error, the activity corresponding to one gram of thorium in a mineral was the same for the different minerals examined, which indicated that the activity of one gram of thorium with its equilibrium amounts of disintegration products—the normal specific activity of the thorium series, as it can be called—was a constant.

Measurements were also made of the activities of a number of specimens of thorium oxide which had been separated by chemical methods from the minerals and from certain thorium salts prepared by the Welsbach Company. The relative ionization produced by a known weight of each of these oxides in the form of a thin film was determined in the electroscope. The specific activity of the oxides prepared directly from the minerals was found to correspond to the normal specific activity of the thorium series found in the minerals. The activity of the oxides prepared from the Welsbach salt was, however, found to be much lower than the normal. These results led to the conclusion that the chemical process employed by the Welsbach Company was in some way peculiar since it apparently resulted in the separation of over one-half of the radiothorium corresponding to the thorium present.

The question of the radio-activity of thorium in minerals and salts has been examined also by Dr. Dadourian,* who employed a method based upon the measurement of the activity of the deposit obtained by exposing a negatively charged plate to the emanation evolved by a solution of the thorium salt or mineral. The results obtained by Dadourian and the writer were in close agreement and led to similar conclusions. Results of a similar character were also obtained by McCoy and Ross† and by Eve.‡

Among the salts examined by Dadourian were two specimens of thorium nitrate, the one prepared from North Carolina monazite and the other from Brazilian monazite, which had been supplied by the Welsbach Company to the writer nearly two years before. Mr. H. S. Miner, the chemist of the Welsbach Company, stated that the former salt was about two years old and the latter at least one year and a half old at the time they were sent to me. A third salt examined by Dadourian was a specimen of thorium nitrate which had been purchased from Eimer & Amend about three years before the time at which he tested it. It had, however, been used in the meantime by the writer for the preparation of thorium-X, that is, the original salt had been dissolved in water, the thorium had been precipitated as hydroxide with ammonia,

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* This Journal, xxi, 427, 1906. † Ibid., xxi, 433, 1906.

‡ Ibid., xxii, 477, 1906.

and the washed hydroxide had been reconverted into nitrate. In order to again obtain the solid salt the solution of the nitrate had been evaporated to dryness under conditions identical with those under which a considerable number of other salts have been prepared and which give a salt containing about forty-eight per cent of thorium oxide. The number given by Dadourian as expressing the specific activity of the thoria in this salt is therefore undoubtedly too high and the correct value would be about 9·0. The reason for this low value will appear later in this paper.

The specimen of Welsbach salt examined by the writer consisted of a kilogram of thorium nitrate made from North Carolina monazite and had been received about fifteen months before the time of my experiments.

The three Welsbach salts examined by Dadourian and the writer were therefore at least four years old, three and one-half years old and one and one-third years old, respectively. The oldest salt contained about forty per cent of the radiothorium in equilibrium with the thorium present and the youngest salt must have contained at least thirty per cent of its equilibrium amount of radiothorium. The difference in ages of these two salts was about three years and they had both been prepared from the same mineral by the same process. If radiothorium was a product formed directly from thorium it was obvious that its period of decay (recovery) could not be less than half-value in about six years and might be somewhat longer.

In April, 1906, the belief that the above data might have an important bearing in indicating the rate of disintegration of radiothorium was privately communicated to Dr. Otto Hahn, the discoverer of radiothorium. Dr. Hahn replied that the data supplied were difficult to reconcile with the results of his own experiments, made directly with a preparation of radiothorium, which seemed to show a half-value period of about two years for this substance. He made, however, at the same time the interesting suggestion that the lack of agreement could be explained if a rayless product having a slow rate of change intervened between thorium and radiothorium.

The rate of disintegration of radiothorium has since been determined by Blanc,* who finds that the half-value period is 737 days, and the existence of a product intermediate between thorium and radiothorium has recently been demonstrated by Hahn† in a very convincing manner.

Hahn made a careful examination of a series of samples of the intermediate chemical products obtained in the technical

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* Rend. della R. Accad. d. Lincei, xvi, 291, 1907.

† Berichte d. chem. Ges., xl, 1462, 1907.

preparation of pure thorium nitrate from monazite by the firm of Dr. O. Knöfler and Co., in Berlin. He found only insignificant differences in the specific activity of the thorium series in these samples and no differences indicating the separation of any considerable proportion of the radiothorium.*

On testing samples of the pure thorium nitrate which had been prepared by the same firm some years before, he found that these showed a conspicuously lower activity than the freshly prepared salts, and this decrease in activity appeared to continue for about three years, after which the activity remained fairly constant for some time. He also states that he has been able to obtain preparations which are free from thorium, but which show with the passage of time a marked increase in their activity and in their power to produce thorium emanation. These preparations must contain the intermediate product between thorium and radiothorium. He therefore reaches the conclusion that it is this intermediate product, for which he suggests the name "mesothorium," and not the radiothorium, which is separated from the thorium in the technical process of preparing pure thorium nitrate.

The films of thorium oxide which were originally used for the determination of the activities given in my earlier paper, and also a number of others which had been prepared and measured at the same time or shortly afterward, have been carefully preserved. The activity of these films has been recently re-measured in the larger of the two electroscopes described in the earlier paper and it has been possible to compare their present activities with their activities at the time of the first measurement. It was found that the specific activities of all the oxides has decreased by an amount equal to from 15 to 30 per cent. of their former values.

The results obtained are shown in the following table. In column I the decrease in the activity of each oxide is given in terms of its activity when first measured. In column II is given the approximate time which elapsed between the two measurements. In column III is given the decrease to be expected in the activity of each oxide if the activity had been falling at a rate corresponding to half-value in 737 days (the rate of decay of radiothorium). Oxides numbered 1 to 8 are the oxides given corresponding numbers in my earlier paper. Oxide No. 9 was prepared from thorianite by a chemical process differing only slightly from that used in preparing oxide No. 5. Oxides No. 10 and 11 were separated from certain

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* During the past year I have made an examination of similar chemical products kindly supplied by the Welsbach Company. The results obtained were similar to those obtained by Hahn, and no marked differences were noted in the thorium specific activity of the freshly prepared materials.

technical products supplied by the Welsbach Company and obtained by them in the process of preparing pure thorium nitrate from monazite.

TABLE.

Number	Source of oxide	I Decrease %	II Time days.	III Decrease calc.
1	Mantle dust	18	500	38%
2	Welsbach nitrate	32	489	38
3	" "	15	347	28
4	" "	22	365	30
5	Thorianite	30	489	38
6	"	26	428	34
7	Monazite	26	428	34
8	Miner's oxide	30	365	30
9	Thorianite	30	408	33
10	Welsbach residue No. 3	23	331	27
11	Welsbach residue No. 4	19	331	27

It will be noted that none of the oxides has lost its activity at a rate greater than that corresponding to a fall to half-value in 737 days, while most of the oxides have lost their activity at a lower rate. The behavior of the oxides indicates that at the time they were first measured they each contained much less mesothorium than the quantity in equilibrium with the thorium present. Oxides numbered 2, 5, 8, 9 and 10 in particular must have contained but a small proportion of their equilibrium amounts of mesothorium since the rate of fall of their activity has so closely approached that of radiothorium itself.

The results which have been obtained clearly indicate that the low specific activity of the thorium series in the salts prepared by the Welsbach Company can not be attributed to any special peculiarity in the chemical methods employed in the Welsbach works. It also appears that the chemical separation of thorium from mesothorium can be effected without difficulty by a variety of reactions.

A portion of the Welsbach nitrate from which the three oxides Nos. 2, 3 and 4 had been indirectly prepared has been preserved in its original crystalline form. A small amount of this nitrate was converted directly into oxide by ignition, and the specific activity of this oxide was determined a few days later. This was done shortly after the second series of measurements of the older oxides had been carried out. It was found that the specific activity of the thorium series in the original nitrate is now practically the same as it was at the time when the first series of measurements was made. The observation of this fact at once suggested the possibility that even the precipitation of thorium as hydroxide from a solution of the nitrate is effective in separating thorium from mesothorium, since this was the only treatment to which the thorium in oxide No. 2 had been subjected.

Over two years ago I had made some experiments with the object of obtaining a more definite knowledge of the chemical behavior of thorium-X. At that time a considerable number of thorium-X residues had been prepared by the well-known method of precipitating the thorium as hydroxide from a solution of the nitrate, filtering off and washing the hydroxide, evaporating the filtrate to dryness, and gently igniting the residue to remove the ammonium salts present. The amount of thorium nitrate used in some of these experiments was as much as a hundred grams and the volume of the filtrate was often more than two liters. In these experiments it was always found that the residue, after the removal of ammonium salts, contained very appreciable amounts of thorium. This thorium was finally removed from the residue by a second treatment with ammonia in a solution of small volume. A number of such thorium-free residues had been prepared and measurements of their activity had shown a steady fall for a period of about 30 days. After 30 days the residues still retained a definitely measurable activity, which was comparatively small, however, and amounted to a leak of only a few divisions per minute in the electroscope. This residual activity, which was observed further in some instances for a period of about one week, appeared to be fairly constant during that period, after which its progress was not further followed. It was attributed at the time to the presence of a little radium in the original nitrate.

Several of these old thorium-X residues have been preserved, and as soon as the possibility that they might have originally contained mesothorium suggested itself they were introduced into the electroscope and their activities noted. The activity of each of them was found to have risen enormously, until it has now reached a value which is many times greater than the minimum value to which it had originally fallen. These thorium-free residues, weighing together not more than a few milligrams, have now an activity equal to that of several grams of thorium oxide of normal activity and spontaneously evolve an emanation which is identical with that of thorium, falling to half-value in 54 seconds and producing the characteristic thorium-active deposit. These residues therefore contain radiothorium (and its products) which has been formed by the disintegration of the mesothorium originally present. If the half-value period of mesothorium is about 7 years, as suggested by Hahn, then these residues must still contain mesothorium and their activity will continue to increase for some time longer.

It is obvious, therefore, that the chemical process first described by Rutherford and Soddy for preparing thorium-X from thorium, consisting in the precipitation of the thorium as hydroxide from a solution of the nitrate, can be employed also for the separation of mesothorium from thorium. It has the advantage that the mesothorium is obtained in a relatively concentrated form, but it can be applied with advantage only where thorium nitrate of some age is available, since fresh thorium nitrate will contain little if any mesothorium.

The fact that the two oxides numbered 3 and 4, which were obtained through the intermediate formation of the normal and "basic" sulphates, respectively, also show a decrease in their activities is not in itself very suggestive, since in the preparation of the sulphates the nitrate was first converted into hydroxide. Also in the cases of the other oxides, No. 5 to No. 11 inclusive, the chemical operations through which the thorium passed from the first decomposition of the mineral to the final separation of the pure thorium salt were too complicated to make it possible to determine at what particular step the mesothorium was removed. From various data it appears probable, however, that the precipitation of thorium by sodium thiosulphate is effective in separating thorium from mesothorium.

A further point which appears to be worthy of notice in passing is the similarity in chemical behavior shown by thorium and radiothorium on the one hand, and by thorium-X and mesothorium on the other. We have no good evidence as yet of the chemical separation of thorium and radiothorium. These two elements appear to remain together most persistently through elaborate chemical operations which result in the separation of the thorium from every other known element. In contrast to this is the facility with which thorium-X and mesothorium can be separated from thorium and radiothorium. The chemical similarity of mesothorium and thorium-X is further indicated by what follows. Nearly two years ago an attempt was made to separate radiothorium from thorium by precipitating barium sulphate in a dilute solution of a thorium salt. This experiment was performed because it was thought that the entrainment of radiothorium by barium sulphate might explain the presence of radiothorium in the radium-barium sulphate residue for thorianite where Hahn had first obtained it. The precipitated barium sulphate was highly active when first prepared, but its activity fell regularly at a rate corresponding to half-value in 4 days, until at the end of about 40 days it had reached a negligible value. At the start it therefore contained thorium-X but no appreciable amount of radiothorium. This precipitate of barium sulphate has recently been examined and is now quite active. It gives off thorium emanation but contains no thorium. Its present activity is therefore due to radiothorium formed from the mesothorium which was precipitated with it. From this it seems probable that the radiothorium which Hahn separated from the residue of insoluble sulphates, obtained some time before in working up a considerable quantity of thorianite, had not been present in the residues when first prepared, but had been formed in them later through the disintegration of mesothorium. This supposition is further strengthened by Hahn's statement* that his radiothorium probably contained some mesothorium.

It appears quite likely, therefore, that the entraining action of barium sulphate on mesothorium was directly responsible for the presence of radiothorium in the thorianite residues.

Summary.

Measurements of the changes which have taken place in the activity of certain thorium preparations have given results which are strongly in support of Hahn's assertion that an intermediate product having a slow rate of change and not emitting α-rays exists in the thorium series between thorium and radiothorium.

Certain methods for the separation of this intermediate product from thorium have been described.

Sloane Laboratory, Yale University,
New Haven, Conn., June 16, 1907.

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* Loc. cit.

Art. X. — *Wave-lengths and Structural Relation of Certain Bands in the Spectrum of Nitrogen;* by E. E. Lawton, Ph.D.

While engaged upon a study of the spectrum of nitrogen, it became necessary to photograph in juxtaposition the solar spectrum and the spectrum given by the capillary portion of a nitrogen Plücker tube, which had been exhausted to about 1^{mm}. Upon investigating, it was found that so little has been done on this spectrum in recent years that most of the measurements of the wave-lengths of the lines in the spectrum are far inferior in precision to the measurements which can be made with the instruments now available.

The measurements of Ångström and Thalén,* Boisbaudran,† and Hasselberg,‡ expressed in Ångström units, give only one decimal place; in general, the error varies from 0·2 to 0·5 of that unit. Deslandres§ has published a table of wave-lengths of nearly the whole negative spectrum; but these results give only one decimal place. Ames‖ and Hermesdorf¶ have also studied the same spectrum. Ames, however, measured only the second line in each band, while Hermesdorf obtained the wave-lengths of six bands, particularly those of the band with its head at λ 3577. The other bands measured have their heads at λ 3805, 3755, 3710, 3536, and 3371. These measurements have been obtained with a strong dispersion, and the accuracy of measurement is given as 0·01 Ångström unit. Hermesdorf's accurate investigation of the wave-lengths of a part of the spectrum is the only one that the writer has been able to find in the literature that brings our knowledge of the wave-lengths apace with the present instruments. Hence, the object of the present work has been to extend, if possible, our knowledge in this direction.

My own results have been obtained from measurements made on photographs taken with a large concave Rowland grating, which is installed in Sloane Physical Laboratory. The grating has 20,000 lines per inch, and a radius of 21·5 ft. By means of an adjustable shutter the spectrum given by the capillary part of a Plücker tube, such as is ordinarily used in spectroscopic analysis, was placed side by side with the stand-

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* Acta Soc. Upsala, iii, 1875.

† "Spectres Lumineux."

‡ British Association Reports, p. 188, 1886.

§ Comptes Rendus, ci, p. 1256, 1885; ibid., ciii, p. 375, 1886; Annales de Chem. et de Phys., xv, p. 5, 1888.

‖ Phil. Mag., p. 58, 1890.

¶ Annalen der Physik, xi, p. 161, 1903.

ard spectrum. The solar spectrum, with Rowland's values, was used as the standard, and the unknown wave-lengths were obtained by interpolation. The nitrogen tube had been exhausted to about 1^{mm}. Many photographs were obtained with exposures varying from forty-five to ninety minutes, the longer time always giving the best results. These photographs* show for this spectrum a complicated structure. The heads of bands lie toward the red, with the tails extending up the spectrum, and the lines of the bands are degraded on the side toward the head. Each band offers at the head an intense triplet. In the bands measured, the second and third lines of this triplet are clearly doubles, and it is quite probable that the head of the band which forms the first line of the triplet is a double also.

Considering a single band—near the head there is a confusion of lines showing no regularity of intensity; but as the lines become more and more remote from the head, the lines are seen to be grouped in series of threes, or triplets, and while the distance between the lines of a single triplet diminishes the distance between triplets increases. The lines of each triplet show the same intensity, which gradually diminishes with an increase of distance from the head until they finally disappear, or, as is sometimes the case, become hidden in the next band. The irregularity of intensity shown by the lines near the head has been pointed out by Deslandres,† using the band λ 3577, as due to several secondary series, if I may be permitted to call them such, which are quite distinct from those series of lines which form the triplets of the tail. To these secondary series belongs the strong triplet seen in the head of each band. In the same paper Deslandres considers that the third line of the triplets in the tail is a double, but I have seen no indications that this is so, and neither do Hermesdorf's‡ measurements indicate this to be the case.

The second group of this spectrum extends from λ 5000 to λ 3000 and is made up of five series of bands.§ All except the lower part of this group has been photographed during this investigation. The first attempt to secure a photograph of the lower part showed some faint lines at about λ 4600, but a later attempt proved unsuccessful, owing to the weakening of the tube. Eye observations, however, showed some strong lines in this lower region. Using the photographic method, some good plates of the region λ 4200 to λ 3000 have been

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* It may be worthy of remark here, as a matter of interest, that there are no telluric lines in the solar spectrum corresponding to the lines of this nitrogen spectrum. Nothing more than what might be termed accidental coincidences were observed.

† Comptes Rendus, cxxxviii, p. 317, 1904.

‡ Loc. cit.

§ Comptes Rendus, ciii, p. 375, 1886.

obtained. At λ 4059 and λ 3998 there are two bands which present beautifully the phenomena of triplets. Just above there is a group of six bands which overlap each other in such a way as to entirely obliterate the triplets.

The wave-lengths of the bands beginning at λ 4059 and λ 3998 have been measured and the results are given below. The stronger dispersion has made it possible to measure nearly a hundred more lines in these two bands than did the early observers. The measurements have been made with the aid of a micrometer-microscope especially arranged for the purpose, and in each case measurements have been made by setting on the center of intensity of the lines. Each result given in the table is the mean of at least eight measurements. Taking $10^{-7\,\text{mm}}$ as the unit, the precision of measurement should be at least equal to 0·01 of that unit, except in the case of the extreme triplets, which being rather faint, the setting is more uncertain. The measurements of the wave-lengths follow.

Wave-lengths of the bands beginning at 4059·458 and 3998·419.

4059·458
·207
·015
4058·895
·694
·511
·403
·084
4057·883
·576
·351
·119
4056·979
·628
·504
·266
·030
4055·831
·524
·359
·077
4054·639
·408*
·245
4053·896

4053·790
·347
·107
4052·898
·730
·370†
·271†
4051·987
·657
·291
·059
4050·863
·482†
·268†
·179
4049·781
·167
4048·943
·442
4047·959
·597
·164
4046·964
·679
·494

4046·227
4045·781
·446
·350
·016
4044·727
·336
4043·873
·185
4042·927
·744
·399
·208
4041·853
·571
·200‡
4040·815
·509
4039·902
·189
4038·731
4037·780
·447
4036·981
·281

* Very faint.
† A heavy double.
‡ Faint and difficult to measure.

4035·655
4034·938
·374
·065
4032·883
·326*
4031·771
4030·779
·236
4029·672
4026·580
·099
4027·589
4026·357

4025·869
·361
4024·004
4023·552
·072
4021·613
·175
4020·704
4019·160
4018·730
·317
4016·641†
·195

4015·792
4013·991
·556
·199
4011·333
4010·879
·534
4008·589
·151
4007·830
4005·774
·394
4004·984

3998·419
·289
3997·946
·696
·591
·360
·138
3996·959
·829
·505
·048
3995·889
·608
·494
3994·617
·382
·151
3993·639
·372
·258
3992·912
·512
·180
3991·997
·540
·335
·077
3990·907
·496
·376
·059
3989·802
·426

3989·126
3988·978
·681
·587
·331
3987·839
·281
3986·993
·498
·043
3985·687
·282
·037
3984·802
·284
3983·884
·543
·418
·131
3982·831‡
·405
·001
3981·569
·274
3980·883§
·492
·285
3979·934
·643
·222
3978·904
·565
·397

3978·229
3977·941
·557
·224
3976·774
·351
·072
3975·521
·251
3974·918
·563
·314
3973·680
3972·961
·378
3971·781
3970·938
·393
3969·821
3968·864
·338
3967·801
3966·693
·130
3965·689
3964·474
3963·990
·487
3962·157
3961·681
·212
3959·792
·347

* This line hazy and setting uncertain.

† All the triplets above this were very faint.

‡ Very broad line and difficult to measure.

§ Very faint.

3958·870
3957·392
3956·932
·482
3954·892
·419
3954·017
3952·254
3951·866
·457
3949·694
3949·259
3948·826
3946·972
·562
·173

To Deslandres* we owe most of our knowledge of the laws governing the bands in the nitrogen spectrum, and the lines in a band. These laws, three in number, are briefly as follows:

1. In a given band the interval from one line to the following in any series, calculated in vibration numbers, are in arithmetical progression, i. e., the lines are connected by a relation of the form,

$$\frac{1}{\lambda}=\mathrm{N}=a+bn^2$$

where a and b are constants, and n is a series of positive integers.

2. When two or more series arise from the edge of a band, they are similar in all respects, and all bands belonging to the same substance have the same number of series.

3. In a series of bands the vibration numbers of the edges form a series similar to that of the line in a single band.

With these laws as a basis, Deslandres† has, quite recently, investigated the band at λ 3577 in the second group of the negative spectrum. He finds that there are seven series of lines and all can be expressed by the formula

$$\mathrm{N}=\mathrm{A}\left(m+\frac{p}{q}\right)^2+c$$

where A, c, p, q, are constants, and m a series of integers. The application of the formula to the wave numbers of a band is not given by Deslandres, hence the above measurements furnish an opportunity for the application of the formula. Taking the band beginning λ 3998, the formula has been applied to the triplets of the tail. The constants have been determined by the method of trial and error giving the following formulæ:

1st line of triplet.

$$\mathrm{N}=2501{\cdot}457+0{\cdot}0251257(m+0{\cdot}85)^2$$

2d line of triplet.

$$\mathrm{N}=2502{\cdot}145+0{\cdot}025296(m+0{\cdot}5)^2$$

3d line of triplet.

$$\mathrm{N}=2502{\cdot}786+0{\cdot}02490(m+0{\cdot}5)^2$$

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* Comptes Rendus, ciii, p. 375, 1886. Annales de Chemie et de Physique, xv, p. 5, 1888.

† Comptes Rendus, cxxxviii, p. 317, 1904.

The results as calculated by these formulæ are given in the following tables:

1st line of the triplet.

	Calculated $N = \frac{1}{\lambda}$	Observed $N = \frac{1}{\lambda}$	Difference
$m =$ 15	2507·769	2507·623	+0·146
16	2508·591	2508·467	+ ·124
17	2509·462	2509·387	+ ·075
18	2510·384	2510·328	+ ·056
19	2511·357	2511·300	+ ·057
20	2512·380	2512·383	— ·003
21	2513·452	2513·469	— ·017
22	2514·575	2514·601	— ·026
23	2515·749	2515·776	— ·027
24	2516·972	2517·000	— ·028
25	2518·246	2518·297	— ·051
26	2519·571	2519·611	— ·040
27	2520·945	2520·992	— ·047
28	2522·370	2522 403	— ·033
29	2523·845	2523·878	— ·033
30	2525·460	2525·385	+ ·075
31	2526·945	2526·916	+ ·025
32	2528·571	2528·514	+ ·057
33	2530.247	2530·201	+ ·046
34	2531·973	2531·842	+ ·131
35	2533·749	2533·588	+ ·161

2d line of the triplet.

$m =$ 15	2508·222	2508·155	+0·067
16	2509·032	·978	+ ·054
17	·892	2509·861	+ ·031
18	2510·702	2510·776	— ·074*
19	2511·763	2511·758	+ ·005
20	2512·776	2512·788	— ·012
21	2513·838	2513·863	— ·025
22	2514·958	2515·042	— ·084†
23	2516·115	2516·157	— ·042
24	2517·329	2817·384	— ·055
25	2518·594	2518·642	— ·048
26	2519·909	2519·947	— ·038
27	2521·275	2521·350	— ·075
28	2522·692	2522·710	— ·018
29	2524·159	2524·181	— ·022
30	2525·677	2525·669	+ ·008
31	2527·246	2527·211	+ ·035
32	2528 864	2528·817	+ ·047
33	2530·532	2530·450	+ ·082
34	2532·244	2532·120	+ ·124
35	2534·024	2533·851	+ ·173

* Broad line with the center of intensity uncertain.

† A second measurement verified this result.

3d line of the triplet.

	Calculated $N = \frac{1}{\lambda}$	Observed $N = \frac{1}{\lambda}$	Difference
$m = 14$	2508·021	2507·969	− 0·052
15	·778	2508·754	+ ·024
16	2509·565	2509·535	+ ·030
17	2510·412	2510·407	+ ·005
18	2511·308	2511·300	+ ·008
19	2512·294	2512·252	+ ·042
20	2513·244	2513·255	— ·011
21	2514·296	2514·317	— ·021
22	2515·391	2515·394	— ·003
23	2516·537	2516·560	— ·023
24	2517·732	2517·763	— ·031
25	2518·977	2519·006	— ·036
26	2520·272	2520·287	— ·015
27	2521·617	2521·631	— ·014
28	2523·011	2523·030	— ·019
29	2524·455	2524·480	— ·025
30	2525·949	2525·973	— ·024
31	2527·493	2527·498	— ·005
32	2529·083	2529·073	+ ·010
33	2530·730	2530·713	+ ·017
34	2532·423	2532·398	+ ·025
35	2534·160	2534·101	+ ·059

It is seen from these results that the formula applies fairly well to the third line of the triplet, but the agreement between the calculated and observed values is not so good in the case of the other two lines. Another thing to be noticed is that values of N for small values of *m* do not exist. The same result was obtained by the writer when Deslandres'* formula was applied to the measurements of Hermesdorf. If the residuals are plotted, they show in each case that the curve approximates a parabolic form. Considering the complex structure of the nitrogen spectrum, the agreement is as close as could be anticipated, and it is evident that it will require a more complicated formula, than has as yet been proposed, in order that the residuals may be brought within the limits of observation.

The points of chief interest which have been brought out by the foregoing are:

1. The wave-lengths of the lines of the bands beginning λ4059 and λ3998 have been measured, nearly half of them for the first time; and all the lines have been measured with a degree of precision hitherto not attained for this portion of the spectrum.

2. Application has been made of Deslandres' formula to the band λ3998, and the constants determined giving as close an agreement between the calculated and the observed values as can be expected, considering the complex nature of the spectrum.

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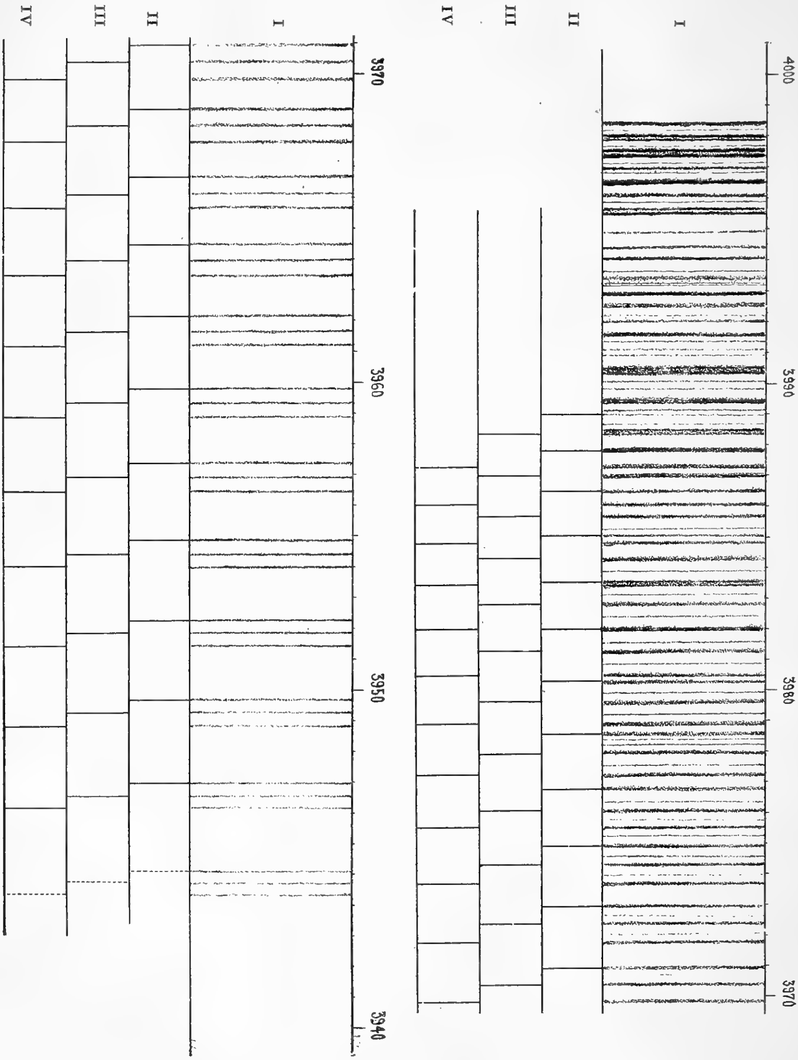
* Loc. cit.

Accompanying this article is an enlarged drawing of the band λ 3998. The drawing is made to scale; and the intensity of the different lines indicated in the drawing. (I) is the band itself (last triplet estimated, too faint for measurement). (II), (III) and (IV) show the triplets resolved into series.



In conclusion, it is a pleasure to acknowledge my indebtedness to Professor Arthur W. Wright, who obtained the excellent photographs used in this investigation, and whose kind criticisms and advice were continually of great assistance.

Art. XI.— *The Tertiary Peneplain of the Plateau District, and Adjacent Country, in Arizona and New Mexico;* by H. H. Robinson.

Introduction.—The existence of a base-level of erosion, or as it is now interpreted, a peneplain, in the Grand Canyon District of Arizona at the close of the period of the great denudation and just previous to the inauguration of the canyon cycle, was strongly insisted upon by Dutton in his "Tertiary History of the Grand Canyon District." His point of view may be illustrated by the following quotation:

"Thus there is a general accord of testimony that at the period of the older basaltic eruptions very large bodies of Permian strata lay upon the Carboniferous platform. In truth, it seems as if the summit of the Permian then constituted the surface of the country, just as the summit of the Carboniferous does now. The fact that the older basalts, wherever found, rest upon the same geological horizon, suggests to us the further inference that the region near the (Colorado) river was then flat and destitute of deep canyons and valleys, such as now exist there, and, therefore, destitute of great hills, buttes, or mesas. The meaning of this is a base-level of erosion . . . . This, it is true, looks at first like drawing a very broad and rather remote inference from a very slender basis, and would not be justified at all if it were not in general harmony with a wide range of facts. Many facts take form and coherence around it which would otherwise seem mysterious."*

It is desired to present in this article evidence from the vicinity of the San Francisco Mountains, which are located on the San Francisco Plateau† south of the Grand Canyon, in support of Dutton's conclusion, and to show that the peneplain he described existed not only in the Grand Canyon District, but extended over the greater part of the southern Colorado Plateau and into the region south of the present plateau, now known as the Mountain District of Arizona. And it is further desired to point out the influence that this peneplain, in connection with later faulting, may have had upon the drainage system of the Grand Canyon District.

Tertiary History of Southern Plateau District.—Before describing the several localities where this ancient peneplain is now exposed, a brief summary of the Tertiary history of the

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*Mon. II, p. 224, U. S. G. S., 1882.

†Name applied to that portion of the Colorado Plateaus, exclusive of Coconino Plateau, bounded on the north by the Colorado River, on the east by the Little Colorado and on the south and west by the Aubrey Cliff.

Southern Plateau District will be presented in order that the problem under discussion may be given its proper setting. The data for this have been taken from the reports of Gilbert,* Dutton,† Davis,‡ and especially from the more detailed work of Huntington and Goldthwait§ in the Toquerville District of Utah. Although the sequence of events is based principally on observations in the southwestern part of the plateau, it is believed to be equally applicable to the entire southern portion of the plateau country, since the facts where best known, as at the Mount Taylor Mesa and adjacent region in New Mexico, fit into it without apparent discord.

During early Eocene time, certainly, the southern plateau country was a land area on which sediments were deposited partly in lakes, partly probably as fluviatile deposits. It is possible that the region was uplifted and eroded in the latter part of the Eocene, since only strata of lower Eocene age are found in the southern part of the High Plateaus of Utah. The extensive volcanic activity present in the Basin Range country of Nevada and Arizona, and the High Plateaus of Utah, was absent, as there are no traces of volcanic plugs or dikes, which can be referred to this period, to be seen anywhere in the southern portion of the plateau. At this time the plateau had been differentiated but slightly, if at all, from the Basin Range country, as is rather clearly indicated by the character and distribution of the Eocene deposits, especially in the High Plateaus of Utah, although it may be noted that Lindgren‖ places the initial separation of the Sierra Nevadas and Wasatch Mountains from the Basin Range country in middle Cretaceous time.

In the latter part of the Eocene, or possibly in early Miocene time, uplift occurred by monoclinal folding, which, on the whole, appears to have raised the western part of the plateau country above the eastern. In the southeastern section this folding gave rise to an elevated tract of country, the axis of which had a trend somewhat west of north, while a second elevated region extended westward for an indefinite distance from the Echo Cliff monocline situated on the east side of the Colorado River. This tract appears to have had its principal extension northward, and did not affect the extreme south-

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* Survey West of the 100th Meridian, vol. iii.

† (*a*) Tertiary History of Grand Canyon District, U. S. G. S. Mon. II, 1882. (*b*) Mt. Taylor and the Zuni Plateau. U. S. G. S. 6th Ann. Rept. 1885.

‡ (*a*) An Excursion to the Grand Canyon of the Colorado, Bull. Mus. Comp. Zool. Harvard Coll., vol. xxxviii, Geol. Ser. vol. vi, No. 4, 1901. (*b*) An Excursion to the Plateau Province of Utah and Arizona, Bull. Mus. Comp. Zool. Harvard Coll., vol. xlii, Geol. Ser., vol. vi, No. 5, 1904.

§ The Hurricane Fault in the Toquerville District, Utah. Bull. Mus. Comp. Zool. Harvard Coll. vol. xlii, Geol. Ser., vol. vi, No. 1, 1903.

‖ The Age of the Auriferous Gravels of the Sierra Nevada. Jour. Geol., vol. iv., pp. 894–896, 1896.

western part of the plateau country. The folding presumably gave rise to closed basins with the resultant formation of lakes, and deposition of sediments in them, and also to open basins, in which fluviatile deposits were laid down. The cycle of erosion begun at this time has continued unbroken to the present.

With the next period of uplift, known as the "First Period of Faulting," it would appear that the plateau district was rather clearly marked out, since the faulting on both the east and west borders was such as to lower the country on either side of the plateau, or to raise the plateau itself. The date of this first period of faulting cannot be definitely fixed, but from what is known of the history of the Basin Ranges, it may be provisionally placed at the close of the Miocene.

By far the greater part of the erosion of the southern portion of the plateau country had been accomplished by the time the "Second Period of Faulting" occurred near the close of the Pliocene. At the close of this cycle of erosion, known as "The Period of the Great Denudation," the relief produced by the monoclinal folding and the faulting of the first period had been obliterated to a large extent, and the surface of the entire southern plateau country, and even a greater area, had been reduced to a peneplain.

Immediately after the development of the peneplain, and before the second period of faulting, widespread eruptions of basalt occurred over much of the southern portion of the plateau, and it is to this capping of lava that the peneplain owes its preservation. In the San Francisco Mountains, as determined by the writer,* a second period of volcanic activity ensued in very late Pliocene, or early Quaternary time, during which San Francisco Mountain and the neighboring large cones were built up by flows of andesite, trachy-andesite, and rhyolite. To this same general period it seems probable that Mount Floyd, the Sierra Blanca and Mount Taylor should be assigned.

The second period of faulting near the close of the Pliocene gave rise to the Plateau district essentially as it stands to-day, and introduced the "Canyon Cycle of Erosion," during which, in Pleistocene time, the Grand Canyon of the Colorado has been cut, a considerable amount of the soft strata overlying the present surface rock of the plateau—the resistant Upper Aubrey cherty limestone—has been stripped off and cliff profiles refreshed. The amount of erosion accomplished during this cycle is, however, insignificant when compared with that of the period of the great denudation.

During the canyon cycle of erosion a third period of volcanic activity occurred in the San Francisco Mountains characterized by eruptions of basalt from many small cones. These erup-

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* Unpublished report; to be published by the U. S. G. S.

tions took place principally before or during the period of glaciation that is marked by the morainal material and waste fans of San Francisco Mountain, while a few of the cones and flows are of very recent geological age, and may possibly date from historic time. To this same period of eruption are assigned the recent basalts, not only on the plateau, but in the surrounding Basin Range country. They may be easily distinguished in the great majority of cases from the older basalt capping the peneplain by their freshness, uneroded condition, and the fact that they have not suffered displacement by the faulting of the second period.

The history of the Plateau as outlined differs from that of Dutton* for the Grand Canyon District in carrying the period of the great denudation through the Pliocene and of restricting the erosion of the present Grand Canyon to the Quaternary. The fact that the relief produced by the faults of the first period has been effaced, while that resulting from faults of the second period has not, appears to make this change necessary, if but one period of peneplanation exists. The date of the second period of faulting, which inaugurated the canyon cycle of erosion at the close of the Pliocene, is the same as that assigned by Dutton for the cutting of the inner gorge of the Grand Canyon, and is coincident with the very general uplift that affected the western part of the United States at that time. All recent work in the plateau region has shown that numerous complications exist that were not originally suspected and that have not as yet received sufficient attention to permit their being given proper weight. With the history of the region thus incompletely, if not incorrectly, outlined, the description of the peneplain developed at the close of the period of the great denudation may be taken up.

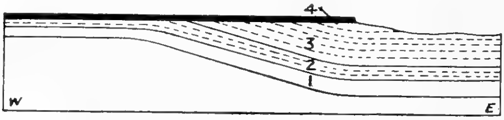

Fig. 1. Black Point Monocline.
1 Upper Aubrey, 2 Moencopie, 3 Shinarump, 4 Basalt.

San Francisco Plateau.—On the San Francisco Plateau the peneplain is graphically displayed in natural cross-section at Black Point† in the Little Colorado Valley by the erosion of the strata along the Black Point monocline.

The strata visibly involved in the monocline extend from the Upper Aubrey through the Moencopie and certainly well

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* Op. cit. (*a*), chap. xii.

† A high point eight miles north of Black Falls on the Little Colorado River; it is not shown on the maps.

into the Shinarump formation.* In the more distant views of Black Point from the south the slope shows no outcrops east of a heavy bed of sandstone, corresponding to the conglomeratic or coarse sandstone member situated near the base of the Shinarump, which is located about one-third the distance between the stripped surface of the Upper Aubrey cherty limestone and the end of the point overlooking the valley, measured from the cherty limestone. This lack of outcrops is due to the fact that that portion of the Shinarump consists of very soft and easily weathered marls. Between the sandstone and the cherty limestone exposures are not infrequent and are occasioned by the sandstone beds of the Moencopie, a formation composed principally of soft argillaceous and calcareous shales.

The feature that attracts attention, as soon as the inclined position of the beds is recognized, is that an exceedingly smooth surface, outlined by the black basalt, has been cut across the basset edges of the strata. It is in fact a very perfect plane of erosion and it would be hardly possible for so smooth a surface to be developed across strata varying in hardness from a compact sandstone to a barely consolidated marl except at a base-level of erosion. To the west of the steeply flexed portion of the monocline the peneplain is located on a small thickness of the nearly horizontal shales of the Moencopie formation, but whether the beveling finally reaches the Upper Aubrey limestone cannot be said. It does not do so within a distance of 10 miles, beyond which the peneplain is hidden from view by a cover of recent basalt.

The exposure at Black Point is of interest because it permits the peneplain to be traced directly from a region of disturbed into one of undisturbed strata where its surface is very closely parallel to the plane of stratification. Evidence is thus obtained which permits the peneplain to be extended so as to include the large areas of horizontally bedded Moencopie shales protected by basalt that occur especially in the Little Colorado Valley, and which substantiates the general conclusion of Dutton.

Another locality where the planation of the strata may be seen is at the north end of Anderson Mesa some eight miles southeast of Flagstaff.

On the west side of the mesa the basalt caps cherty limestone; on the east side 400 feet of red shale and conglomerate

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* The stratigraphic sequence in this region is as follows:

Shinarump formation = Triassic
Moencopie " = Permian (?)
U. Aubrey cherty limestone }
" " cross-bedded sandstone } Upper Carboniferous.
L " red sandstone. }

lie between the lava and the limestone. The contact between the limestone and shale may be traced around the north end of the mesa for two miles, in which distance it gradually rises 270 feet, thus making it certain that the mass of shale is wedge-shaped. Here then is a smooth surface developed across such widely different rocks as the very resistant Upper Aubrey cherty limestone and the soft shales of the Moencopie formation. The section thus shows the cherty limestone to be involved in the planation and furnishes the clue to the correct interpretation of the surface underlying the basalts of the Black and Mogollon mesas farther south.

Fig. 2. Anderson Mesa, north end.
1 Upper Aubrey cross-bedded sandstone, 2 Upper Aubrey limestone, 3 Moencopie, 4 Basalt.

The presence of the Upper Aubrey formations at Slate Mountain, 14 miles northwest of San Francisco Mountain and six miles southwest of Cedar Ranch, makes it evident that the red shales and marls at Cedar Ranch lie either as a beveled wedge between the cherty limestone and capping basalt, as at Anderson Mesa, or as a degraded down-faulted block; a point that could probably be made clear by tracing a bed of conglomerate by its numerous pebbles westward along the face of the mesa. Whichever be the case, it is certain that the level contact surface between the basalt and the underlying sedimentaries is here, as elsewhere, a peneplain.

At the three localities that have been described the surface of the peneplain, as judged by the line of contact between the sedimentary rocks and the overlying basalt, is remarkably smooth. Of equal smoothness is the contact between the Moencopie shales and basalt at all points in the vicinity of the San Francisco Mountains. Judged by the character of this contact, of which many miles are exposed in the Little Colorado Valley, it may be said with a high degree of certainty that the surface of the peneplain was one of practically no relief. The contact between the cherty limestone and basalt was not so extensively seen as that between the Moencopie shales and basalt. Where displayed on the west side of Anderson Mesa, on both sides of Oak Canyon and in the Aubrey Cliff west of Williams, the contact shows the same degree of smoothness that characterizes the shale contact and creates the impression that the peneplain as developed on the resistant Upper Aubrey cherty limestone was of extremely low relief. The fact, too, that so far as known no monadnocks rise above the surface of the basalt covering the peneplain points to a very small amount of relief, as the maximum thickness of the lava, where shown in the walls of canyons and about the edge of the field, is not over 100 feet.

The peneplain may be actually traced over very considerable areas by means of the basalt which caps its surface. A general acquaintance with the region leads to the belief that the basalt may be safely used to estimate the present and former extent of the planation, since wherever the peneplain is unmistakably present the basalt rests upon its surface.

The peneplain may now be traced on the San Francisco Plateau over the western side of the Little Colorado Valley between the Atchison, Topeka and Santa Fé Ry. and Coconino Point. The eastern boundary is everywhere one of erosion, while westward the recent basalts cover its surface, the boundary being an irregular line ranging from 8 to 15 miles distant from the river. The exposures at Cedar Ranch and Anderson Mesa are at the summit of easterly-facing mesa cliffs now 400 to 700 feet above the surface of the plateau. This means, of course, that the peneplain once had a greater extension eastward, though it cannot be stated positively that the surface was formerly continuous between these localities and the Little Colorado Valley. From the section at Anderson Mesa it is possible to trace the peneplain westward to the Aubrey Cliff, especially as there is evidence of its existence under the old lava on the down-faulted block of Moencopie strata at Sycamore Canyon. The peneplain is definitely known to cover between 1,000 to 2,000 square miles and originally had a much greater extension in all directions, except the northeastern. In that direction, on the east side of the Little Colorado, higher land is encountered within 10 to 15 miles, which must have marked the limit of the peneplain. This is on the assumption that there has been no marked later faulting or warping which would raise the region east of the Little Colorado above that on the west. This remains to be proved, but it is believed, as the result of a study of the region west of the river, that no large faults are present and that the tilting has tended to lower the region east of the river rather than raise it.

Mohave Peneplain. — Huntington and Goldthwait,* in connection with their study of the Hurricane and Grand Wash faults, have described an area of some 3,000 square miles, to which they have given the name Mohave peneplain. The evidence for planation, as in the San Francisco Mountain

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* Op. cit., pp. 226–245.

region, consists largely of areas of smoothly beveled strata of widely different degrees of hardness, which have been protected by basalt. A typical case is that of Bellevue Ridge, 4 miles south of Dry Canyon (figure 3), concerning which the authors say:

"Here the level surface on which lies the uplifted lava is composed of Moencopie shale, Shinarump conglomerate, Painted Desert shale and sandstone, and Kanab sandstone, all dipping strongly to the east. Where the strata are exposed to erosion the hard Shinarump and Kanab form strong cuesta-like ridges separated by valleys excavated in the soft Moencopie and Painted Desert. Only under conditions approaching closely to base-levelling would it be possible for a level surface such as that beneath the lava to truncate smoothly strata of such varying hardness."

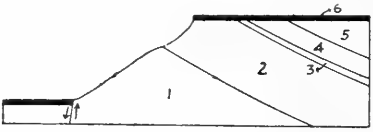

FIG. 3. Bellevue Ridge.
1 Upper Aubrey limestone, 2 Moencopie shales, 3 Shinarump congl., 4 Painted Desert shale and sandst., 5 Kanab sandst., 6 Basalt.

The surface of the peneplain has been displaced, as shown in the figure, from 1,000 to 1,500 feet by the recent Hurricane fault, which belongs to the second period of faulting.

The Mohave peneplain, as described, did not extend beyond the present western boundary of the plateau, as the Basin Range country consisted of "ancient mountains well dissected and mature, and presenting nearly the same appearance as today." To the east, in the vicinity of Toquerville, the High Plateaus marked the boundary, but farther south the peneplain presumably extended eastward to the Kaibab plateau.

Black Mesa.—Black Mesa is the name applied to the elevated belt of country on the San Francisco Plateau, which extends from the San Francisco Mountains as far as Clear Creek Canyon, a distance of 50 miles. The eastern boundary of the mesa is an erosion cliff that has an average height of 500 feet; the western, except for the part along Oak Creek Canyon, is more strikingly marked by the Aubrey Cliff—the limit of the plateau—which rises fully 1,000 feet above the Verde Valley. The surface of the mesa is entirely covered by basaltic lavas, both of the older and more recent periods of eruption, and diversified by many small cones. It is necessary, therefore, to form an idea of the surface underlying the lavas from the outcropping strata at the edges of the mesa.

On the western side these strata belong predominantly to the Upper Aubrey limestone and sandstone formations. On the eastern side, however, the overlying red beds of the Moencopie and Shinarump formations outcrop beneath the lava cap. The strata possess a slight dip to the northeast, and it is evident that the lava rests upon the eroded edges of the beds. In view of the peneplained condition of the contact between the lava and underlying sedimentaries at the north end of the mesa, Anderson Mesa section, figure 2, and in the region farther north, it is regarded as practically certain that the peneplain exists under the older lava throughout the entire extent of the mesa, although the surface may be slightly more irregular in the vicinity of Beaver Creek.

The presence of isolated lava-capped buttes beyond the eastern edge of the mesa makes it certain that the peneplain once had a greater extension in that direction, and it is considered as highly probable that it formerly extended, as did the peneplain in the San Francisco Mountain region, somewhat to the north of the present position of the Little Colorado River. That it originally had a greater extension westward into the present mountain district of Arizona, a point that will be referred to later, would appear equally certain, since the western boundary is now marked by a cliff due to erosion.

Mogollon Mesa.—This mesa is a continuation of the Black Mesa and extends in a direction a little south of east for a distance of 100 miles from Clear Creek Canyon to the White Mountains. On the north the boundary of the mesa is not always distinctly marked. The southern edge, on the contrary, is sharply limited by the Aubrey Cliff, which, where it overlooks the Tonto Basin, closely duplicates the upper 2,000 feet of the walls of the Grand Canyon of the Colorado.

Marvine traversed the mesa in journeying from the Little Colorado River to Fort Apache, and his report, with cross-section, is given in Volume III of the Survey West of the 100th Meridian.* He states that the lava capping the mesa is "identical with that upon the Black Mesa." His section shows that the lava on the north side of the mesa is underlaid either by the Upper Aubrey sandstone or by the uppermost beds of the Lower Aubrey sandstone. On the southern side the strata are the Lower Aubrey sandstones† of a horizon below the beds that occur on the north side of the mesa.

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* Pages 215–218 and pl. iv. Note that the south end of cross-section is incorrect. See foot-note on page 217.

† Reagan, Geology of the Fort Apache Region, Am. Geol., Nov., 1903.

Marvine's description shows that there is a beveling of the strata in the Mogollon Mesa similar in character to that found in the Black Mesa and suggests that the surface underlying the older lava of the mesa may very likely be peneplained. It is to be noted, however, that several outcrops of Cretaceous strata have been found among the lavas in the vicinity of Mineral (St. Johns, Ariz., topographic sheet) and north of Fort Apache, from which it is to be inferred that the surface was not so flat as farther west.

It seems probable that the peneplain originally stretched northward beyond the Little Colorado, as was the case to the west, and that it may also have extended somewhat farther south. Eastward the distance to the next locality where traces of the peneplain are found is 125 miles, and as the intervening region has never been geologically studied or topographically mapped, it is not possible to say whether the peneplain formerly existed there. It is safe to say, however, that if it was not developed, the region must have possessed an extremely mature topography.

The Mount Taylor region of New Mexico.—The peneplain thus far described occurs in the southwestern and southern portions of the plateau. There is evidence, also, that it exists in the eastern part—in the Mount Taylor plateau and surrounding country. Dutton in his report on the Zuni Mountains* gives the following description:

"Just north and northeast of Grants the map shows two detached lava-capped masses, separated from the great volcanic mesa on which Mount Taylor stands. These two masses are separated from each other by a high, narrow saddle. The two are really one long tongue of sedimentary rock. Directly in the saddle the junction of the Cretaceous and Jura-Trias appears, but it is exposed in a well-developed monocline dipping eastward. The angle of dip is about 16° to 18°. The monocline, *before the eruptions of lava*,† was beveled off smoothly by erosion, so as to form a nearly horizontal surface across the basset edges of the upturned strata. The course of the monocline is a little east of south, and it just touches the sharp southwestern angle of the Mount Taylor mesa, where the edges of the Cretaceous beds beneath the lava cap are flexed up by it."

Gilbert states,‡ in regard to this same fold, that it may be seen in the Acoma mesa, south of Mount Taylor, which is capped by lava. Dutton also describes the San Mateo monocline, north of Mount Taylor, which carries Cretaceous strata, dipping 15° east, under the Mount Taylor plateau. On account

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* Op. cit. (b), p. 151 and pl. xiv.

† The italics are Dutton's.

‡ Op. cit., p. 559.

of the pronounced dip of the strata at the localities described, the beveling of their edges was very apparent. It is to be noted, however, that the strata under the Mount Taylor plateau lava have a gentle dip north and west, thus making the peneplain coextensive with the plateau. But the peneplain now stands through erosion on an average of 700 feet above the surrounding country, which indicates that it must originally have had a much greater extension than at present.

Evidence of the existence of the peneplain in the region south of Mount Taylor is found at Tres Hermanos buttes and Mesa Lucera, in addition to the Acoma mesa. It is derived, as elsewhere, from the relation that exists between the eroded strata of folds and faults and the overlying basalt.

Gilbert has described* this relation at Tres Hermanos buttes, located 50 miles south of Mount Taylor, as follows:

"From the buttes a fold runs 10 miles northwest to the Acoma plateau, beneath which it disappears. . . The throw is between 1,500 and 2,000 feet, and is to the southwest. The fold is older than the basalt of the vicinity. The eroded edges of the strata upturned by it support the lava caps of the Hermanos buttes and of the Acoma plateau. The level line of the Acoma lava shows that the folding has not continued since the eruption, and the antiquity of the eruption is measured by a general denudation of the country of more than 500 feet."

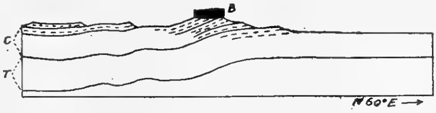

Fig. 4. Monocline at Tres Hermanos Buttes.
C Cretaceous, T Triassic, B Basalt

Gilbert's cross-section of the monocline, in which proportions were estimated, is given in figure 4.

It shows that the strata involved in the fold had suffered great erosion before the lava covered them. The situation appears to duplicate that at Black Point (figure 1), except that the lava cap has been largely removed, and as the result the underlying strata have been considerably dissected. As the capping lava may be traced to the Acoma mesa and hence to the Mount Taylor plateau, it is believed that Dutton's description of the peneplain at the latter locality may be applied to this locality.

At Mesa Lucera, 35 miles southeasterly of Mount Taylor, the relation of the basalt to the displacements is also described by Gilbert:*

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* Op. cit., p. 557.

"Upon the San José, a few miles west of its junction with the Puerco of the East, there is exposed a complex disturbance, consisting of a number of faults and folds, that were not sufficiently studied to warrant an attempt at their representation. The residual throw is to the east and the trend of the dipping strata north and south. The basalt of the Lucera plateau, and Mesa Redonda, rests on the disturbed strata, and is not tilted with them."

Nothing definite can be said in regard to the original extent of the peneplain in this part of the plateau, since topographic maps are lacking and much of it has never been geologically studied. The opinion only may be stated that it must have covered a very large area, at a minimum estimate possibly 5,000 square miles.

The Mountain District of Arizona.—The peneplain in the Black and Mogollon mesas is terminated on the west and south by an erosion cliff overlooking the Mountain district, which makes it highly probable, as noted, that it formerly extended somewhat into that district. The facts on which this conclusion is based are meager, and what is here presented may be considered largely suggestive and as indicating a point for future study.

In the Black Hills and Bradshaw Mountains, west of the Black Mesa, it seems possible to obtain a rather definite idea as to the presence of the peneplain. The topography of the Black Hills and of considerable areas about the Bradshaw Mountains* is of the mesa type and has been produced by the erosion of horizontal flows of basaltic lava. The eroded eastern edges of the flows, capping the Black Hills from Jerome for 40 or more miles southward, overlook the Verde valley and face the eroded and lava-capped Aubrey Cliff, from 10 to 20 miles distant. To explain the present position and condition of the lava flows it is necessary to assume that the surface on which the lava rests originally continued across the Verde valley, and has since been obliterated, in connection with faulting, by the erosion of the valley.

The lava in the Black Hills† rests either upon a small thickness of limestone or upon granite, while in the Bradshaws it lies on granitic or metamorphic rocks. The formations are, therefore, of a very much lower horizon than those upon which the lava rests in the Aubrey Cliff. This difference may be explained by the erosion, essentially to grade, of the relief produced either by a monocline or fault. The first case would duplicate the condition found at the Black Point monocline (figure 1); the second, that near the point where the

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* Jerome and Bradshaw Mountain topographic sheets, U. S. G. S.

† Reid, Sketch of the Geology and Ore Deposits of the Cherry Creek District, Ariz. Econ. Geol., vol. i, No. 5, 1906.

Virgin River cuts the Hurricane fault in Utah,[*] except that the throw of the fault would be reversed. It seems probable that the displacement has been caused by faulting rather than by folding, and that there have been two distinct movements. The first would account for the difference in the stratigraphic horizons on which the lavas rest, respectively, in the Black Hills and Black Mesa, while the second faulting displaced the lavas and initiated conditions favorable to the development of the present topography.

The surface underlying the basalt in the Black Hills has not been definitely described, but as the character of this surface is known both to the east and west, it may be supposed that it is about as thoroughly peneplained as is the corresponding surface in the Black Mesa. In the Bradshaw Mountains[†] is found the southwestern limit of the peneplain. The floor on which the lavas rest, in the region east of the mountains proper, is thus described:

"The thickness of the wide eastern basalt flows is very variable; the upper surface is relatively horizontal, but the bottom fits the hollows in the underlying granite topography. Thus, near Richinbar the granite reaches the level of the surface of the mesa at several points, while near Bumblebee, 2 miles to the west, the contact of the lava and granite lies 800 feet lower."

Elsewhere, if one may judge from the structure sections, the planation was more thorough. This is shown on those sections which cut Yavapai schist areas. On section C–C, for instance, the present surface of the schist departs from a straight line joining the Bigbug Mesa lava and that east of Cedar Canyon on an average of about 300 feet, the maximum being 800 feet at Cedar Canyon. These figures indicate an amount of erosion that compares favorably with that in the neighboring plateau district since the eruption of the older basalts and confirms the impression that considerable areas about the Bradshaw Mountains may formerly have been peneplained.

The entire belt of country immediately south of the Mogollon Mesa is, from the point of view of this article, an unknown region. The only description suggesting planation is that of Marvine,[‡] of the region west of Fort Apache. It is as follows:

"West of the post is a more open country, the floor of which tends to be of the Red Wall limestone, though the preservative effect of the hard basalt has been to keep it covered with mesa-like buttes and ridges of the banded red and yellow Lower Aubrey beds. . .

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[*] Huntington and Goldthwait, op. cit., p. 225 and fig. 5.

[†] Jagger and Palache, Bradshaw Mountains folio, Ariz., No. 126, U. S. G. S., 1905.

[‡] Op. cit., p. 219 and pl. iv.

Where crossed, the Salt River flowed in a canyon in the Red Wall limestone, the northern side of which, being descended after night-fall, was not examined. It was much lower than the southern side, however, which reached a height of nearly 1,800 feet above the stream. Of this about ten or twelve hundred feet were of Red Wall, capped by some sandstone, the remainder being basaltic lava... The limestone must all be affected by a strong, constant northeast dip, for, passing over the high basalt top southward 2 or 3 miles, the Lower Tonto (vitreous) sandstone is encountered at a height equal to that of the limestone near the river, the whole thickness of the latter, together with that of the Tonto shales, being covered with lava."

The Bradshaw Mountains, and the locality just described, lie about 30 miles beyond the border of the plateau and appear to mark the limit of the peneplain toward the south. That it did not exist in the vicinity of Clifton, Arizona, nor apparently at Globe, is indicated by the following quotation:*

"The country was now (in the Tertiary) a land area with rough topographic features, to which the faulting contributed important elements. An active erosion following the epoch of faulting has not been able to entirely efface its influence, and, though obscured by the Tertiary lava flows, these fault carps are still dominent features visible in the granite bluffs of the Coronado and Copper mountains, and the down thrown valley between them."

It would seem, however, from the thoroughness of the planation of the plateau, as though in general erosion must have reduced the relief of the Basin Range country to a mature type, and it would follow that many intermontane valleys were thoroughly graded contemporaneously with the development of the peneplain in the plateau country.

Conclusion.—The area covered by the remnants of the peneplain in the southwestern part of the plateau is about 5,000 square miles. Such isolated masses of lava-capped red shale and sandstone as Red Butte and others, at present unmapped, clearly indicate that the peneplain originally extended over a much larger region. The boundaries of this area may roughly be considered on the west as the boundary of the plateau, on the north and northeast the Kaibab Plateau and the high cliffs that limit the Grand Canyon District and San Francisco Plateau in those directions, on the south and southwest a line about 30 miles beyond the border of the plateau and parallel to it, comprising in all some 20,000 square miles of country. In the

* Lindgren, Copper Deposits of the Clifton-Morenci District, Ariz., P. P., No. 43, U. S. G. S., p. 95, 1905.

southeastern part of the plateau about Mount Taylor the area is estimated at not less than 5,000 square miles. The region over 100 miles wide intervening between these two areas may have been a peneplain or lowland. The encanyoned course of the Zuñi River,* and also of the Puerco of the West, across the Defiance monocline and against the dip of the strata, suggesting a superposed origin for these streams, points to this conclusion. In fig. 5 the location of the various localities that have been described is shown and the approximate position of the boundaries of the peneplain indicated by the dotted line.

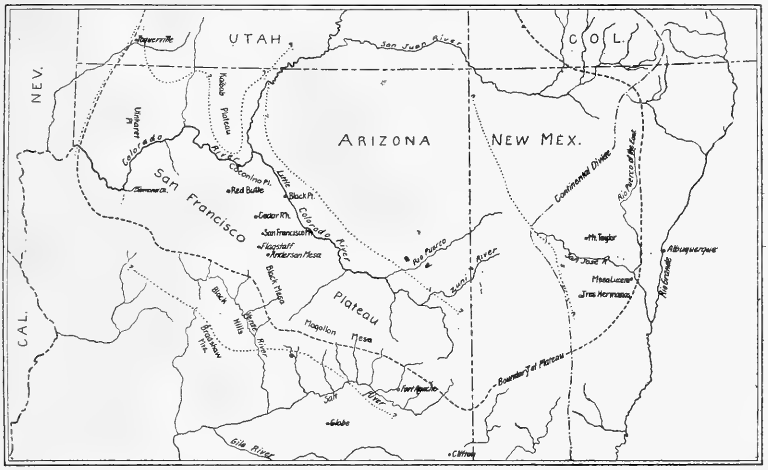

Fig. 5. Southern portion of the Colorado Plateaus in Arizona and New Mexico.

While it is possible to show the existence of the peneplain at many localities, the question whether the several parts represent a single peneplain or not is more difficult to answer. Incomplete knowledge concerning the extent of the later faulting and warping by which the peneplain was raised from a low altitude to its present height and different portions of it relatively displaced, introduces an important element of uncertainty. The Mohave peneplain, as represented by the surface underlying the older basalts of the Sheavwits and Uinkaret plateaus, is certainly a unit, as is also the area in the Little Colorado Valley. The portion in the Black and Mogollon mesas and Black Hills is a unit, and the same appears to be true of the Mount Taylor region. It is believed that they

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* Dutton, op. cit. (b), pp. 145, 146.

all are the eroded remnants of a single peneplain, with the possible exception of the Little Colorado Valley area. There are a few isolated facts regarding the actual elevation of the peneplain above the present plateau surface and the relation of the different parts to one another, that point toward the existence of two separate peneplains, the older of wide extent, the younger local in character. The conclusions that would follow were such the case, involving the extension of the older peneplain over an area much larger than that described and introducing greater detail into the geologic history of the region, make it desirable not to go into this matter until the facts that appear to support it have been verified and much more field work has been done.

Influence of the peneplain and later displacements upon the drainage system of the Grand Canyon District.—That the Grand Canyon District was formerly thoroughly peneplained appears certain, and the surface was developed for the most part upon the soft strata-marls, shales and sandstones—of the Moencopie and Shinarump formations. The slope, as determined by Huntington and Goldthwait for the Mohave peneplain, was toward the south, and it would seem natural that the principal streams, following the maximum slope, likewise should have had courses to the south or southwest. After the faulting, which raised the peneplain above base-level, the well-recognized tendency of streams to readjust themselves under such conditions would become operative, and an entirely new drainage system would develop.

The effect of the faulting was to raise the eastern part of the district above the western and apparently to produce a slight, though not constant, tilting of the surface to the north. The streams that would develop on this new surface might at first be controlled, for instance, by the lava-capped areas, but eventually they would cut down to the Upper Aubrey cherty limestone, or other resistant rock. Upon this they would either be superposed or become adjusted to the structure produced by the folding and faulting. The large streams would most likely be partly superposed, partly subsequent, while the small streams would be subsequent, provided the rate of uplift were not too rapid.

The Colorado River may be considered as a superposed stream in the vicinity of the Kaibab Plateau. The peneplain died out against the flanks of the Kaibab at what is now an elevation of about 7,000 feet, though originally, of course, the elevation was much less. When the faulting and tilting occurred a depression was formed between the peneplain and upland that marked out the course of a master stream. As a result of this uplift there would be a slight ponding on the east side of the Kaibab until the waters rose to the highest point on the boundary at the southern end of the plateau, when overflowing this point they would continue northwestward. What may have determined the southwestern course from Kanab Creek to the Uinkaret Plateau is uncertain, although it may have been influenced by the lava flows now represented by the eroded remnants in Mounts Emma, Logan and Trumbull. At the west side of the Uinkaret Plateau the river turns southwest and then south to Diamond Creek, where it changes its course abruptly to the northwest, which direction it holds until it reaches the Grand Wash and passes beyond the border of the plateau. The course of the river was observed by Gilbert* in 1871 from Diamond Creek, and his description may be here quoted:

"At the mouth of Diamond Creek center four valleys of denudation, whose relation to the structure of the Plateau is very interesting. Two of these valleys are occupied by the Colorado and are portions of the Grand Canyon; that is to say, the river turns here abruptly at a right angle, and its two courses appear to have been determined by distinct causes. The third valley is the canyon cut by Diamond Creek, and is a prolongation eastward of the lower course of the Colorado. The fourth is that of Peach Spring Wash, and prolongs southward the upper course of the Colorado . . . . The character and remarkable straightness (of Peach Spring Wash)—I refer to its general course, and not to its details—are due to the fact that it was primarily determined by a fault; . . . its throw is to the west, and the amount of its dislocation near the river is about 600 feet. Its strike is north 25° east. For a few miles at least it is included in the upper course of the Grand Canyon, and, as I looked down Peach Spring Wash, and commanded with my eye a long vista of the canyon beyond, I was strongly impressed with the idea that the dislocation that had determined the one, had also marked out the other for a long distance. Later geographical determinations show that from the neighborhood of the Uinkaret Mountains to the mouth of Diamond Creek, a distance of thirty miles, the general direction of the canyon is straight and coincident with the observed trend of the fault. If what now appears probable shall hereafter be demonstrated—that the canyon for a long distance follows closely the line of faulting—the necessary deduction that the fault antedates the beginning of the canyon will be an interesting addition to the cronology of the river.

"The identity in direction of Diamond Creek with the lower course of the Grand Canyon is not a mere coincidence, but

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*Op. cit., p. 79. See also Mt. Trumbull and Diamond Creek topographic sheets, U. S. G. S.

depends on their common relation to the Plateau structure. The Aubrey Cliff, which crosses Arizona in a northwest direction, here intersects the Colorado. Since the general dip of the strata is to the north, and the escarpment is due merely to their unequal denudation, there lie, at the foot of the escarpment, a series of monoclinal valleys, of which the Tonto Basin, the Upper Verde Valley, and Aubrey Valley are examples. Diamond Creek runs, in like manner, parallel to the cliff, and differs from the others only in having excavated a deep gorge, which its low level of discharge enabled it to do. The same Aubrey Cliff that follows its northern and northeastern margin reappears beyond the Colorado, and, for forty miles, bears the same relation to the lower course of the Grand Canyon, leading to the belief that the stream was here guided, at the first, by the monoclinal valley, and that the Aubrey Cliff, as a topographic feature, is more ancient than the Grand Canyon. The cliff now rises from three to five miles back from the brink of the canyon, and may be supposed to have retired to that position by slow waste during the excavation of canyon."

Gilbert's observation in regard to the course of the Colorado between Diamond Creek and the Uinkaret Plateau—that it coincides with a fault—has been verified by the later work of Dutton* on the Hurricane fault. While the river from Diamond Creek to the Grand Wash, in the light of present knowledge, should be regarded as adjusted to the structure underlying the peneplain rather than guided by a preëxisting valley. The description is very clearly that of a subsequent stream, and as it applies to one-third of the course of the Colorado in the Grand Canyon District, its bearing on the origin of the river is evident.

If the boundary between the peneplain and lowlands in the Little Colorado Valley lay not far to the east of the river, as the observations at Black Point seem to show, then, when the uplift and tilting occurred, a northwestward sloping depression would be formed along the boundary. The waters of the streams on both slopes of this depression would be gathered along its line of lowest level into a trunk stream, which would flow northwestward until the unfavorable southward slope at the northern boundary of the peneplain was met. At that point it would be turned sharply south, joining the westerly flowing consequent that would there be developed. Or, if the peneplain extended still farther east than is supposed, the Little Colorado may be even more simply explained as a consequent that developed on the uplifted peneplain, and is now strictly governed by the underlying rock structure. As the dip of the strata is in general northeastward, the river in

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* Op. cit. (*a*), chap. vi.

either case would occupy a monoclinal valley, like the Colorado from Diamond Creek to the Grand Wash, the eastern wall of which would be well marked where resistant strata were encountered, or indistinct where they were soft.

The actual conditions appear to agree closely with the inferred. The profile of the river is quite unique in that it is a distinctly reversed curve, the upper and lower ends being much steeper than the intermediate portion. This may be illustrated by the following figures: For the first 40 miles, measured from the mouth of the river, the average grade is 34 feet per mile, for the last 40 miles it is 55 feet, while for the intervening stretch of 200 miles the grade is but 9 feet per mile. In more detail the grades of the first 200 miles are: (*a*) 25 miles at 35 feet per mile, (*b*) 15 miles at 31 feet, (*c*) 35 miles at 15 feet, (*d*) 100 miles at 7·5 feet, (*e*) 25 miles at 18 feet, with the remaining 80 miles at increasingly steeper grades. The two points to notice are the steep grade for the first 25 miles (*a*), and the low grade for the 100-mile stretch (*d*). The first shows the effectiveness of the heavy Carboniferous formations, in which the river has cut a precipitously walled canyon, in preventing a normal grade from being developed in the lower course of the stream; the second illustrates the same point, since it has resulted from the river being obstructed by the same formations in the vicinity of the "Crossing" north of Canyon Diablo. The river is thus closely controlled by the strata it flows upon, and is far from uniformly graded. The character of the river, near Winslow, in section (*d*) has been described by Marvine.* He said: "At this point, and above, the river is not at all typical of this region, inasmuch as it does not flow in a canyon. On the contrary, its flood plain is, in places, over a mile or more in width, through which it winds its muddy current in quite a tortuous course. It practically occupies a monoclinal valley between the Carboniferous and Triassic." The river continues in this monoclinal valley until the deep canyon at its mouth is reached, and of its course in the vicinity of Tanner's Crossing, Davis† has said that "It may be plausibly regarded as a subsequent stream; such was certainly its habit where we crossed it."

The river in its course northward passes through the Shinarump and Moencopie formations, and especially in its lower course, though also between Grand and Black Falls, through the Carboniferous. The western slope of the valley is clearly a stripped structural surface, and, except near the river, is marked by the Upper Aubrey cherty limestone. The north side of the valley is limited by a series of prominent cliffs,

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* Op. cit., p. 214.

† Op. cit. (*a*), p. 153.

mostly of Triassic sandstones, from Moencopie Wash southward to the vicinity of Winslow. From there, south and east, the soft shales and marls overlying the sandstones are encountered and the cliffs become much diminished in height.

The smaller streams of the Grand Canyon District appear to be, without exception, consequent in origin. Davis* has already ascribed such an origin to several on the north side of the Colorado. Among others are Peach Spring Wash and Diamond Creek, described by Gilbert in the passage quoted. All the washes that head in the Black and Mogollon mesas and run northeasterly into the Little Colorado are clearly consequent. In the vicinity of San Francisco Mountain the courses of Hull Wash, Oak and Sycamore Creeks are governed by faults. A similar example is Bright Angel Creek, as shown on the recently published Bright Angel topographic sheet, and the fault that has marked out its course may be traced south of the canyon by the line of the Grand Canyon Railroad.

The antecedent origin of the Green and Colorado rivers, advanced by Powell and Dutton, has been generally accepted for many years. It is to be noted, however, that Emmons,† as the result of his work on the Uinta Mountains in 1871, ascribed a superposed origin to the Green River. while Gilbert,‡ in 1876, said that:

"A large share of the drainage of the Plateaus is not consequent. How much is superposed, and how much antecedent remains to be determined. With the solution of the problem are involved the determination of the antiquity and history of the Green and Colorado rivers, and the physical history of the great Tertiary lakes."

Jefferson, in 1897,§ advanced "an independent and confirmatory argument for the consequent origin of the Green-Colorado . . . based on the curvature of the river and especially on its meanders. The meanders are surprising in themselves from the steepness of the river and their deep incision; yet more surprising is the location of strong meander reaches just up stream from structural displacements." Davis,‖ in the same year, pointed out that the origin of the Green River was still an open question, and after visiting the Grand Canyon District in 1900¶ wrote:

"That the facts now on record, combined with such knowledge of the region as our party was able to gather, warrant the consideration of at least one hypothesis alternate to the

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* Op. cit. (*a*), pp. 153–157.

† Explorations of the 40th Parallel, vol. ii, pp. 194, 205.

‡ This Journal, 3d ser., vol. xii, 1876, p. 102.

§ Science, vol. vi, 1897, p. 293.

‖ Ibid., vol. v, 1897, p. 647.

¶ Op. cit. (*a*), p. 166.

theory of antecedence, as an explanation for the origin of the drainage lines in the Grand Canyon District. I do not, on the one hand, consider the antecedent origin of the Colorado disproved, but, on the other hand, such an origin does not seem compulsory."

It would seem, however, that certain facts, such as the thorough peneplation of the Grand Canyon District, with the uplifting and warping of the peneplain by later faulting, the dependence of the course of the Colorado upon structure, as described by Gilbert, and the consequent origin, so far as known, of all branch streams, furnished sufficient evidence for definitely abandoning the idea of the antecedent origin of the Colorado River and for substituting a consequent origin in which superposed and subsequent conditions are both present.

While it is believed that the general question of the origin of the drainage system of the Grand Canyon District rests on a rather definite basis, it is realized that the number of facts is at present much too small to allow exact reasons being given for the location of considerable portions of the courses of the Colorado and Little Colorado, though not of the smaller streams. The problem involves the study of a large area, and it is hoped that whoever may have occasion to visit the region will succeed in gathering information that will assist in its correct solution.

Yale University, New Haven, Conn., June, 1907.

ART. XII.—*The Heat of Combustion of Silicon and Silicon Carbide;* by W. G. MIXTER.

[Contributions from the Sheffield Chemical Laboratory of Yale University.]

THE direct determination of the heat of combination of silicon with oxygen presents many difficulties. The reaction occurs only at high temperatures; the product is not volatile and hence encloses silicon and prevents complete oxidation. Troost and Hautfeuille* from the thermal effect of the reaction of silicon tetrachloride with water obtained 227000^c for the formation of silicon dioxide from crystalline silicon. Berthelot's† result by the same method was 179600^c for the formation of gelatinous silicic acid from crystalline silicon. Ostwald‡ states, "die Bildungswärme sämmtlicher Siliciumverbindungen ist noch sehr unsicher."

Preliminary tests made by burning a mixture of silicon and carbon in the bomb showed that more than half of the former could be burned. The method would give good results if the solid products contained only silica, silicon insoluble in hydrofluoric acid and silicon carbide. The last was always present; hence its heat of formation was determined, as described later, in order to have the data needed for the work on silicon.

The writer is indebted to the Carborundum Company, Niagara Falls, for an abundant supply of carborundum powder and silicon for the investigation. Crystallized silicon was prepared as follows: One part of silicon was dissolved in four parts of molten aluminum and the mixture allowed to cool slowly: the metal was dissolved out with hydrochloric acid, and the silicon, which was in small crystals, was digested with hot hydrofluoric acid. The product at this stage contained 2·8 per cent of aluminum. Treatment with molten potassium pyrosulphate reduced the aluminum content one-half. Next the crystals were pulverized in an agate mortar and the finer portions separated by levigation for one minute in water. Finally the powder was digested with a mixture of hot sulphuric and hydrofluoric acids, washed and then heated to drive off the acid not washed out. Thus prepared, the silicon contained a little aluminum, a trace of carbon and 99·95 per cent of silicon. The last was determined by dissolving the powder in a hot concentrated solution of pure sodium hydroxide and making the usual separation of silica. The carborundum was purified by means of molten pyrosulphate and, after washing, it was floated in water and only the finer portion retained. It was next treated with nitrohydrofluoric acid to remove silicon and silica, 40

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* C. R., lxx, 252.

† Thermochimie ii, 125, Ann. de Chimie et Phys. [5], xv, 213.

‡ Grundriss der allgemeinen Chemie, dritte Auflage, 268.

grams losing only 0·5 gram. It was finally digested with only hydrofluoric acid, but there was no further loss in weight. The purity of the product was found as follows: 0·5254 gram was fused in a platinum crucible with 5 grams of potassium nitrate and 10 of sodium carbonate, and the silica was separated with the usual precautions. Silicon found 69·9, calculated 70·3 per cent for SiC; Si=28·4.

Combustions with Sodium Peroxide.

The bomb used in all of the work was one described in the paper on carbon.* It was lined with silver cups 1^{mm} in thickness. Owing to the danger of melting the lower cup the combustible mixture was usually placed in a thick silver dish resting near but not in contact with the bottom of the bomb. This dish was usually melted by the combustion. Silver, as is well known, is oxidized by molten sodium peroxide, but the amount of oxide formed is small and the error caused is slight. A nickel dish was tried, but this was attacked much more than the silver one. After a combustion with sodium peroxide the fused mass resulting was dissolved in a large quantity of water and the insoluble unburned substance was collected, purified and its weight deducted from the amount of material used for the experiment. In case of silicon some may have dissolved in the dilute alkaline solution, but this was not likely, as silicon is taken up slowly by concentrated alkali. In order that the iron used for ignition should burn well the bomb was filled with oxygen at atmospheric pressure. The carbon used was the acetylene modification described by the writer.†

Experiment 1.

Carbon	1·0530	grams.
“ not burned	—0·0143	“
“ burned	1·0387	“
Iron for ignition	0·072	“
Sodium peroxide	19	“
Water	2954	“
“ equivalent of calorimeter	311	“
“ “ “ sodium peroxide and carbon	4	“
“ “ “ system	3269	“

Minutes.	Temperature.
0	18·452
1	18·454
2	18·458
3	22·012
9	22·012
10	22·009
11	22·006
12	22·003

Temperature interval.

22·012—18·458+0·009=3·563°

Heat observed 3269×3·563=11648^c

“ of oxidation of iron $—115^c$

11533^c

For 1 gram of carbon 11103^c

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* This Journal, xix, 435.

† Loc. cit.

Experiment 2.

Carbon	1·2214	grams.
“ not burned	—0·0107	“
“ burned	1·2107	“
Iron for ignition	0·060	“
Sodium peroxide	21	“
Water equivalent of system	3244	“

Minutes.	Temperature.	Temperature interval.
0	18·241	22·405 − 18·245 + 0·032 = 4·192°
1	18·243	
2	18·245	
15	22·405	
16	22·404	
17	22·399	
18	22·397	
19	22·394	
20	22·391	
21	22·388	

Heat observed 3244 × 4·192 = 13599^{c}
“ of oxidation of iron −96^{c}
13503^{c}

For 1 gram of carbon 11149^{c}

The motor stopped for a time after the ignition, hence the interval before the maximum temperature was observed was longer than usual.

Experiment 3.

Silicon	1·2320	grams.
“ not burned	—0·0003	“
“ burned	1·2317	“
Iron for ignition	0·058	“
Sodium peroxide	12·5	“
Water equivalent of system	3380·6	“

Minutes.	Temperature.	Temperature interval.
0	18·176	21·242 — 18·184 + 0.009 = 3·067°
1	18·180	
2	18·184	
8	21·242	
9	21·240	
10	21·238	
11	21·236	
12	21·234	
13	21·233	

Heat observed, 3380·6 × 3·067 = 10368^{c}
“ of oxidation of iron −93^{c}
10275^{c}

For 9 grams of silicon 8342^{c}

Experiment 4.

Silicon	1·4934	grams.
“ not burned	0·0031	“
“ burned	1·4903	
Iron for ignition	0·050	
Sodium peroxide	15	“
Water equivalent of system	3454	“

Minutes.	Temperature.	Temperature interval.	
0	18·425	22·060—18·431+0·008=3·637^c	
1	18·428		
2	18·431	Heat observed, 3544×3·637	12562^c
8	22·060	“ of oxidation of iron	—80^c
9	22·059		
10	22·058		12482^c
11	22·056		
12	22·054	For 1 gram of silicon 8379^c	
13	22·052		

Experiment 5.

Silicon carbide	1·105	grams.
“ “ not burned	0·075	“
“ “ burned	1·030	“
Iron for ignition	0·072	“
Sodium peroxide	11	“
Water equivalent of system	3565·6	“

Minutes.	Temperature.	Temperature interval.	
0	18·442	21·120—18·450+0·007=2·677°	
1	18·446		
2	18·450	Heat observed, 3565·6×2·677	9545^c
8	21·120	“ of oxidation of iron	—115^c
9	21·120		
10	21·118		9430^c
11	21·117		
12	21·116	For 1 gram of silicon carbide 9156^c	
13	21·115		

Experiment 6.

Silicon carbide	1·3987	grams.
“ “ not burned	0·0073	“
“ “ burned	1·3914	“
Iron for ignition	0·0534	“
Sodium peroxide	15	“
Water equivalent of system	3432·8	“

Minutes.	Temperature.	Temperature interval.
0	18·126	21·836—18·132 + 0·013 = 3·717°
1	18·128	
2	18·132	Heat observed 3432·8 × 3·717 = 12760^{c}
8	21·836	" of oxidation of iron —85^{c}
9	21·832	
10	21·829	12675^{c}
11	21·827	
12	21·825	For 1 gram of silicon carbide 9110^{c}
13	21·923	

The results of the combustions with sodium peroxide are as follows for 1 gram of each substance:

	Acetylene carbon	Crystalline silicon	Silicon carbide
	11103^{c}	8342^{c}	9156^{c}
	11149^{c}	8379^{c}	9110^{c}
Mean	11126^{c}	8360^{c}	9133^{c}

For 12 grams of acetylene carbon	133512^{c}
" 28·4 " " crystalline silicon	237424^{c}
	370936^{c}
For 40·4 grams of silicon carbide	368973^{c}
Difference	1963^{c}

The above results indicate that the formation of silicon carbide is accompanied with but little thermal change. The heat of combustion of the diamond according to Favre and Silbermann is 93240^{c}, 1488^{c} less than that of acetylene carbon in oxygen; assuming, if the diamond had been burned with sodium peroxide, that the result would have been 1488^{c} less, we have 515^{c} for the heat of formation of silicon carbide from the diamond and crystalline silicon.

Using Thomsen's* data for the union of sodium oxide and carbon dioxide, deForcrand's† for the heat of formation of sodium peroxide from the oxide, and the heat of combustion of acetylene carbon, the thermal effect of carbon and sodium peroxide may be calculated thus:

$$\begin{array}{lcr} Na_2O,\ CO_2 & = & 75920^{c} \\ C,\ O_2 & = & 94728^{c} \\ \hline & & 170648^{c} \\ 2Na_2O_2—O_2 & = & —38380^{c} \\ \hline 2Na_2O_2,\ C & = & 132268^{c} \end{array}$$

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* Thermochemische Untersuchen iii, 233.

† C. R. cxxvii, 514.

The agreement of the calculated with the experimental result indicates, in the reaction between carbon and an excess of sodium peroxide, that sodium metacarbonate is formed and not the orthocarbonate. The latter is not known, but if it may result by the union of the metacarbonate and sodium oxide the thermal effect would be about the same as that of the oxidation of sodium oxide.

Combustions in Oxygen.

The combustions were made as follows: A mixture of acetylene carbon and silicon carbide or silicon was placed in a shallow silver foil dish supported near the middle of the bomb. The object was to expose a large surface of the mixture when burning to oxygen. Naphthalene and anthracene were tried but did not answer as well as finally divided carbon. That the temperature was sufficient to volatilize silicon was shown by the deposition of silica on the sides of the bomb in the form of a white powder. It settled very slowly in water and passed through filter paper. Under the microscope it was found to be spheroidal and non-crystalline. The silica from burning silicon carbide was all in a finely divided form, while in that from silicon globules 2 or 3^{mm} in diameter were found. The residue left by the combustion was treated with nitric acid to dissolve silver present and, after thorough washing, was repeatedly digested with hydrofluoric acid until its weight when dry was constant. Finally the residue was treated with nitrohydrofluoric acid, the loss being silicon and the powder remaining silicon carbide. The thick platinum electrodes, placed 4 or 5^{cm^3} above the combustible mixture in the bomb, were more or less melted by the combustions. In one instance a globule of platinum silicide formed which was found to contain 7 per cent of silicon. In no instance was silicon found in the platinum melted by the burning of silicon carbide.

Experiment 7.

Silicon carbide	0·9820	grams.
" " in residue	0·1700	"
Silicon " "	0·0068	"
Silicon carbide burned	0·8052	"
Iron for ignition	0·0466	"
Oxygen	11	"
Water and water equivalent of system	3433	"

Minutes.	Temperature.	Temperature interval.	
0	18·013	21·520—18·014+0·015=3·521°	
1	18·014		
2	18·014	Heat observed, 3433×3·521 =	12088^{c}
7	21·520		
8	21·517	" of oxidation of iron,	—75^{c}
9	21·513	" " " " carbon	—6331^{c}
10	21·509		
11	21·505	" " " " silicon carbide	5682^{c}

For 1 gram of silicon carbide 7057^{c}

Experiment 8.

Silicon carbide	1·5029	grams.
" " in residue	0·3720	"
Silicon " "	0·0470	"
Carbon	0·6301	"

For 1 gram of silicon carbide 6659^{c}

Experiment 9.

Silicon carbide	0·744	grams.
" " in residue	0·158	"
Silicon " "	0·000	"
Silicon carbide burned	0·586	"
Carbon	0·931	"
Iron for ignition	0·049	"
Oxygen	11.	"
Water and water equivalent of system	3448.6	"

Minutes.	Temperature.	Temperature interval.	
0	18·485	21·818—18·488+0·007=3·337°	
1	18·488		
6	21·818	Heat observed, 3448.6+3·337 =	11508^{c}
7	21·816	" of oxidation of iron	—78^{c}
8	21·814	" " " " carbon	—7349^{c}
9	21·813		
10	21·811	" " " " silicon carbide	4081^{c}

For 1 gram of silicon carbide 6963^{c}

Experiment 10.

Silicon carbide	1·1125	grams.
" " in residue	0·0436	"
Silicon " "	0·0422	"
Carbon	0·944	"

For 1 gram of silicon carbide 6882^{c}.

Experiment 11.

Silicon carbide	1·0130	grams.
“ “ in residue	0·0984	“
Silicon “ “	0·0089	“
Silicon carbide burned	0·9057	“
Carbon	1·1220	“
Iron for ignition	0·0530	“
Oxygen	11·	“
Water and water equivalent of system	3387·5	“

Minutes.	Temperature.	Temperature interval.	
0	18·308	22·573 − 18·314 + 0·012 = 4·271°	
1	18·311		
2	18·314	Heat observed	15322^{c}
7	22·573	“ of oxidation of iron	-85^{c}
8	22·571	“ “ “ “ carbon	-8857^{c}
9	22·567		
10	22·563	“ “ “ “ silicon carbide	6380^{c}
11	22·561		
		For 1 gram of silicon carbide	7044^{c}

If the weight of carbide equivalent to the free silicon left by a combustion be deducted from the amount of carbide taken for an experiment, and the carbon equivalent to the free silicon be added to that taken, the results calculated on this basis will be essentially the same as those given. The following table shows the proportions of silicon carbide and free silicon remaining after the combustions:

			Silicon carbide.	Silicon.
Experiment	7	7057^{c}	18 per cent.	0·7 per cent.
“	8	6659	25 “ “	3 “ “
“	9	6963	20 “ “	0 “ “
“	10	6882	33 “ “	3·8 “ “
“	11	7044	10 “ “	0·8 “ “

It was found in the work on silicon that where the products of combustion contain much free silicon there is a variable error. For this reason the figures of experiments 8 and 10 should not be included in the final result. The mean of the other three experiments is 7009 calories for the heat of combustion of 1 gram of silicon carbide in oxygen at 20°. For 40·4 grams it is 282164 calories at constant volume and 283750 calories at constant pressure.

The combustions of silicon in oxygen yielded poor results, and for this reason the details of the calorimetric work are omitted in the following statement of the results:

Experiments	*12*	*13*	*14*	*15*	*16*	*17*	*18*
Silicon taken	1·011	0·5331	1·4904	0·9058	1·0468	1·1932	1·2031
“ in residue	0·056	0·0300	0·3537	0·1150	0·1504	0·2159	0·2040
“ of SiC “ “	0·080	0·0990	0·0798	0·0224	0·0388	0·0758	0·0490
Silicon burned	0·875	0·4041	1·0569	0·7684	0·8576	0·9015	0·9500
Carbon taken	1·0033	1·2320	0·6300	0·8690	0·9511	1·0862	1·0493
Result for 1 gram of silicon	6608^c	7060^c	6668^c	6972^c	6096^c	6460^c	6287^c

It was observed that the products of some of the combustions of silicon gave off a gas when digested with cold dilute hydrofluoric acid. This gas was presumably hydrogen or a hydrocarbon resulting from the interaction of a soluble modification of silicon or a silicon compound and the acid. This is the most probable explanation of the wide variation in the results. The substance noted as silicon carbide in the foregoing table was the residue insoluble in nitrohydrofluoric acid. It was repeatedly found to yield carbon dioxide when fused with lead chromate and in one portion 68·7 per cent of silicon was obtained: calculated, 70·3 per cent for SiC. The carbide from the combustions was in the form of a light grey amorphous powder.

The heat of oxidation of silicon may be calculated as follows:

$$\begin{array}{lcr}
\mathrm{SiC,\ 2O_2} & = & 283750^{c} \\
\mathrm{Si,\ C} & = & 1963^{c} \\
\hline
 & & 285713 \\
\mathrm{C,\ O_2} & = & 94728^{c} \\
\hline
\mathrm{Si,\ O_2} & = & 190985^{c}
\end{array}$$

Berthelot's* result is 180593^c for the formation of gelatinous silicic acid from 28·4 grams of silicon.

Lithium orthosilicate is known and it is probable that sodium orthosilicate results when silicon burns in an excess of sodium peroxide. On this assumption the thermal effect of the combination of one molecule of silicon dioxide with two molecules of sodium oxide may be calculated thus:

$$\begin{array}{lcr}
\mathrm{2Na_2O_2,\ Si} & = & 237000 \\
\mathrm{2Na_2O_2 - O_2} & = & 38000^{c} \\
\hline
 & & 275000 \\
\mathrm{Si,\ O_2} & = & -191000 \\
\hline
\mathrm{2Na_2O,\ SiO_2} & = & 84000^{c}
\end{array}$$

Experiments were made to determine the heat of combination as follows: Silicon dioxide in the form of a bulky impalpable powder, obtained by igniting silicic acid resulting from the decomposition of silicon fluoride in water, was used. A mixture of sodium peroxide, carbon sufficient to form an excess of sodium oxide, and silicon dioxide was ignited in the bomb. The temperature of the reaction was sufficient to melt silver. Less than 50^{cc} of oxygen were evolved. No free silica was found

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* Loc. cit.

after dissolving the fused mass in a large volume of cold water. The mean of two results which agreed closely was 71000^c for one molecule of silicon dioxide. The difference of 13000^c between the calculated and observed result is due either to an error of 5 per cent in the heat of oxidation of silicon or to the formation of a mixture of silicates in the experiments with silica. In the latter instance the conditions are less favorable to the formation of only the orthosilicate. Hence we may consider that 84000^c deduced from the reaction of silicon with sodium peroxide is the better result.

Summary of results.

$SiC, 2O_2$ = 283800^c
Si crystalline, C amorphous = 2000
Si " , O_2 = 191000^c
$2Na_2O, SiO_2$ amorphous = 84000^c

The figures given for the heat effect of the union of silicon and carbon are too small to indicate more than this, namely, that the formation of silicon carbide from its elements is accompanied with very small evolution or absorption of heat.

ART. XIII.—*The Vanadium Sulphide, Patronite, and its Mineral Associates from Minasragra, Peru;* by W. F. HILLEBRAND.

IN the Engineering and Mining Journal, Sept. 1, 1906, p. 385, and in Informaciones y Memorias of the Society of Engineers of Lima, Peru, vol. viii, pp. 171–185, 1906, two accounts are given by Foster Hewett and José J. Bravo, respectively, of a remarkable vanadium occurrence at Minasragra, about 46 kilometers from Cerro de Pasco in Peru and 43 from the railway. The two accounts agree in all essential points that are common to both, though that of the Peruvian writer is much the more detailed as to the geography and geology of the region. The data immediately following are drawn from the publications referred to, and from additional information furnished by Mr. Hewett.

Cretaceous sedimentaries—shales, sandstones and limestones —dipping at about 45° have been intruded by two (Hewett) or three (Bravo) series of eruptive dikes, and at the point of greatest frequency of these intrusives occurs the vanadiferous deposit, which had as yet been opened up only very superficially by a few pits along an extension of 400 feet on the outcrop. The vanadiferous materials occur in vein formation and are three in kind, aside from alteration products that cover the surrounding surface. Under the hanging wall is a thickness of about eight feet of an amorphous material of complex mineral composition which will be designated hereinafter as the "ore." Its color is dark, almost black (dark green like olivenite, according to Hewett, bright lead-gray with metallic luster on fresh surfaces but soon tarnishing, according to Bravo). Adjoining this material, without distinct line of demarkation beneath, is a singular hard coke-like carbonaceous matter, from eight inches to two feet in thickness, which blends on the farther side into a lustrous black substance of from four to six feet thickness, designated as asphaltite by both the above named writers, although it is a sulphur compound of carbon with very little hydrogen.

These three substances will now be considered in detail, beginning with the last, which from its unique position among carbonaceous mineral substances seems worthy of a specific name for the purpose of more ready separation from those bitumens and coals which it so strongly resembles in its superficial aspects. The name *quisqueite* is suggested by Mr. Hewett, after the settlement nearest to the locality of occurrence. The materials described in the following pages were furnished by Mr. Hewett, and a portion of the chemical data published by him were based on incomplete preliminary tests by myself. The reason for examining them in detail in the laboratory of the U. S. Geological Survey is not only that they represent an occurrence and association so unique, but chiefly that an as yet undescribed association of vanadium and carbonaceous matter in eastern Utah presents some points of similarity with that of Peru, and by reason of the higher concentration in the latter they seem to offer a convenient stepping-stone to future research upon the North American occurrence.

As to the source of the materials composing this vein deposit, nothing can at present be said, nor is a satisfactory explanation at hand for the comparatively sharp separation, in what would seem to be one vein, of such unlike materials. Mr. Hewett remarks that "the appearance of the materials as well as their occurrence strongly suggests that they were forced into the shales in a plastic or even liquid condition. Subsequent metamorphism has altered the composition of the asphaltite and the condition of the sulphur in the sulphide material." It is conceivable that the injected material was originally homogeneous and that segregation took place after injection. Possible evidence in favor of this view is afforded by the fact that the rich vanadiferous ore contains several per cent of carbonaceous matter similar in composition to the quisqueite, that the carbonaceous matter is itself vanadiferous, and that both are extremely rich in sulphur. In order to account for the coked matter between the two, it would seemingly be necessary to assume that the requisite heat came from the side of the vanadium sulphide ore. The adjacent dike undoubtedly played the chief rôle in this connection.

This is not the only known association of vanadium with carbonaceous matter, an association which is undoubtedly significant though we are as yet unable to explain it. Aside from the above mentioned occurrence in Utah, vanadium has been reported in numerous coals, in grahamite that probably came from West Virginia, and Mr. Hewett tells me that it is a constituent of the grahamite from Oklahoma. The enormously high proportion of vanadium in the Peruvian occurrence is of special interest, not only on that account but because it offers an opportunity to determine its state of combination in at least this particular case. It is possible that in some instances such sources may have furnished the vanadium of deposits of secondary minerals like those of the western United States.

Quisqueite.

This material, the asphaltite of Hewett and Bravo, though rich in carbon, is worthless as a combustible because of its content in sulphur, which exceeds that of the carbon in the specimen examined. Mr. Hewett reports 45 per cent of sulphur and that, though not holding a flame, the material burns when heated with the blue flame of sulphur. It is brittle, with density 1·75 and hardness about 2·5. It is infusible and apparently not affected by the usual solvents for bitumen, except that carbon disulphide extracts much sulphur. It leaves a variable amount of highly vanadiferous ash—3·31 per cent, containing 0·544 V_2O_5 (Hewett), 0·80 per cent, likewise high in vanadium (Hillebrand). Much sulphur sublimes when the mineral is heated in a closed tube and later hydrogen sulphide is evolved. It is oxidized by long boiling with strong nitric acid. The following is the composition of the sample analyzed:

S soluble in CS_2	15·44
S combined	31·17
C	42·81
H	0·91
N	0·47
O by diff.	5·39
Moisture at 105°	3 01
Ash	0·80
	100·00

The ash afforded roughly: SiO_2, 0·04; Al_2O_3, 0·08; Fe_2O_3, 0·10; NiO, 0·06; V_2O_5, 0·52. These are, however, results of minor quantitative value because of the minute amount analyzed. It is practically certain, for reasons to appear later, that the vanadium, iron and nickel existed in the original material as sulphides, and, therefore, assuming that the main analysis is correct, that the oxygen reported is too low.

The composition of this material is, so far as my knowledge extends, unique, and there are no data known that throw light on its chemical structure.

The Coke-like Material.

The quisqueite seems to have been converted on its upper side into a sort of coke, though this differs markedly from artificial cokes. Its hardness is 4·5. Glancing blows of a hammer cause much sparking. It is somewhat vesicular, though without large cavities. The openings are mostly short thin contraction cracks without orientation, which are best observed under a lens. They are for the most part lined or filled with a thin brilliant pitchy black coating, often reticulated, of what appears to have been originally fused matter and to which the luster of much of the specimen when freshly broken open is due. There are also rather numerous minute blowholes lined with or sometimes loosely filled with the brittle pitchy matter just mentioned. Elsewhere the surface is rather dull and of a color having a suggestion of red when contrasted with the pitch black of adjacent parts. The texture is extremely fine-grained like that of steel and the fracture rather conchoidal. These peculiarities of texture often give rise to great unevenness on large fracture surfaces. In the closed tube there appears a sublimate of sulphur and then the odor of hydrogen sulphide.

The composition of the sample analyzed follows:

S soluble in CS_2	0·64
S combined	5·36
C	86·63
H	0·25
N	0·51
O by diff.	4·64
Moisture	none
Ash	1·97
	100·00

The ash is highly vanadiferous.

THE VANADIUM ORE.

The remainder of the deposit, about eight feet in thickness, is a complex mixture of mineral substances. The color in mass, as earlier mentioned, is dark, almost black, with perhaps a suggestion of green as stated by Hewett. It breaks for the greater part unevenly, but often somewhat smoothly along planes of weakness, portions of which show permanent brilliant metallic luster. This is due to a thin coating of presumably carbonaceous matter like that noticed in the coke-like material. Bravo reports enclosures of brilliant black "asphaltite" and also sulphur visible to the naked eye. No sulphur was to be seen in the samples at my disposal,* but there were many patches and points of a dull pyritous mineral, whiter than pyrite and usually of a faint reddish cast, apparently due to tarnish. These consist of an iron-nickel sulphide, of which more later, carrying vanadium and siliceous and titaniferous matter. Heated in the closed tube, the ore gives off sulphur copiously and then hydrogen sulphide. It does not melt.

The chief component was given in both the earlier publications as a vanadium sulphide, to which Hewett gave the name *patronite* and Bravo that of *Rizo-Patronita*, in honor of Senor Antenor Rizo-Patron, the discoverer of the ore and its vanadium contents. The paper of Hewett was published Sept. 1,

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* Specimens received from Mr. Hewett since this was written do show free sulphur on some of the parting surfaces in the form of scales.

1906, and that of Bravo bears the date Aug. 31 of the same year, hence must have appeared a little later, although in the August number of the Boletin de la Sociedad de Ingenieros. Hewett's name, therefore, has the right of priority and being shorter is preferable, even though that given by Bravo may better conform to Spanish usage as to derivation, since it embodies the whole patronymic.

The following analyses given by those authors show the composition of the ore incompletely, since appreciable percentages of nickel and titanium were overlooked, and, moreover, they also show that it varies much in respect to the relative amounts of siliceous and sulphide components.

	Analysis by J. O. Handy (Pittsburg)	Analysis by H. Bunting (Lima)
SiO_2	10·88	22·22
Al_2O_3	3·85	8·32
Fe	2·45	1·98
V	16·08	15·36
MoO_3	0·50	----
S soluble in CS_2	6·55	41·81
S combined	54·06	
CaO	----	0·33
Moisture	trace	----
Undetermined	[5·63]*	9·98†
	[100·00]	100·00

Both I (in Mr. Hewett's paper) and Bravo reported the solubility of the vanadium in fixed caustic alkalies, and Bravo likewise in ammonia. I may say that ammonia does not act so quickly as the fixed alkalies. Bravo analyzed the alkaline extract for sulphur and vanadium, after first removing free sulphur, and reported 32·89 per cent vanadium and 67·20 per cent sulphur, corresponding approximately to the formula VS_3 the ratio as calculated by me from his values is 1:3·28).

The complete analysis of this ore is extremely difficult and in some respects the results given on p. 147 is lacking in precision. The following behavior threw light on the nature of the mineral components.

Repeated treatment in a Soxhlet extractor with carbon disulphide removed considerable sulphur. After thorough drying of the capsule and contents, hot water was passed through. The aqueous filtrate was blue-green and held a sulphate or sulphates of vanadium. This operation was followed by extraction with warm caustic soda as long as the filtrate came through colored. Hereby nothing but vanadium, sulphur and some of the siliceous components were taken out, and the

* Largely carbonaceous.

† Carbon.

solution was of a cherry-red color. In it the proportions of vanadium and sulphur were determined.

It may be said here that the analysis was of necessity made with interruptions, and it was noticed that the values obtained for free sulphur increased with lapse of time. The first determination gave 4 5 per cent, the second 5·5 per cent, and the third 7 per cent sulphur, each on a separate portion of the same sample. This seemed to indicate a progressive oxidation of the vanadium sulphide with liberation of free sulphur, or else that the ore contained insoluble as well as soluble sulphur and that the former on exposure of the powder to air underwent rather rapid conversion to the soluble modification. Heating the powder for some hours with a little carbon disulphide in a sealed tube in a steam bath did not result in an increased yield of free sulphur, nor did heating the powder to 60° for some hours in the air do so, hence the latter explanation seems improbable. To test the former the portion of powder that had afforded 7 per cent sulphur and had then been extracted by hot water was allowed to dry thoroughly and left exposed to air under an inverted beaker for three weeks, after which time it was again tested for free sulphur and sulphate, both of which were found, thus apparently confirming the supposition of oxidation. But the free sulphur found in this test was so far in excess of that converted to sulphate that it would seem as if the liberation of sulphur took place much faster than the oxidation of that which remained in combination with the vanadium (see page 148).

It was impracticable satisfactorily to examine the material remaining in the Soxhlet capsule after extraction by carbon disulphide and water, but separate portions of the ore, treated directly with alkali, were used in part. From the residue thus obtained strong nitric acid after a few minutes action took out all the iron-nickel sulphide together with most of the remaining vanadium, all the molybdenum and some titanic oxide, silica and alumina, besides acting to a slight degree perhaps on the carbonaceous component of the ore. The sulphur of the metallic sulphide was apparently wholly oxidized by the nitric acid. The solution was analyzed, but for more exact determination of the composition of the sulphide large amounts of the ore, only coarsely broken up, were thoroughly extracted by alkali, the black residue was dried and rubbed down gently with the finger, and from it the sulphide was extracted by an electromagnet and purified by repetition of the treatment.

The residue not dissolved by nitric acid is black and contains most of the carbonaceous matter of the ore besides the titaniferous and siliceous matters not removed by the foregoing operations. The carbonaceous material contains much sulphur and seems in this respect to resemble the quisqueite already described. On burning it off there is left a straw-colored residue in which nothing mineralogically definite was recognized except a few quartz grains. It is not unlikely that it consists chiefly of a clay-like substance and titanium dioxide in an amorphous state. Some vanadium in an oxidized form, perhaps a constituent of the clay, is also present.

It thus appears that the sulphur and vanadium exist in four different forms in the powdered ore. Mr. Hewitt states that lead, zinc, copper, arsenic, antimony, calcium, magnesium, silver, gold, and platinum were sought but not found. Uranium and germanium were looked for in vain by myself. Prof. B. B. Boltwood, who kindly examined for me both the vanadium ore and the quisqueite, reports hardly any evidence of radio-activity.

Bulk Analysis of the Ore.

The results in the following analysis are not in all cases highly accurate, and the summation is affected by indeterminable errors, among which is too high water, because some of it is derived from the hydrogen of the carbonaceous matter. This error is to a large extent offset by the oxygen of the carbonaceous matter. The vanadium sulphide constitutes about two-thirds of the ore, the metallic sulphide over one-tenth. It is not only an ore very rich in vanadium and from which the latter can be very readily extracted, but it also carries a percentage of nickel that may prove commercially of much value, since it will be left wholly in the residues after extraction of the vanadium.*

S (total)	58·79	(4·5 free)
V "	19·53	
Mo	0·18	
Fe	2·92	
Ni	1·87	
C	3·47	
SiO_2	6·88	
TiO_2	1·53	
$Al_2O_3(P_2O_5)$	2·00	
Fe_2O_3	0·20	
MnO	trace	
Cr	trace?	
Alk.	0·10?	
H_2O	1·90	
O from V. sulphate	0·38	
	99·75	

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* Specimens received from Mr. Hewett since this paper was written showed in some cases no visible metallic sulphide, in others but a few specks. Tests were not made to ascertain if the amount actually present is less than in the specimen first received.

Free Sulphur and Water-Soluble Extract.

Several determinations of the sulphur extractable by carbon disulphide were made at considerable intervals of time. The first gave 4·5 per cent, the second 5·5, and the third 7 per cent, thus, as already said, indicating a progressive liberation of free sulphur. The extractions were made in a Soxhlet apparatus till an extract was found free from sulphur.

The first determination of the water-soluble extract gave 0·41 per cent SO_4 and the solution held vanadium, as shown by its blue-green color and by qualitative test. Much later, in another portion, there was found 1·23 per cent SO_4 and 0·92 per cent V, with ratio V to SO_4 of 1 to 0·71. The vanadium was in an intermediate stage of oxidation between V_2O_4 and V_2O_5, as ascertained by direct titration and again after reduction by sulphurous acid.

When the powder that had served for the last test, and which had afforded 7 per cent free sulphur, was allowed to dry and left exposed to the air for three weeks and then again extracted by carbon disulphide and hot water in turn, there was found additional 0·81 per cent of SO_4 and 0·40 per cent of V, but the vanadium of the aqueous extract was all in the V_2O_4 state, for after titrating directly and then again after reduction by sulphurous acid, the results were identical. The ratio of V to SO_4 was not, however, the same as in the previous test, being 1 to 1·07. In this last test there was found 3·83 per cent of free sulphur in addition to the 7 per cent found at first, and since the sulphur in the SO_4 is but 0·27 per cent, or but one-fourteenth of the free sulphur formed during the three weeks, the ground will be apparent for the earlier remark (p. 146) concerning the greater rapidity of splitting off of free sulphur from the original sulphide than of oxidation of the lower combination of vanadium and sulphur that presumably resulted from this division. But the variation in the two ratios given above between vanadium and SO_4 has not been cleared up. These approximate very roughly to 1 to 1, which indicates a similar ratio in the lower sulphide, to whose direct oxidation the sulphate is supposed to be due, that is, VS. But much more knowledge is needed, based on numerous and varied tests, before the reactions involved in the changes above indicated can be written.

Patronite.

Several determinations of the sulphur and vanadium in the alkaline extract, after first removing free sulphur and the water-soluble constituents, gave the following results :

V	19·16	18·89	19·09	18·46
S	47·74	47·84	45·65	44·74
Ratio V : S	1 : 3·97	1 : 4·04	1 : 3·82	1 : 3·87

The determinations with the two highest ratios were earlier analyses in which least free sulphur was found and presumably least oxidation had taken place. They point to a formula VS_4 for the sulphide instead of VS_3 as reported by Bravo, whose actual ratio was 3·28. A sulphide of this composition seems very singular and the possibility suggested itself that the compound might be ortho-sulphovanadic acid, but this would probably be soluble in water and an amount equal to that in the ore would need, moreover, above 1 per cent of hydrogen, whereas the total as represented by the water found is less than 0·20 per cent, and this unquestionably belongs largely with the siliceous and aluminous matter of the ore.

In the light of the observation relating to the splitting off of free sulphur from the sulphide, a process that is evidently connected with exposure to air, the possibility has to be considered that the free sulphur found in the test showing least may all have been originally combined with the vanadium to form a still higher sulphide than VS_4. The ratio calculated on this basis is less than 1 to 4·5, indicating a formula not above V_2S_9. Lacking, as we do, any knowledge regarding the higher sulphides of vanadium, speculation at present would be premature.

Whatever may be the true formula, the mineral is new and the name patronite may well be applied to it.

The Iron-Nickel Sulphide, a Highly Nickeliferous Pyrite.

The bulk analysis of the ore indicates a greater percentage of the iron-nickel sulphide than would be supposed by inspection, and than was obtained by separation in the manner already outlined. Much of it is evidently in a state of fine division and escapes in the washings. Indeed, it was sought to recover only the grains of some size. It was noticed after separation that while some of the larger grains especially showed the pyritous color on fracture surfaces, all were more or less covered with a black coating of what is assumed to be the carbonaceous material of the ore and that most of them were black throughout, apparently from the same cause since on solution in nitric acid a considerable carbonaceous residue was left. In a few instances apparent crystals, seemingly of octahedral habit, were observed, but otherwise the fragments were quite destitute of crystalline structure. The color is rather whiter than that of pyrite, as said before, becoming of a reddish cast by tarnish. The mineral is not attracted by a hand magnet but attaches itself readily to an electromagnet. The density of the material analyzed was 4·33, but this value is of little worth since, despite repeated purification, the fragments contained a good deal of carbonaceous, siliceous and titaniferous matter in a state quite invisible to the eye. Heated in a closed tube much sulphur is evolved. The mineral is very insoluble in hydrochloric acid but is readily attacked by nitric acid with complete oxidation of the iron, nickel and sulphur. The other constituents remain more or less unattacked according to the duration of contact with the acid.

The results given below are for the four chief constituents the mean of concordant determinations. It is to be noted that if the vanadium was counted as the element, every analysis gave a summation of approximately only 97 per cent. This is accounted for in part probably by the extreme oxidizability of the mineral when exposed in powder form to the air, especially when wet. Hot water extracts from the powder ferrous and nickelous sulphates with only a very little vanadium. If the powder is left moist on the filter, relatively large additional quantities of iron and nickel can be extracted next day, and for several successive days, with very little vanadium. But the discrepancy cannot be apparently in large part thus accounted for. It seems necessary to assume that the vanadium is in an oxidized form, perhaps as a constituent of the siliceous-aluminous material. In this case its condition would be that of trivalency in all probability, a condition which also affords a more satisfactory summation than that of quinquivalency. Against its presence in combination with silica and alumina is its great excess over that in which it is known to occur in such forms in nature. On the other hand, the matter insoluble in nitric acid still contains some vanadium.

The following experiment seems to put it beyond question that the vanadium is not a constituent of the metallic sulphide.

	Mean	Atom. Ratio		Calc. to 100
S	45·06*	÷ 32·06 = 1·455	= 2·02	52·31
Fe	25·38	÷ 55·9 = 0·454	0·721 = 1·00	29·46
Ni	15·70	÷ 58·7 = 0·267		18·23
Co	trace			100·00
V	4·31	= 6·33 V_2O_3 or 7·66 V_2O_5		
Mo	0·09			
C	0·47			
H_2O	1·38	(partly from H of carbonaceous matter)		
TiO_2	0·93			
SiO_2	1·93			
Al_2O_3	2·45	(with a little P_2O_5)		
	97·70			

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* This does not include the sulphur that may have been held by the undissolved carbonaceous matter.

When the powder was exposed over night in a covered platinum crucible to the action of strong hydrofluoric acid, nearly half the vanadium and much of the silica, alumina and titanium were extracted, but only about one twenty-fifth of the iron and nickel, these two showing exactly the ratio afforded by the main analysis below. Boiling with dilute sulphuric acid yielded results somewhat similar.

If the vanadium is disregarded, the iron-nickel sulphide has the formula $(FeNi)S_2$ with iron to nickel as 1·70 to 1, or nearly 5 to 3. A pyrite with such a high proportion of nickel is unknown. But a single one of the analyses quoted in Hintze's Handbook of Mineralogy shows anywhere near 6 per cent nickel, this one, however, showing also about 3 per cent of cobalt. The nearest approach to the present case is seen in the mineral gunnarite $3FeS_2,2NiS$, incompletely described by Landström (Geol. Fören., ix, 368, 1887,) with density 4·3 and a tin-white color with a tinge of yellow, tarnishing yellowish brown. The present mineral would seem to be quite distinct from gunnarite and for the present is to be regarded as a highly nickeliferous pyrite. Should it seem proper to give it a specific name later, *bravoite* is suggested, after Senor José J. Bravo, the Peruvian writer on the vanadium occurrence at Minasragra.

The Carbonaceous Material of the Ore.

A determination of carbon and sulphur in 0·2459 gram of the residue insoluble in alkali and nitric acid gave 0·0475 carbon and 0·0254 sulphur, of which last 0·0036 was soluble in carbon disulphide. These figures indicate a similarity to quisqueite, although the sulphur is lower.

The Oxidation Products of the Ore.

Oxidation products are reported to cover the surface of the ground in the vicinity of the vein outcrop. The specimen examined by me resembles porous limonite in appearance. There was found in it by a rough partial analysis about 45 per cent V_2O_5, 14–15Fe_2O_3, 15H_2O, 20 or more of siliceous gangue, nearly 1 of MoO_3 and a little SO_3. Nickel is absent, or practically so. The material does not represent a single species, for it contains probably more than one vanadium compound, among them doubtless the minute micaceous scales, greenish sometimes and sometimes yellowish, that may be seen with a lens.

Lab. U. S. Geological Survey,
May 22, 1907.

Art. XIV. — *Mineralogical Notes*; by Waldemar T. Schaller.*

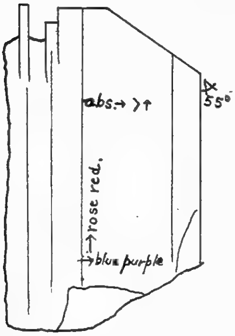
1. Purpurite from two new Localities.
2. Manganotantalite from Mt. Apatite, Maine.
3. Evansite from two American Localities.
4. Tourmaline from Elba.
5. Zinnwaldite from Alaska.
6. Forms of Pisanite—a correction.

1. Purpurite from Two New Localities.

South Dakota. — Some specimens of ore found near Hill City, S. Dak., were seen to contain a considerable amount of purpurite,† and through the courtesy of Mr. J. N. Smith, who sent in the first specimens, a larger quantity of material was obtained. Almost all the fresh cleavage surfaces of the black iron-manganese phosphate which chiefly forms the ore are covered with a film of purpurite. On breaking the black phosphate transverse to the cleavage but little purpurite is seen, and it seems probable that the latter is formed from the black mineral.

The properties of the mineral as seen under the microscope agree with those determined on the original mineral (from North Carolina). One small piece showing crystal outline was noticed, and is shown in the accompanying sketch (fig. 1). The extinction is parallel and the pleochroism is as follows: Parallel to the cleavage lines (vertical direction), rose-red; normal to the cleavage lines, blue purple. The absorption parallel to the cleavage lines (rose-red) is less than at right angles to this direction. On account of the frequent occurrence of small platy masses showing cleavage lines, the mineral has probably two cleavages at right angles to each other, one more perfect than the other. It is probably the imperfect one which is normal to the figure and whose traces show in the vertical lines.

1



On account of the larger quantity of material, a determination of the density was made, the value previously given being unsatisfactory. The material was broken into small pieces and the fragments of purpurite picked out. The final sample was not pure, as a small amount of the black substance could not be separated. The density determination was made by weighing the mineral in water in a small test tube

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* Published by permission of the Director of the U. S. Geological Survey.

† This Journal (4), xx, 146, 1905.

suspended from the balance arm. The result obtained is 3·40, which shows that the figure previously given, about 3·15, is entirely too low.

The sample was air-dried for several weeks and then analyzed, with the results given below:

		Ratio.	
P_2O_5	43·45	306	1·00
Fe_2O_3	38·36	240	1·06
Mn_2O_3	12·08	76	
CaO	1·37	24	
H_2O	4·82	268	·88
Insol.	·19		
MgO, Na_2O, Li_2O,	trace		
	100·27		

The ratios agree fairly closely with those found in the original paper, giving as the formula of the mineral $(Fe,Mn)_2O_3.P_2O_5+H_2O$. In the South Dakota mineral, the iron greatly predominates over the manganese.

Connecticut.—A small specimen from the well known mineral locality of Branchville, Conn., was kindly furnished the writer by the late Prof. Penfield. This specimen is coated with a purple mineral which in its optical properties as seen under the microscope agrees well with purpurite.

Only a very small amount of material (0·0197 gram), which was fairly pure, could be obtained for analysis. A direct determination of the water was made but the phosphoric acid had to be determined by difference. The results obtained are as follows:

		Ratio.	
Fe_2O_3	27	17	32
Mn_2O_3	23	15	
P_2O_5	[44]	31	
H_2O	6	33	
	100		

The ratios are nearly 1:1:1, giving the same formula as before, namely:

$$(Fe,Mn)_2O_3.P_2O_5+H_2O.$$

Considering now the three analyses of purpurite from North Carolina, South Dakota and Connecticut, it is seen that the iron and manganese vary reciprocally, so that purpurite is, without question, an isomorphous mixture of

$$Fe_2O_3.P_2O_5+H_2O.$$

$$Mn_2O_3.P_2O_5+H_2O.$$

In the South Carolina mineral, the manganese predominates; in that from South Dakota, the iron predominates, while in the Connecticut mineral the iron and manganese are present in nearly equal amounts. These relations can also be shown by the following table:

Purpurite from	$Fe_2O_3.P_2O_5.H_2O$.	$Mn_2O_3.P_2O_5.H_2O$.
South Carolina contains (approx.)	35 per cent	65 per cent
Connecticut " "	53 "	47 "
South Dakota " "	76 "	24 "

Should the two end products be found at some future time, it would not be inappropriate to designate them as ferripurpurite and manganipurpurite, retaining the name purpurite for either the isomorphous mixture of the two end products or else for the whole group, in a way similar to that in which the terms garnet or mica are now used.

2. *Manganotantalite from Mt. Apatite, Maine.*

The crystals here described were received from Prof. C. Palache, who suggested they were manganotantalite. They are associated with the minerals so characteristic of these lithium-bearing pegmatites, as albite, lepidolite, etc. The crystals are mostly small, several millimeters in length, and are usually tabular to the *a* face (Dana's orientation). A specific gravity determination gave a value of 7·14, showing that in these crystals the tantalic acid largely predominates over the columbic acid. A partial analysis further showed that iron was almost entirely absent, so that the crystals may well be termed manganotantalite. The analysis gave the following results:

Ta_2O_5 Cb_2O_5	85·35
FeO	·16
MnO	14·49 (by diff.)
	100·00

The forms present are: $b = \{010\}$, $a = \{100\}$, $c = \{001\}$, $m = \{110\}$, $g = \{130\}$, $j^* = \{320\}$, $z = \{530\}$ $d = \{730\}$, $k = \{103\}$, $u = \{133\}$, $n = \{163\}$. The angles measured are shown below. Most of the faces were dull and gave poor reflections.

		Measured.		Calculated.
$b \wedge m$	$= 010 : 110$	50° 28′		50° 22′
$b \wedge g$	$= 010 : 130$	21 27		21 55
$b \wedge z$	$= 010 : 530$	63 10		63 34
$b \wedge d$	$= 010 : 730$	70 15,	70° 06′	70 27
$c \wedge k$	$= 001 : 103$	19 38		19 42
$b \wedge n$	$= 010 : 163$	30	approx.	30 50
$n \wedge n'''$	$= 163 : 1\bar{6}3$	118	approx.	118 20
$n \wedge n'$	$= 163 : \bar{1}63$	22	approx.	19 54
$b \wedge u$	$= 010 : 133$	50 45		50 03
$u \wedge u'''$	$= 133 : 1\bar{3}3$	81 15		79 54
$u \wedge u'$	$= 133 : \bar{1}33$	30 04		29 57

Measurements for the new prism $j = \{320\}$ are as follows:

Cryst. No.	Size of face.	Refl.		Meas.	Calc.
1	narrow	p.	110 : 320	9° 39′	10° 44′
2	broad	p.	010 : 320	61 21	61 05
2	"	g.	320 : $3\bar{2}0$	57 12	57 48
3	"	f.	010 : 320	61 12	61 06
4	"	g.	010 : 320	61 13	61 06

The faces of {133} and {100} are large, those of {163}, {103}, {110}, {320}, small, while the others are usually very narrow faces.

3. Evansite from Two American Localities.

Idaho.—Some specimens of evansite, reported as being found in the immediate vicinity of Goldburg, Idaho, were received through the courtesy of Mr. C. R. Potts of that place. The massive, amorphous mineral occurs in seams and is very brittle, with a conchoidal fracture. The hardness is about 3, and the color, while usually brown, varies considerably, becoming at times colorless, also yellow or white or a dark red. The brown specimens resemble common brown opal very much.

An analysis of the brown material gave the following result:

H_2O	36·96
P_2O_5	19·14
Fe_2O_3	5·49
Al_2O_3	34·48
CaO	4·32
MgO	trace
FeO	none
	100·39

Loss of water	
at 107°	20·00
175	7·36
255	3·13
290	·94
to low redness	3·90
blasting	1·61
	36·94

A determination, by means of Thoulet solution, of the relation of the density to the amount of iron present gave the following values:

Color of mineral	Amount Fe_2O_3	Av. density	Limits
dark red	6·60 per cent	2·00	1·990–2·016
brown	5·49 "	1·98	1·972–1·990
yellow	2·15 "	1·94	1·927–1·947

By plotting these values, it is found that the density of the mineral free from iron should be between 1·88 and 1·91, though this value does not necessarily represent that of pure evansite, as the material on which these determinations were made contains appreciable calcium. Forbes* gives the following determinations of the density:

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* See literature at end of paper for references.

Colorless, translucent,	1·822
Colorless,	1·872
Faint yellow,	2·099
Semi-opaque,	1·965

the average of which is 1·939, though possibly the lowest figure more nearly represents the density of the pure mineral. Smith[†] gives as the density of colorless to milky white, translucent material, the value 1·842. Kovář gives for white = 1·874 (·87 per cent Fe_2O_3) and for yellow 1·937 (1·92 per cent Fe_2O_3). These values give an average for all the determinations of 1·93, while an average of the lowest values, representing possibly the purer mineral, gives 1·86.

A determination of the index of refraction of the colorless evansite from Idaho by Dr. F. E. Wright gave 1·485, the index for the colored varieties not varying more than ·01 from this value.

Alabama.—The second sample was received through Prof. Clarke from Mr. Charles Catlett, and the locality is given as "from the coal seam just west of Columbiana, Alabama." It is associated with coal and shows a light yellow color with a resinous luster, and is transparent in small pieces. It is very brittle and easily breaks into small fragments. An approximate analysis serves to identify the mineral; the phosphoric acid being determined by difference.

Al_2O_3	38·33	
CaO	1·03	
MgO	·75	
Loss on ign	38·19	
P_2O_5	21·70	(by diff.)
	100·00	

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1883. Woodward, A. S. Min. Mag., v, 333.
1893. Smith, H. G. Proc. R. Soc. N. S. W., xxvii, 382.
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1902. Petterd,* W. F. Papers and Proc. Roy. Soc. Tasmania, 18–33.
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1903. Vernadsky,* W. and Popoff, S. Centralbl. Min. Geol., 331.

* These references only mention the occurrence of evansite.

[†] Wrongly given as 1·939 in Dana's App. I, p. 25.

4. Tourmaline from Elba.

While analyzing a number of tourmalines from San Diego County, California, it was suggested by Prof. Clarke that it would be advisable to analyze the pale pink variety of tourmaline from the island of Elba. Rammelberg's analysis of tourmaline from this locality indicated that these tourmalines were probably near, in composition, to one of the end products of the isomorphous mixtures which form the mineral tourmaline. A number of these crystals were purchased from the Foote Mineral Company, who wrote in regard to them: "All of these were secured in exchange from the late Prof. Bombicci, who collected them in Elba many years ago." The crystals were picked over and after crushing them to small fragments, each piece was examined under a hand lens and only the transparent pure material was selected. These were then washed with cold dilute HF to remove any albite, mica, etc., that might be adhering to the tourmaline. The sample finally powdered and analyzed was pure. The density of the mineral (determined by Thoulet solution) is 3·04–3·05, as the mineral sank at 3·043 and floated at 3·050. The analysis, made with all care, follows:

		Ratio	
SiO_2	37·89	·632	
B_2O_3	10·28	·147	
Al_2O_3	43·85	2·580	These ratios give the hydrogen atoms equivalent to the metals.
Ti_2O_3	·04	·002	
FeO	·11	·003	
MnO	·11	·003	
CaO	·07	·003	
Na_2O	2·43	·079	
Li_2O	1·66	·111	
H_2O	3·47	·386	
F	·10	·005	
MgO, K_2O	none		
	100·01		
$-O = F$	·04		
	99·97		

Ratio $SiO_2 : B_2O_3$: total H = 4·00 : ·93 : 20·08

This ratio agrees very well with that proposed by Penfield, namely, 4 : 1 : 20. A discussion of the results will be given in the paper on the California tourmalines, as at present it is only desired to place the above analysis on record. The states of oxidation of the titanium, iron and manganese are arbitrarily given.

5. *Zinnwaldite from Alaska.*

The occurrence of zinnwaldite with cassiterite and topaz in the York region, Alaska, has already been mentioned* and the results of a quantitative analysis of this mica are here presented. The sample analyzed was probably fairly pure.

	Analysis	Ratio	
SiO_2	46·80	·775	775
Al_2O_3	24·50	·240	243
Fe_2O_3	·50	·003	
FeO	6·35	·088	111
MnO	1·38	·019	
CaO	·24	·004	
Na_2O	1·73	·033	131
K_2O	9·20	·098	
Li_2O	3·73	·124	124
H_2O	·88	·098	552
F	8·63	·454	
	103·94		
−O=2F	3·63		
	100·31		

In the ratios, the soda and potash are taken together and the small amount of water present is considered as hydroxyl and added to the fluorine ratio. The empirical formula gives:

$$Si_{775}Al_{486}Fe_{111}K_{262}Li_{248}F_{552}O_{2369}$$

The total oxygen is very slightly greater than three times the silica, the ratio O : Si being 3·06 : 1. The mineral is therefore considered as a metasilicate and the formula may be written

$$(SiO_3)_{775}(AlF_2)_{276}K_{262}Li_{248}Fe_{111}(AlO)_{44}Al_{166}$$

or

$$(SiO_3)_{12}(AlF_2)'_{4{\cdot}27}K'_{4{\cdot}06}Li'_{3{\cdot}84}Fe''_{1{\cdot}72}(AlO)'_{{\cdot}68}Al'''_{2{\cdot}57}$$

The above formula shows that the analysis may well be interpreted as a metasilicate.

6. *Forms of Pisanite—a Correction.*

In a paper on "Minerals from Leona Heights, Alameda Co., California,"† the writer described a number of new crystal forms for pisanite $(Fe,Cu)SO_4.7H_2O$. One of these, $g=\{\bar{2}05\}$ has to be withdrawn as its determination is based on an error. The face measured and described as $\{\bar{2}05\}$ is the base $\{001\}$.

meas. $\{\bar{2}05\}$, $\phi=90°\ 03'$ $\rho=15°\ 00'$
calc. $\{001\}$, $\phi=90\ \ 00$ $\rho=15\ \ 11$

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* Bull. 262 U. S. Geol. Survey, 129, 1905.

† Bull. Dept. Geol. Univ. Cal., iii, 191–217, 1903.

Art. XV.—*The Thermoelectromotive Forces of Potassium and Sodium with Platinum and Mercury;* by Harold C. Barker.

Following Seebeck's discovery in 1821, many investigators have measured the thermoelectromotive forces produced when the two junctions of a given metallic conductor with a second metallic conductor are maintained at different temperatures. But comparatively few attempts have been made to determine the values of these thermoelectromotive forces for couples consisting of sodium or potassium combined with other metals, for the obvious reason that the ease with which the alkali metals oxidize renders their manipulation difficult.

Matthiessen[*] compared the thermoelectromotive forces of silver-sodium and silver-potassium couples with that of a silver-copper couple, and expressed his results in terms of the latter. The two couples were placed in series with a galvanometer, and the ratio deduced from the observed deflections when the two couples were alternately arranged, by a commutating device, to assist or oppose each other. The difference of temperature between junctions did not exceed 26° in any case given. The sodium and potassium were contained in straight wide thermometer tubes into which the metal was introduced melted, in an atmosphere of hydrogen. Into the ends of the tubes short platinum wires had been fused, and to these the silver wires were soldered. The results cannot be regarded as of great value at this time; they merely express the ratio between the thermoelectromotive forces of, for example, silver-sodium and silver-copper for a particular small temperature difference between junctions.

Tait[†] made some measurements with couples of which one member was sodium or potassium in order that the lines of these metals might be included in his "First Approximation to a Thermoelectric Diagram." I can find no record of the observations on which his results were based, nor any statement as to the means of measurement adopted for the particular cases. It may be presumed, however, that the method was similar to that used by him in other cases, and consisted essentially in a measurement of the thermoelectric current-strength based upon the observed deflections of a sensitive galvanometer. As to the construction of the couples, he states that he had prepared for him "a long quill tube of German glass with platinum wires inserted near the ends; exhausted it by

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[*] Pogg. Ann., ciii, p. 412, 1858.

[†] Proc. Edinb. Soc., viii, pp. 350–362, 1873–1874.

means of a Sprengel pump, and drew in melted sodium from a bath of paraffin."

Naccari and Bellati* measured the thermoelectromotive forces of sodium-copper and potassium-copper couples, and, in order to refer to lead, of a lead-copper couple. The circuit was simply completed through a galvanometer of high sensibility, and the deflection noted. Then, the resistance of the couple and of the galvanometer being determined, and the galvanometer calibrated by a Daniell cell of known electromotive force and resistance, the thermoelectromotive force was calculated. The metals were melted under petroleum of high boiling point in wide vertical tubes, and narrower tubes filled by simply inserting, with the upper end closed with the finger, and then removing the finger and thus allowing the pressure of the petroleum in the large tube to force the molten metal up into the narrow tube. When the metal had cooled and solidified, the tube was withdrawn and the ends of the copper wires, which were threaded, forced into the solid metal. The sodium tube was straight; the potassium tube, in order that measurements might be made with one junction at a temperature above the melting point, was terminated by a U. The junctions were surrounded and protected by petroleum, contained in glass globes provided with the necessary tubulures. Heat was applied by means of a water-bath.

I have not had access to the original communication, and have had to depend on an abstract in the Journal de Physique, 1877, which, while quite full in many respects, gives but few numerical results, stating only the values found for the "specific heat of electricity" and the temperatures of the neutral points.

This is the most recent investigation of the thermoelectric properties of potassium and sodium of which I have found a record.

The present communication deals with the measurement of the thermoelectromotive forces of potassium-platinum and sodium-platinum couples for varying temperature-differences between 0° and about 90°, and, for the purpose of comparison, of a mercury-platinum couple through the same range, by a potentiometer method. There was available for this use a Leeds potentiometer, adjusted to read directly in volts when used in connection with a Weston standard cell of 1·0193 volts. The potentiometer was carefully tested and some corrections made. The certified electromotive force of the cell was verified by a comparison made by the National Bureau of Standards.

The galvanometer used was a high sensibility D'Arsonval

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*Nuovo Cimento, xvi, pp. 120–130, 1876.

instrument manufactured by Leeds and Northrup, of most excellent performance. It was used, of course, with telescope and scale.

The form of the thermo-couples finally arrived at after many trials and rejections was as shown in the accompanying diagram. For clearness, the branch EF is represented in the plane of the paper; it was actually bent in a plane at right angles thereto, as toward the reader.

This apparatus was constructed of ordinary glass tubing of about $0{\cdot}4^{cm}$ diameter, with platinum wires fused in at A and B. The distance between A and B is about 55^{cm} and the vertical distance AC or BD about 10^{cm}. The branch EF is about 15^{cm} long. The platinum wires were of number 32 B & S gauge, and each was about 100^{cm} in length. Three such pieces of apparatus were built, as nearly as possible, alike; the six pieces of platinum wire required were cut from a single piece of about 600^{cm} length supplied by Eimer & Amend.

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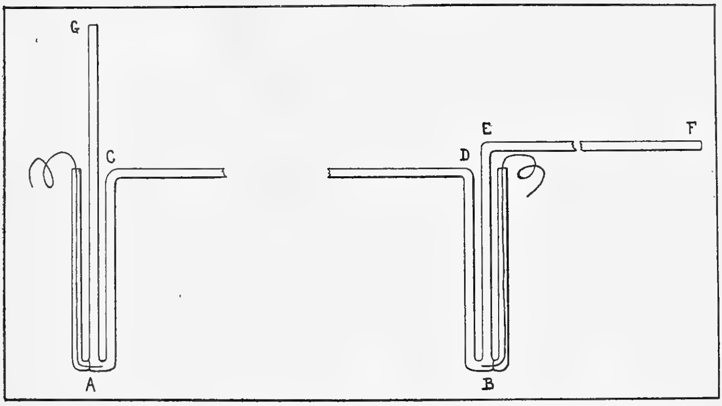

The tubes were filled respectively with potassium, sodium and mercury, these metals being drawn in at the end F by suction applied by the mouth to a rubber tube connected at G. Mercury, of course, was simply drawn in at the ordinary room temperature. To introduce the other two metals, the tubes were heated, filled with melted paraffin and again emptied, and then filled with the metal, previously melted under paraffin in a test tube. In drawing in the alkali metals, the mouth was protected against accident by a glass trap interposed in the rubber tube between the mouth and the opening G. The paraffin used was ordinary white paraffin of commerce melting at about 45° to 50°.

It was found that the potassium and sodium in lumps of several cubic centimeters could be introduced with perfect safety into a mass of melted paraffin, and, when melted under it, showed in each case a brilliant metallic surface, which remained untarnished indefinitely. Sodium when thus melted could be simply poured from vessel to vessel without apparent risk; potassium was transferred when needful by means of a narrow glass tube closed at one end by the finger, into which the metal was drawn by suction. Paraffin oil was first tried, but abandoned in favor of solid paraffin, as the oil was found not without action on sodium, especially when the latter was melted; moreover, the solid paraffin was more convenient and cleanly to handle.

A tube thus prepared will remain unimpaired indefinitely, the precaution being taken to protect the free ends of the alkali metal by a plug of paraffin a fraction of a centimeter long. The surface of both metals in contact with the walls of the tube is beautifully clean and lustrous, sodium being distinctly crystalline in appearance, while potassium is not crystalline, or obscurely so.

The sodium and potassium were the commercially obtainable metals, presumably of fair purity. Cooling curves gave the melting point of the potassium at 63·5°, and a rough spectroscopic examination showed no impurity other than the expected trace of sodium. The mercury was the pure redistilled metal supplied by a reputable firm.

The purpose of the mercury tube was to afford a comparison with a metal whose thermoelectric behavior is less subject to variation than is the case with commercial platinum, different specimens of which have long been known to vary widely in this respect. Mercury was chosen as readily obtainable in the pure state and free from crystalline or other structure, following the example of K. Noll* and also as readily introduced into a tube of the form described.

When placed in position for measurement, the vertical parts of a tube were inserted in wide test tubes containing mercury so that the junctions were deeply immersed. These mercury receptacles were surrounded respectively by water and by melting ice contained in double walled copper vessels. In each test tube a thermometer was also inserted, graduated to 0·2°, with the bulb as closely adjacent as possible to the actual platinum-metal junction. The platinum wires were led to thin glass mercury cups floating in a large mass of mercury, and from these cups copper wires were used to connect with the binding posts of the potentiometer.

The thermometer at the cold junction was found to be indispensable, the temperature being always a little above zero, and

* Ann. der Physik, 1894.

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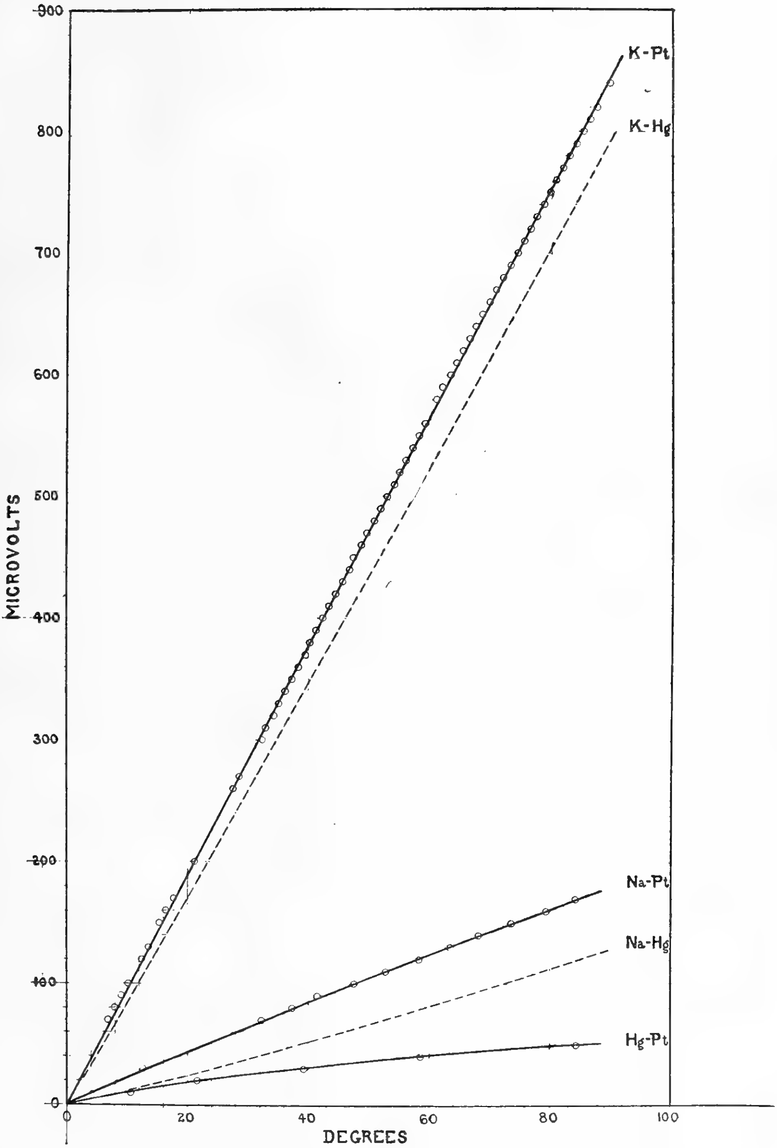

subject to slow but considerable variation, in spite of much precaution.

To obtain a series of observations, the other junction was surrounded, as stated before, with water, which had been heated, generally to boiling, or which was colder than the air of the room, and corresponding values of temperature and electromotive force read at intervals as the temperature of this junction fell or rose, chiefly through radiation. Inasmuch as the least difference in electromotive force between successive points at which the potentiometer, as it was constructed, could be set was 10 microvolts, it was the uniform practice to set the potentiometer at the point whose corresponding electromotive force would next be reached, in following the variation in temperature in either direction; and, depressing the galvanometer key shortly before, watch the slowly decreasing deflection until it was reduced to zero, when the temperatures of the hot and cold junctions were read in close succession. No difficulty was met with by reason of variation of zero point, and none from variation of electromotive force of the storage cell used to supply the potentiometer current, this latter variation being very slow and of small extent. The deflection of the galvanometer followed the variations in temperature closely and regularly. Under the circumstances of actual measurement a variation of the setting of the potentiometer of one step of 10 microvolts caused a difference of deflection of the galvanometer of over 20 scale divisions (millimeters), each of which was very easily divisible by the eye into at least five parts; I conclude, therefore, that I would be quite justified in stating the electromotive forces measured to 0·1 microvolt, if this seemed desirable.

The results obtained are embodied in the subjoined tables and in the accompanying curves. In the tables the column headed E gives the electromotive force in microvolts at which the potentiometer was set; that headed T gives the temperature difference between junctions, one of which was invariably near zero. The thermometer readings have been corrected for the determined variation in the positions of the fixed points, but in no other way. The value of T given is the mean of all the observed values.

In each of the three cases the electromotive force developed was such as to cause current to flow from the enclosed metal to the platinum at the heated junction. The electromotive forces are therefore all of the same sign and are treated as positive.

Under N is stated the number of observations made at the corresponding potentiometer setting. This must not be regarded as indicating the number of separate series of observations made with a given couple, or even with a given couple in a given range. Thus, in the case of the potassium-platinum couple, eight series of observations were made at different times during a period of about two weeks, and four of these embraced the higher range of temperature in common. In no case, however, are there more than three observations at a given point, as the aim was rather to supply points wanting in preceding series than to obtain additional values for the same point.

The column headed D gives the mean of the absolute values of the deviations of the individual observations from their mean, expressed in degrees, and also in microvolts. It will be

TABLE I.

Potassium-Platinum

E	T	N	D		E	T	N	D	
			°					°	
840	89·60	1	---	---	460	48·71	2	0·21	2·0
---	---	---	---	---	450	47·32	1	---	---
820	87·52	2	0·04	0·4	440	46·73	2	0·01	0·1
810	86·38	1	---	---	430	45·58	1	---	---
800	85·28	3	0·07	0·7	420	44·46	1	---	---
790	84·09	2	0·11	1·0	410	43·36	1	---	---
780	83·00	1	---	---	400	42·36	1	---	---
770	81·91	2	0·03	0·3	390	41·26	1	---	---
760	80·72	1	---	---	380	40·24	1	---	---
750	79·80	1	---	---	370	39·56	1	---	---
740	78·76	2	0·06	0·6	360	38·37	2	0·07	0·7
730	77·54	2	0·08	0·8	350	37·34	1	---	---
720	76·54	2	0·14	1·3	340	36·24	2	0·06	0·6
710	75·47	2	0·01	0·1	330	35·14	1	---	---
700	74·40	3	0·08	0·8	320	34·34	1	---	---
690	73·24	1	---	---	310	33·02	1	---	---
680	72·02	1	---	---	300	32·40	1	---	---
670	70·86	1	---	---	---	---	---	---	---
660	69·80	2	0·06	0·6	270	28·64	1	---	---
650	68·64	3	0·16	1·5	260	27·70	1	---	---
640	67·55	2	0·07	0·7	---	---	---	---	---
630	66·52	1	---	---	200	21·22	1	---	---
620	65·44	1	---	---	---	---	---	---	---
610	64·30	1	---	---	170	17·70	1	---	---
600	63·32	2	0·08	0·8	160	16·40	1	---	---
590	61·92	1	---	---	150	15·34	1	---	---
580	60·98	1	---	---	---	---	---	---	---
---	---	---	---	---	130	13·56	1	---	---
560	59·20	3	0·00	0·0	120	12·44	1	---	---
550	58·14	2	0·20	1·9	---	---	---	---	---
540	57·19	2	0·05	0·5	100	10·18	1	---	---
530	56·01	2	0·09	0·8	90	9·02	1	---	---
520	54·93	2	0·09	0·8	80	7·88	1	---	---
510	54·12	1	---	---	70	6·82	1	---	---
500	52·96	1	---	---					
490	51·88	1	---	---					
480	50·84	1	---	---					
470	49·62	1	---	---					

TABLE II.

Sodium-Platinum					Mercury-Platinum				
E	T	N	D		E	T	N	D	
			°					°	
170	84·24	4	0·54	1·0	50	84·42	6	2·35	0·9
160	79·29	4	0·60	1·1	40	58·56	5	1·24	0·6
150	73·60	5	0·62	1·2	30	39·31	2	0·25	0·1
140	68·14	4	0·52	1·0	20	21·69	2	0·13	0·1
130	63·46	3	0·36	0·7	10	10·64	3	0·29	0·3
120	58·29	3	0·34	0·6					
110	52·79	5	0·72	1·4					
100	47·58	4	0·77	1·5					
90	41·51	2	0·33	0·7					
80	37·32	2	0·04	0·1					
70	32·16	1	- - -	- - -					
- - -	- - -	- - -	- - -	- - -					
30	12·64	2	0·40	0·8					

noticed that, as expressed in microvolts, the highest values for each of the three couples are not widely different.

The successive observations of a given series were frequently and even prevailingly much more concordant than those of different series. A similar observation was recorded by W. H. Steele in his well known paper,* who says that "One is led to the suspicion that the thermoelectric constants are not really constants, but that they vary in a given specimen in a manner which, if not arbitrary, yet arises from changes in condition which are inappreciable." While not perceiving in just what sense a natural phenomenon can be regarded as "arbitrary," I can otherwise fully appreciate the comment quoted, since I have myself failed to trace such variation to its causes with any certainty.

The curves are virtually self-explanatory; in addition to those obtained by direct experiment, the curves deduced from them for potassium-mercury and sodium-mercury are indicated.

I hope to find opportunity at some future time to make further measurements with a potentiometer system better adapted to the measurement of such small electromotive forces, and with metals of whose purity I shall have more assurance. The foregoing values are therefore presented as preliminary approximations rather than as final results. It is also highly desirable to extend the temperature range in both directions.

My thanks are due Prof. A. W. Goodspeed, both for suggesting the domain of investigation, and for placing the resources of his laboratory most freely at my disposal; and I should be most remiss if I failed to acknowledge my indebtedness to Dr. R. H. Hough for his constant advice and aid, particularly in the construction of the special apparatus required.

University of Pennsylvania, Philadelphia.

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* Phil. Mag., Feb. 1894.

ART. XVI.—*The Reaction between Potassium Aluminium Sulphate and a Bromide-Bromate Mixture;* by F. A. GOOCH and R. W. OSBORNE.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—clx.]

WHEN the water solution of a neutral aluminium salt is boiled, hydrolysis may take place until an equilibrium is brought about between the free acid formed and other active products. If a product is inert toward the acid set free in the liquid, or if the acid is continuously removed or destroyed, the process goes on until no further hydrolytic action is possible under the conditions.

In the basic acetate process for the separation of alumina, the insoluble aluminium compound is a basic salt inert toward the free acetic acid formed under the conditions.

In Chancel's method of precipitating alumina, by the action of sodium thiosulphate upon the boiling solution of the soluble aluminium salt, the insoluble product is likewise a basic salt, in this case the sulphate, and the sulphuric acid set free is fixed as sodium sulphate while the thiosulphuric acid formed in metathesis is destroyed at the temperature of the reaction with formation of the comparatively inactive sulphur dioxide and sulphur; though as Norton has shown* the basic salt is not quantitatively insoluble until the mixture is superheated under pressure.

In Stock's process† for the determination of alumina, aluminium sulphate in solution is heated at the boiling temperature with a mixture of potassium iodide and potassium iodate. The sulphuric acid produced hydrolytically is fixed by the iodide-iodate mixture and comparatively inert iodine is set free and taken up by sodium thiosulphate to form sodium iodide and sodium tetrathionate. In this process, as Moody has shown‡, the first insoluble product is a basic salt; but prolonged boiling of the mixture of aluminium sulphate, potassium iodide and potassium iodate finally brings about the complete hydrolysis of the insoluble basic salt, so that the entire amount of iodine set free in the process, when properly collected and titrated, may serve as an accurate measure of the acid produced and therefore of the acidic ion of the aluminium salt.

In an extension of this process to other elements Moody found that a sufficiently prolonged treatment with the iodide-iodate mixture completely liberated the acidic ion from the

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* Ber. Dtsch. Chem. Ges., xxxiii, 548, 1900.

† Norton, this Journal, xii, 118, 1901.

‡ Moody, this Journal, xx, 181, 1905.

sulphates of iron, chromium, cobalt, nickel, ammonium and from stannic chloride. The hydrolysis of zinc sulphate under similar conditions comes to an end before the acidic ion is entirely liberated and when the product is one-fifth sulphate and four-fifths hydroxide.

In the work of which the present paper is an account, the reaction of a mixture of potassium bromide and potassium bromate upon aluminium sulphate has been studied. Assuming that the acidic ion is entirely liberated from the aluminium salt, the reaction should follow the equation

$$\begin{aligned}2KAl(SO_4)_2 + 5KBr + KBrO_3 + 3H_2O \\ = 2Al(OH)_3 + 4K_2SO_4 + 3Br_2.\end{aligned}$$

For this work a bromide-bromate solution was made up by dissolving 36 grms. of potassium bromide and 10 grms. of potassium bromate (the proportions indicated in the equation) in water and making up to 500^{cm^3}. Pure crystallized potassium alum was the aluminium salt used and this was weighed out exactly in every experiment.

The first set of experiments was made to find out whether precipitation is complete when the bromide-bromate mixture acts upon the aluminium salt. In every experiment a portion of the alum was weighed out, dissolved in a small amount of water in a beaker and a portion of the bromide-bromate solution was added. In experiment (1) the mixture was boiled over a flame until at the end of an hour no more bromine seemed to be liberated and the cooled liquid was colorless. The precipitate was, so far as possible, transferred to an ashless filter paper, washed, ignited and weighed as Al_2O_3; but to get the entire amount of precipitate it was necessary to dissolve from the beaker, by means of hydrochloric acid, a closely adherent film of precipitate; and from the solution the dissolved alumina was recovered by precipitation with ammonia and determined separately. In experiments (2) and (3) the precipitation was brought about by passing a current of steam into the solution, interrupting the process to concentrate the liquid by evaporation without boiling and again passing in steam.

TABLE I.

	$KAl(SO_4)_2.12H_2O$ taken grms.	Time of heating hrs.	KBr taken grms.	$KBrO_3$ taken grms.	Al_2O_3 taken grms.	Al_2O_3 found grms.	Error grms.
(1)	1·0012	1·	3·6	1·	0·1078	·1070	0·0008 −
(2)	0·5017	2 + 2·5	2·	0·5	0·0539	·0529	0.0010 −
(3)	0·5029	3 + 2·5	2·	0·5	0·0541	·0559	0·0018 +

In these experiments the precipitation proved to be complete, or nearly so; though in (3) there is obvious contamination of the precipitate due perhaps to the prolonged treatment in glass. As will appear, however, the process of hydrolysis did not go to the point of forming aluminium hydroxide.

The degree to which the acidic ion is removed hydrolytically from the salt under the conditions is shown in the following series of experiments in which portions of the alum were treated with the bromide-bromate mixture under conditions which permitted the collection and titration of the bromine set free in the reaction.

The apparatus used consisted of a Voit flask, used as a distilling flask, sealed to the inlet tube of a Drechsel wash bottle, used as a receiver, to the exit tube of which was sealed a Will and Varrentrapp absorption tube. The Voit flask was charged with 0·5 grm. of alum dissolved in a little water and 25^{cm^3} or 30^{cm^3} of the bromide-bromate mixture. The solution was boiled for the time indicated and the bromine liberated passed in a current of hydrogen, sent through the whole apparatus, to the receiver containing in the cylinder and trap a solution of 4 grm. of potassium iodide in 200^{cm^3} of water. The iodine set free by the action of the bromine liberated in the reaction was titrated by $\frac{n}{10}$ sodium thiosulphate with the aid of a starch indicator.

TABLE II.

A

Theory 6Br to $2KAl(SO_4)_3.12H_2O$.

No.	$KAl(SO_4)_2.12H_2O$ Time hrs.	taken grm.	KBr used grm.	$KBrO_3$ used grm.	Bromine liberated grm.	Theory for bromine grm.	Error in terms of bromine grm.	Error in terms of Al_2O_3 grm.
(1)	0·5	0·5000	1·8	0·5	0·2052	0·2527	0·0475—	0·0101—
(2)	1·5	0·5000	2·16	0·6	0·2064	0·2527	0·0463—	0·0097—
(3)	2·0	0·5000	2·16	0·6	0·2084	0·2527	0·0443—	0·0094—
(4)	2·5	0·5000	2·16	0·6	0·2099	0·2527	0·0408—	0·0091—
(5)	3·5	0·5000	2·16	0·6	0·2119	0·2527	0·0408—	0·0087—
(6)	4·	0·5000	2·16	0·6	0·2120	0·2527	0·0407—	0·0086—

B

Theory 5Br to $2KAl(SO_4)_2.12H_2O$.

(1)	0·5	0·5000	1·8	0·5	0·2052	0·2106	0·0054—	0·0011—
(2)	1·5	0·5000	2·16	0·6	0·2064	0·2106	0·0042—	0·0009—
(3)	2·0	0·5000	2·16	0·6	0·2084	0·2106	0·0022—	0·0005—
(4)	2·5	0·5000	2·16	0·6	0·2099	0·2106	0·0007—	0·0001—
(5)	3·5	0·5000	2·16	0·6	0·2119	0·2106	0·0011+	0·0002+
(6)	4·0	0·5000	2·16	0·6	0·2120	0·2106	0·0014+	0·0003+

From these experiments, in which approximately three times the amounts of potassium bromide and potassium bromate, corresponding to the complete hydrolysis of the alum, were used, it is obvious that the hydrolysis is not complete. At the end of an hour nearly five-sixths of the acidic ion have been liberated and this proportion is not much exceeded after four hours boiling, the liberation of bromine proceeding very slowly during the greater part of this time.

In the following series of determinations the proportions of potassium bromide and potassium bromate with reference to one another and to the aluminium salt were varied in order to test the effect of such variation on the course of the action.

TABLE III.

A

Theory 6Br to $2KAl(SO_4)_2.12H_2O$.

	Time hrs.	$KAl(SO_4)_2 12H_2O$ taken grm.	KBr taken grm.	$KBrO_3$ taken grm.	Theory for bromine grm.	Bromine found grm.	Error in terms of bromine grm.	Error in terms of Al_2O_3 grm.
(1)	3	0·5000	*0·32	*0·09	0·2527	0·1437	0·1090—	0·0232—
(2)	3	0·5000	3·2	0·09	0·2527	0·1814	0·0713—	0·0152—
(3)	3	0·5000	0·32	0·90	0·2527	0·1853	0·0674—	0·0144—
(4)	3	0·5000	3·2	0·90	0·2527	0·2182	0·0345—	0·0073—
(5)	3	0·5000	6·	2·	0·2527	0·2199	0·0328—	0·0069—
(6)	4	0·5000	6·	2·	0·2527	0·2229	0·0298—	0·0063—
(7)	5	0·5000	6·	2·	0·2527	0·2320	0·0207—	0·0044—

B

Theory 5Br to $2KAl(SO_4)_2.12H_2O$.

	Time hrs.	$KAl(SO_4)_2 12H_2O$ taken grm.	KBr taken grm.	$KBrO_3$ taken grm.	Theory for bromine grm.	Bromine found grm.	Error in terms of bromine grm.	Error in terms of Al_2O_3 grm.
(1)	3	0·5000	*0·32	*0·09	0·2106	0·1437	0·0669—	0·0143—
(2)	3	0·5000	3·20	0·09	0·2106	0·1814	0·0292—	0·0062—
(3)	3	0·5000	0·32	0·90	0·2106	0·1853	0·0252+	0·0054—
(4)	3	0·5000	3·2	0·90	0·2106	0·2182	0·0076+	0·0016+
(5)	3	0·5000	6·	2·	0·2106	0·2199	0·0090+	0·0019+
(6)	4	0·5000	6·	2·	0·2106	0·2229	0·0123+	0·0026+
(7)	5	0·5000	6·	2·	0·2106	0·2320	0·0214+	0·0045+

In the result of experiment (1), in which the amounts of bromide and bromate were equivalent to one another and to the acidic ion of the aluminium salt, it will be noted that the liberation of the bromine falls considerably short of five-sixths

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* These amounts are nearly equivalent to the acidic ion of the aluminium salt.

of the equivalent of the acidic ion. In experiment (2) the bromide was increased tenfold and in experiment (3) the bromate tenfold with similar though incomplete effects. In experiment (4), in which both the bromide and the bromate amount to ten times the theoretical equivalent of the acidic ion, the results show a liberation of bromine somewhat in excess of the five-sixths proportion. In experiments (5) (6) (7) further increase in the amounts of bromide and bromate and in the time of boiling advanced the reaction so that amounts of bromine were liberated considerably in excess of the five-sixths proportion. These results seem to indicate that the deficient hydrolytic effect is advanced by large increase in the proportions of either the bromide or the bromate or both, and would seem to confirm the natural inference that the products of the action of the bromide and the bromate upon aluminium sulphate take part essentially in the hydrolytic action as well as the sulphate itself. These products naturally increase with the concentration of the reacting substances. With a very large increase in the amounts of the bromide and bromate and prolonged boiling, it would be natural to expect the completion of the hydrolysis to the point of liberating bromine equivalent to the entire amount of the acidic ion.

Experimental difficulties such as the necessity and difficulty of supplying water frequently during the boiling, the periodical titration of the iodine liberated in the receiver, made of doubtful value experiments extended over many hours. When, however, the residue left in the Voit flask in experiment (7) was treated with a mixture of 1 grm. of potassium iodide and 0·5 grm. of potassium iodate, the iodine set free on boiling for an hour longer indicated that the acidic ion had been very nearly liberated.

The iodine-iodate mixture is extremely sensitive to the action of small amounts of free acid. Experiment showed that the bromide-bromate mixture is also a very delicate indicator of free acid; 0·00018 grm. of sulphuric acid proving to be sufficient to liberate bromine from the bromide-bromate mixture when boiled in the Voit flask under the experimental conditions.

That the progress of the hydrolytic reaction is so much more rapid in the case of the iodide and iodate is apparently due to the specific action of these substances upon the basic aluminium sulphate rather than to a more exact removal of the free acid.

It will be recalled in this connection that, as Moody has shown,* the iodide-iodate mixture, taken in moderate amount, does not further hydrolyze the basic salt produced in the action

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* Moody, this Journal, xxii, 184, 1906.

upon zinc sulphate. A reasonable excess of the bromide-bromate mixture is able in a moderate time to carry the hydrolysis of aluminium sulphate to a fairly definite point corresponding nearly to the removal of five-sixths of the acidic ion, while the iodide-iodate mixture under similar conditions of prolonged action removes practically all the acidic ion.

Some experiments to test the effect of a mixture of potassium chloride and potassium chlorate indicated that the hydrolysis of aluminium sulphate under otherwise similar conditions is very slight compared with that produced by the bromide-bromate mixture or by the iodide-iodate mixture.

ART. XVII.—*The Preparation of Formamide from Ethyl Formate and Ammonium Hydroxide;* by I. K. PHELPS and C. D. DEMING.

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

THE action of ammonia on an ester is a typical method for the formation of an acid amide. Hofmann* states that this reaction is particularly easy when the ester itself is somewhat soluble in water; but that in the case of ethyl formate and aqueous ammonia, when allowed to stand at the ordinary temperature, a considerable part of the acid amide is hydrated to ammonium formate, and the amount of acid amide formed is accordingly diminished. He further states that this hydration goes on to such an extent that a yield much in excess of 70 per cent is impossible.

The work given here records the results of experiments which show that such hydration during reaction may be avoided and the formamide may be obtained in amount equal to that indicated by the theory for the action from ethyl formate and ammonia.

Ethyl formate for use in this work was prepared by treating commercial sodium formate with a mixture of absolute alcohol and concentrated sulphuric acid. The crude product obtained as a distillate was fractioned and portions found to boil between 53° and 56° were treated with fused calcium chloride to remove water and alcohol, and redistilled after filtering from the calcium chloride. This distillate was then treated with dry ammonia gas obtained by boiling concentrated ammonium hydroxide in a flask connected with a return condenser and leading the ammonia gas obtained in this way through a lime tower. The ammonium formate precipitated was separated by filtration, and then, by fractional distillation, pure ethyl formate distilling within two-tenths of a degree was obtained free from ammonia gas or other impurity.

In all the experiments recorded in the table definite weights of the pure ethyl formate, chilled in an ice and salt mixture, were treated with ammonium hydroxide of known strength similarly chilled, and the temperature of the mass was not allowed to rise above 0° until after the reaction between the formate and the ammonia solution had been largely completed. The formamide produced in each case was obtained by separating from impurities by fractioning in vacuo in the usual way and distilling the residue after the low-boiling impurities, largely ammonia, ethyl formate, alcohol, and water, had been removed.

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*Berichte, xv, 977.

In certain experiments the ethyl formate and ammonium hydroxide were mixed in a 250$^{cm^3}$ distilling flask and the mixture was fractioned in vacuo as soon as it had become homogeneous. In this process the 250$^{cm^3}$ distilling flask containing the mixture was connected to a 100$^{cm^3}$ distilling flask used as a receiver and the formamide was separated from low-boiling impurities by fractioning in vacuo in the usual way, the distilling flask being heated in a water bath at 60° for fifteen minutes after the pressure on the manometer registered 15^{mm}. The formamide was then distilled over, by heating the distilling flask in a bath of sulphuric acid and potassium sulphate,* and caught in the receiver chilled by a current of cold water.

In other experiments the distillation was not made as soon as the ethyl formate and ammonium hydroxide had become homogeneous. In each of these experiments a definite weight of ethyl formate held in a 250$^{cm^3}$ glass-stoppered reagent bottle was treated with pure, commercial ammonium hydroxide of known strength, after chilling each in a mixture of ice and salt, slowly enough so that at no time during mixing did the temperature of the mixture rise above 0°. The mixture at this time consisting of two layers became homogeneous in about five minutes, but was allowed to stand in the ice mixture for fifteen minutes; for the heat given out showed that the reaction progressed after the mass had become homogeneous. This solution was kept tightly stoppered for a definite time, after which it was transferred to a 250$^{cm^3}$ distilling flask connected to a 100$^{cm^3}$ distilling flask used as a receiver with the

No.	Ethyl formate grm.	Ammonium hydroxide Sp. gr. ·90 cm³.	Time of standing hr.	min.	Formamide Theory grm.	Found grm.
			A			
(1)	50	30	4	30	30·41	19·06
(2)	50	30	240		30·41	23·40
(3)	50	50			30·41	23·57
(4)	50	50			30·41	22·60
(5)	50	50	1		30·41	28·08
(6)	50	50	1		30·41	27·40
(7)	50	50	2		30·41	29·33
(8)	50	50	2		30·41	29·78
(9)	50	50	2		30·41	29·80
(10)	50	50	5		30·41	30·48
(11)	50	50	5		30·41	30·45
(12)	50	50	6	30	30·41	30·50
			B			
	Treatment with NH_4OH and saturation of mixture with NH_3.					
(13)	50	10	4		30·41	30·45
(14)	50	10	4		30·41	30·00
(15)	50	20	4		30·41	30·25

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* H. Scudder, Jour. Am. Chem. Soc., xxv, 161.

use of the least amount of alcohol to remove the last traces from the side-walls of the bottle. The formamide was separated from low-boiling impurities by fractioning in vacuo in the manner described, and the formamide distilled and weighed.

It is obvious from the work recorded in the table that three factors are of influence in the quantitative formation of formamide by the interaction in the cold of ethyl formate and ammonium hydroxide,—the excess of the ammonium hydroxide present, the concentration of the ammonia in the solution, and the time during which the interaction of the two is allowed. From experiments (1) and (2) of section A of the table it is clear that with fixed amounts of ethyl formate and ammonium hydroxide an increase in the length of the time of the reaction is decidedly advantageous. The comparison of experiments (1) and (2) with experiments (5) to (12) shows that increasing the amount of ammonium hydroxide gives a yield in excess of that found with the smaller proportion of ammonium hydroxide. A comparison of experiments (5) to (12) with one another further emphasizes the point that length of time allowed for the completion of the reaction after the mixture has been kept cool during the first of the reaction long enough to prevent hydration is an important factor. It is clear that it is easily possible to obtain the theoretical amount of amide by allowing the mixture to stand five hours or longer. Two hours standing is not quite sufficient.

In section B of the table the results shown were obtained by saturating in the cold, at −10° to 0° for about four hours, the ethyl formate and ammonium hydroxide chilled before mixing in a stoppered reagent bottle fitted with a rubber stopper carrying in one perforation a thermometer dipping into the mixture and in the other the delivery tube for the ammonia gas. This mixture on fractioning in vacuo as described above and distilling the formamide left in the distilling flask gave the theoretical amount of formamide.

An experiment showed that a definite weight of formamide and water when fractioned in vacuo as in the process outlined gave an amount of formamide differing from that taken by less than 0·05 grm.

It is evident that it is possible to obtain from ethyl formate by the action of ammonium hydroxide the theoretical amount of formamide. This may be accomplished by treating the chilled ethyl formate with small amounts of chilled ammonium hydroxide and saturating for some hours in the cold with dry ammonia gas; or, more easily, by treating chilled ethyl formate with larger proportions of chilled ammonium hydroxide and allowing the mixture to stand some hours before distilling in vacuo. The essential thing in the operation is to keep the mixture of the ethyl formate and the ammonium hydroxide at a temperature so low that ammonium formate is not a product of the action.

ART. XVIII.—*A Lower-Middle Cambrian Transition Fauna from Braintree, Mass.;* by H. W. SHIMER.

SOME time ago, while having a driveway excavated at his home on Quincy avenue, in East Braintree, Mass., Mr. Thomas A. Watson found a rather angular slate bowlder, about two feet in diameter. He kindly turned it over to the Massachusetts Institute of Technology.

The slate is quite similar in appearance to that of the celebrated Paradoxides quarry on Hayward Creek; it is similarly metamorphosed but is lighter gray in color and lacks the peculiar purplish tinge of the Hayward Creek slate.

In it the following fauna was found:

Name	Abundance	Previous occurrence	Age
Acrothele gamagei (Hobbs)	r	Hayward Creek	Middle Cambrian
Hyolithes shaleri Walcott	r	Hayward Creek	Middle "
Paradoxides harlani Green	C	Hayward Creek	Middle "
Strenuella strenua (Billings)	R	North Attleboro, North Weymouth and Nahant	Lower "
? Strenuella strenua (Billings)	R		
Olenellus (Holmia) bröggeri Walcott	R	North Weymouth	Lower Cambrian
Ptychoparia rogersi Walcott	r	Hayward Creek	Middle "
Agraulos quadrangularis (Whitfield)	C	Hayward Creek	Middle "

C = very common; c = common; r = rare; R = very rare.

This fauna includes five species of the Middle Cambrian, two of which are very abundant, and two of the lower Cambrian. There is thus a great predominance of the Middle Cambrian element, though it indicates a persistence of the Lower Cambrian element into Middle Cambrian times. So while we have here a transition fauna, the rock must be assigned to the Middle Cambrian period. This very interesting transition fauna is the first recorded from this region to show in any way a passage from the Lower to the Middle Cambrian.

The size and angular character of the bowlder would indicate that it had very probably not traveled far from the parent ledge. Since the glaciers which transported it came from the northwest, we examined the drift in that direction. Under the leadership of Mr. Watson we found on the granite hill south of Quincy Adams very many slate bowlders, some similar in appearance to the one containing the transition fauna, though no fossils were found in them. These decreased in number southeastward; on the granite hill they composed most of the drift. Their great abundance here would indicate their probable derivation from the drift-covered valley of Quincy Adams, a suburb of Quincy. Some support likewise is given to this theory by the east and west strike and southern dip of the Middle Cambrian Hayward Creek beds lying a short distance to the southeast.

Description of species.

Acrothele gamagei (Hobbs).

The two individuals found agree very closely with the type description.

Hyolithes shaleri Walcott.

Parts of several specimens of this species were found. They represent individuals somewhat below the normal in size.

Olenellus (*Holmia*) *bröggeri* Walcott.

One individual was found. This includes most of the glabella, and one eye-lobe. The eye-lobe is narrow, elongate, and crescent shaped; it begins to arch outward from the most anterior glabellar furrow. The glabella in outline and furrows is very similar to the type description. Its surface is covered with "the inosculating, fine, raised fretwork that as far as known is confined to the genus Olenellus."*

Strenuella strenua (Billings).

Our specimen consists of the characteristic ends of two pleura. They belong without doubt to this species, as they are similar in every respect to an individual described from the Lower Cambrian of North Weymouth.†

? *Strenuella strenua* (Billings). Fig. 1.

Referred to this species with extreme doubt is a specimen that may be a thoracic axis. It consists of eight strongly arched segments, and tapers to an unusual degree for an axis. It bears a median row of tubercles, one upon the central portion of each fold, the series becoming more marked toward the broad end of the axis. The middle of each fold is marked by the groove-like line produced by the overlapping of the anterior portion of the fold upon the posterior.

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The evidence in favor of referring this specimen to *Strenuella strenua* is its marked convexity, the median row of tubercles, and the presence of the pleura of that species near it, though it is very doubtful if they are near enough to have formed part of the same individual.

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* Walcott, 10th Ann. Rept. U. S. G. S., part 1, p. 640.

† This Journal, xxiii, 199–201.

Dr. G. F. Matthew, who kindly examined the photograph of the specimen, suggests that it may be a group of pleura belonging to one of the spinous trilobites. This would explain its curved character, indicated by the lack of parallelism between the transverse grooves.

This specimen is in the collection of the Boston Society of Natural History; catalogue number 13, 341.

Agraulos quadrangularis (Whitfield).

This species is exceedingly abundant but most of the individuals differ from the normal mature form of the Hayward Creek Middle Cambrian. In transverse view the glabella is higher and more arched; the longitudinal contour is of uniform elevation in the posterior two-thirds and descends abruptly in the anterior one-third, but as its height is greater than that of the normal species so is its descent more conspicuous. The anterior edge of the cephalon is truncate even in those forms showing no compression, while in the normal species it is rounded.*

The sides of the glabella are sub-parallel and do not taper strongly forward as is usually the case with the normal form. The spine is about half the length of the cephalon exclusive of the occipital ring, while in the normal form it is about one-third.

The very small (young) and very large (old) forms of *A. quadrangularis* of Hayward Creek beds are quite similar to this variety. It thus seems that this variety represents an earlier (younger) form of the normal (mature) species and that the large forms of the latter were merely gerontic specimens showing a return in shape to the characters of youth.

Ptychoparia rogersi Walcott.

One specimen, somewhat crushed laterally, represents the anterior and most of the central portions of the cephalon. The anterior head fold is well shown and the glabellar outline.

Another specimen consisting of only the most anterior portion of the glabella and cephalon shows this anterior fold more faintly.

Paradoxides harlani Green.

There appears to be no difference between our many representatives of this species and the normal mid-Cambrian forms from Hayward Creek. One individual attained an enormous size, measuring over three inches across the wider anterior portion of the glabella. Several hypostomes were found, one two inches wide and attached to the frontal doublure of the head. Separate pygidia were also quite abundant.

Massachusetts Institute of Technology, Geological Department.

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* Bull. Am. Mus. Nat. Hist., i, 147.

SCIENTIFIC INTELLIGENCE.

I. GEOLOGY AND NATURAL HISTORY.

1. *The Bermuda Islands. Part IV. Geology and Paleontology;* by A. E. VERRILL. 168 pp., 88 text-cuts, 12 plates. Trans. Conn. Acad. Science, vol. xii, 1906–7.—Although the text of this work was printed and a number of copies were distributed in March, 1906, the complete work, with all the plates, has only recently been issued (May, 1907).* This part contains a very detailed account of the geology of the island, and the changes they have undergone, by submergence and elevation, erosion, etc. The rocks are nearly all composed of wind-drifted shell sands more or less consolidated, but a narrow belt of marine limestones, formed in shallow water, and containing numerous marine shells and foraminifera, mostly like those now living there, occurs in many places a little above sea-level. The origin and nature of the materials are fully discussed.

The most noteworthy novelty is the division of the rocks into three distinct geological formations, representing periods parallel with those of the North American coastal area. The earliest, named the "Walsingham" formation, is composed in part of very hard, compact limestones, of æolian origin. In this formation land snails of many species are found, most of which are now extinct, including the large forms of *Pœcilozonites Nelsoni*, of which three varieties, all extinct, are recognized and figured. This formation was deposited during a period of marked elevation, probably at least 125 feet above the present level when greatest, as shown by the submerged drainage channels and eroded escarpments, submerged peat deposits, etc. This period is considered to be preglacial and probably Pliocene. The larger sizes of the land shells and their abundance indicate a warmer and more moist climate, with abundant vegetation. This was followed by a long period of submergence, ending in a depression rather greater than at present. To this period, named the "Devonshire," the raised marine limestones, with fossils, are referred, but the æolian rocks of this age cannot be distinguished from the later ones. It probably corresponds to the glacial and Champlain (or Leda-clay) period of New England. The later æolian rocks, named the "Paget" formation, contain in many places an abundance of land shells, nearly all of which are still living on the islands, though some have undergone some changes, recognizable as varietal. The phenomena of erosion in all its forms are very fully discussed and illustrated. The elevated shore cliffs, exposed to heavy seas, furnish excellent object lessons of this kind. New

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* The delay was largely due to a strike in the printing office.

explanations of the origin of the remarkable structures popularly called "fossil palmetto stumps" are given. These have been variously interpreted by different writers. In this article they are explained as due, at least in most cases, to the solvent action of carbonated rain-water, localized at first in depressions of the surface rock by any one of several causes, but continued downward by the formation of a central core of clay, etc., around which the water can percolate and evaporate. They are compared to the tubular "sand-pipes" of the English white chalk, described by Lyell and others.

In the chapter on the paleontology all the land-shells hitherto found fossil are described and figured, and a list is given of the marine fossils of the Devonshire formation, with some figures. Of the latter about ten species are not certainly known to be now living in Bermuda waters, but they are all West Indian. The Walsingham formation contains 17 species and 6 named varieties of land shells, of which 9 species and 4 varieties are extinct. This paper contains a Bibliography and a copious index.

2. *The Bermuda Islands. Part V, Section I;* by A. E. VERRILL. 147 pp., 28 plates, 1 map, and 120 cuts in the text. Trans. Conn. Acad. Science, vol. xii, 1907.—This part is devoted entirely to descriptions of the characteristic life of the coral reefs, particularly the corals, actiniæ, gorgonians, hydroids, echinoderms, and siliceous sponges. The remaining groups are to be treated in a subsequent section. Nearly all the species are well illustrated by photographic half-tones, or by drawings. A number of new species and a new genus of sponges are described, and two new gorgonians, one representing a new genus. Figures of the spicules of all the gorgonians and sponges are given. Many of the figures of the corals, gorgonians, and actiniæ are from photographs of the living animals, by A. H. Verrill. Those of the gorgoniæ are remarkably good. Nothing like them has been published hitherto. Bibliographies of each group are given, and the index is very complete. This work is admirably adapted for the uses of students of tropical marine life, not only at Bermuda, but in the West Indies and Florida also, for the species are nearly all found in the West Indies.

3. *Maryland Geological Survey, Calvert County;* by GEORGE BURBANK SHATTUCK, BENJAMIN L. MILLER and others. Pp. 227, pls. xiv, figs. 11. Baltimore, Jan., 1907 (The Johns Hopkins Press).—This volume is the fourth of a series of reports on the county resources, and is accompanied by topographic, geologic and agricultural soil maps on a scale of approximately a mile to an inch. Calvert County constitutes a peninsula on the west side of Chesapeake Bay, bounded on its own western side by the Patuxent River. Its surface is an undulating plain with an extreme elevation of 180 feet near the northern limits. The geological formations are Miocene and Pleistocene with some Eocene.

J. B.

4. *Maryland Geological Survey, St. Mary's County;* by George Burbank Shattuck, Benjamin L. Miller and others. Pp. 209, pl. xvi, figs. 12. Baltimore, March, 1907 (The Johns Hopkins Press).—This volume, of the same form as the preceding, is the fifth of the series of county reports. St. Mary's County is the most southern county on the western shore of the Chesapeake, lying south of Calvert County, and its geology is similar in many respects to the latter. Both volumes contain full discussions of the physiography, geology, economic resources, soils, climate, hydrography, magnetic declination and forests. They are printed and illustrated in the handsome style customary with the Maryland Survey. J. B.

5. *Geological Survey of India.*—The first part of Volume xxxv of the Records of the Geological Survey of India (Calcutta, 1907) contains the report of the Director, Dr. T. H. Holland, for the year 1906 and two other papers. The former is a concise summary account of the results obtained by the Survey, and brings out many facts of interest. We may note an abstract of the work of L. Leigh Fremor on manganese-bearing rocks of Vizagapatam. The typical rock of the series, consisting of potash-feldspar, manganese-garnet, and apatite, having commonly a granular, medium granitic structure or sometimes assuming a pegmatitic form, is called *kodurite* after the Kodur manganese mine. Types marked by quartz, pyroxene, and biotite are noted. The name *spessart-andradite* (shortened to *spandite*) is suggested for the typical manganese garnet. It is also shown that the aluminous laterites, or bauxites of India, which occur on a large scale, are likely to prove important as a source of aluminium.

A brief statement is made in regard to the Dokachi meteoric fall, which is described in full in the same number by Mr. Fremor. This fall took place on October 22d, 1903, and was accompanied by some remarkable phenomena, the fire-ball being seen over most of Bengal and Assam and beyond. Twenty-four fragments have been collected by the Survey, ranging from 1,571 to 0·73 grms.; these were obtained along a band running west by south from Bibandi in the Dacca district to near the east bank of the Ganges at Kolapára, a distance of six miles, the larger fragments having fallen near the western end of the line towards which the meteor was travelling when disruption occurred. The fragments are nearly all covered with a crust, and on some of the faces of the smaller fragments the formation of a younger crust shows the fusion that occurred after disruption. Many more stones were found in the various villages, the minimum number being estimated at about 100. Several plates give reproductions of photographs showing the aspects of prominent specimens.

6. *Brief Descriptions of some recently described New Minerals.*—Rutherfordine—or, better, *rutherfordite* (since Shepard's name given in 1850 has now no standing in the literature)—is a uranyl carbonate described by W. Marckwald from the Uruguru Mts. in German East Africa, and named after Prof. Ernest

Rutherford. It occurs as an alteration-product forming a crust over masses of pitchblende (U_3O_8 87·7 p. c., sp. grav. = 8·84). It has a yellow color and specific gravity of 4·82 ; it is highly radio-active. An analysis gave :

UO_3	CO_2	PbO	FeO	CaO	H_2O	Gangue
83·8	12·1	1·0	0·8	1·1	0·7	0·8 = 100·3

For this the composition $UO_2.CO_2$ is calculated.—*Centralbl. Min.*, p. 761, 1906.

Hellandite is a silicate of complex composition containing yttrium and erbium with aluminium and calcium chiefly ; it is described by W. C. Brögger from the pegmatite veins in the neighborhood of Kragerö, Southern Norway. It occurs in prismatic crystals referred to the monoclinic system. The material was more or less altered ; the freshest had a nut-brown color with hardness = 5·5 and sp. gravity = 3·70 ; more altered crystals had a brownish red color with the sp. gravity ranging from 3·55 to 3·33. An analysis of somewhat altered crystals by L. Andersen-Aars gave :

SiO_2	Al_2O_3	Fe_2O_3	Mn_2O_3	Ce_2O_3	Y_2O_3	Er_2O_3	ThO_2	CaO	MgO	Na_2O	K_2O
23·66	10·12	2·56	5·91	1·01	19·29	15·43	0·62	9·81	0·10	0·23	0·06

H_2O 11·75 = 100·55

A relation in form and composition to guarinite is suggested, as also to dauburite and topaz.—*Zeitschr. Kryst.*, xlii, 417.

Podolite is described by W. Tschirwinsky as a phosphate and carbonate of calcium having the composition $3Ca_3P_2O_8.CaCO_3$, analogous to apatite. It occurs in the phosphorite of Government Podolia in South Russia. Minute prismatic hexagonal crystals, yellow in color, are noted ; also small spherulitic forms with fibrous structure. Only a minute quantity of the crystals was available for analysis ; from this the approximate results obtained were :

P_2O_5 39·04 CaO 51·15 Fe_2O_3 3·04 CO_2 3·90 = 97·14

The evolution of CO_2 was obtained from perfectly clear and homogeneous crystals, free from calcite, when treated with hydrochloric acid. The name *carbapatite* earlier suggested for this mineral by P. Tschirwinsky is now withdrawn by him.—*Centralbl. Min.*, No. 9, 1907, p. 279.

Nepouite is a hydrated silicate of nickel and magnesium described by E. Glasser from New Caledonia. It is related to the similar compounds called garnierite and noumeite, but occurs in minute hexagonal scales often grouped in vermicular forms analogous to the chlorites. Analyses lead to the formula $3(Ni,Mg)O.SiO_2.2H_2O$, but show a wide variation in the relative amounts of nickel and magnesia, from NiO 50·7 and MgO 3·00 to NiO 18·21 and MgO 29·84.—*Bull. Soc. Franç. Min.*, xxx, 17, 1907.

Gorceixite and Harttite are phosphates identified by E. Hussak among the "favas" of the diamond-bearing sands of

Minas Geraes, Brazil. The name *fava* is given locally to spherical or bean-shaped rolled masses of some heavy minerals found in the diamond washings and regarded as a good indication of the presence of the gem. They are for the most part brown or red in color, less often white. Early investigations of them have been made by Damour, Gorceix and others. Hussak has identified among the favas, a barium-aluminium phosphate to which he gives the name *gorceixite.* The color is light- to dark-brown and the structure like jasper ; hardness = 6 ; specific gravity 3·04–3·12. An analysis by G. Florence, after the deduction of SiO_2, TiO_2, Fe_2O_3, gave :

P_2O_5	Al_2O_3	BaO	CaO	CeO	H_2O
24·48	37·68	16·60	3·82	1·67	15·74 = 100

For this the composition $BaO.2Al_2O_3.P_2O_5.5H_2O$, is calculated.

The name *harttite*, after Prof. Fred. Hartt, is given to favas of a flesh-red to yellow or white color; hardness about 5·5, sp. gravity 3·14–3·21. Microscopic examination showed a micro-crystalline structure and suggested hexagonal crystallization. Analysis by G. Florence gave :

P_2O_5	Al_2O_3	SO_3	SrO	CaO	H_2O
21·64	34·40	11·78	17·17	2·19	12·81 = 100

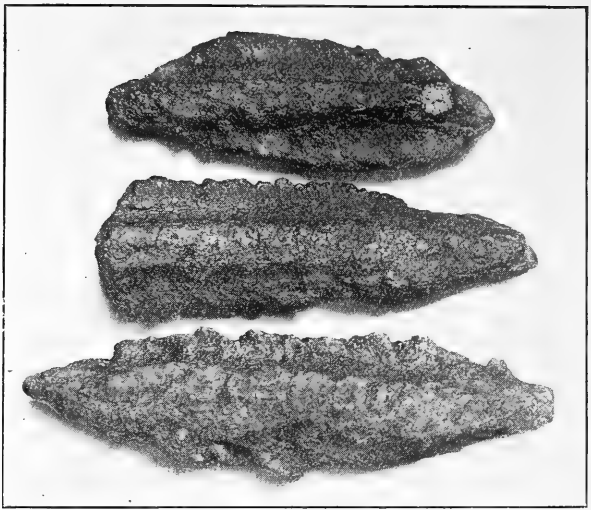
The calculated composition is $Sr(Ca)O.2Al_2O_3.P_2O_5.SO_3.5H_2O$; this shows a close resemblance to svanbergite. Other favas proved to be phosphates of aluminium and lead closely similar to plumbogummite.—*Min. Petr. Mitth.*, xxv, 335, 1906.

7. *Chiastolite from Bimbowrie, South Australia.*—The argillaceous schists of Mt. Howden, ten miles north of Bimbowrie, South Australia, have furnished some remarkable specimens of chiastolite of unusual size and showing some new features for the mineral. An account of them was published by C. Anderson in the Records of the Australian Museum, vol. iv, pp. 298–302. The locality has been specially developed by Mr. G. R. Howden, who has furnished specimens to the Australian Museum and also to the Yale Museum at New Haven.

The chiastolite occurs either embedded in argillaceous schist or as rolled pebbles with quartz, jasper, etc. Some of the common forms show a simple cross of nearly pure mineral with also a light-colored core, surrounded by four dark lines, forming a rectangle when cut normal and a lozenge when cut oblique to the axis. These specimens measure up to 2¼ inches in cross-section.

A very peculiar form is that called "fish crystals," the structure of which is best revealed in weathered specimens. These have an elongated and flattened form, the length often reaching five or six inches. They have a central core with projections on opposite sides (see fig. 1); these show a peculiar series of grooves and ridges, curved on either side of the axis and in opposite directions. In some cases, also, the longer arms are slightly bent in opposite directions. This deformation is well marked when the grooving is most apparent.

1



Other specimens show a complex and beautiful structure in the cross-section, as suggested in figure 2 (drawings by Mr. Howden). This variety, which is locally known as *howdenite*, occurs in square or rhombic faces, often with concave faces, and enclosed by a green crust from $\frac{1}{16}$th to $\frac{1}{8}$th inch in thickness. The purer portions show many tints of color from white or gray to yellow, pink, red and purple.

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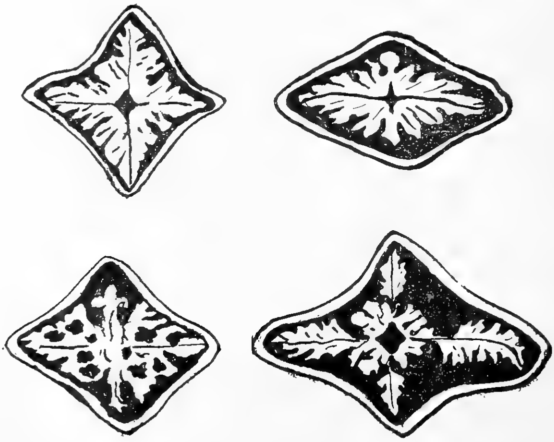

OBITUARY.

Professor **Angelo Heilprin**, the naturalist and geologist, died on July 17 at the age of fifty-four years. A notice is deferred.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XIX.—*Plains in Cape Colony*; by Professor E. H. L. SCHWARZ, Rhodes University College, Grahamstown, Cape Colony.

THE southern coastal belt of Cape Colony is divided into two portions, the western with its lofty and rugged mountain ranges, the eastern with more gentle topography. Standing on one of the lofty peaks near the junction of the two zones an almost bird's-eye view can be obtained of the lower country to the east: one sees the land stepped or parcelled out into narrow shelves with abrupt margins facing the sea. The highest of these lies at this point about 2,500 feet and the width of the terraced portions is 30 miles. Travelling through this country, say from Port Elizabeth to Bellevue, the highest point on the railway near here, the terraces are scarcely apparent, as the great fall of the rivers has caused deep gullies to be cut, and the subsequent denudation has widened them sufficiently to obscure the details, while the Addo bush, a scrub forest, covers the more characteristic features; besides this, in the Port Elizabeth area, a belt of soft Cretaceous deposits has been faulted down against the older rocks, and this has allowed wide alluvial plains to be developed.

Farther east in Pondoland the shelves are far more distinct. The rock is of uniform hardness throughout, and, supporting a rich covering of grass, it has been cleared to a large extent by repeated burning of all obscuring bush and forest.

In the west the shelves are not very apparent except the extensive 700-foot one all along the coast, but in favorable spots, especially at the head streams of the great rivers where erosion has had little opportunity of acting, the terraces can be picked out, and the level certainly carried up to 4,000 feet, perhaps higher, to the full maximum elevation of the continent, namely, 6,000 feet.

These shelves cannot be other than surf cut: we see them forming now along the shores by the action of the waves (figs. 1 and 2), the cliffs crumbling with the attack of the breakers, and the fallen debris washed to and fro with the perpetual surge that desolates this treacherous coast-line; the ledge thus cut is sometimes washed bare, at others covered with what is really a coral reef, but in which the lime-secreting organisms are the red algae, shells and worms. Behind the actual coast the individual ledges may attain a width of 30 miles as at Caledon, but near Port Elizabeth they are much narrower, seldom reaching five miles in width, while the subsidiary smaller ledges are much less. It is this narrowness that struck me while examining the country in the Zitzikamma, a coast district east of Port Elizabeth, and induced me to revert to my original idea of their being surf cut, after having temporarily thought them to be plains of river erosion, for it is impossible for a shelf to be cut by a river when the fall from the mountains behind is so great and the course so short. Besides this indirect evidence there are undoubted sea-beaches left on these ledges to attest to their having been cut by the surf. Over the flats one finds great beach bowlders between which are wedged the broken shells of Pectunculus and other marine forms, mostly of a sub-tropical aspect, foreign to the shells now living along the coast; elsewhere, as at Sandflats, foraminiferal sand had collected in large masses and is used

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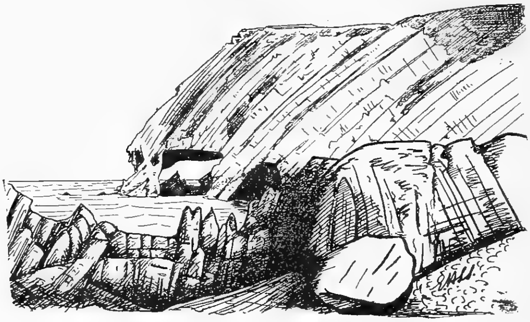

FIG. 1. Arch and cave along the Knysna coast, near Seal Point, Cape Colony. The rock is quartzite belonging to the Table Mountain Series. The undermining of the cliffs by the battery of the waves is shown, but the coast ledge cut by the dragging to and fro of the debris is covered at high tide. The top of the cliffs belongs to the 700-foot ledge and is here about 600 feet above sea-level.

for building purposes. I am busy collecting material from these sea-beaches, but the process is a slow one, as in most cases the shells themselves have been dissolved out leaving only imperfect casts behind, but the evidence so far is that the forms represented belong to living species, though these are now confined to the warmer waters farther north. These sea-beaches extend from 10 feet above sea-level, or actually at sea-level, at Port Elizabeth, and can be followed on the ledges up to 1,300 feet on the Addo Hills; on the higher ones the calcareous material has all disappeared.*

2

FIG. 2. The mouth of the Groot River, Zitzikamma, Cape Colony, a little east of the spot shown in fig. 1. The coast ledge is revealed at low water; the ledge behind belongs to the 700-foot shelf. The rock is quartzite of the Table Mountain Series: the abrupt change of strike is seen.

Besides these exposed shelves, there is a submerged one likewise divided into subsidiary ledges which range from 20 to 60 fathoms, the outermost deepest one lying 90 fathoms below the ocean surface. The edge of this plain is called the Agulhas Bank, beyond which is very deep water; it is a zone of danger to the shipping, as the waves from the Antarctic are broken here and boil and swirl before sending their crests towards the land over the shallower sea-bottom. The edge of the Agulhas plateau continues the southwesterly coast-line of the eastern side of South Africa to the longitude of Cape Town, and the submerged plain must always be considered as part and parcel of the present continent. Dr. Gilchrist has reported bowlders on this plateau 40 miles from land and this in itself is sufficient evidence of the surface having once been above the sea; besides this I am unable to conceive of any

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* Rogers, A. W., Ann. Rept. Geol. Comm., p. 43. Capetown, 1906.

natural cause for its existence. Strong currents wash over the bank and drag the sand to and fro over it, but the sand here is mostly—I might almost say entirely—composed of comminuted shells, and even if the grains were quartz, the erosive action of such sand suspended in water would hardly be greater than that of hailstones on land. Beyond the Agulhas Bank the ocean deposit is glauconitic.

It has been too much the fashion lately to ascribe every plane surface on land to the action of rivers, but every plain must be considered apart, and the causes that led to its formation examined with no preconceived ideas, for there are many ways of explaining such surfaces.

(1) A plain may result from the long emergence of a rugged land, when the rocks piled high, in some cases above the crushing strength of the rocks at the base, will in time flatten out. Such a plain is hardly likely to arise on the earth under present conditions, as denudation works more rapidly than such action could, but in planets without an atmosphere it might become operative. At all events, it is a curious coincidence that in a former paper,* when estimating the maximum height of a rock mass which could be self-supporting, the figure came out approximately the same as the height of the highest mountain in the world; that is to say, if my figures are correct, any mountain thrust up to a higher altitude than Mount Everest would slowly subside by mass flowage to a mean of approximately 30,000 feet.

(2) A plain may arise by an inland sea being filled up, and then the whole being elevated by block uplift. Supposing the southern portion of the Caribbean Sea, or parts of the Yellow Sea, were elevated, a natural plain would result. Such a plain I believe once existed in South Africa. There is an old Permian shore-line running approximately northeast-southwest, through the Southern Transvaal†; on the southward side of this there are found Karroo sediments filling in a wide basin whose southern border is now beneath the sea. Towards the close of the Jurassic period, elevation of the whole of South Africa took place, and this plain was steadily raised 2,000 feet. At this time there was a simple watershed extending from what is now Cape Town to Delagoa Bay, lying parallel to the old shore line, and from which the rivers came off in orderly succession, some to the northwest, others to the southeast. These rivers are still the dominant ones in South Africa, and are only obscured in the east by a gigantic dam of lavas, which

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* An unrecognized agent in the deformation of rocks. Trans. S. A. Phil. Soc., vol. xiv, p. 387. Capetown, 1903.

† Schwarz, E. H. L., The Volcanoes of Griqualand East, S. A. Phil. Soc., Capetown, vol. xiv, p. 108, 1903; see also Passarge, S., Die Kalahari, p. 63. Berlin, 1904.

was poured out at this time and forms the Drakensburg; this thrust back the waters over the main watershed in what is now called the Orange River.

I have elsewhere* given my reasons for considering the old Karroo plain, now elevated 6,000 feet above sea-level, to have been one of original deposition. Similar plains may be formed in inland lakes as well as in enclosed portions of the ocean, and I think it should be definitely recognized that such a plain can be and has been formed by giving such a surface the technical name of a *plain of deposition* to distinguish it from a plain of denudation, qualifying the term by the adjectives marine and freshwater, according to circumstances. Generally the term also includes the contingency of block elevation. I believe the greatest example of this form of plain is that of the pampas of South America. Ordinary deltas would come under this category as well.

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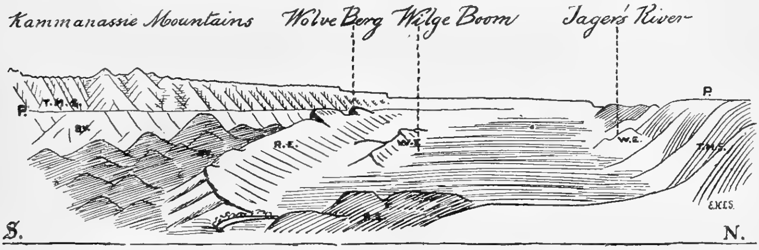

FIG. 3. The upper end of the Olifant's River, Oudtshoorn; showing the 4000-foot archplain, P. The Cretaceous beds, R.E. and W.E., were deposited on a plain at this level, were tilted and subsequently cut down to the same level. Behind are the folded mountains with a remarkably straight crest; on the north, the Swartberg mountains show a similar crest, and these two suggest that they once were part of a peneplain at that level; the folded ranges, however, are far younger than the original plain of deposition. In the low ground is a temporary peneplain cut in soft Cretaceous beds and due to the barring of the river further down. T.M.S., Table Mountain beds; B.V., Borkkeveld beds (Devonian); R.E., Red (Enon) Conglomerate; W.E., White (Enon) conglomerate.

(3) During the extrusion of lavas South Africa sank, to rise again at the termination to its former level, now 4,000 feet above the sea, so that there are two clearly marked levels at this elevation, some cut in older rocks, and some cut in Lower Cretaceous rocks which were deposited on the older 4,000-foot level, were folded and tilted, and again eroded or planed down (fig. 3). Both of these 4,000-foot levels extend far inland and must have also been represented by coast plains at about the

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* Schwarz, E. H. L., The Rivers of Cape Colony, Geographical Journal, pp. 265-279; London, 1906; see also Baviaan's Kloof, a contribution to the theory of Mountain folds, Addresses and papers, Brit. & S. A. Association for the Advancement of Science, pp. 56-67. Johannesburg.

same elevation. In the long narrow valleys between the mountains the character of the plains becomes that of a double bevel—clearly a plain of river erosion (fig. 4), so that we must in this instance distinguish between a plain of marine erosion, a plain of river erosion and one which has been of so general a nature that it includes both. A surf-cut shelf will naturally be a little below that of a river eroded plain, but with long base-levelling, both will so nearly approach the same plane that they will become indistinguishable if only moderately old. I have loosely referred to these great plains as peneplains, and if we can include a marginal zone of marine denudation the term will stand, but I am rather inclined to think that writers have always excluded marine denudation from their definition, and in such case we must either coin a new word, such as archplain, or refer to them simply as plains of denudation.

4

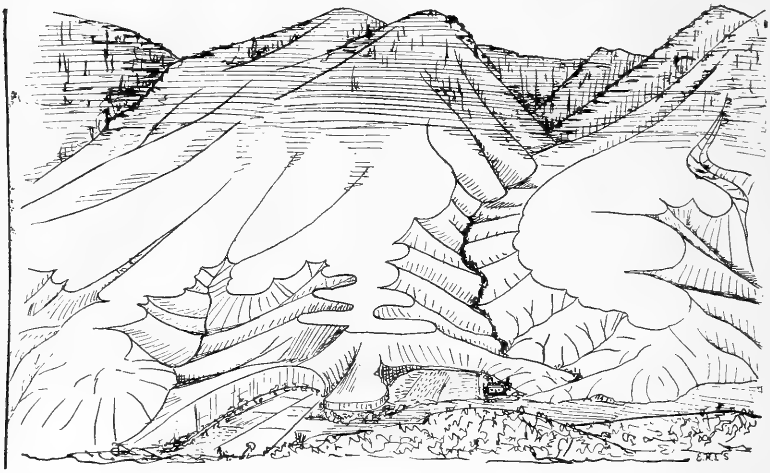

Fig. 4. Bird's-eye view of the northern half of the double level in the Kammanassie River, Oudtshoorn, Cape Colony. The 4000-foot plateau which opens out towards the sea and becomes a plain of marine denudation, in the narrow valleys between the mountains becomes a double level of (river) erosion. The river which runs parallel to the Olifants has reached the same temporary base level at a much slower rate, owing to the more resistant rocks traversed, and hence no alluvial plains have formed along its course.

(4) Peneplains or plains of river erosion have been sufficiently described by Tarr, Davis and others. Temporary peneplains may be formed by the barring of rivers. Of these we have many excellent examples in South Africa. On the southward side of the main watershed the country is everywhere

deeply cut into by kloofs and river gorges, but on the north, the great falls of the Orange river at Augrabies interposes a bar of resistant granite to the downward sawing of the river. As a consequence, behind the falls there are extensive plains, the rivers are low grade and when they do happen to have water in them, which is not often, the water spreads out into great kolks and floors some of which are 300 and 400 square miles in extent, for instance, Verneuk Pan. In one place on the southward side of the main watershed, north of Willowmore, an effective bar is produced by the rivers being deflected along the strike of the beds; where the neighboring rivers, exactly similar in fall and volume, strike the mountains at right angles, they have sawn through them with apparently no difficulty, but in this particular spot the rivers run parallel to the strike of the same mountains, the erosion has been insufficient to allow the rivers behind to cut downwards and a temporary peneplain has resulted.*

(5) Plains of marine erosion are seldom more than ledges, and I would suggest that in order to keep the two forms distinct they should not be referred to as plains. They are cut by the surf, which undermines the cliffs, and by the off-shore currents which drag the debris backwards and forwards. Generally, however, they may be said to be formed between wind and water, i. e. between high and low waters. Where the rock is soft, for instance in the case of the Upper Cretaceous deposits of Eastern Pondoland, the ledge is so rapidly cut and extends so far that the outermost edge is only exposed at extremely low tide. This case has puzzled me as to whether erosion has gone on below the general low-water mark or whether the submergence is due to slight sinking; remembering, however, the recent sea-beaches round Port Elizabeth elevated only 10 feet or so above high-water mark, showing recent emergence, I am inclined to include off-shore currents as effective in denudation in exceptional cases and where the rock is soft. In regard to the submarine plains such as those on which the Maldive Islands stand, I cannot agree with Stanley Gardiner* that they can have been formed by submarine erosion. Soundings in many places showed that the surface had been swept by currents clear of all deposit, but as this is only composed of soft muds, the shells of foraminifera and such like, even on dry land it would have very little effect in wasting rocks harder than itself. In hard rock such as we mostly find on our coast line, the process of cutting shelves is a slow one and the resulting ledge when elevated above the sea is a correspondingly narrow one.

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* Schwarz, E. H. L., Geological Survey of parts of Prince Albert, Willowmore and Uniondale, Ann. Rept. Geol. Comm., p. 97; Capetown, 1904; see also Geographical Journal, p. 272, 1906.

I am of opinion that our levels up to 2,500 feet along the coast are surf-cut, but most of them where they run between narrow valleys grade into bevels of river erosion, so that we must not draw too fine a distinction between such surfaces as are cut by marine and river erosion. As, however, the dominant feature of all of them is marine erosion, we can legitimately call them coast ledges (fig. 5).

Dr. Reusch has described the same phenomena in Norway and uses the term Strandflade or coast plane, but plane cannot in English be used for a natural surface, while plain includes the ideas of both length and breadth and is inadmissible. Ledge or shelf appears to me to be the only term we can use, while a collection of these ledges rising step-like on the borders of a continent might be called a klimakotopedion,—a stepped or terraced plain. On the Atlantic border of Europe and America the klimakotopedia are submerged.

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Fig. 5. View overlooking the coastal plateau near Plettenberg Bay, Cape Colony. The ridges on the left are part of the dissected 1500-foot ledge, and those beyond belong to the 700-foot ledge. The break from the one to the other is shown. The crests of the mountains behind rise to the 6000-foot level, the highest peak being 5497 feet.

(6) When a continent has been shaped it retains its outlines for a considerable period unchanged. South Africa, including the Agulhas ledge, is sharply bounded on the west by a north and south coast line, and an almost straight northeasterly one on the eastern side. Now there is a limit below which denudation as regards the present history of South Africa has never acted. This I have called the absolute base level of erosion.† I had in view when suggesting the term the comparison of the surface features of South Africa and Europe, the latter with dissected topography, the other with the story of its elevation still so apparent in the flat tablelands, and I wished to obtain some quantitative estimate of the relative positions of

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* Stanley Gardiner, J., The Indian Ocean, Geographical Journal, vol. xxviii, pp. 320; London, 1906; this Journal, xvi, 203, 1903.

† Schwarz, E. H. L., Coast Ledges in Southwest of Cape Colony, Quart. Journal, Geol. Soc., vol. lxii, p. 84. London, 1906.

the two continents in respect to some datum. The absolute base level of erosion I found to lie submerged some 9,000 feet in Europe and 1200 feet in South Africa.

Beyond the absolute base level of erosion lie the plains of the abyss, but we cannot legitimately include these in possible land forms unless we can prove that the theory of the permanence of ocean basins is an illusionary one.

(7) Finally there is the plain of deposition due to subsidence. Of these we have many examples along our coast, and to understand them it must be remembered that our rivers run out to the sea through rock gates and never form deltas. Elevation and subsidence are alternate motions in the earth's crust, and whereas the evidences for elevation are so marked in South Africa, those for subsidence are necessarily as plain. In the mouths of the Knysna, Keurboom, Kowie and Buffalo rivers, the rock channel has been cut to a hundred or more feet below present sea-level. In the last cited case the contours of the rock bottom have been accurately surveyed by Mr. J. J. Godfrey by means of bore-holes, and show a normal V-shaped river channel with three terraces, the deepest part being 124 feet below low water mark. In this lie accumulations of clay, sand and shells; the latter were sealed up while yet decomposing and have yielded reservoirs of marsh gas which caused explosions in the bore-holes when tapped. The actual river bottom lies now 14 feet below low-water mark.* These subsidence plains of deposit are naturally limited in extent, but they are sufficiently large in some places to be taken into account in the present connection. In the Knysna estuary they form wide salt-meadows which are partially covered at high water, but with very little work could be reclaimed.†

* Schwarz, E. H. L., The Rock Channel of the Buffalo River, East London, Records Albany Museum, Grahamstown, vol. ii, p. 1, 1907.

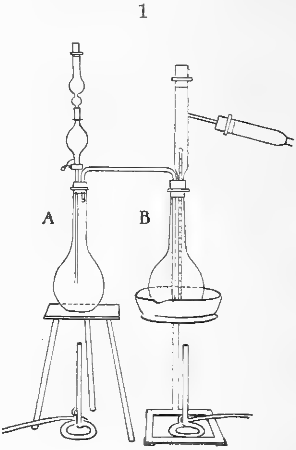
† The Coastal Plateau in George, Knysna, etc., Ann. Rep. Geol. Comm., p. 85, map. Capetown, 1906.

Art. XX.—*The Use of Zinc Chloride in the Esterification of Succinic Acid;* by I. K. and M. A. Phelps.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—clxii.]

In a former paper* from this laboratory it has been shown that in the action of succinic acid with ethyl alcohol containing hydrochloric acid to form diethyl succinic ester, the largest yield from a known weight of succinic acid is obtained where maximum dehydration is accomplished. In the work given here the action of zinc chloride in forming diethyl succinic ester in the mixture of succinic acid and ethyl alcohol both with and without the addition of hydrochloric acid is shown.

The apparatus figured was used in all of the experiments recorded here. Two round bottom flasks of 500$^{cm^3}$ capacity, each provided with inlet and outlet tubes held in rubber stoppers, were connected as shown. Of these, B, connected to a condenser through a Hempel column, carried a thermometer, and from flask A an inlet tube adjusted to dip beneath the liquid to the same depth as the thermometer. The flask A carried a separating funnel provided with a drying tube, as well as the exit tube to the flask B. In the flask B succinic acid was heated, by means of a bath of acid potassium sulphate, in some experiments with a definite amount of absolute alcohol alone, in others with the same amount of absolute alcohol containing hydrochloric acid gas, while from the flask A gaseous alcohol in most cases, and in a few cases gaseous alcohol with hydrochloric acid, was driven over into the mixture in B where esterification took place. The crude succinic ester left in flask B was freed from impurities by treating with sodium carbonate solution after first removing the zinc chloride by washing with water. The ester was freed from carbonate by rinsing with distilled water containing sodium chloride. The mass of ester carried mechanically with the several wash waters was extracted by shaking out separately three times with ether. The ether extracts and the succinic ester were gathered in a 250$^{cm^3}$ distilling flask fitted in the usual way for a vacuum distillation with a 100$^{cm^3}$ distilling flask used as a receiver, and, after fractioning off low boiling impurities, largely ether, alcohol, and water, was



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* This Journal, xxiii, 368.

distilled and collected in the receiver, cooled by a stream of water striking it constantly, and then weighed.

The pure zinc chloride of commerce was freshly fused for use in the experiments. The alcohol employed was made as anhydrous as can be obtained by successive treatments with fresh quicklime. The alcohol containing hydrochloric acid was charged with the dry gas in the proportion of ten grams to the liter. The succinic acid used was in most cases the pure acid of commerce, in the others, pure succinic acid made by recrystallizing the product formed by the hydrolysis of the pure ester in the presence of nitric acid.

The result obtained in experiment (1) of the table was found by heating with an acid potassium sulphate bath in the flask B a known weight of succinic acid with 40^{cm^3} of the total amount of absolute alcohol used in presence of ten grams of zinc chloride at a temperature of 100° to 110°, while driving into it the remainder of the alcohol in the form of vapor from flask A. All vapors from the flask passed through the Hempel column to the condenser. The Hempel column had an active surface of beads of 10^{cm} in height and a diameter of 2^{cm}. At its lower end it was in connection with a tube 5^{cm} in length and of $0{\cdot}5^{cm}$ bore, and had an opening blown in its side $1{\cdot}5^{cm}$ from the end. By the use of a column of this construction the hot vapor is enabled to go upward while the condensed liquid flows downward readily. It was found that by the use of this column neither succinic ester nor succinic acid distilled in such amount, if at all, that it could be detected in the liquid distillate. The impure ester in flask B, when all alcohol as vapor from flask A had been passed into it, was cooled and then poured into a separating funnel containing water with ice, using a small amount of ether to rinse the ester from the flask, and the zinc chloride was removed as far as possible. After separating the ester from this solution any acid impurities were neutralized with an excess of sodium carbonate in solution, and the ethereal solution was then washed with distilled water. The aqueous solutions in which the ester had been washed were shaken out three times separately with ether. The ethereal extracts were gathered in a 250^{cm^3} distilling flask connected in the usual way for a vacuum distillation with a 100^{cm^3} distilling flask used as a receiver. The low boiling impurities, ether, alcohol, and water largely, were separated by a vacuum fractionation, the 250^{cm^3} flask being heated in a bath of hot water at 60° finally for fifteen minutes after the manometer registered 15^{mm} and the succinic ester was then distilled and weighed.

The procedure in case of experiments (2) and (3) was the same excepting that the alcohol used was charged with hydrochloric acid in the proportion of ten grams to the liter; and in case of (3), and, also, in case of all other experiments in the table where only one gram of zinc chloride was used, the rinsing with cold water before neutralizing with sodium carbonate was omitted. In experiments (4) to (10) the 40^{cm^3} of alcohol heated with the succinic acid contained 1·25 per cent of hydrochloric acid gas, while absolute alcohol in amounts recorded in the table distilled into this mixture heated at 100° to 110°.

	Succinic acid	$ZnCl_2$	Alcohol with HCl		Reaction time		Succinic ester		
No.	grm.	grm.	cm³	per cent	hr.	min.	Theory grm.	Found grm.	per cent
(1)	50	10	200	0	2	30	73·7	66·90	90·8
(2)	50	10	200	1·25	..	50	73·7	71·25	96·7
(3)	50	1	200	1·25	..	45	73·7	69·40	94·2
			160	0					
(4)	50	10	40	1·25	4	..	73·7	69·70	94·6
			160	0					
(5)	50	10	40	1·25	..	45	73·7	72·00	97·7
			60	0					
(6)	50	1	40	1·25	..	20	73·7	53·15	72·1
			60	0					
(7)	50	1	40	1·25	..	55	73·7	52·05	70·6
			160	0					
(8)	50	1	40	1·25	1	..	73·7	70·30	95·4
			160	0					
(9)	50	1	40	1·25	..	45	73·7	71·78	97·4
			160	0					
(10)	50	1	40	1·25	..	50	73·7	71·88	97·5

From an inspection of the results in the table, it is evident that in presence of zinc chloride to the amount of ten grams with the proportions of succinic acid and alcohol given in the table, a fair yield of succinic ester is possible. Introducing hydrochloric acid and shortening the time of the reaction tends to increase the yield as shown by (2). Reducing the amount of zinc chloride present gives satisfactory results, as is clear by comparing (5) with (9) and (10). Although the amount of alcohol present in (6) and (7) during the reaction is double that theoretically required to esterify the acid present, it is not sufficient for the esterification under the conditions of the experiments. The simplest conditions of all those given in the experiments where a yield is satisfactory are those under which (8), (9), and (10) were made.

Hence, it is clear that in presence of zinc chloride diethyl succinic ester is easily obtained in large amount closely approximating that theoretically possible from a known amount of succinic acid. This is most easily done by heating at a temperature about 100° succinic acid with alcohol containing a small amount of hydrochloric acid in presence of zinc chloride in small quantity, while gaseous alcohol is driven into the mixture.

ART. XXI.—*On the Volumetric Estimation of Lanthanum as the Oxalate;* by W. A. DRUSHEL.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—clxiii.]

NEARLY thirty years ago Stolba* stated that cerium, lanthanum and didymium may be estimated by treating their oxalates with potassium permanganate in the presence of sulphuric acid, but gave no experimental evidence in the form of analytical results. Later this statement of Stolba was confirmed by a paper from this laboratory† in which it was shown that cerium may be estimated by precipitating cerium oxalate with a definite amount of a standard solution of ammonium oxalate used in excess. The precipitated cerium oxalate was decomposed by dilute sulphuric acid and the oxalate estimated by permanganate, and the ammonium oxalate in excess of the amount required for the precipitation was also estimated by permanganate. By this process the results were checked.

The work to be described was undertaken to determine the best conditions for the estimation of lanthanum as the oxalate and also to furnish the desirable experimental data in support of Stolba's original statement.

For this work about ten grams of pure ammonium lanthanum nitrate were prepared by separating the lanthanum and didymium from the cerium in a kilogram of the mixed sulphates by Mosander's chlorine method. The mixture of lanthanum and didymium chlorides thus obtained, having been shown to be free from cerium by the hydrogen peroxide test, was converted into a mixture of ammonium lanthanum nitrate and ammonium didymium nitrate. By fifty recrystallizations about forty grams of pure ammonium lanthanum nitrate were obtained. This salt was dissolved in eighty cubic centimeters of water, and the solution through a depth of nineteen centimeters showed no trace of absorption bands. A few cubic centimeters of the solution evaporated to dryness and ignited gave a pure white oxide. Out of this solution of the double nitrate about ten grams were recrystallized for the experimental work of this paper.

The procedure is as follows:

From a neutral lanthanum solution (a 1 per cent ammonium lanthanum nitrate solution being used in this work) the oxalate is precipitated by a measured amount of standard $\frac{n}{10}$ oxalic acid, or ammonium oxalate after the addition of a few drops of

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* Sitzber. d. Böhm. Gesellsch. d. Wissenschaften, iv, July, 1879. Zeitschr. für Anal. Chem. xix, 194.

† Browning, this Journal, viii, p. 451, 1899.

acetic acid. The precipitate is thoroughly stirred and allowed to settle. It is then filtered through a perforated crucible fitted with an asbestos felt. After thoroughly washing with water the crucible and precipitate are placed in a beaker with 100 to 300$^{cm^3}$ of water and 10 to 30$^{cm^3}$ of (1:4) sulphuric acid. The contents of the beaker are heated nearly to boiling and at once titrated to color with standard potassium permanganate. The filtrate is similarly titrated as a check on the titration of the precipitate. The lanthanum is calculated as La_2O_3 from the two titrations. The mean of the two closely agreeing values thus obtained is taken.

The solution of ammonium lanthanum nitrate used in this work was standardized by evaporating measured portions to dryness and carefully igniting the residue to constant weight.

Table of Results.

[LANTHANUM.......................138·9]

	La_2O_3 taken as the double nitrate	La_2O_3 found.			
		Precipitate	Filtrate	Average	Error
	gram.	gram.	gram.	gram.	gram.
1.	0·0148	0·0152	0·0144	0·0148	0·0000±
2.	0·0148	0·0149	0·0139	0·0144	0·0004−
3.	0·0296	0·0302	0·0291	0·0296	0.0000±
4.	0·0296	0·0302	0·0293	0·0297	0·0001+
5.	0·0592	0·0599	0·0586	0·0593	0·0001+
6.	0·0592	0·0598	0·0585	0·0592	0·0000±
7.	0·1184	0·1191	0·1179	0·1185	0·0001+
8.	0·1184	0·1191	0·1182	0·1187	0·0003+
9.	0·2368	0·2376	0·2362	0·2369	0·0001+
10.	0·0148	0·0149	0·0145	0·0147	0·0001−
11.	0·0148	0·0150	0·0147	0·0148	0·0000±
12.	0·0296	0·0298	0·0293	0·0295	0·0001−
13.	0·0592	0·0596	0·0589	0·0593	0·0001+
14.	0·1184	0·1190	0·1182	0·1186	0·0002+
15.	0·1036	0·1040	0·1029	0·1035	0·0001−

In experiments 1 to 9 ammonium oxalate was used in making the precipitation, in 10 to 15 oxalic acid was used.

In conclusion the author acknowledges his indebtedness to Prof. Philip E. Browning for helpful suggestions during the progress of the work.

ART. XXII.—*Studies on the Mode of Growth of Material Aggregates;* by ALFRED J. LOTKA.

I.

IN a material system in which the physical conditions vary with the time, certain individual constituent elements may have a transitory existence *as such*, each lasting just so long as its conditions and those of its neighborhood continue within certain limits.

Although the "life period" of each individual element may be thus limited, an aggregate of a number of such individuals may nevertheless have a prolonged existence, and may even grow, provided that the variations in the conditions of the system do not exceed certain limits, and that by some process or other new individuals are continually formed as the old are eliminated.

Aggregates of this kind play an important rôle in nature, and a study of their mode of growth or decay would be of considerable interest.

The general problem is evidently one of extreme complexity, but some special cases which lend themselves to simple mathematical treatment would seem to be rather instructive.

Let us then consider an aggregate which at time t_0 consists of N_0 individuals of a specified kind. If N_t is the number of individuals in the aggregate at time t, let us examine the relation between N_0 and N_t.

In the first place we note, that if

B_t = number of individuals added to the aggregate per unit time at the instant t,

and if

D_t = number of individuals eliminated therefrom per unit time at the instant t,

then,

$$\frac{dN}{dt} = B_t - D_t. \tag{1}$$

$$N_t = N_0 + \int_{t_0}^{t} (B_t - D_t)\,dt. \tag{2}$$

D_t is in general a function of N_t, its value depending:

1. On the character of the limitation of the "life period" of the individuals.

2. On the "distribution of ages" among the individuals.

B_t may also in some cases be more or less directly dependent upon N_t and upon the "distribution of ages" in the aggregate.

We will for the present restrict our considerations to cases in which:

1. The individuals are either all of one class as regards their general properties, and especially as regards those which affect the character of the limitation of their "life period"; or, if they belong to a number of different classes (e.g., males and females of a community of living organisms, etc.) then the relative proportion of individuals of each class among those formed during any element of time is constant.

2. The "length of life" of each individual is independent of the total number of individuals in the aggregate, and of the distribution of ages among them.

3. The general conditions of the system, in so far as they affect the "length of life" of the individuals (see § 2), are, on an average, uniform and constant throughout.

4. The variations in the conditions of the system are of such fixed type that, when conditions 1, 2 and 3 are satisfied, the number of individuals surviving age a out of any large number Ω counted at the moment of their formation and picked out at random, can be expressed in the form $\Omega\, p(a)$, where $p(a)$ is a (univalent) function containing only a.

Then, if $c(a)$ is such a factor that out of the total N_t the number of individuals whose age lies between the age limits a and $(a+da)$, is given by $N_t c(a) da$, it readily follows that

$$c(a) = \frac{B_{t-a}}{N_t}\, p(a). \tag{3}$$

$$D_t = -N_t \int_0^\infty c(a) \frac{d \log p(a)}{da}\, da. \tag{4}$$

$$= -\int_0^\infty B_{t-a} \frac{d\, p(a)}{da}\, da. \tag{5}$$

We may substitute these values in (2):

$$N_t = N_0 + \int_{t_0}^t B_t dt + \int_{t_0}^t N_t \int_0^\infty c(a) \frac{d \log p(a)}{da}\, dt\, da. \tag{6}$$

$$= N_0 + \int_{t_0}^t B_t dt + \int_{t_0}^t \int_0^\infty B_{t-a} \frac{d\, p(a)}{da}\, dt\, da. \tag{7}$$

Lastly, given that the average mass of one individual at age a is $m(a)$, we have for the total mass M_t of the aggregate at the instant t:

$$M_t = N_t \int_0^\infty c(a)\, m(a)\, da. \tag{8}$$

$$= \int_0^\infty B_{t-a}\, p(a)\, m(a)\, da. \tag{9}$$

The history of such an aggregate as we have been considering may be represented in a system of rectangular cöordinates by plotting as ordinates the values of $N_t c(a)$ corresponding to the values of a measured along the Y axis and the values of t measured along the X axis. The surface so obtained may be called the $N_t c(a)$ surface; any section of the same taken at 45° to the planes of xz and yz is of the form:

$$\begin{aligned} z &= N_{t_0}\, c(0)\, p(a). \\ &= B_{t_0} p(a), \end{aligned}$$

where t_0 is the value of t corresponding to the point at which the section cuts the X axis.

Special Cases.

A. Let $c(a)$ be of fixed form.

Then $$c(0) = \frac{B_t}{N_t} = \text{constant} = b \text{ say};$$

while, by (4) $$\frac{D_t}{N_t} = -\int_0^\infty c(a) \frac{d \log p(a)}{da} da$$

$$= \text{constant} = d \text{ say};$$

hence $$\frac{dN}{dt} = B_t - D_t = N_t(b-d) = rN \text{ say};$$

$$N_t = N_0 e^{rt} \tag{10}$$

Substituting these values in (3) we have:

$$c(a) = be^{-ra}\, p(a). \tag{11}$$

b, d and r are respectively the rates "per head" of formation, of elimination, and of increase in number of individuals in the aggregate. From the obvious relation,

$$\int_0^\infty c(a) da = 1 \tag{12}$$

or by (4) and (11), they must satisfy the condition:

$$b = \frac{1}{\int_0^\infty e^{-ra} p(a) da} \tag{13}$$

$$d = -b\int_0^\infty e^{-ra}\frac{dp(a)}{da}\,da \tag{14}$$

$$= -\frac{\int_0^\infty e^{-ra}\frac{dp(a)}{da}\,da}{\int_0^\infty e^{-ra}p(a)\,da.} \tag{15}$$

Substituting (13) in (11) we have:

$$c(a) = \frac{e^{-ra}\,p(a)}{\int_0^\infty e^{-ra}p(a)\,da.} \tag{16}$$

For the mass of the aggregate we have:

$$\mathrm{M}_t = \mathrm{N}_t\int_0^\infty c(a)\,m(a)\,da.$$

If $m(a)$ as well as $c(a)$ is independent of t

$$\int_0^\infty c(a)\,m(a)\,da = \text{constant} = \bar{m} \text{ say;} \tag{17}$$

then

$$\begin{aligned}\mathrm{M}_t &= \bar{m}\mathrm{N}_t \\ &= \mathrm{M}_0 e^{rt}.\end{aligned} \tag{18}$$

The above is the type toward which tends, for instance, a population in which the influence of emigration and immigration is negligible, and general conditions are approximately constant. Equations (10) and (18) then give the number* and mass of the population as a function of the time (geometric progression); equations (13), (14) and (15) are three different forms of the same relation between the birth-rate per head and the death-rate per head, while equation (16) gives the "age scale."

A comparison was made between some observed values and the corresponding figures calculated according to the above formulæ. Below are given the results for England and Wales, 1871–1880, which, in spite of very considerable emigration and immigration, show comparatively close agreement. For 1881–1890 the divergence is greater.

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* Compare M. Block, Traité théorique et pratique de statistique, 1886, p. 209.

England and Wales 1871–1880 (Mean).

		Observed*	Calculated
Birth-rate per head	b	·03546	·0352
Death-rate per head	d	·02139	·0211
Excess	$(b-d)=r$	·01407	(·0141)

Age Scale.	a_1 — a_2	$1{,}000\int_{a_1}^{a_2} c(a)\,da$	
1,000 individuals, in age-groups of 5 and 10 years :	0 — 5	136	138
	5 — 10	120	116
	10 — 15	107	106
	15 — 20	97	97
	20 — 25	89	87
	25 — 35	147	148
	35 — 45	113	116
	45 — 55	86	87
	55 — 65	59	59
	65 — 75	33	33
	75 — ∞	13	13

Special Cases.

B. Let B be constant.

Then
$$D_t = -B\int_0^\infty \frac{dp(a)}{da}\,da \qquad \text{by (5)}$$
$$= B$$
$$\frac{dN}{dt} = B - D = 0;$$

i.e., N also is constant, and we have a "stationary condition" or "kinetic equilibrium."

Here evidently
$$b = d$$
and
$$c(a) = bp(a). \tag{19†}$$

Furthermore,
$$b = \frac{1}{\int_0^\infty p(a)da} = \frac{1}{l} \text{ say,} \tag{20}$$
and
$$c(a) = \frac{p(a)}{l}. \tag{21}$$

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* Mean b and d from 46th Ann. Rep. Reg. Gen. Births, etc., England and Wales, p. xxxi ; $p(a)$ from Supplt. to 45th Ann. Rep. Reg. Gen. Births, etc., England and Wales, pp. vii and viii.

$$\text{assuming ratio : } \frac{\text{male births}}{\text{female births}} = 1{\cdot}04.$$

† Compare Farr, Roy. Soc. Trans., 1859, p. 837.

l is evidently the "mean length of life"; its reciprocal then, by (20), is that value of b which just suffices to keep the aggregate from decreasing under the conditions corresponding to the particular form of $p(a)$ by which l is given.

Thus, in the case of England and Wales, while according to the three life tables 1838–54, 1871–80, 1881–90, the mean length of life has risen from 40·9 to 42·9 and 45·4, the "equilibrium birth-rate per head" has been correspondingly reduced from ·0245 to ·0233 and ·0220.

II.

Isothermal Monomolecular Reaction.

We will consider a system undergoing the chemical change,

$$A' \rightleftarrows A$$

which we will suppose to take place at constant volume and temperature, and in a homogeneous system.

Let N denote the total number of molecules of A.
" N′ " " " " " " " A′

Also, when $t = 0$, let $N = 0$

$N' = N_0'$

Hence, $N + N' = N_0'$.

Let D′ denote the number of molecules of A′ decomposed per min.
" D " " " " " " A " " "
" B′ " " " " " " A′ formed " "
" B " " " " " " A " " "

The reaction is monomolecular in either sense. Hence, by the law of mass action:

$$D' = k'N' \qquad D = kN.$$

(k and k' are the reaction coefficients.)

Then, for the aggregate of N molecules of A we have:

$$B = D' = k'N' = k'(N_0' - N).$$

$$\frac{dN}{dt} = B - D = k'(N_0' - N) - kN$$
$$= k'N_0' - (k + k')N.$$

Integrating:

$$N_t = N_0' \frac{k'(1 - e^{-(k+k')t}}{k + k'}. \qquad (a)$$

The total mass of the aggregate follows immediately from the relation:

$$M_t = mN_t$$

where m = absolute molecular weight of A.

Similarly, for the aggregate of N′ molecules of A′ we have:

$$N_t' = N_0' \frac{k + k' e^{-(k+k')t}}{k+k'}. \qquad (b)$$

$$M'_t = m' N_t'.$$

Both N_t and N_t' approach towards a limiting value as t approaches ∞, viz:

$$N_\infty = N_0' \frac{k}{k+k'}$$

$$N'_\infty = N_0' \frac{k'}{k+k'}.$$

These limiting values, of course, represent a state of equilibrium, for when they are reached, further increase in t produces no further increase in N.

In this particular case evidently no knowledge of the form of $p(a)$ and $c(a)$ is required in order to determine $\frac{dN}{dt}$, and therefore N_t. We can, however, conversely deduce the form of $p(a)$ and $c(a)$.

For, since D depends only upon N, and *not at all* upon the previous history of the system,* it is evident that the stability of the molecule is independent of its age. (Otherwise D would depend on the distribution of ages in the aggregate, and hence on its past history.)

Hence, if we pick out a large number n out of the total number N of molecules, such that all these n molecules have (nearly) the same age, then the fractional rate of decrease among these will be the same as for the whole aggregate.

We have then $$-\frac{dn}{dt} = -\frac{dn}{da} = kn$$

Therefore $$n = n_0 e^{-ka},$$

i.e. $$p(a) = e^{-ka} \qquad (c)$$

In this case we have for the mean length of life:

$$l = \frac{1}{k} \qquad (d)$$

Similarly $$p'(a) = e^{-k'a} \qquad (e)$$

$$l = \frac{1}{k'}. \qquad (f)$$

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* Except in reactions which have a "period of induction."

Introducing the relation (c) into (4), we have:

$$D_t = kN_t \int_0^\infty c(a)da.$$

From the nature of $c(a)$ it is evident that

$$\int_0^\infty c(a)da = 1.$$

Hence $$D_t = kN_t,$$

which, of course, is not a new result.

The form of $c(a)$ follows from the relation:

$$c_t(a) = \frac{B_{t-a}}{N_t} p(a) \qquad (3)$$

$$= e^{-ka} \frac{k'N'_{t-a}}{N_t} \qquad \text{(by } c\text{)}.$$

$$= e^{-ka} \frac{k+k'e^{-(k+k')(t-a)}}{(1-e^{-(k+k')t})} \qquad \text{(by } a \text{ and } b\text{)}. \qquad (g)$$

When $t=\infty$ i.e., for equilibrium:

$$c_\infty(a) = ke^{-ka}. \qquad (h)$$

We cannot determine $c'(a)$ exactly, as we do not know the ages of the N_0' molecules originally present at time $t=0$. By simply neglecting these N_0' molecules, we can, however, find an approximate expression which will give $c'(a)$ more and more nearly as time advances, and the number of survivors of the original N_0' molecules diminishes.

We thus obtain:

$$c_t'(a) = ke^{-k'a} \frac{k'(1-e^{-(k+k')(t-a)})}{k+k'e^{-(k+k')t}}. \qquad (i)$$

$$c'_\infty(a) = k'e^{-k'a}. \qquad (k)$$

Equation (i) holds good (approximately) when t is sufficiently large, for values of a small as compared with t.

Equation (k) holds good for all finite values of a.

Equations (h) and (k) correspond to equations (19) and (21) developed for the general case.

The above conclusions still hold if other substances enter into the reaction beside A and A′, provided that their concentration is practically constant, (e.g., if they are present in large excess).

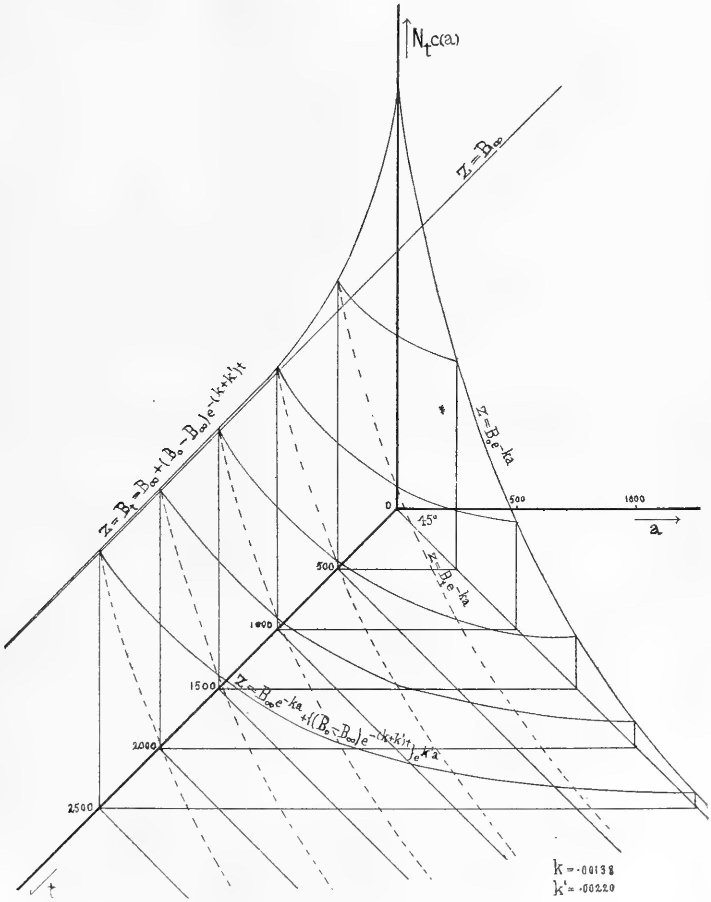
As a concrete example, we may, for instance, quote the case of the reaction:

$$HCOOH + C_2H_5OH \rightleftarrows HCOOC_2H_5 + H_2O$$

which, in the presence of excess of alcohol and water, is monomolecular in either sense. According to the values of the velocity coefficients observed by Kistiakowski,* at 25° C. in a solution containing 73·2 per cent alcohol, the mean "length of life" of a molecule of formic acid is here 7 hrs. 36 mins., while that of a molecule of ethyl formate is 12 hrs. 6 mins.

Representing the history of the aggregate A (ethyl formate) by an $N_t c(a)$ surface, we should obtain a figure such as that indicated below.

1



We have not the requisite data for constructing the entire $N_t c(a)$ surface for A′; when equilibrium is reached, however,

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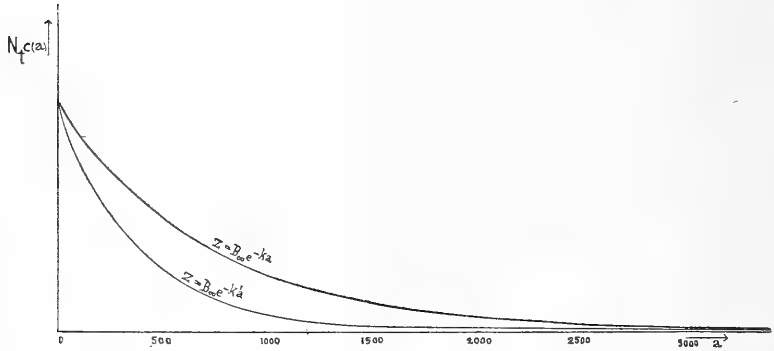
* Zeitschr. f. phys. Chemie, xxvii, 1898, 250.

all sections given by t = constant are alike both for A and also for A′, and take the form indicated in fig. 2.

We note that although the zero ordinate—the number of molecules formed per unit time—is the same for A and A′, nevertheless molecules of one kind—A say—preponderate in the system, as shown by the greater area of the curve A; this is because, in the "struggle for existence," the stabler (fitter) molecules A have the advantage, and are, on an average, "longer-lived."

Viewed in this way, chemical action clearly presents itself as a case of "Inorganic Evolution."

2



The physical interpretation of these results would be somewhat as follows:

From the point of view we have taken, we must suppose that the condition of each molecule at a given instant in general departs somewhat from the average condition of all molecules.

For a given molecule of the kind A, there will, in general, sooner or later, come a moment when the variations in its condition reach a certain limit—we may speak of it as the "limit of stability" of the molecules A—at which that molecule of A ceases to exist *as such*, and passes into the condition A′.

The number D of molecules which are thus eliminated from the aggregate A in a unit of time will depend:

1. On the nature of the "limit of stability" of the molecule A.

2. On the "distribution" of the variations in the condition of the molecules in the aggregate.

Any agency which affects either of these factors will, in general, affect also D, the rate at which molecules are eliminated from the aggregate.

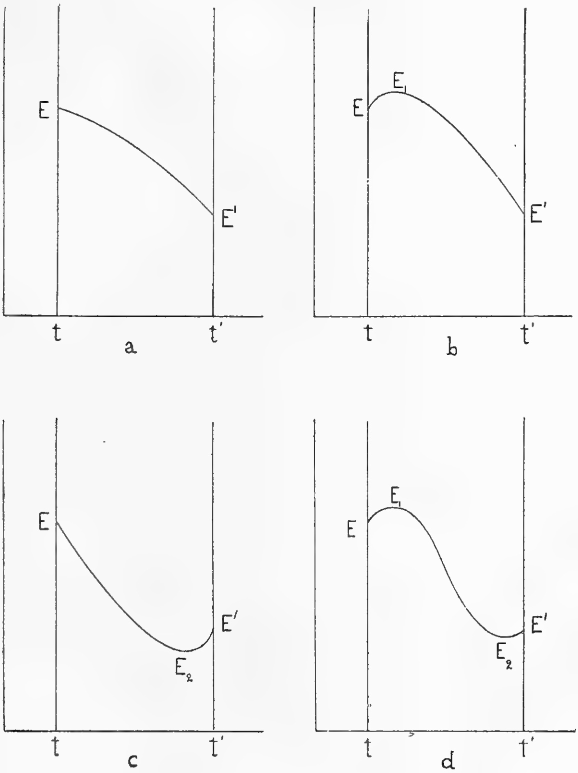
Let us consider each of these factors a little more closely.

I. Limit of Stability of a Molecule of the kind A.

The circumstance which leads to the elimination of a molecule of the kind A is its spontaneous passage from the condition A to the condition A′.

Now, in order that this passage may take place spontaneously, it is necessary:

3



1. That the free energy E of that molecule in the state A be > E′, its free energy in the state A′.

2. That during the passage of the molecule from the state A to the state A′, its free energy diminish continually.

A diagram will help to illustrate these conditions.*

Suppose the free energy E of the molecule plotted as ordinate against the time as abscissa during its passage (not necessarily spontaneous) from the state A to the state A′.

Then, if condition (1) is satisfied, the curve $E = \phi(t)$; or, as

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* It is here assumed that, whatever may be the events immediately preceding the change A A′, *during* this change the molecule may be regarded as an isolated system. Without this assumption the conditions for the change A A′ are more complicated.

we may express it, the "path" of the change from A to A′ might, for instance, assume any such form as the above (fig. 3), for in each case $E > E'$.

Evidently, however, the change A A′ will not take place spontaneously, except in the case represented by fig. 3a, which is the only one satisfying also condition (2).

Now, we have no means of ascertaining the character of the "path" of the change A A′ by direct observation. The following considerations, however, will show how, from the properties of the aggregate as a whole, we can draw inferences as regards the character of this path for the individual molecules.

A. Time $t'-t$ required for the change.

Since kN molecules pass from A to A′ per unit of time, and each takes on an average $(t'-t)$ to complete the change, there will, at a given instant, be $kN(t'-t)$ molecules actually undergoing change. The dilution of these in the aggregate will be at least $\frac{1}{k(t'-t)}$.

Now it is a matter of universal observation that in all ordinary chemical reactions* at any rate, this dilution is so great that the material in the state of transition cannot be detected, no matter what the value of k, or the methods† of analysis, or the general circumstances. In other words, such a system as the one we have been considering, can always be fully described with regard to its composition (within the limits of experimental error) as consisting of a certain quantity of A and a certain quantity of A′.

We conclude that in all ordinary cases the time $t'-t$, during which the molecule is in the transitional state, is very small.‡

B. The form of the path A A′.

In general, the type of the path A A′ will, for each molecule, depend on its condition at any particular instant, and it may be different for different molecules of the same aggregate.

(*a*) Let us first of all suppose that for all molecules for which the condition (1) is satisfied $(E > E')$, the path is of type (*a*); in this case then the fulfilment of condition (1) will be sufficient to determine the change A A′, and it follows that all molecules for which $E > E'$ will actually be undergoing

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* Evidence of the transitional state in tautomeric change, however, appears to be furnished by the work of Baly and his collaborators.

† Ordinary methods of analysis, of course, would not reveal the presence of such transitional bodies. But physical methods should, if they were sufficiently sensitive. In this connection again we must turn to the work of Baly for suggestions.

‡ But see remark regarding tautomerism on the next page.

this change. Hence, the aggregate can never contain any molecules for which $E > E'$, except those $Nk(t'-t)$, which are actually undergoing the change from A to A′; this number we saw is always negligible for any ordinary chemical change going on with measurable velocity.

Therefore, A can never, for any length of time, exist except in equilibrium with A′. This conclusion agrees with the facts observed in the case of change of physical state unimpeded by supercooling or superheating, and, perhaps, with certain types of chemical reaction (e.g., dissociation); but it does not correspond to the characteristics of an ordinary chemical reaction taking place with measurable velocity.

(β) Next, suppose that the path is of type (*b*) for all molecules for which $E > E'$. In that case no spontaneous change from A to A′ will take place, although the aggregate may not be in stable equilibrium with A′; and this condition will continue indefinitely.

Cases of this kind are: Physical change arrested by superheating or supercooling; also, in practice, every "unstable" chemical compound, which may be preserved (practically) unchanged indefinitely under certain conditions.

(γ) Next suppose the path A A′ is of type (*a*) for some molecules, of type (*b*) for others. Then the former will be actually undergoing change, while the latter, although having $E > E'$, will remain in the form of A.

Such an aggregate may, therefore, for an undetermined length of time, contain molecules for which $E > E'$, i.e., it may have a prolonged existence in a state in which it is not in equilibrium with A′, but is undergoing gradual change towards that equilibrium.

This description evidently fits the case of the typical chemical time-reaction,* and to its more detailed study we will return presently, after we have briefly considered some of the remaining types of the path A A′.

(δ) A path of type (*c*) or (*d*) for some of the molecules would imply that they were more stable in their transitional state than in the form A or A′.

Such a state of affairs is imaginable—the "stable" form A_2 would then correspond, not to an ordinary chemical compound, but to a condition of the molecule intermediate between two compounds. A case of this kind is perhaps presented by the phenomenon of tautomerism.†

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* The presence of a maximum in the path of chemical change is indicated in many cases by the increased reactivity (i.e., increased free energy) of substances in the "nascent" state. But the mere fact that the transitional state is evanescent implies such a maximum.

† In this case then the "transitional" state would be prolonged, and we might expect to be able to detect the material present in that state. In this connection note the work of Baly and his collaborators. Compare also G. Oddo, Über Mesohydrie Chem. Centr. Blatt, 1906, p. 1811.

The path A A′ might, of course, also be of more complicated form, having a number of maxima and minima. But such a case does not seem to be of any particular interest in the present connection.

Let us now return to the case (γ), as applied to the system which we have been considering, viz., that in which the change

$$A' \rightleftarrows A$$

is going on.

A geometrical representation of the conditions in this system, in accordance with the conception outlined above, may be obtained as follows:

With our attention fixed first of all upon one particular molecule, at a time when it is in the condition A′, let a curve be drawn, whose ordinates represent the values of E′, the free energy of this molecule, corresponding to the times measured off as abscissae.

On the same diagram let a second curve be similarly drawn, such that its ordinate for a given abscissa represents the minimum value E of the free energy which the molecule would have at that instant, supposing it to be in the state A, and to retain its actual total energy.

Lastly, on the same diagram, let a curve be drawn, whose ordinate for a given abscissa represents the least maximum value E_1, through which the free energy of the molecule must pass under the existing conditions, if the molecule is at the instant corresponding to the abscissa, transformed from the state A′ to the state A (limit of stability).*

Now we have no means of directly ascertaining the exact† form of these three curves for a given molecule, but we do know something of the general aspect which they must present.

The principal features of interest are indicated in fig. 4, and are best described by reference to this:

We will suppose that, as shown in the figure, at the moment $t = 0$, when we begin our observation, $E' < E$. As time goes on E′ and E vary somewhat, and the corresponding curves may cross at some point t_1 at which $E' = E$. To the right of this $E' > E$, and the first condition for the transformation A′ A is fulfilled. Following up these two curves further, we may find them recrossing, but sooner or later we shall come to a point where, with $E < E'$, the curve representing E′ will meet the third curve E_1. At this instant t_2, the second condition

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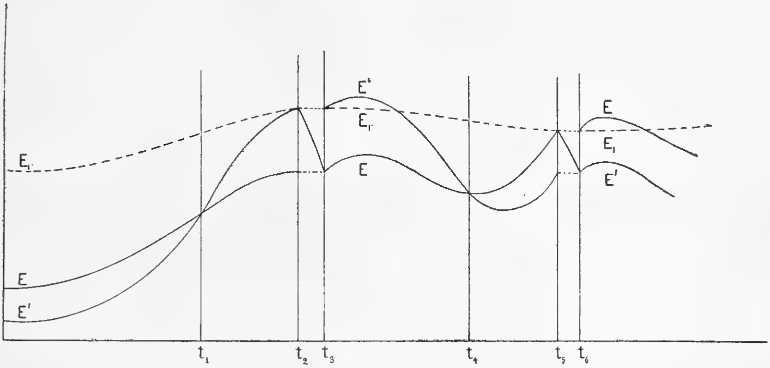
* For the sake of simplicity it is here assumed that the path which contains this least maximum, contains no other maximum.

† The mean state of the molecule will presumably satisfy the law of equipartition. See Rayleigh, Phil. Mag. (5), xlix, 98; Kelvin, Phil. Mag. (6), ii, 1, 7; also W. F. Magie, Science, xxiii, 161, 1906.

also for the spontaneous change from A′ to A, is satisfied, and this change actually takes place.

Now we can continue our curves, tracing first of all the value of the free energy during the change from the condition A′ to A. This part of the curve is the "path" of the *spontaneous* change, and must, therefore, be of type (*a*), as shown. We then continue our set of three curves, very much as before, except that now the values of E are the actual values, those of E′ auxiliary ("calculated").

4



The continuation of this figure then shows features precisely similar to those which we noted in the earlier part, and it is, therefore, unnecessary to follow up their description any further. We only note that t_3 denotes the instant at which the molecule of A is formed, t_4 a point at which the curves E E′ cross, t_5 the moment when the molecule is eliminated from the aggregate A.

The interval $t_3\ t_5$ represents the length of life of the molecule A, and this, we saw, has the value (*a*) for ne^{-ka} out of n molecules counted at the moment of their formation, or, has a mean value $\frac{1}{k}$ for all molecules.

We can distinguish a number of separate fields in this diagram.

In the field $t_3\ t_4$ the molecule is in the state A, and is stable in that condition.

In the field $t_4\ t_5$ the molecule is still in the state A, though in a meta-stable condition. It does not here pass into the state A′, for in order to do so, it would have to cover a path of type (*b*); i.e., the second condition for a spontaneous change is not fulfilled.

Lastly, the field $t_5\ t_6$ represents the molecule during its spontaneous transition from the state A to A′.

II. Distribution of Variations.

The above considerations apply to one individual molecule. The entire aggregate A will comprise :

1. Molecules whose condition corresponds to the field $t_3\ t_4$. These are stable; neither condition (1) nor condition (2) is satisfied for their elimination from the aggregate A.

2. Molecules whose condition corresponds to the field $t_4\ t_5$. These are in meta-stable condition, but do not change because condition (2) is not satisfied.

3. Molecules whose condition corresponds to the field $t_5\ t_6$. These are undergoing change, and being eliminated from the aggregate.

The number of molecules in the third class, we saw, is always small (at any rate in ordinary cases) and is given by

$$kN(t'-t).$$

The distribution of the remaining molecules between the first and second class is evidently closely connected with reaction velocity and equilibrium. A change in temperature, being accompanied by a change in the total energy of the system, must lead to a change in the distribution of the energy in the system, and so to a change in the distribution of the variations in the condition of the molecules. But any agency which produces such a change will affect D, and hence arises the connection between D and the temperature.

We still have to consider the influence of agencies which affect the "limit of stability" of the molecule.

There is one special case which is of interest here, namely, that in which, while the values of E and E′ are unaffected for each molecule, E_1 is changed—lowered, say. The effect of such a change will evidently be that, while the total and free energy of the system as a whole is unchanged for a given composition (and volume), the rate D will be changed—raised.

We see that this corresponds exactly to the effect of introducing a catalyser into the system.

We may go a step further and ask ourselves in what way the value of E_1 may be lowered.

The answer is that this may take place in one of two ways :

Either the character of the path A A′ may be changed for some or for all the molecules; the formation of intermediate compounds in certain reactions or the production of local differences in concentration, and other unknown effects, may be of this character.

The effect of the catalyser would in this case be closely analogous to that of "nuclei," or "crystals" in supercooled systems, or of gas bubbles in a superheated liquid. In these cases change of state is arrested because in the absence of "germs" the system would have to pass through a stage in which its free energy had a value greater than its actual value,* in order to reach the final lower value. The introduction of the germ furnishes another path requiring no such maximum value to be passed, and the change then takes place spontaneously.

But the catalyser might also produce its effect in another way, namely, by providing mechanism through which a portion of the energy set free by one molecule during its descent along the downward limb of the path A A′ is diverted into such a channel that it raises another molecule up the ascending limb of that path.† This possibility is of some interest because a large class of natural phenomena, especially in the living world, depend on an action of this kind. We may only mention here the phenomenon presented by an organism which obtains its food by a series of (muscular) efforts, the energy for which is derived from food previously ingested. The phenomenon as a whole takes place spontaneously, although for each portion of food there is a stage in the process through which it passes when it requires the application of external energy. Another example of the same kind taken from the world of mechanics is the continuous operation of a heat engine in which the working substance goes through a cycle.

Lastly we note that according to the view developed above, such agencies as elevation of temperature, or the introduction of a catalyser, which increase k, will shorten the life of the molecule, since we found that the probability at the moment of formation that a given molecule will reach age a is given by e^{-ka}.

This brings us to the close of our consideration of the system A + A′. A similar treatment might of course be applied to more complicated chemical systems, but, although the results obtained would of course differ in form from those deduced above, the underlying principles would be the same. Indeed, the development outlined in this paper appears to promise perhaps more interesting suggestions in the treatment of aggregates, the elements of which, unlike the molecules in chemical

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* Owing to the dependence of vapor-pressure, solubility, or melting-point on the form of the surface of contact between the two phases.

† A somewhat similar idea has been expressed by Raschig (Zeitschr. f. ang. Chem., 1906, p. 1761), who compares the action of the molecules on one another to that of the consecutive members of a file of dominos set up on end, and overthrown in a body by the fall of the first in the file.

reaction, are accessible to individual observation; and it is hoped on a future occasion to prosecute the work further in this direction.

For the present, however, we will conclude with a brief summary of the main points developed so far:

1. We have recognized the problem of chemical dynamics as a special case of a wider problem: The former is the study of the laws governing the changes in the distribution of matter among different chemical compounds, as determined mainly by their chemical character; the latter is the study of the laws governing the distribution of matter among complexes of any specified kind, as determined by their general physical character.

The statement of the wider problem may be taken to represent the quantitative formulation of the problem of evolution in its most general terms.

2. We have illustrated a statistical method which is sufficiently general in its application to comprise such widely different cases as that of the growth of a population under certain simple conditions, on the one hand, and that of a simple chemical equilibrium reaction, on the other. The fundamental feature of this method is the splitting up of the characteristics governing the rate of growth of a material aggregate into two factors—the one relating to those properties of the system which determine the formation of new individuals, and the other relating to those properties of the system which determine the limitation of the "life period" of the individual constituents.

3. Incidentally we have suggested a physical conception of the character of chemical action, of the "passive resistance" which checks its velocity, of catalytic action, of the "nascent" state, and of tautomerism.

Art. XXIII.—*The Catalan Volcanoes and their Rocks*; by HENRY S. WASHINGTON.

INTRODUCTORY.

THE volcanoes in the vicinity of Olot in Catalonia seem to have been first noticed by F. Bolos in 1796,* and later by Maclure,† and were described in the nineteenth century by several geologists, among whom may be named Lyell‡ and Carez.§ Within the last few years renewed attention has been directed to these volcanoes by the Spanish Society of Natural History, which appointed a commission to undertake a monographic study of them. A preliminary report of this commission appeared in 1904,‖ and it is expected that the final results of its labors will be published in the near future. The same year also saw the publication of the two latest papers on these volcanoes. The one is a small, illustrated pamphlet by Gelabert,¶ who describes the physical features of the district in a rather popular way, and without any petrographical or chemical discussion. The other is a brief but very instructive sketch of the general volcanological features of the vicinity of Olot by Sapper.**

While the main physical and geological features are thus well known, the petrographical characters of the rocks have been comparatively neglected. Recognized in the field by the earlier observers as basalts, they were studied by Quiroga,†† who established the presence of feldspar basalts, nephelite basalts, and limburgites—determinations which my own observations substantiate. Some of Carez's and Sapper's specimens were reported to be feldspar basalts, which is a sufficiently accurate designation for many of the rocks in the absence of chemical analyses.

It was to collect material to supply these deficiencies in our knowledge, and especially to undertake the chemical investigation of these presumably interesting rocks, that the writer visited the region in the summer of 1905 with the aid of a grant from the Carnegie Institution of Washington. Head-

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* Cf. L. M. Vidal, Bull. Soc. Geol. Fr., vol. xxvi, 1898, p. 675.

† Cf. C. Daubeny, Description of Volcanoes, London, 1848, p. 295.

‡ C. Lyell, Principles of Geology, 1840, vol. iii, p. 185.

§ L. Carez, Étude des Terrains Crétacés et Tertiaires du Nord de l'Espagne, Paris, 1881, p. 299.

‖ S. Calderon, Bol. Soc. Esp. Hist. Nat., p. 330, 1904.

¶ J. Gelabert, Los Volcanes extinguidos de la Provincia de Gerona. San Feliu de Guixols, 1904, 120 pp., small 8vo, with map.

** K. Sapper, Die Catalonischen Vulkane, Zeits. d. deutsch. geol. Ges., vol. liv, p. 240, 1904.

†† Cf. S. Calderon, Bull. Soc. Geol. Fr. (3), vol. xiv, pp. 13, 114, 1885.

quarters were made at both Gerona and Olot, from which a considerable number of the cones and lava flows were visited, especial attention being paid to those near Olot. Not much stress was laid upon the general geology, the tectonics, and the stratigraphy, as these were beyond the main scope of the investigation, and will be fully covered by the forthcoming report of the commission referred to above. At the same time, a short sketch of the main physical and topographical features of the volcanoes themselves will be given here, as they are but little known in this country and the descriptions may be of interest.

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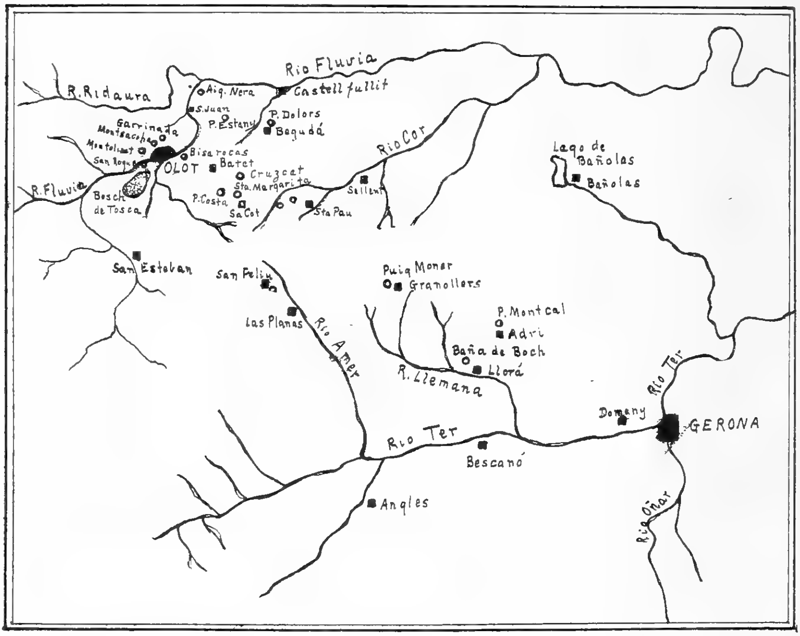

Sketch Map of the Catalan Volcanoes
1 : 400,000

Study of the region is somewhat hampered by the want of an accurate and detailed map, a need which the Spanish Commission purposes to fill. The only map available was one of the Province of Gerona by Marti and Mariño, on a scale of 1 : 200,000, and published at Barcelona by Barral Hermanos in 1900. No contour lines or other physiographic features, except the hydrography, are presented in this, even the volcanoes being omitted, so that the map leaves much to be desired. It is probably on this that the sketch map mentioned by Sapper is based, of which I was unable to obtain a copy, and it also serves as the basis for the map on the same scale given by Gelabert, on which the positions of the volcanoes are roughly indicated. A sketch map of the district is given in fig. 1, based on the map mentioned above. Only the more prominent volcanic cones are shown (by small circles), and the railroad, which extends from Gerona to San Feliu, is omitted.

I would take this opportunity to express my thanks to Señores Calderon and Fernandez Navarro for courtesies and assistance shown me in Madrid preparatory to my visit to Olot.

Topography and Geology.

Prevolcanic Geology.—The volcanoes which form the subject of the present paper are situated in the modern Province of Gerona (embraced within the ancient Catalonia), in northeastern Spain, between the eastern end of the Pyrenees on the north and the Sierra de Monseny on the south. The area occupied by them is part of the Eocene gulf which extended partially across northern Spain from the Gulf of Lyons, the volcanic area proper occupying the site of a Pliocene bay, which formed the last filled and most eastern part of this. The chief sedimentaries of the district are nummulitic limestones of Eocene age, with some later conglomerates, and a small patch of Silurian shales and limestones near Llorá, along the Rio Ter. These earlier rocks are quite variable in dip and strike, and faulting is common in the Eocene limestones. The fault scarps thus produced are quite prominent features in the topography, being often several hundred feet in height. From such observations as I made, it seemed that the area is one of faulted blocks, the dips being in diverse directions and usually at rather low angles, seldom over 25°, though I was able to devote so little time to this phase of the geology that I cannot speak decisively on the subject.

In the depressions and fault valleys thus formed were laid down thin deposits of Quaternary sands, clays, and conglomerates, which, with the Tertiary strata, underwent very considerable erosion prior to the beginning of the volcanic activity.

It would seem that there was some feeble vulcanicity manifested in the Tertiary,* but the era of the volcanoes which interests us here began about the middle of the Quaternary, and continued into the present period, as is evident from the excellent state of preservation of the volcanic cones, though there is no historic record of any eruptions. The influence of

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* Cf. S. Calderon, Bol. Soc. esp. Hist. Nat., 1905, p. 340.

these upon the preëxisting topography was comparatively slight, and consisted largely in the building up of cinder cones and the filling of the river valleys by lava flows, resulting in the formation of some lakes and marshes. But, on the whole, the preëxistent drainage persisted, and the rivers now follow their old courses, having cut new channels either through or alongside of the lava flows, coming out into their old beds when the lava ends. Excellent illustrations of this are to be seen in the valleys of the Fluvia and of the Amer; in the latter case the relations of the lava flow to the old drainage, and the abrupt end of the former being especially well seen from the railroad, a few kilometers below Las Planas.

The Lava Flows.—The igneous ejections are readily referable to two distinct periods, a separate type of eruption distinguishing each. The earlier seem to have been uniformly quiet, and formed extensive flows of basalt, which poured out into the river valleys and other depressions as explained above. The points of origin of most of these are not readily made out and are somewhat problematical, owing to their subsequent burial beneath later ejections and recent deposits. But in general they seem to have issued from at or near the sites of scoria cones now in existence. These flows, of which Gelabert enumerates ten principal ones, varied in length from 5 to 15 kilometers, and seem to have been uniformly quite thick, up to 40 or 50 meters. Of these the most important are: one which issued from near Santa Margarita and flowed northeasterly down the valley of the Rio Cor, past Santa Pau and Sellent, a distance of about 10 kilometers; a second which issued from near La Garrinada and flowed easterly down the valley of the Fluvia past Puig Estany and Bagudá as far as Castellfullit, a columnar structure being especially well developed in this; a third which flowed from near Baña de Boch down the valley of the Riera de Llémana as far as the chapel of Sant Medir near Llorá; and a fourth which issued from near the Puig Montcal at Adri and flowed southeasterly as far as Domeny, near Gerona, a distance of about 12 kilometers.

Partially filling the preëxisting river valleys, these flows present a characteristic feature of the topography, and when they have been cut into by subsequent river erosion, or where the river has cut for itself a channel between the lava and the adjacent limestone, highly typical and very striking illustrations of columnar structure are revealed. Of these the best known is that at Castellfullit, which has been described by almost every writer who has visited the region. The flow here is about 50 meters thick, and forms a precipitous tongue of dark gray, prismatic lava, crested with the little village above, and with the turbulent stream below. The upper half is made up of several series of curved prisms, which Carez refers to five separate flows, though they seemed to me to be parts of but one thick flow, the apparent superposition of the series of columns being due to local variations in the conditions of cooling. This rests over the greater part of its area on a thin stratum of loose, scoriaceous material, which lies from 18 to 25 meters above the river level. Below this the lava is decidedly platy, rather than columnar, though even this assumes in places a distinctly columnar structure, the prisms being thin and often radiating. The base of this is difficult to see, owing to the abundant talus, which contains, by the way, many fragments of Roman glass, but it is distinctly seen in places to rest upon Quaternary gravels, but little above the water level. The small "basalt hill" mentioned by Sapper and marked on his map, which lies a short distance to the east of the tip of the tongue, across the brook, is evidently an integral part of the main flow, as it shows the same succession of prismatic and platy lavas separated by a thin scoriaceous layer. In this case the River Fluvia, and the small tributary from the south, have carved channels between the lava flow and the limestone. A photograph of this flow is reproduced in fig. 2.

Other excellent examples of basaltic columns are shown in the same flow north of La Garrinada, along the small Rio Ridaura, where the stream has cut into the lava itself, and in places has formed deep pot-holes, as well as in the first flow mentioned above near Sellent, and in that from Baña de Boch, below the Chapel of Sant Medir near Llorá.

An area of rough lava, known as La Malatosquera or the Bosch de Tosca, extends westwardly from the Fuente de San Roque near Olot some two kilometers, the breadth being about half the width. It is a wilderness of the roughest *aa* lava, cultivated in spots and cut up by a labyrinth of walls and narrow paths. Scattered over its surface are many small knolls and protrusions of lava blocks cemented by finer-grained and scoriaceous material. These do not seem to be definite cones as reported by Gelabert, but are rather due to small, local explosions of steam, and the heaping up of solid blocks, such as are frequently found in extensive rough lava flows. This area, which overlies a more compact and massive lava flow visible at the fountain of San Roque, is apparently later than most of the main flows, but is not connected with any definite cone, for, though very close to that of Montolivet, it is yet clearly distinct from this, and is probably to be considered as intermediate between the two phases of activity.

The Cinder Cones.—Protruding through, and scattered over the surfaces of these lava flows, and consequently later than they, and in some cases resting on Quaternary deposits, are many well-formed cinder cones, of which Gelabert enumerates thirty-four. The greater number of these are in the neighborhood of Olot, where they occur very close together, while others are met with, but more widely separated, to the east, near the town of Gerona, but mostly to the west of this. As far as my observations permitted me to judge, it would seem that none of these cones are based immediately upon the Eocene limestone, but that they rest either upon Quaternary deposits or upon the earlier lava flows, in most cases the latter being true. Furthermore, it would appear that the place of origin of these cones, as well as of the lava flows, is never near the upper edge of a fault block, but always in or near the fault valley, and sometimes close to the face of the fault scarp. A similar emplacement was observed in the case of some of the smaller and most recent cinder cones in Sardinia, and such a situation above or near a well-marked fault is readily conceivable as most favorable to the formation of a volcano.

2

Castellfullit from the north.

These small volcanoes are invariably typical cinder cones, lava beds not entering materially into the structure of most of those examined by me; though massive flows occur at the base of some of them, many of which are held to belong to the earlier eruptive period, and a compact lava stream was noted at the summit of La Garrinada. The material of which they are composed, therefore, is predominantly highly scoriaceous, and may be either in the form of blocks of very vesicular lava, scoriæ, or very fine lapilli, which may be mingled with the larger blocks or may make up the cone to the exclusion of the former.

The largest of these cones is Puig* Moner, near Granollers, about half way between Gerona and Olot (which I could not visit), whose height above the surrounding country Gelabert gives as 550 meters.

But this is exceptionally high, and the great majority have altitudes above their bases of about 100 meters or so, ranging from only 30 meters to about 200. They all show well-defined craters, and many are breached more or less on one side. For the most part they have but one crater, though La Garrinada possesses three and Puig Montcal, according to Gelabert, as many as four. While some of these craters are comparatively deep, most of them are quite shallow, and they are usually overgrown with a more or less dense forest vegetation, as are most of the outer slopes, though the bottoms of a few are given up to cultivation, as at Montsacopa and Santa Margarita. In general the original form is well preserved, as is seen at Montsacopa and La Garrinada, though others, as Cruzcat, have suffered very considerable denudation. But on the whole the state of preservation is so good that a comparatively recent origin must be ascribed to them all.

While detailed descriptions of the volcanic cones visited would be out of place here, and are especially unnecessary in view of the imminent publication of the work of the Spanish commission, yet a few notes on some of the more important ones may be welcome, as these volcanoes are comparatively little known.

The best known are the three in the immediate vicinity of the town of Olot, namely Montolivet, Montsacopa, and La Garrinada. The first of these (fig. 3), which lies northwest of Olot, is crescentic in form, having been breached on the north side, the highest point of the rim, where a fortified watch tower stands, being 105 meters above the base. The diameter of the crater is about 300 meters, the sides being covered with oaks, and the bottom (which lies about 75 meters below the summit) being give over to cultivation, while a driven well,

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* The Catalan word for these cones is *puig*, which is the etymological equivalent of the French *puy*.

which furnishes an abundant supply of water, has been sunk in the center. This cone is built up of scoriæ, and lapilli exclusively, well-defined bedding not being evident. On the southwest slope these materials are heaped up against and over a low fault scarp of Oligocene conglomerate, the beds of which dip at low angles to the southwest, and which separate the products of this cone from the lower massive flow which is exposed along the Fluvia at the picturesque Fuente de San Roque, at the beginning of the lava field of Bosch de Tosca mentioned above.

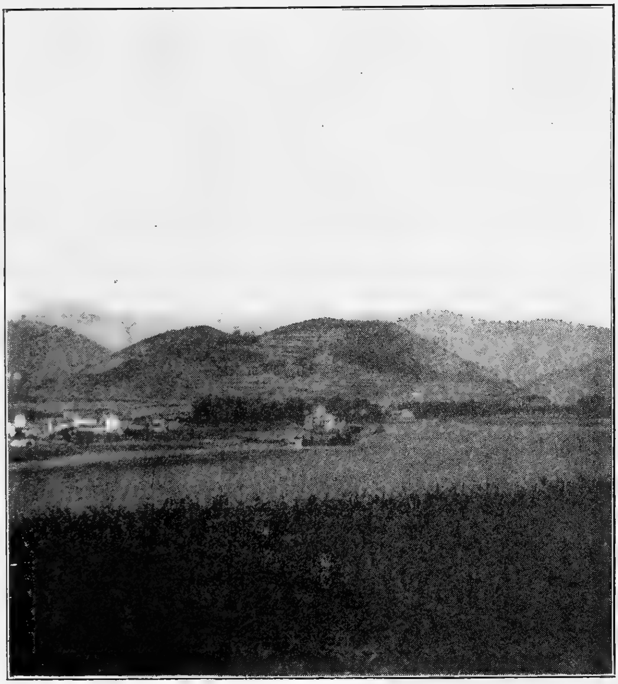
3

Montolivet from the east.

The second of these volcanoes, Montsacopa, lies north 52° east of Montolivet, and just north of Olot, the summits being about a kilometer apart but the volcanic slopes intermingling, though the juncture is masked by a road and cultivated fields. The height of its southern rim, on which stands the pilgrimage chapel of San Frances, above the base I measured with an aneroid as 66 meters, though Gelabert gives it as 100 meters. The summit is occupied by a well-defined, circular crater, some

120 meters across and very shallow, the cultivated bottom being only 13 meters below the highest, southern rim, and but 5 or 6 below the lowest, northern rim. On the southern flank is a very shallow and broad, saucer-shaped depression, which may be the remains of an original second crater, though the extensive cultivation of this side renders any definite determination difficult. This cone, which is quite bare of forest vegetation, is made up entirely of loose scoriæ and lapilli, though some large blocks of more compact but still highly vesicular lava are exposed on the top along the south rim. Like Sapper, I could see no trace of solid lava beds mentioned by Carez, though I passed around its northern flank, where Sapper supposed that they might be found. The loose material is well exposed in an extensive opening above and just behind the cemetery of Olot, where the volcanic agglomerate is extracted for use in making cement and road metal.

4



La Garrinada from the south.

Immediately adjoining Montsacopa on the northeast is the cone of La Garrinada, fig. 4, the height of whose summit, (on the northeast) is 102 meters above the base as measured by my aneroid. This volcano possesses three well-defined craters. Of these the southern one is the largest, some 300 meters across, and also the lowest, the southern rim being almost at the base of the volcano and scarcely more than two meters above the crater floor. The northern and highest rim of this crater is 32 meters above the base and is coincident with the rim of the second or middle crater, which has a diameter of about 250 meters. The rim between these two is not very well defined, but my observations agreed with those of Sapper in leading to the conclusion that the more southerly and lower crater was the later. The northern rim of this second crater forms the highest portion of the cone, and forms a semi-circular ridge, the inner walls of which are quite steep. To the east and west of the northern saddle, between this crater and the one to be next mentioned, the ridge is formed largely of massive blocks of compact lava, which are evidently the remains of a lava flow, though the lower portions of it have been removed or covered up. On the northern slope of the volcano is the third crater, which is also the smallest, not more than 150 meters across. The walls of this are even steeper than those of the second crater, and the bottom is some 20 meters below the saddle, on which is built a small farmhouse with a well of fresh water, this saddle being 80 meters above the base and so some 20 meters below the highest summit. Contrary to the opinion of Sapper, it seemed to me that this northern crater was later than the middle one, and that it was formed by a small flank explosion, which destroyed a large part of the more solid lava flows which must have covered this slope, leaving a precipitous face along part of the northern rim of the second crater. There was no apparent way of deciding as to the relative ages of the most southern and most northern craters, but the relative states of preservation seemed to indicate the former as having been formed prior to the latter. La Garrinada is built up largely of loose scoriæ and lapilli, though solid lava, in blocks and probably in flows, enters into its structure, without, however, affecting seriously its essential character of a typical cinder cone.

The cones of Estany (A of Sapper's map), which lies about two kilometers to the east of La Garrinada on the road to Castellfullit, and that of Las Bisarocas, about one kilometer east of Olot, are both typical cinder cones, the former about 100 and the latter 90 meters high, each with a well-defined crater, and composed of loose material, similar to that of the cones just mentioned, though blocks of compact lava occur at the summit of Bisarocas and a lava flow was found at the east base of Estany.

To the southeast of Olot volcanic cones are more numerous, some twenty being marked by Gelabert. Of these the most important is Cruzcat, the highest of those around Olot, its summit being about 180 meters above the base. This is extensively breached on the west side, is not very well preserved, and is covered with a thick forest growth. Like the preceding, it is built up largely of loose scoriæ and lapilli, though there is also a considerable amount of more or less compact lava, which seems to be uniformly finely vesicular. This volcano has ejected an immense quantity of bombs, large numbers of which are to be found on and in the lava- and lapilli-covered plain to the west of it, north of the road from Olot and from 4 to 5 kilometers from the town. These are of very varied shapes, some ovoidal and quite regular, others elongated, flattened and twisted, and they are all composed of more or less vesicular lava. According to Gelabert, who figures many of them, some contain nuclei of feldspar or olivine, but these would seem to be unusual.

Another interesting cone in this vicinity is Santa Margarita, whose summit is 124 meters above the road between it and Cruzcat, but about 200 above the lowest part of the base, which is to the southeast. This likewise shows a well-formed, circular crater, which is some 300 meters across, and the cultivated bottom of which lies 66 meters below the highest point of the rim, the northeastern part. This volcano is composed of very loose, fine lapilli, except in the western portion of the rim, where limestone is exposed, and which evidently formed part of the original opening produced by a maar-like explosion, the southwest wind which evidently prevailed carrying the bulk of the loose ejectamenta toward the northeast, as pointed out by Sapper.

Of the other and smaller cones seen in this vicinity it is needless to give any details, as they differ in no essential respects from those already described.

Dikes seem to be very rare in the districts about Olot and Gerona, only one having been observed by me. This is 25 centimeters wide, cutting tuffs and agglomerates on the road to Santa Pau, about 3 kilometers from Olot. The rock of this does not differ materially from those of the volcanic cones, as will be seen later. Gelabert mentions and figures several dikes which cut the granite of the region around Hostalrich, 20 to 30 kilometers to the south of Gerona.

As will be seen later, the lavas of the flows and of the cones do not differ materially from each other in any respect except in structure, the former being uniformly compact and the latter more usually vesicular, while the chemical and mineralogical features remain much the same. It is clear, therefore, that, while the two may be referred to two periods, yet that the only essential difference lies in the fact that the eruptions which produced the cones were the final, explosive effects of the vulcanicity, the commonly small size of these cones testifying to the comparative feebleness of these last manifestations.

Such a formation of small cinder cones of the Puy type, and comparatively free from lava flows, during the last, feeble phases of vulcanicity, is a not uncommon phenomenon*, as exemplified by the volcanic regions of the Auvergne and the Eifel. It is of especial interest to note, in this connection, that very similar cinder cones, composed of basaltic material closely allied to those of the Catalan volcanoes, marked the close of volcanic action in Sardinia and on Pantelleria and Linosa; the rocks of which are held to be related petrologically to those of Catalonia,† as will be described in subsequent papers.

PETROGRAPHY.

In the field the rocks of the Catalan volcanoes would be unhesitatingly considered basalts, which vary in texture from compact forms, dark gray to almost black in color, to highly vesicular, spongy scoriæ and lapilli, the color of these being black when fresh, but often yellow or red through surface decomposition. The more compact forms frequently show phenocrysts of olivine and augite, both minerals being usually visible in the same specimen; while phenocrysts of feldspar are extremely rare. In some flows, most notably that of the Baña de Bosch, in the bed of the Llemana near Llorá, the lava contains rounded nodules, varying in size from a few centimeters to a decimeter or more, which are made up of small grains of greenish yellow olivine, with a few grains of magnetite.

Examined microscopically, it is seen that augite in large amount, and less quantities of olivine and of magnetite, are present in all these rocks, while hornblende and biotite are entirely wanting. With these there frequently occurs much plagioclase feldspar, usually a labradorite, orthoclase not having been definitely recognized. In a few of the specimens this plagioclase is the only salic mineral present, so that these are true feldspar-basalts, according to current nomenclature. In other cases a considerable amount of nephelite, or of glass with probably a nephelitic composition, is present with the feldspar, giving rise to nephelite-basanites; while, again, neither feldspar nor nephelite is present, a glass base replacing them, so that the rock may be called a limburgite. From the de-

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* Sir A. Geikie, Textbook of Geology, 1903, vol. ii, p. 764.

† Cf. H. S. Washington, Quart. Jour. Geol. Soc., vol. lxiii, p. 69, 1907.

scriptions which follow it would appear that the feldspar-basalts proper differ from the others both chemically and texturally to such an extent that they may be considered as belonging to a distinct rock group. On the other hand, it is clear, from the microscopical as well as the chemical study, that the only essential difference between the nephelite-basanites and the limburgites lies in the presence of feldspar and in the crystallinity, the chemical composition being about the same and modal and textural transition forms being common, so that they may strictly be considered to be merely textural variants of the same rock. But for purposes of description a distinction may be made between the feldspathic and feldspar-free forms.

In terms of the quantitative classification these basalts are somewhat difficult to classify accurately without chemical analyses. Those that have been analyzed by me, seven in number, all fall in the salfemane class, and there can be no doubt that all the others may be safely referred to the same chief division. As regards the order, the great majority of those analyzed fall in the sixth, the lendofelic portugare, only one of the analyzed rocks falling in the perfelic order gallare. But this ordinal position is correlated with easily distinguishable microscopical differences, so there is little or no hesitation in referring the unanalyzed specimens to the one or the other order. For the most part these rocks are alkalicalcic, the greater part of those analyzed falling in limburgase, with the perfelic one in camptonase, and a few in the domalkalic monchiquase: but these differences in rang are not discernible by purely microscopic means. As regards the subrang they are all dosodic without exception, the subrangs represented being camptonose, monchiquose, and limburgose, so that we are safe in assuming that the unanalyzed rocks are likewise dosodic, however uncertain we may be in regard to their proper rang.

For purposes of description* the camptonose rocks, which are all referable to one type and which are readily distinguished from those belonging to the other divisions, will be considered first. In view of the impossibility of discriminating microscopically between the limburgose and monchiquose rocks, these will be described together, but considered under the head of two distinct types, a feldspathic and a non-feldspathic, which correspond with the current groups of nephelite-basanites and limburgites.

The several types will not be named here in the systematic and definitive manner proposed for the quantitative classification, that is, by the use of a root derived from the name of a

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* In the following descriptions many terms will be used which have been recently proposed. Cf. Cross, Iddings, Pirsson, and Washington, Jour. Geol., vol. xiv, p. 692, 1906.

locality and the suffix *–al*, but they will be considered as merely provisional and applicable only to the rocks described in this paper, and indicated by the use of a locality name alone, without any suffix. This method is adopted for the reason that, in the case of such basaltic rocks, whose modal and textural features present no marked peculiarities, but can be duplicated in many rocks from well-known localities, and some of which have been thoroughly studied in the earlier days of the science, it does not seem fitting that the systematic, typal adjectives should be based upon these little known and as yet imperfectly described occurrences.

If the quantitative system of classification, or some modification of it, is eventually adopted by petrographers generally, it will be the task of some future master of the science to undertake the comparative study of igneous rocks and the coördination of the various types, the distinctive typal adjectives being bestowed with judicious consideration of all the facts as to which locality is the most representative, the best studied, or the longest known. For the present, in the application of the quantitative system, it would seem to be wisest, and the part of moderation, to be conservative in the matter of systematic typal adjectives, and to bestow them only in the case of the more unusual magmas, the less common combinations of mode and textures (which may conveniently be called *motexes*), or when redescribing in terms of the new classification some well-known rock which is commonly recognized as adequately representative of some usual motex (combination of mode and texture). In other cases it may be suggested that such a simple, substantival form, without the suffix *–al*, be employed as is done here, admittedly in a provisional way and with but a limited and local application. In certain cases, of course, these provisional type designations may eventually be rendered entirely systematic and definitive by the addition to the locality root of the suffix *–al*, if the rock described proves to be worthy of this distinction.

Camptonose (feldspar-basalt), Castellfullit type.

Megascopic characters.—Color, medium to dark gray: texture, phanerocrystalline, fine-grained, porphyritic, perpatic: phenocrysts, 5 per cent or less of the rock volume, 1 to 3^{mm} long, of black or dark green augite and yellow olivine: groundmass, very fine-grained, but many very minute, white tables, evidently of feldspar, and black grains, evident with the hand lens. Some specimens, on weathering, show a mottled surface of patches of light and dark gray.

Microscopic characters.—Minerals present, labradorite, augite, olivine, and ores. The labradorite, of the average composition Ab_1An_1, forms about one-half of the rock, is subhedral to euhedral, thin tabular, the tables from 0·3 to 0·7^{mm} long and 0·02 to 0·05^{mm} thick, twinned according to the Carlsbad and albite laws, zonal structure not present. The augite, which forms about one-quarter of the rock, is very pale greenish gray, with an extinction angle on *b*(010) of 39°. The phenocrysts are subhedral to anhedral, stout prismatic to equant, from 0·5 to 2^{mm} long, running serially down to the abundant small, (0·01 to 0·05^{mm}) anhedra of the groundmass. The olivine phenocrysts, slightly larger than the augites, are euhedral to subhedral, the usual domes and pinacoids being present, almost equant, often fragmentary, quite colorless and fresh. There is little or no olivine in the groundmass. Anhedral to subhedral ore grains, from 0·01 to 0·05^{mm}, are common, scattered uniformly through the rock. The large amount of TiO_2 shown by the analysis indicates that it is highly titaniferous, but nothing that could be definitely identified as ilmenite or titanite was seen. Between these constituents there is a small amount of a colorless, distinctly anisotropic base, which may be considered to be probably alkali-feldspar, as the analysis indicates that a considerable quantity of this must be present. The texture is essentially intersertal, characterized by the divergently arranged tables of plagiocase, with interstitial granular augite, olivine, and ore. As the augite is not xenomorphic towards the other constituents, and is not poikilitic, the texture cannot be regarded as ophitic in the true sense of this term. The mottled, weathered specimens showed no definite peculiarities under the microscope which could be connected with this appearance.

Mode.—The mode of the specimen from Castellfullit which was analyzed was estimated by Rosiwal's method, a large number of measurements being made on two sections, with the following results:

Feldspar	53·7
Augite	25·8
Olivine	10·8
Ores	8·9
Apatite	0·8
	100·0

Chemical composition.—A specimen of the upper, prismatic flow at Castellfullit was analyzed, with the results shown in I of the table of analyses on page 239, which may be regarded as typical of this type. The silica is distinctly higher than in the other rocks of the district, but in other respects it does not differ widely from them. The rather high total oxides of iron, and especially the great preponderance of ferrous over ferric oxide, as well as the comparatively large amount of TiO_2, are the chief features to be noted.

Classification.—The norm of this rock is as follows:

Or	8·90	52·71	55·27
Ab	24·63		
An	19·18		
Ne	2·56	2·56	
Di	19·59	32·47	44·95
Ol	12·88		
Mt	4·18	11·48	
Il	7·30		
Ap	1·00	1·00	
	100·22		
Rest	·37		
	100·59		

$\frac{Sal}{Fem}$	= 1·23	Class III	Salfemane
$\frac{F}{L}$	= 20·59	Order 5	Gallare
$\frac{K_2O+Na_2O}{CaO'}$	= 1·04	Rang 3	Camptonase
$\frac{K_2O}{Na_2O}$	= 0·28	Subrang 4	Camptonose

The relations of norm and mode are clear on comparison of the figures above with the mode given on a previous page. The modal augite takes up all the normative diopside, with a little of the normative anorthite, olivine, and magnetite, but the divergence of the mode from the norm is not a serious one. As the soda-lime feldspar was determined optically as a labradorite of about the composition Ab_1An_1, there must be present about 15 per cent of a soda-orthoclase, of about the composition Or_3Ab_2, and this, with 3 or 4 per cent of nephelite, is to be looked for in the colorless, doubly-refracting base. On the whole therefore the mode may be considered to be a normative one, and the rock may be briefly described as a femphyro-interserti-camptonose. In the current classifications it is a feldspar-basalt, texturally of the common intersertal type.

Occurrence.—This type of camptonose was observed by me only in the district around Olot, where it forms extensive flows with well-developed prismatic structure. Some prominent localities where this type was collected are: the upper flow at Castellfullit,* a flow of Puig Estany near the 45 kilometer stone on the road from Olot to Castellfullit, a flow from the Puig Dolors in the Torrent Mal near Castellfullit, and the flow in the valley of the Rio Ridaura north of La Garrinada and also near San Juan las Fonts. A slightly weathered lava, mottled in light and dark gray, which was met with as blocks on the south slope of La Garrinada, near the lowest crater, as well as at Castellfullit, also apparently belongs to this type.

* My specimens of the lower flow were unfortunately mislaid, but in the field no difference could be detected between these and those of the upper flow.

Limburgose and monchiquose (nephelite-basanite), Las Planas type.

As was mentioned above, no distinction can be made out either in the field or under the microscope between the rocks which belong to the two subrangs, so they will be described together. Furthermore, as no exact dividing line can be drawn between the more nearly holocrystalline and compact rocks, which show evident nephelite, and the highly scoriaceous ones, in which a glass base replaces the nephelite, they will be described under one type. This is not strictly correct, but the abundance of transitional forms, and the comparatively unimportant character of the differences between the extremes, seems to render it the more judicious procedure.

Megascopic characters.—Compact to highly vesicular and scoriaceous: very dark gray to black, the latter especially in the scoriæ, which weather to yellow and red; perpatic, the aphanitic groundmass thinly sprinkled with small phenocrysts of black or dark green augite and light yellow olivine, from 1 to 5^{mm} in diameter. Nodular masses of granular, yellow olivine present in some cases.

Microscopic characters.—The not very numerous phenocrysts of colorless or very pale, greenish gray augite, and colorless olivine, are similar to those in the last type, the former subhedral and stout prismatic or fragmentary, and the latter more often euhedral. These are common to all the specimens.

The groundmass varies more widely. In all cases small, thin tables of plagioclase, usually about Ab_1An_1, are present, the laths varying in length in different specimens from 0·5 to $0{\cdot}05^{mm}$, being uniformly less broad and thinner in the more scoriaceous rocks. These tables show a diverse arrangement, and flow structure is seldom seen. With them are usually present numerous very small anhedral grains of colorless augite, olivine being rare as a true groundmass constituent. In other and usually the more scoriaceous specimens, these small groundmass augite grains are rare or even entirely wanting, being replaced by an aggregation of dark, minute, dusty particles, which render the base almost opaque in spots. Ore grains are common and well developed, though very small, in the more compact specimens; but in the more scoriaceous are merged in the dusty aggregate just mentioned. The base in which these lie is often quite holocrystalline, in which case it is feebly doubly refracting, and is considered to be nephelite, at least in great part. That this attribution is correct is shown by the occasional presence in some of the more compact and holocrystalline specimens of rectangular sections, with parallel extinctions and low birefringence, which are undoubtedly nephelite. In the more scoriaceous material the base is entirely vitreous, and is apt to be much obscured by the abundant black dust spoken of above.

The textures offer nothing of special interest, being common to many such basaltic rocks. The feldspars are not sufficiently large, or numerous enough to render the rock ophitic, and in the more compact forms the texture may best be designated as hyalopilitic, while in the more glassy ones it is simply vitrophyric.

Mode.—Owing to the very small size of the groundmass constituents and the consequent extensive overlapping, as well as the presence of glass in many cases, no satisfactory estimate of the mode by Rosiwal's method was possible. However, by making certain readjustments from the figures furnished by the chemical analyses, on the basis of the relations between norm and mode observed in the Castellfullit rock, the modes of three of the more compact analyzed specimens were calculated to be approximately as follows: column I representing that of the Llorá specimen, II that of the rock from the summit of Garrinada, and III that from Las Planas.

	I	II	III
Labradorite, (Ab_1An_1)	35·0	35·0	38·0
Nephelite	12·0	10·0	6·0
Augite	25·0	30·0	28·0
Olivine	15·0	8·0	13·0
Ores	11·0	15·0	14·0
Apatite	2·0	2·0	1·0
	100·0	100·0	100·0

Chemical composition.—Analyses of five rocks of this type will be found in columns II to VI of the table on page 239. Of these, the first three represent the more compact forms, II and IV being flows and III being a somewhat scoriaceous lava block, while the last two (V and VI) are scoriaceous lavas from the recent cones. As compared with the analysis of the Castellfullit flow, they are distinctly lower in silica, but resemble it in other respects, and each other in all, very closely. The greatest variation is seen in the relative figures for the iron oxides, where there seems to be evident an increase of ferric oxide at the expense of ferrous in the more scoriaceous lavas of the cones, which may reasonably be referred to the difference in the conditions which obtained during the extrusion and solidification, the possibilities of the oxidation of ferrous to ferric oxide being greater in a vesicular lava than in a compact flow. The uniformly high figures for TiO_2, which vary within very narrow limits, are also to be noted as an important feature.

Classification.—The calculated norms of the five rocks analyzed are given below, the ratios being omitted. It is seen that the specimens from Llorá and La Garrinada fall in the subrang monchiquose (III.6.2.4), while those from Las Planas, Cruzcat, and Montsacopa fall in limburgose (III.6.3.4), the difference in rang depending on slight differences in the amounts of the alumina and the alkalies. This is shown in the norms by the distinctly higher anorthite and lower albite or nephelite in the last three. It cannot justly be said that the differences are very significant, and as it seems probable that the rocks are for the most part in limburgose, they may be referred to collectively as monchiquose-limburgose.

	II	III	IV	V	VI
Or	15·57	12·79	11·12	13·90	13·34
Ab	10·22	12·58	15·20	8·64	13·86
An	10·84	11·95	14·18	14·73	16·12
Ne	12·92	11·08	6·82	12·07	9·51
Di	19·17	23·76	22·02	24·18	21·03
Ol	17·19	8·68	14·10	10·49	9·98
Mt	4·18	4·64	5·34	4·64	6·73
Il	8·21	8·66	9·42	7·75	8·06
Ap	1·68	1·68	1·34	1·34	1·68
Rest	·79	·68	·47	1·53	·35
	100·77	99·70	100·01	99·27	100·66
Symbol	III.6.2.4	III.6.2.4	III.6.3.4	III.6.3.4	III.6.3.4

II. Monchiquose, Llorá.
III. Monchiquose, La Garrinada.
IV. Limburgose, Las Planas.
V. Limburgose, Cruzcat.
VI. Limburgose, Montsacopa.

Occurrence.—This seems to be the most abundant rock type in the district, being represented both in flows and at the cones. Among the former the following localities may be mentioned: the flow from Baña de Boch, below the Chapel of Sant Medir, near Llorá; the end of the extensive flow from Puig Montcal, collected at Domeny, but not very fresh; and the extensive flow to the southwest of Olot, as at San Esteban le Bas, San Feliu de Pallarols, and the quarries in the valley of the Amer at Las Planas. Among the cone occurrences may be named: the compact lavas from Cruzcat and from the summit of La Garrinada, and the scoriaceous ones from Montolivet, Montsacopa, Bisaroca, Puig Costa, and others. The lava field of Bosch de Tosca is also made up largely of this type, and the dike found 3 kilometers from Olot, on the road to Santa

Pau, is transitional between this and the succeeding type, the feldspar tables being extremely small and very sparingly present.

Limburgose (limburgite), San Roque type.

Rocks of this type were but rarely met with, and they differ from the most vitreous of those just described chiefly in the absence of feldspar. While, therefore, they may be regarded as probably but a variant of the other type, yet they may be discussed separately on account of the mineralogical dissimilarity.

Megascopic characters.—Compact, dark gray, aphanitic, almost wholly aphyric, only a few very small nodules of brownish augite being visible, though in certain lights the fresh fracture shows an ill-defined glimmer, due to the presence of scarcely visible, minute prisms (of augite).

Microscopic characters.—The rock is microporphyritic, about 10 per cent of microphenocrysts of augite and 5 of olivine being present. The former are anhedral to subhedral, from 0·3 to 1·0^{mm}. long, stout prismatic to fragmentary, and of a pale brownish gray color: the latter euhedral to subhedral, 0·2 to 0·5^{mm} in diameter, colorless. Both carry inclusions of small magnetite grains. The microgroundmass consists of numerous, subhedral prismoids of pale brownish augite, 0·1 to 0·03^{mm} long, and fewer magnetite anhedra, of about the same size, but no olivine, embedded in a colorless, isotropic base, which is evidently glass. No flow texture is evident, and the small augite prismoids are too stout and nearly equant for the texture to be considered typically hyalopilitic.

Mode.—As the type is highly vitreous, the mode is indeterminate, and the small size and crowded arrangement of the groundmass augites renders any exact estimate of their amount difficult. Consideration of the norm given below, and study of the sections, however, indicates that the following figures will express roughly the mode of the San Roque rock :

Augite	35·0
Olivine	5·0
Magnetite	10·0
Glass	50·0
	100·0

It may be said of this that the microphenocrysts of augite constitute about 10 per cent and the small groundmass crystals about 25, while olivine seems to be present only as microphenocrysts, of which certainly not more than 5 per cent are present. On referring to the norm given later, it will be seen that, therefore, the other 10 per cent of normative olivine has probably taken up silica to form modal augite, thus increasing the amount of nephelite potentially present in the mode over that shown by the norm, and this, with the feldspar, is represented by the glass base.

Chemical composition.—The chemical composition of the rock of the massive flow exposed at the Fuente de San Roque is shown in column VII of the table of analyses on page 239. It does not differ in any essential respect from the others, the only feature of note being the slightly higher ratio of potash to soda, though the figures for each of these can be almost duplicated from the other analyses, and the ratio is but 1 : 2, so that the rock is clearly dosodic. Alumina is slightly higher than in the other analyses, but ferrous oxide greatly surpasses ferric, and the amount of titanic oxide is of the same order as in the rest.

Classification.—The norm of this rock is as follows:

Or	13·34	47·37	54·61
Ab	11·79		
An	22·24		
Ne	7·24	7.24	
Di	17·79	32·55	45·31
Ol	14·76		
Mt	3·48	11·08	
Il	7·60		
Ap	1·68	1·68	
Rest	·46		
	100·38		

$\frac{\text{Sal}}{\text{Fem}} = 1{\cdot}25$ Class III Salfemane

$\frac{\text{F}}{\text{L}} = 6{\cdot}54$ Order 6 Portugare

$\frac{K_2O + Na_2O}{CaO'} = 1{\cdot}11$ Rang 3 Limburgase

$\frac{K_2O}{Na_2O} = 0{\cdot}50$ Subrang 4 Limburgose

The high ordinal ratio, which is near the limiting value of 7·00, indicates that the rock is close to the border of the 5th order, gallare, and that it might be regarded as transitional and called a camptonose-limburgose. But the simpler term would seem to be sufficient for the present. In the prevailing classifications the rock is undoubtedly to be considered as a limburgite, since no feldspar is present, but only glass as a colorless (salic) constituent, along with augite, olivine and ores. Limburgite is used here in the sense of Rosenbusch* as denoting "the feldspar-free extremes of the rock series of the trachydolerites, tephrites and basanites, and the leucite-, nephelite- and melilite-rocks: they represent therefore the pyroxenic rocks of the essexite family and belong to the theralitic magmas." It is evident from this that Rosenbusch intends to denote by the term limburgite a rock derived from magmas so deficient in silica, and at the same time so distinctly alkalic in character, that lenads (leucite or nephelite) would

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*Rosenbusch, Elemente der Gesteinslehre, 1901, p. 376.

form were the rock holocrystalline. They are thus contrasted with the otherwise mineralogically similar vitreous and feldspar-free basalts proper, to which the older name "magma-basalt" is more truly applicable, though of doubtful form and etymology. These are less markedly deficient in silica, or even with a slight excess of this, and at the same time not as strikingly alkalic in character as the rocks mentioned above, so that lenads would not be necessarily present, and if so only in very small amount, were the rock holocrystalline, but there may be considerable olivine if there is a deficiency in silica.

These magmatic differences between the limburgites and the augitites on the one hand, and the feldspar-free vitreous basalts on the other, which are only vaguely recognized in the prevailing classifications, are clearly brought out in the quantitative classification. In this the typical examples of limburgites and augitites, so far as they are represented by good analyses, fall in the lenic orders of salfemane, especially in portugare, and the greater part of them in the alkalicalcic rang limburgase and the dosodic subrang limburgose: while (it may be added), the most typical monchiquites, in which a highly sodic and an analcitic base is abundant, fall in the same order, but in the domalkalic rang monchiquase and the dosodic subrang monchiquose. On the other hand, the basalts proper belong almost exclusively to perfelic orders, germanare and gallare, and to docalcic rangs and presodic subrangs of these, notably hessose and auvergnose.*

Occurrence.—Clearly recognizable specimens of this type were obtained by me only at one locality, the massive flow at the Fuente de San Roque, about one kilometer west of Olot, on the south bank of the Fluvia River. Other specimens which much resemble this, but which contain traces of feldspar and are therefore transitional toward the former type, were obtained near a small wine-shop above the chapel of Sant Medir, at Llorá, and at the dike 3 kilometers from Olot, on the road to Santa Pau, already mentioned.

General Characters of the District.

Mineralogical characters.—These are so simple and are so evident from the descriptions which have been given above, that little need be said of them here. Augite, olivine and titaniferous magnetite are invariably present, the first always in very notable amount, and the last two in much smaller quantities. Hornblende, biotite, and titanite (which last might be expected in view of the richness of the rocks in titanium), are entirely absent, not a single grain of either of these having been observed by me in any of the sections.

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*Cf. Iddings, Prof. Paper U. S. Geol. Surv., No. 18, pp. 90, 91, 1903; and Washington, Prof. Paper U. S. Geol. Surv., No. 14, pp. 75, 76, 80, 1903.

Of the salic minerals a plagioclase of about the composition Ab_1An_1 is the most common, though it is quite wanting in some of the rocks. Alkali feldspar seems to be rare, though its presence in some amount is demanded by the chemical composition. It would seem that, in most cases, the conditions did not permit of its crystallization, and that it solidified as a glass. Nephelite, sometimes in almost euhedral crystals but usually as an ill-defined base, is more common, but this, too, is prone to solidify as a glass. The other prominent salic minerals, quartz, leucite, and the sodalites, are not found in these rocks.

Chemical characters.—The chemical features of the Catalan rocks are shown by the analyses in the table annexed, all of which were made by the writer. Considering the small size of the district, and the general uniformity in the mineralogical and textural features, they would seem to be sufficiently numerous to convey a just idea of the true relations.

	I	II	III	IV	V	VI	VII
SiO_2 ---	47·66	44·55	43·64	44·29	44·20	44·82	44·80
Al_2O_3 --	14·36	12·48	13·12	12·62	13·96	14·06	15·51
Fe_2O_3 -	2·83	2·81	6·40	3·61	3·19	4·56	2·35
FeO --	8·44	8·54	5·52	8·84	8·41	7·27	8·52
MgO --	8·19	10·85	9·36	10·06	8·03	8·60	8·83
CaO ---	9·36	7·99	9·52	9·23	9·79	9·56	9·91
Na_2O --	3·51	4·04	3·89	3·25	3·66	3·69	2·99
K_2O ---	1·54	2·57	2·18	1·82	2·35	2·30	2·29
H_2O+ -	0·17	0·56	0·49	0·21	0·76	0·30	0·16
H_2O- --	0·20	0·18	0·16	0·09	0·12	0·05	0·09
CO_2 ---	none	none	none	none	none	none	none
TiO_2 --	3·83	4·32	4·55	4·92	4·10	4·25	4·01
ZrO_2 ---	n.d.	n.d.	n.d.	0·02	n.d.	n.d.	n.d.
P_2O_5 ---	0·45	0·70	0·74	0·57	0·62	0·67	0·68
SO_3 ----	n.d.	0·05	n.d.	0·05	n.d.	n.d.	n.d.
MnO --	n.d.	n.d.	n.d.	n.d.	0·51	none	0·08
NiO ---	n.d.	n.d.	n.d.	n.d.	0·14	n.d.	0.13
BaO ---	n.d.	n.d.	n.d.	0·06	n.d.	n.d.	n.d.
SrO ---	n.d.	n.d.	0·03	0·04	n.d.	n.d.	n.d.
	100·54	99·64	99·60	99·68	99·84	100·13	100·35
Subrang	III.5.3.4	III.6.2.4	III.6.2.4	III.6.3.4	III.6.3.4	III.6.3.4	III.6.3.4

I. Camptonose (feldspar-basalt). Upper Flow, Castellfullit, near Olot.

II. Monchiquose (nephelite-basanite). Below Chapel Sant Medir, Llorá, near Gerona.

III. Monchiquose (nephelite-basanite). La Garrinada, Olot.

IV. Limburgose (nephelite-basanite). Las Planas, South of Olot.

V. Limburgose (nephelite-basanite). Cruzcat, South of Olot.

VI. Limburgose (nephelite-basanite). Montsacopa, Olot.

VII. Limburgose (limburgite). Fuente San Roque, Olot.

Apart from the silica of the Castellfullit camptonose (feldspar-basalt), which is about 3 per cent higher than in any of the other rocks, all these analyses reveal a remarkable uniformity as regards all the constituents. With the exception just noted, silica is rather low and varies only between 43·64 and 44·82, alumina between 12·48 and 15·51, the total iron oxides between 10·87 and 12·45, magnesia between 8·03 and 10·85, lime between 7·99 and 9·91, soda between 2·99 and 4·04, potash between 1·54 and 2·57, titanium dioxide between 3·83 and 4·92, and phosphoric pentoxide between 0·45 and 0·74. The only variation of moment is that in the relative amounts of ferric and ferrous oxides, the former being between 2·35 and 6·40, and the latter between 5·52 and 8·84, the maximum for ferric oxide and the minimum for ferrous being found in the same specimen (III), and apart from this the figures being fairly concordant. As noted above, it would seem that the conditions of extrusion had some influence over these relations, the ratio of ferrous to ferric oxide being in general higher in the massive flows and lower in the scoriaceous lava, this being due presumably to the more favorable conditions for oxidation in the latter. A somewhat similar state of affairs has been observed in the basalts of Sardinia, Pantelleria and Linosa, as will be described in subsequent papers.

Apart from this general uniformity, and the chief characters of the main constituents, such as the rather low silica and alumina, the high iron oxides, moderately high magnesia and lime, and rather high soda (for salfemic rocks) and low potash, the most striking feature is the very large amount of titanium dioxide. While most or all of the figures for this constituent here given can be duplicated in analyses of igneous rocks from other localities, yet the vast mass of analyses hitherto published reveal scarcely a single district where the figures for titanium dioxide are uniformly so high as those of Catalonia. Aside from analyses of my own of rocks from Pantelleria and Linosa, and not considering titaniferous ores, the only ones which show figures surpassing those here given are those of the melilite-basalts of the Hegau by Grubenmann, which are all dofemanes and rich in perofskite; while figures approximately the same as those for Catalonia are seen in analyses of salfemanes and dofemanes from German Kamerun, Magnet Cove, Brazil, and some localities in New England.

Of the other minor constituents few call for any special notice. Phosphoric pentoxide is fairly but not abnormally high, zirconia seems to be present merely in traces, as is also true of baryta and strontia, while manganese is present in the usual small amounts. Nickel is invariably present apparently, and was determined in two cases, the figures being rather high for this rare constituent, while its presence in approximately similar amounts in the other specimens was indicated by the greenish color of the filtrate from the ammonia precipitate. In this respect, as in the high titanium, these rocks resemble the basalts of Sardinia, Pantelleria, and Linosa.

Relations to other Districts.

It would seem most natural to connect the igneous rocks of the Catalonian volcanoes with those of the igneous areas which extend in a well-defined zone down the east coast of Spain; including the Columbretes Islands,* the islands of Mallorca and Iviza,† the igneous areas of Murcia‡ and Cabo de Gata,§ and the island of Alboran.‖ This connection is, indeed, assumed to be true by the Spanish geologists, as Quiroga and Calderon,¶ who also point out the preponderance of salic rocks toward the southern end and of more femic ones towards the northern. While the tectonic relations and those of time, as most of these eruptions are, apparently, of comparatively recent geologic date, like the flows and cones of Catalonia, favor this view, yet it cannot be accepted as definitely proven.

With the exception of the Murcian rocks, of which excellent analyses by Dittrich are published by Osann, the analyses of the other localities leave much to be desired both as to completeness and accuracy. Titanium especially is apt to be neglected in them, and the amount of this constituent is a highly important feature of the more femic rocks, for the purpose of comparison with those of Catalonia. In the only analyses in which it is reported, those of the rocks of the Columbretes and of Murcia, the amounts are low, the highest figure being 1·60 per cent, in a verite of Fortuna in Murcia, so that there is little resemblance in this respect with the Catalan rocks. Furthermore, the Murcian rocks described by Osann are relatively and absolutely much higher in potash, and leucite even appears in some of them, while hornblende and biotite are not uncommon at many of the localities south of Catalonia. It would seem best, therefore, to look upon any connection of the Catalan rocks with those of the more southerly localities with doubt, and as a matter to be settled in the future by more satisfactory analyses and further investigation.

The possibility may be suggested here of a connection of the Catalan rocks with those of the central volcanic line of Spain,

* F. Becke, T. M. P. M., vol. xvi, p. 155, 1896.

† Cf. S. Calderon, Bull. Soc. Géol. Fran., vol. xiii, p. 112, 1885.

‡ A. Osann, Rosenb. Festschr., p. 263, 1906.

§ A. Osann, Z. d. G. G., vol. xl, p. 694, 1888; vol. xli, p. 297, 1889; vol. xliii, pp. 323, 688, 1891.

‖ F. Becke, T. M. P. M., vol. xviii, p. 525, 1899.

¶ Cf. Calderon, Bol. Soc. Esp. Hist. Nat., p. 335, 1905.

which runs north and south in the provinces of New Castile and Aragon, and where nephelite-basalts and limburgites are the prominent types.* It must be said, however, that no analyses have yet been made of these rocks, so far as I am aware of, so that the question must be left an open one. The matter of the geologic age does not seem to be decisive one way or the other, as the volcanoes of the central line belong to the Tertiary, while there is reason for thinking that the Catalan activity began at about the same time, and also the earliest eruptions at Cabo de Gata antedate the Pliocene.

Looking north, it would seem to be probable that some of the volcanoes along the southern French littoral, as at Agde and Montpellier, are connected with those of Catalonia. "Basalts" are known to occur here, though no analyses of them have yet appeared, to the best of my knowledge. Through the kindness of Prof. Lacroix I have obtained some specimens of these rocks, and hope in the near future to make some analyses of them, so as to test this point chemically.

Chiefly on account of the character of the basalts, and their high content in titanium, but on other grounds as well, I have elsewhere† expressed the opinion that the Catalan volcanoes are connected genetically with those of Sardinia, Pantelleria, and Linosa, and possibly with eruptions in Tripoli, and even with the volcanoes of the Great Rift Valley in East Africa.

But the full discussion of the question of this comagmatic region or petrographic province must be postponed until many more analyses are made and the various districts have been described in detail.

Locust, N. J., May 1, 1907.

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* Calderon, Bol. Soc. Esp. Hist. Nat., p. 336, 1905.

† H. S. Washington, Q. J. G. S., vol. lxiii, p. 78, 1907.

ART. XXIV.—*Anemonella thalictroides* (L.) Spach; an anatomical study; by THEO. HOLM. (With five figures in text, drawn from nature by the author.)

AMONG the plants that have been changed from one genus to another *Anemonella* offers a good example. It was an *Anemone* according to Linnæus, who called it *A. thalictroides*, and it was placed as the last species of this genus. According to Richard it became a *Thalictrum*: *Th. anemonoides*, and as such it was accepted by De Candolle and Gray; Bentham and Hooker brought it back to *Anemone*, while Prantl removed it from there, and placed it once more under *Thalictrum*, as a member of the section *Camptonotum*. Meanwhile our plant had been raised to generic rank as *Syndesmon* by Hoffmannsegg, though only as a name (1832), but a few years afterwards Spach (1839) described it as a monotypic genus: *Anemonella*. As such it was finally accepted by Gray in his manuscript to the Synoptical Flora.

In several respects our plant is quite remarkable and possesses some features in common with *Anemone* (the involucre and the white, petaloid calyx), some others with *Thalictrum* (the costate achenium with one pendulous ovule), and finally with *Isopyrum* (the habitus). In accordance with our own observation the ovule of *Anemonella* has two integuments, and in this respect it agrees with *Thalictrum*, but not with *Anemone*, in which only one integument is developed. In Lecoyer's[*] monograph of *Thalictrum*, our plant is considered a close ally of *Th. tuberosum* and enumerated as a member of the section "Brévistaminés"; the same disposition has been made by Marié[†] in a paper dealing with the anatomy of the *Ranunculaceæ*.

The anatomical treatment by Marié is, as far as concerns *Anemonella*, very incomplete, since only dried material was studied. For this reason we have examined the plant again, and the following notes may, thus, be considered as a supplement to the various diagnoses already given by other authors. But to draw a comparison between our genus and *Isopyrum* from an anatomical point of view, as attempted by Marié, is at present not possible; because *Isopyrum* is actually an aggregate of several very distinct types, of which *I. thalictroides* seems to be the only one, that has been studied, so far, from satisfactory material. We shall therefore confine ourselves to treat *Anemonella* alone, but leave the comparison between

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[*] Bull. Soc. Roy. de Bot. Belgique, vol. xxiv, p. 78, 1885.
[†] Ann. d. Sc., ser. 6, vol. xx, p. 40, 1885.

this and other genera to future students, who might have access to suitable and more ample material of the family.

We have already described the seedling of *Anemonella*,* and from this will be seen that the cotyledons are epigeic, and that the hypocotyl may not be developed; since then we have noticed, however, that a hypocotyl is most frequently present, and not so very short either. The primary root does not persist for more than about one season, and becomes replaced by secondary roots, all of which become tuberous at the base, but not until during the fall; they die off during the next spring, when new ones become developed. A rhizome of the mature plant may be seen in the accompanying figure 1, which was collected in the month of April. In this specimen there is an old, shrivelled root from the previous year (r), and several tuberous, which are active; besides these there is, furthermore, a slender secondary root (R), which will become tuberous during the fall. Characteristic of these roots is that only the base is tuberous, while the apex is very long, filiform and amply ramified. Sometimes these roots become branched from the tuberous base, as illustrated in figure 2; in one of these the tuberous portion is four-cleft, each division being terminated by a long, filiform apex.

The very slender stem bears two sessile, involucral leaves, which are opposite and trifoliolate; the inflorescence is a cyme with one central and two or a few more lateral flowers. Of these the terminal is often larger than the others, and has generally a larger number of sepals, from six to nine, while the lateral flowers very often have only five. The achenium has eight very strong ribs (figures 3 and 4), and contains a single pendulous ovule with two integuments.

Our plant is vernal, and one of the earliest to bloom; it inhabits open, especially deciduous woods along the Atlantic coast from Canada (Ontario) to Florida, westward to Minnesota. It is generally associated with *Luzula campestris*, *Houstonia coerulea*, *Hypoxis erecta*, etc.

THE INTERNAL STRUCTURE OF THE VEGETATIVE ORGANS.

The roots.

As stated in the preceding pages, the roots of *Anemonella* are tuberous, when fully developed. But when we examine fruiting specimens, we always notice that besides the tuberous there may be a few others which are slender in their entire length. These are young and develop from the very short rhizome, a little above the tuberous. The function of these slender roots, however, is also to store nutritive matters, and their increase in thickness commences at a very early stage,

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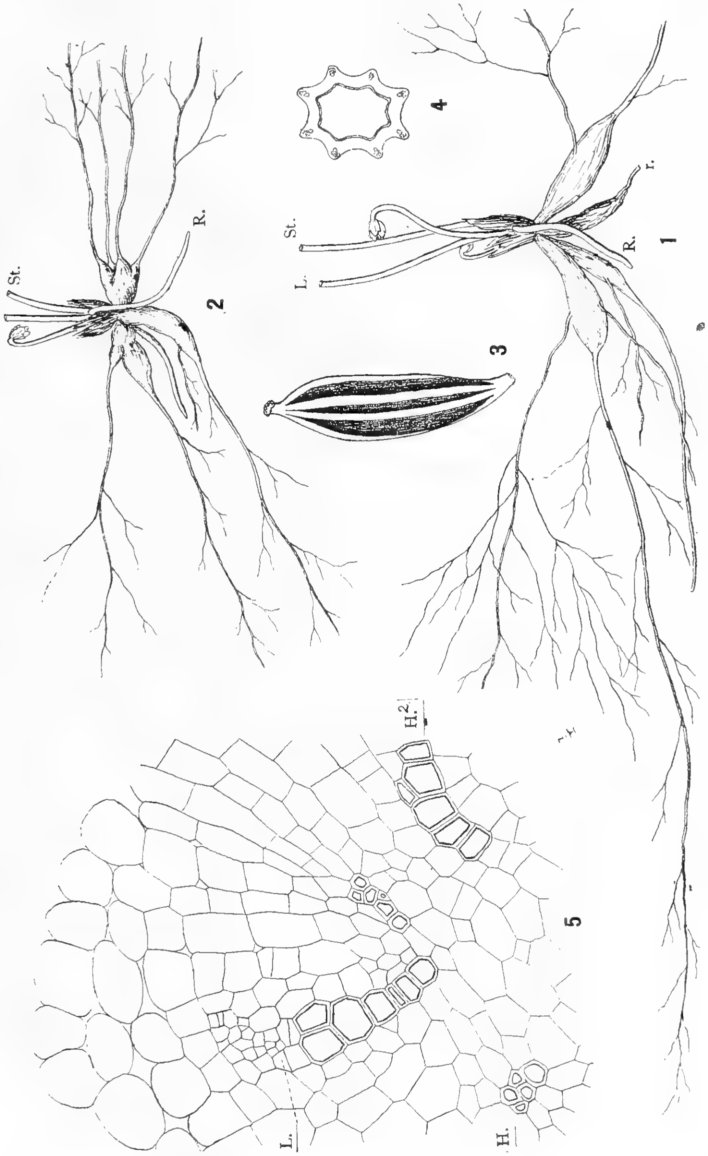
*Mem. Torr. Bot. Club, vol. ii, No. 3, p. 57, 1891.

even if they do not become tuberous until at the end of the season.



In the old roots we must distinguish between the tuberous base and the long, filiform apex. The latter shows only a very slight indication of increase in thickness by a few cell-divisions inside the leptome. Otherwise the structure is very primitive. There is an epidermis with numerous hairs, and four strata of thin-walled cortical parenchyma. Endodermis is thin-walled, and the pericambium consists of one layer outside the leptome, but of two outside the proto-hadrome. Four broad groups of leptome alternate with four rays of vessels, which extend to the center of the stele, no pith being developed.

In the tuberous portion of this same root the structure is very different on account of the large increase in thickness. Epidermis, the cortical parenchyma and endodermis have been thrown off, but replaced by a few strata of pericambial cork; inside the cork is a large secondary cortex of thin-walled parenchyma with narrow, rhombic intercellular spaces. The stele now represents eight rays of mestome radiating from the broad central pith. The primordial hadrome is readily to be seen as four very short rays (H in fig. 5, which represents only one-half of the stele), while the secondary rays are longer (H^2); outside these secondary rays of vessels are corresponding strands of leptome (L), thus constituting ordinary collateral mestome-bundles. The primary leptome is no longer visible, but three secondary leptomatic strands have become developed outside each of the primary and secondary rays of hadrome. There are thus twenty-four strands of leptome in the tuberous root-portion, but only four of these border directly on hadrome (the secondary); all the others are isolated, but arranged very regularly in eight radii, corresponding with the hadromatic rays.

A corresponding structure is to be observed in the slender roots (R in figs. 1 and 2), and as stated above, these roots become tuberous during the first season. Epidermis and the primary cortex become thrown off very early, but are replaced by the endodermis and a few layers of pericambial cork. A secondary cortex is amply developed at this stage and the stele shows very distinctly four primary and four secondary rays of hadrome. Outside the latter are numerous strata of cambium and groups of secondary leptome. A thin-walled pith occupies the center of these roots. These roots are secondary, and they all grow in a horizontal direction; their increase in thickness depends upon the formation of a secondary cortex from the pericambium, and upon the development of secondary mestome originating from cambial strata in the shape of arches inside the primary leptome; they are not contractile, and possess no exodermis. It is now interesting to see, that the primary root of the seedling is vertical, that it shows the same manner of increase in thickness as the secondary, and that it possesses an exodermis with very distinct foldings on the radial cell-walls; in other words, the primary root is contractile and at the same time able to store nutritive matters. It is diarch and contains a broad central pith.

In *Ficaria ranunculoides* the roots are, also, tuberous, but lack the long, filiform apex observable in *Anemonella*. Moreover, the swelling of the root in *Ficaria* depends merely upon the presence of a broad primary cortex, while the stele shows only a few secondary vessels at the very base of the root, in the immediate vicinity of the overwintering bud. In *Isopyrum biternatum* the roots are very different, since they attain a tuberous development in several places on the same root, and very irregularly.

The flowering stem.

This represents a long internode terminated by the inflorescence, and bears only two, opposite involucral leaves. It is cylindric, glabrous and perfectly smooth. The cuticle is thick, and the outer cell-walls of epidermis are moderately thickened. There is no collenchyma, and the cortex consists of three layers with distinct intercellular spaces surrounding a closed sheath of thick-walled stereome of about three strata. The stele contains nine collateral mestome-strands arranged in one circular band, separated from the stereome by a few layers of thin-walled parenchyma. The mestome-strands contain cambium between the leptome and hadrome; the vessels do not show the arrangement in the letter V as is otherwise quite frequently to be observed in this family, A broad, thin-walled pith occupies the central portion of the stele.

The leaf.

The long and very thin petiole is cylindric and smooth, and in regard to the internal structure it agrees in most respects with the stem. However, there are only four large and two very small mestome-bundles, and the hadrome shows here the position of the vessels in the shape of the letter V. But otherwise the structure is identical with that of the stem. The petioles of the leaflets show the same structure, but contain only three mestome-strands.

The leaf-blade is dorsiventral; the cuticle is smooth on both faces, and the lateral cell-walls of epidermis are undulate, especially on the lower face. The lumen of epidermis is wider on the dorsal than on the ventral face, and the outer walls are moderately thickened; the stomata, which are confined to the dorsal face, are surrounded by mostly five, ordinary epidermis-cells; they are level with epidermis, and the air-chamber is wide, but shallow. The chlorenchyma consists of two layers of high palisades and three open strata of pneumatic tissue. A few cells of collenchymatic tissue support the leptome side of the larger veins, which are, furthermore, surrounded by thin-walled parenchyma-sheaths.

The development of collenchyma in *Anemonella* is rather weak so far as concerns the stem and the leaves, and, as we have seen from the preceding pages, stereome is the only mechanical tissue that is represented in stem and petioles. A very firm structure is, on the other hand, to be observed in the achenium, when fully mature. We find here ridges of collenchyma and a ventral epidermis, of which the outer and radial cell-walls are extremely thickened. There are eight collateral mestome-strands, one in each rib, and they are surrounded, at least partly, by thin-walled parenchyma sheaths. The chlorenchyma represents a few strata of homogenous tissue with much chlorophyll.

In bringing together these facts derived from the internal structure, our genus may be characterized as follows: The tuberous portion of the roots contains a broad secondary cortex and pith; the hadrome is represented by four short rays alternating with four long ones, of which the latter are secondary; isolated strands of leptome occur in rays throughout the secondary cortex, but radiating from the center of the root and located in the same radii as the eight rays of vessels. The stem has no collenchyma, and no endodermis, but a closed sheath of stereome, which surrounds the single circular band of mestome-strands. The petiole shows the same structure as the stem. The leaves are bifacial; they possess normal palisade cells, and the larger veins are supported by collenchyma, besides that they are surrounded by typical parenchyma-sheaths; no stereome is developed in the leaves; finally may be mentioned that the stomata lack subsidiary cells. *Anemonella* has, thus, a monostelic axis, while *Thalictrum* has an astelic. However, the general structure of the North American *Ranunculaceæ* is so little known, that it is impossible at present to decide whether our genus, from an anatomical viewpoint, is more closely related to *Anemone* than to some of the other genera, even if the ovule possesses two very distinct integuments, a character which it shares with *Thalictrum*.

Brookland, D.C., April, 1907.

EXPLANATION OF FIGURES.

FIGS. 1 and 2.—Rhizomes of *Anemonella thalictroides*; R = young roots, which will become tuberous during the fall; r = an old tuberous root from the preceding year; St. = base of flowering stem; L = petiole of leaf; natural size. Fig. 3.—Achenium. Fig. 4.—Same in cross-section; both magnified. Fig. 5.—Transverse section of part of tuberous root; H = primordial hadrome-ray; H^2 = secondary hadrome-ray; L = secondary leptome; × 320.

ART. XXV.—*Mineralogical Notes*; by CHARLES PALACHE.

1. Zoisite Crystals from Chester, Mass.
2. Phenacite as an Alteration Product of Danalite from Gloucester, Mass.
3. Crystal Form of Chalmersite.

1. *Zoisite Crystals from Chester, Mass.*

THE crystals of zoisite here described were found some years since by Mr. E. L. Cowles of Chester, to whom the writer is much indebted for the generous loan and gift of material for study and for information concerning its occurrence.

Mr. Cowles states that the zoisite was obtained from "a vein from two to five feet in width, located about three miles below Chester," which is taken to mean down the valley of the Westfield River from Chester village. The locality is in the town of Chester and is distinct from the well-known locality in Huntington.

The zoisite occurs in a rock consisting of a confused aggregate of tremolite needles and prisms with colorless to pinkish diopside in stout prismatic crystals. In parts of the specimens these minerals constitute the whole rock and again they are cemented with granular calcite, suggesting that the rock as a whole is a metamorphosed limestone. The zoisite is confined to portions of the rock which appear to have once been open cavities, into which the zoisite as well as tremolite and diopside crystals projected. These cavities were afterwards infilled, partly with quartz in which many of the crystals are imbedded, partly with coarse granular calcite, removal of which with dilute acid yielded the measured crystals. Irregular small patches of lustreless granular graphite are also sparingly present in the rock.

The zoisite crystals are slender prisms up to 3^{cm} in length with lense-shaped cross section, the greatest diameter of which is about $1{\cdot}5^{cm}$. The prisms are deeply striated in the direction of their length and commonly show a brilliant cleavage parallel to the side pinacoid which truncates the thin edges of the lenticular prism section. They are white in color, transparent and glassy in parts, but largely opaque and milk-white owing to the presence of many flaws and cross-joints which traverse them in various directions.

Comparatively few of the crystals are terminated and only one whose termination was complete was detached for measurement. This crystal is shown in the figure* in about the

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*The figure was drawn and the table of angles compiled by Mr. H. E. Merwin.

proportions of the original, which measured 1^{cm} in length by 5^{mm} in maximum diameter. A number of fragments showing partial terminations were also measured and a list of the forms found upon them is presented in the table. The list includes

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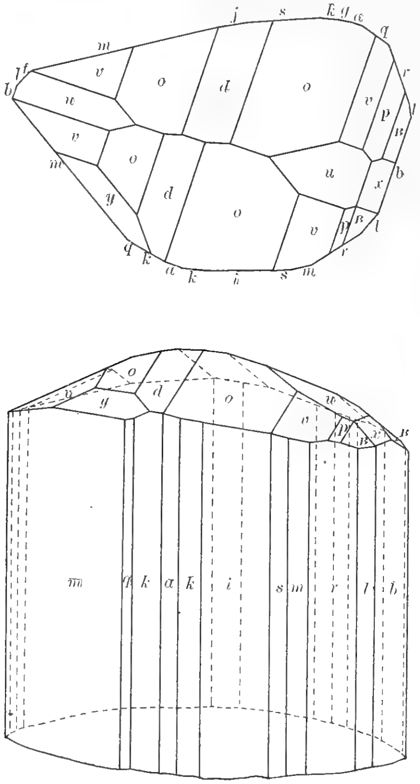

most of the forms previously observed on zoisite and a number of new forms of which a few are well established by the data observed.

In the prism zone the dominant forms are *m* and *b*, present on every crystal; *a*, *k*, *q*, and *l* are also frequently well developed. The remaining prism forms are present only as narrow line faces and, as the zone is striated, are somewhat uncertain forms. Where they occur with several faces of each symmetrically developed on a single crystal and in good agreement with calculated position, they have been accepted as good forms.

TABLE OF FORMS AND ANGLES OBSERVED ON 7 MEASURED CRYSTALS.

		Calculated				Measured Average				Limits (in minutes)						
										φ		ρ				
	Symbol	φ		ρ		φ		ρ		+	—	+	—	No. of faces	No. of crystals	Quality
b	010	00°	00′	90°	00′	00°	00′	90°	00′	10′	--′	--′	--′	8	7	good
a	100	90	00	90	00	89	56	90	00	0	12	--	--	7	5	good
k	310	78	20	90	00	78	24	90	00	30	15	--	--	10	6	fair
q	210	72	47	90	00	72	30	90	00	--	44	--	--	8	5	fair
n	530	69	36	90	00	69	54	90	00	29	--	--	--	2	2	poor
s	320	67	33	90	00	67	45	90	00	16	--	--	--	5	4	poor
m	110	58	13	90	00	58	16	90	00	26	16	--	--	16	7	good
r	120	38	54	90	00	39	16	90	00	68	47	--	--	4	3	poor
t	130	28	17	90	00	28	15	90	00	5	9	--	--	5	4	good
l	140	21	58	90	00	22	02	90	00	25	9	--	--	9	5	good
u	021	00	00	34	26	00	00	34	32	--	--	22	12	4	3	fair
x	041	00	00	53	54	00	00	53	50	--	--	--	--	1	1	poor
d	101	90	00	28	57	90	02	28	27	28	13	11	22	5	4	poor
o	111	58	13	33	04	58	08	33	08	27	44	31	4	14	5	good
v	121	38	54	41	23	38	48	41	34	11	21	37	5	11	6	good
p	131	28	17	49	26	28	16	49	35	15	19	22	12	10	6	good
New forms well established.																
g	510	82	57	90	00	83	08	90	00	25	2	--	--	2	1	poor
h	410	81	12	90	00	81	04	90	00	27	28	--	--	5	2	poor
i	950	71	00	90	00	70	55	90	00	--	9	--	--	2	1	fair
j	540	63	38	90	00	63	27	90	00	14	33	--	--	3	1	poor
y	221	58	13	52	28	58	12	52	28	19	12	2	1	4	4	good
A	212	72	47	30	05	71	14	30	26	--	105	26	--	2	2	fair
B	141	21	58	55	56	21	38	56	18	--	--	--	--	1	1	fair
Uncertain and vicinal forms.																
	720	79	58	90	00	79	47	90	00	13	28	--	--	4	4	poor
	11.4.0	77	18	90	00	77	20	90	00	21	17	--	--	2	2	poor
	940	74	24	90	00	74	34	90	00	29	--	--	--	3	2	poor
	470	42	41	90	00	42	41	90	00	16	17	--	--	2	2	poor
	151	17	53	60	58	16	37	62	15	--	--	--	--	1	1	poor
	481	38	54	73	37	37	03	72	46	--	194	--	77	2	2	fair
	5.10.1	38	54	77	13	37	27	76	30	--	249	106	--	2	3	poor
	10.20.1	38	54	83	31	40	34	82	56	220	--	--	61	5	5	poor
	16.24.1	47	55	85	12	47	30	84	41	--	52	27	129	3	4	fair
	18.45.1	33	47	86	54	33	18	86	29	81	142	66	97	7	7	poor

The terminations are chiefly characterized by the strong development of the parallel zone of pyramids, *o*, *v*, and *p* and the dome *d* in the same zone. Three narrow line faces of pyramids in this zone new to the mineral were observed, of which two, A(212) and B(141), seem to be established by the observations. The latter is one of the forms mentioned by

Dana* as found by him on zoisite from Ducktown, Tenn. but not supported by measurements and therefore excluded from recent lists of forms.

The form *y* (221) is well developed on several crystals with good faces and is much the best established of the new forms.

On nearly every crystal the edges between brachypinacoid and terminal planes are replaced by groups of very steep pyramidal faces which are sometimes curved and reëntrant, again plane and smooth, affording good reflections. The measured angles indicate forms of large and complex indices and the variation in position is so considerable in different crystals that they can only be regarded as vicinal forms. Some of the measurements made upon them are however presented in the table since they are very characteristic for the locality.

The axial ratio calculated from the measurements of thirteen good faces on a single crystal coincides almost exactly with the value calculated by Tschermak for zoisite from Ducktown, Tenn.

	a	:	*b*	:	*c*
Tschermak, Ducktown	0·6196	:	1	:	0.3429
Palache, Chester	0·6191	:	1	:	0·3429

2. *Phenacite as an Alteration Product of Danalite from Gloucester, Mass.*

In 1903 an abundance of danalite in small grains and masses up to 8^{cm} diameter was found in a small ballast quarry opened in granite on the line of the railway, about half way between Gloucester and Rockport, Mass. On some of the larger masses of pale to dark pink danalite can be seen faint indications of octahedral planes. Most of them are quite irregular and much fissured, showing the beginnings of decomposition, and in one case the greater portion of such a mass has undergone complete alteration, the resulting products showing that all the essential constituents of the danalite were retained in the cavity.

It will be remembered that danalite is a silicate of beryllium iron, manganese and zinc, containing sulphur. The decomposition products found in this cavity comprise phenacite, sphalerite, pyrite, manganiferous siderite, hematite, quartz, chlorite, albite and kaolin. The fragmentary condition of the cavity when found made it impossible to attempt a quantitative estimate of the proportion of the original chemical constituents preserved in this aggregate. But it is evident that in a qualitative sense phenacite represents the beryllium content of the danalite, sphalerite and pyrite the sulphur, zinc and part of the

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* Dana, J. D., Mineralogy, 1877, 290.

iron, siderite and hematite the manganese and part of the iron; quartz may represent silica set free in the reaction. Chlorite is probably derived from biotite, and albite and kaolin from feldspar present in the granite.

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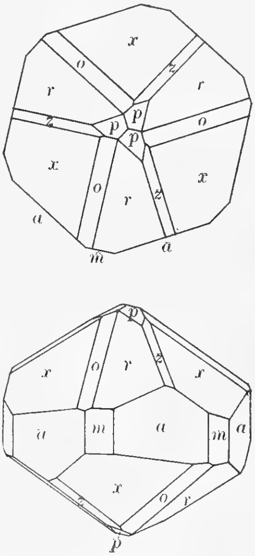

The novelty of this paragenesis for phenacite and the fact that very few occurrences of this mineral are known in New England seemed to make it worth while to record the following facts concerning the mineral contents of this small cavity.

Phenacite.—Phenacite is in sharply formed yellowish white crystals, short prismatic or lense-shaped in habit, implanted on the quartz of the cavity wall or loose and wholly imbedded in siderite. The crystals vary in size from 5^{mm} in greatest diameter downward and proved to be sufficiently well developed to permit of measurement, although the faces are pitted and somewhat dull. The following forms were determined: $m\,(10\bar{1}0)$, $a\,(11\bar{2}0)$, $r\,(10\bar{1}1)$, $z\,(01\bar{1}1)$, $p\,(11\bar{2}3)$, $o\,(4\bar{2}\bar{2}3)$, and $x\,(\bar{1}3\bar{2}2)$. The figure* (fig. 2) shows the prevailing habit, which much resembles that of the phenacite from Florissant, Col., described by Penfield. On many crystals, however, the prism planes are much reduced or entirely wanting, giving a lense-shaped appearance to the crystal. The attachment is generally by a side, so that both terminations are seen. The prism planes are brilliant and give good reflections; the rhombohedrons *r* and *x*, which are the dominant terminal forms, are also of fairly good reflecting quality. Faces near the center of the crystal are, however, uneven and appear to have been etched; the planes of the rhombohedron *p* are therefore not usually sharp as in the figure but are replaced by a rounded or irregularly facetted surface. As no new forms were observed the measurements are not here recorded.

Siderite.—Siderite is the most abundant mineral in the cavity. It is transparent with pale brown to pinkish color when freshly fractured, but natural surfaces show an iridescent or steely tarnish. The larger anhedral grains that border the cavity reach a diameter up to 3^{cm} and show a brilliant cleavage. Most of the siderite is in the form of cellular aggregates of distinct but rounded crystals of two generations, the older

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* The figure was drawn by Mr. R. W. Richards.

being larger, dark colored and deeply corroded, the later of a pale pink color, small and with some of their planes still brilliant. It was possible to measure these, and the forms determined, as shown in the figure (fig. 3) were *c*(0001), *r*(10$\bar{1}$1), *s*(05$\bar{5}$1), and *v*(21$\bar{3}$1). The figure gives about the proportions of many of these later crystals, which, being generally attached by their sides to the older crystals, were doubly terminated. Other crystals show a broader base and greater relative development of the form *v*, giving an equidimensional habit, which is also, so far as could be judged, the habit of the older generation of crystals. In view of Schaller's* study of siderite in which he questions the accuracy of the accepted axial ratio, several cleavage rhombohedrons which gave brilliant and single images on the goniometer were measured. The angle measured, 10$\bar{1}$1 to $\bar{1}$101 (average of six), was exactly 73°, which agrees with the accepted value. It is of course recognized that the considerable manganese content of this siderite vitiates the comparison with Schaller's measurements made on pure siderite, but the fundamental angles of siderite and rhodochrosite are identical according to Dana and replacement of iron by manganese would therefore affect the angle but little.

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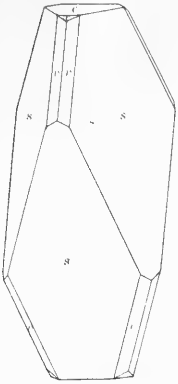

Sphalerite.—Sphalerite is sparingly present as light yellow transparent grain and imperfect crystals too fragmentary to be measured satisfactorily.

Pyrite.—Pyrite is present only in minute amounts in crystals showing cube and octahedron faces, implanted on siderite. These crystals, which are exceedingly minute and somewhat dull, present under the microscope an appearance quite unfamiliar for this mineral. The cube faces of each crystal are divided into four equal areas by grooves running from a slight prominence in the center of each face to the middle of each edge. The appearance suggests interpenetration twinning, but this could not be established by measurement.

Quartz.—Quartz crystals of two types are found in the cavity; (1) simple combinations, *m*, *r*, *z*, with dull faces, attached to the quartz of the cavity walls; (2) fragments or complete crystals imbedded in siderite. The second type is glassy and contains chlorite inclusions. The crystals are prismatic in habit, often much distorted and highly complex in development, as shown by the following forms found on the two measured crystals:

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* Siderite and Barite from Maryland, this Journal, xxi, 364, 1906.

m	$(10\bar{1}0)$	∞R		$(70\bar{7}3)$	$\frac{7}{3}$R		$(70\bar{7}1)$	7R
r	$(10\bar{1}1)$	R		$(23{\cdot}0{\cdot}\bar{23}{\cdot}7)$	$\frac{23}{7}$R	T	$(10{\cdot}0{\cdot}\bar{10}{\cdot}1)$	10R
z	$(01\bar{1}1)$	−R		$(15{\cdot}0{\cdot}\bar{15}{\cdot}1)$	$\frac{15}{4}$R	*s*	$(11\bar{2}1)$	2P2r
i	$(50\bar{5}3)$	$\frac{5}{3}$R	Γ	$(40\bar{4}1)$	4R	ξ	$(11\bar{2}2)$	P2r
			ζ	$(60\bar{6}1)$	6R	ξ_1	$(2\bar{1}\bar{1}2)$	P2l
						t	$(32\bar{5}3)$	$\frac{5}{3}$P$\frac{5}{3}$r
						ρ	$(15\bar{6}1)$	−6P$\frac{6}{5}$l
							$(23\bar{5}2)$	−$\frac{5}{2}$P$\frac{5}{3}$l

The forms *t*, ξ, and ξ_1, which are developed on nearly every crystal examined, seem to be characteristic for the locality. The positive rhombohedrons are variable in different vertical zones on the same crystal but have sharply marked faces which give good reflections. The prism planes are almost wholly replaced by the steeper rhombohedral forms.

Albite.—Wherever the feldspar of the enclosing granite reaches the wall of the cavity it is coated with a parallel group of water-clear albite crystals. The crystals are all albite twins, consisting in nearly all cases of a single pair of individuals, and the forms present were determined by measurement to be as follows:

c (001), *b* (010), *m* (110), M (110), *f* (130), *z* $(1\bar{3}0)$, *x* $(\bar{1}01)$, *n* $(0\bar{2}1)$, *o* $(\bar{1}\bar{1}1)$, and δ $(\bar{1}\bar{1}2)$.

Hematite.—Hematite is seen occasionally as lustrous scales or spangles but more commonly as a red pigment staining the surface of quartz crystals or mingled with the kaolin that coats all the minerals in the cavity.

Chlorite.—Green crystals of chlorite of tabular habit, rudely hexagonal in outline and with rounded edges, are implanted on quartz and feldspar.

Kaolin.—Kaolin forms a thin coating on the various minerals described above. It is finely scaly under the microscope. The kaolin is loosely adherent and when removed leaves the underlying crystals bright and fresh.

3. *Crystal Form of Chalmersite.*

The original description of chalmersite by Hussak* gave somewhat meager data concerning the crystallographic development of the mineral. The following note results from the study of five well-developed crystals taken from a specimen belonging to the Harvard Mineral Collection from the original locality, the "Morro Velho" mine, Brazil.

The crystals studied and all those visible on the specimen from which they were detached are untwinned, unlike Hussak's material which is described as commonly in twin or multiple crystals. The crystals are slender prisms, the largest, measur-

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* Hussak, E., Ueber Chalmersit, etc., Centralb. für Mineral, 1902, 69.

ing about 2^{mm} in length and 0·5^{mm} diameter, being doubly terminated, while the smaller ones show but a single termination. Except for a coarse striation on the brachypinacoid due to oscillatory combination of that form with a prism, the crystal faces are plane and brilliant and despite small size give excellent measurements.

The following forms were observed:

c (001), *b* (010), *a* (100), *m* (110), *l* (130), *f* (012), *g* (011), *d* (021), *y* (103), *p* (111), *o* (236), *r* (233), *s* (263), *t* (136), *u* (1·9·12).

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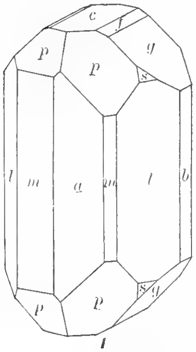

In the prism zone the forms *b* and *l* are dominant, often giving a slightly tabular habit to the prisms. They are striated and less brilliant than the narrow faces of *m*, which are always present The pinacoid *a*, present on all but one crystal, gave rather poor reflections. Of the terminal forms the brachydome *g* and the unit pyramid *p* are dominant; the base *c*, while always present, is broad on but one crystal. The domes *f* and *y* and pyramids *o* and *r*, while found on several crystals as tiny facets, are quite subordinate to the foregoing forms, and the three forms *d*, *t* and *u* were each seen but once on the same crystal.

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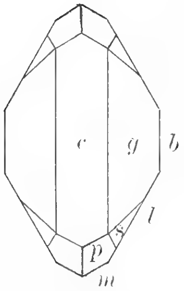

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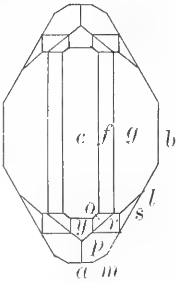

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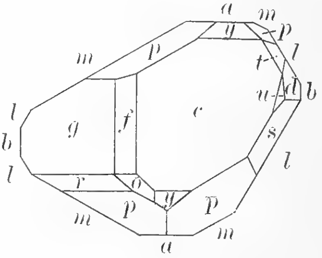

The observed combinations are as follows:

1. *c*, *b*, *a*, *m*, *l*, *f*, *g*, *p*, *s*. Doubly terminated. Figure 4 (drawn by J. B. Marvin, Jr.).

2. *c*, *b*, *m*, *l*, *g*, *p*, *s*. Commonest type on specimen as a whole. Figure 5.

3. *c*, *b*, *a*, *m*, *l*, *f*, *g*, *y*, *p*, *o*, *r*, *s*. Two measured crystals. Figure 6.

4. *c*, *b*, *a*, *m*, *l*, *f*, *g*, *d*, *y*, *p*, *o*, *r*, *s*, *t*, *u*. Figure 7, drawn in about the natural development.

The somewhat complex symbols of the pyramids are supported by concordant measurements and by the simple and normal zonal relations existing between them. The choice of the pyramid *r* as unit would simplify the pyramid symbols slightly, but there would then be no unit prism and the relation in form to chalcocite would be obscured.

The table which follows presents the calculated and measured angles with the range of variation (in minutes) of each form. The measurements were made on the two-circle goniometer.

Symbol	Calculated		Measured		Limits (in minutes)		No. of observations	Quality
	ϕ	ρ	ϕ	ρ	ϕ	ρ		
c 001	-- --	00°00′	-- --	00°00′	----	----	5	good
b 010	00°00′	90 00	00°00′	90 00	0′ to + 7′	—	8	fair
a 100	90 00	90 00	89 57	90 00	−27 to + 7	—	8	fair
m 110	60 12	90 00	60 12·	90 00	−5 to + 5	—	10	good
l 130	30 12	90 00	30 11·	90 00	−9 to + 9	—	6	poor
f 012	00 00	25 43·	00 03	25 36	0 to +12	−23′ to +14′	3	fair
g 011	00 00	43 56·	00 00	43 55·	0 to + 7	−2 to + 3	7	good
d 021	00 00	62 34·	00 11	62 40	—	—	1	fair
y 103	90 00	29 17	90 00	29 17	0 to +12	−5 to + 5	6	good
p 111	60 12	62 43	60 10·	62 43	−5 to + 6	−3 to + 3	12	very good
o 236	49 20	36 29	49 19	36 33·	−11 to +12	−4 to + 7	7	fair
r 233	49 20	55 56	49 24	55 57	−7 to + 7	−6 to + 8	6	fair
s 263	30 12	65 51	30 11·	65 51·	−8 to + 9	−9 to + 7	9	good
t 136	30 12	29 08	29 20	29 12	—	—	1	fair
u 1·9·12	10 59	36 22	11 12	36 30	—	—	1	good

The axial ratio was calculated from the measurements of 50 best faces of 12 forms on 5 crystals. The average values of the closely accordant results differ but slightly from the ratio determined by Hussak.

$$\breve{a} : \bar{b} : \acute{c} = 0{\cdot}5725 : 1 : 0{\cdot}9637 \text{ (Palache).}$$
$$= 0{\cdot}5734 : 1 : 0{\cdot}9649 \text{ (Hussak).}$$

The angles calculated from this ratio in the form of the Winkeltabellen of Goldschmidt are given in the table of measurements above.

As pointed out by Hussak, chalmersite stands in close relationship to the chalcocite group of minerals both in composition and form. If we also include in this group the mineral pyrrhotite, recently shown by the magnetic studies of Kaiser* to be orthorhombic and pseudohexagonal through twinning, and if we calculate its ratio from the angle for the pyramid $20\bar{2}1$, using Seligman's value as the most reliable observation yet

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* Kaiser, E., Die Krystallform des Magnetkies, Centralb. für Mineral, 1906, 261.

obtained, the relations of the group appear as in the following table:

		$\breve{a}$		$\bar{b}$		$\dot{c}$
Chalcocite	Cu_2S	0·5822	:	1	:	0·9701
Stromeyerite	$(Ag,Cu)_2S$	0·5822	:	1	:	0·9668
Sternbergite	$Ag_2S\cdot Fe_4S_5$	0·5832	:	1	:	0·8391
Chalmersite	$Cu_2S\cdot Fe_6S_7$	0·5725	:	1	:	0·9637
Pyrrhotite	Fe_nS_{n+1}	0·5760	:	1	:	0·9524

The propriety of placing pyrrhotite in the Chalcocite Group, long ago suggested by Streng and others, and confirmed by the discovery of the intermediate chalmersite, seems no longer open to question with the established orthorhombic nature of pyrrhotite. The discordant value for the *c*-axis of sternbergite suggests the need of a revision of the crystals of that species.

Harvard University, April, 1907.

Art. XXVI.—*The Mercury Minerals from Terlingua, Texas; Kleinite, Terlinguaite, Eglestonite, Montroydite, Calomel, Mercury;** by W. F. Hillebrand and W. T. Schaller.

In the late fall of 1905 the senior author received for identification from Mr. H. W. Turner, at that time connected with one of the mining companies of Terlingua, Texas, specimens of two minerals from the well-known Terlingua mercury field in Brewster County. One of these proved to be the unidentified mineral referred to as No. 5 by Professor A. J. Moses in his paper† on new mercury minerals from that district, namely terlinguaite, eglestonite and montroydite, the last of these being mercuric oxide, the others oxychlorides. Preliminary tests having shown that No. 5 belonged to the so-called mercury-ammonium compounds, hitherto unknown in nature, a brief announcement‡ of this fact was made in order to secure the field for as full an investigation of this unique mineral and its associates as the material on hand and to be obtained might permit.

This work has been conducted at intervals during the past 18 months and is yet incomplete with reference to the new mineral. It has, however, extended over so long a time and the chances for obtaining more perfect material than that already available are so slight, that it is deemed inadvisable to longer delay publication of the results obtained. The full details of the work herein summarized will be found in a bulletin of the U. S. Geological Survey, the appearance of which will unfortunately be delayed still longer, chiefly on account of the plates that are to illustrate it and the unavoidable delays attending publication. Although the present condensation reproduces the essential points as to the chemistry of the minerals, it but touches their crystallographical side, which, though of much interest for the great number of forms shown by most of the minerals, requires too extended treatment for a résumé of this character. Further, many observations of interest that can not be detailed here were made upon which some of the conclusions were based, particularly in studying kleinite, the mercury-ammonium compound. For these, as well as the details of crystallography and association, reference must be made to the full report.

A few words, however, with reference to their association as observed by us are necessary in this place. The minerals

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* Condensed from a forthcoming bulletin of the U. S. Geological Survey, chemistry by Hillebrand, crystallography, etc., by Schaller.

† This Journal [4], xvi, 253 (1903).

‡ Science, xxii, 844 (1905); J. Am., Chem. Soc., xxviii, 122 (1906); this Journal [4], xxi, 85 (1906).

are deposited on a matrix of two kinds, first a soft siliceous-aluminous, earthy mass, sometimes gray but usually of a pinkish color and containing a small amount of calcium carbonate, and second, a fairly pure layer of calcite with large scalenohedral crystals projecting from the surface. The general associations of the several minerals are given below, but there are many exceptions that will be noted in the full report. Kleinite is found with gypsum, calcite, seldom with barite and calomel, either loose or on a whitish clayey gangue, only once or twice accompanied by terlinguaite; calomel with calcite, mercury and eglestonite on the pinkish earthy gangue; eglestonite with calomel, calcite and mercury on the pink gangue or on calomel; montroydite with calcite, terlinguaite, and mercury on the calcite layer; terlinguaite with calcite, montroydite and mercury on the calcite layer.

Several members of this group of minerals are characterized by a most unusual property, namely, proneness to change color rapidly on exposure to light. With respect to terlinguaite and eglestonite this change is of a permanent character and the result is to impart to the minerals an appearance often quite different from that they originally possessed. With kleinite the change is not to a different color but only to a different shade, and it persists only as long as the exposure itself, the original color returning in the dark. From published and privately communicated statements it would seem as if these minerals, in their earthy forms at least, must be difficult to distinguish as a rule when first found, by reason of the similarity of their original colors, all more or less pronouncedly yellow.

In addition to the specimens first received from Mr. Turner many fine ones were donated by Mr. J. H. Hartley, who was also connected with one of the Terlingua mining companies, and later Mr. R. M. Wilke, of Berkeley, California, gave kleinite when more was needed. All was, so far as known to us, from the properties of the Marfa and Mariposa Mining Co., and chiefly from the Terceiro shaft. Professor A. J. Moses kindly identified the new mineral with his No. 5 and sent us his original measurements of the latter. To these gentlemen, especially to Mr. Hartley for his most generous liberality, also to Dr. P. G. Nutting of the Standards Bureau and Prof. B. B. Boltwood of New Haven, who kindly made certain tests, we take occasion to express our deep sense of obligation.

In the several descriptions that follow we have incorporated data already correctly given by Professors Moses and Sachs,* as well as the new matter gathered by ourselves, in order to present as complete a record as possible of the minerals

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* Sitzb. K. Preuss. Akad. Wiss., 1905, 1091–1094.

described. In general due recognition is given of observations made by others, though it may not have been possible in every case.

Kleinite.

Before describing the unique compound referred to in the foregoing it will be necessary to impose on the reader a little history. On the day preceding the appearance in Science of the announcement regarding the new mercury-ammonium compound there was read at a meeting of the Royal Prussian Academy of Sciences a paper by Professor A. Sachs, of Breslau, descriptive of an oxychloride of mercury which was regarded by him as perhaps identical with the No. 5 of Professor Moses, and to which he assigned the formula $Hg_4Cl_2O_3$, or $3HgO.HgCl_2$, and the name kleinite, after the eminent mineralogist Prof. Carl Klein. This paper appeared in print on Jan. 11, 1906. After reading the announcement of the mercury-ammonium mineral, said to be also identical with the above No. 5 of Professor Moses, Professor Sachs made new analyses of material in his possession and obtained results* agreeing qualitatively in each case and quantitatively in one with those which had already been obtained in Washington. His later data appear in the table below:

	Sulphur-yellow crystals		Orange crystals
Hg	---	---	85·29
Cl	---	---	6·97
SO_3	1·05	0·85	2·57
NH_3	0·44	1·09	2·79

He regarded the sulphur-yellow crystals as the purer, and from the varying values for sulphur and nitrogen argued that these could not be integral components of the mineral. Without committing himself to any view as to the molecular arrangement, the following formula was suggested as the most plausible—$Hg_4 (Cl.\frac{1}{2}SO_4)_2 [O, (NH_2)_2]_3$—which is of the same type as his original oxychloride, $Hg_4Cl_2O_3$, but is far from being in close agreement with his analytical data and is also opposed to the chemical behavior of the mineral as a mercury-ammonium compound. The assumption by Professor Sachs of hydrogen and of oxygen other than that in the SO_4 radical, was purely arbitrary, and it may be said here that his surmises as to the formula of the mineral have not been verified by the results of our work, nor have we found any certain difference in composition between the light yellow and the orange crystals.

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*Centralbl. Min. Geol. Pal., 1906, 200–202.

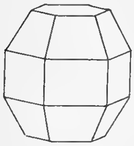
It had been the intention of the senior author to assign to the mineral a name indicative in some manner of its composition when this should have been fully established, but to now substitute for the name kleinite, already in the literature even though applied to an incorrectly identified species, another name, no matter how appropriate, would occasion confusion that it is desirable to avoid; hence the name kleinite is accepted without reserve.

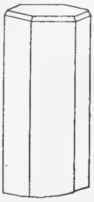
Physical properties.—Most of the material as received was in loose crystals or crystal aggregates, to which adhered more or less of a dull earthy white to reddish foreign matter of a clay-like character. While many of the crystals were very fine and brilliant, much of he material was far too impure for the chemical tests that were contemplated. Even the selected crystals and aggregates held here and there a little of the gangue firmly attached and some must also be included in the crystals themselves in an extraordinarily fine state of division, to judge both from microscopic evidence and from the amount of non-volatile matter that was left on ignition, which ranged from about 0·75 to nearly 3 per cent. This gangue interfered much with the correct determination of the water given off by the mercury mineral on heating and hence with the establishment of a formula.

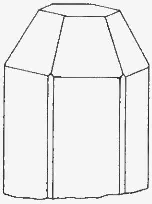
A peculiarity not noticed by other observers is that when exposed to sunlight or even to the diffused light of a room, after having been in the dark, the crystals, at first canary-yellow, almost immediately became much deeper in color, generally reddish yellow or orange, but that they regained their original color very soon when again placed in the dark. This phenomenon could be reproduced as often as desired. It was also noticed that the exposed crystals were not all of the same shade of yellow; there were some that had not changed at all and others that showed all gradations between almost colorless and orange, and one crystal was seen with an orange core and a light outer zone. Professor Sachs also noticed different shades in the same crystal. In powder the color is sulphur-yellow. One of the first specimens received was composed entirely of very pale yellow, coherent crystal masses held together by or holding together a reddish earthy gangue. The lighter crystals that were picked out for separate analysis from samples of the loose crystals varied in color, but all were much lighter than the rest in daylight.

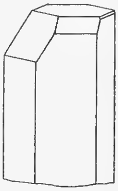
The density was determined on several specimens and found to average for the orange crystals 7·975 and for the light yellow 7·987, but the results are all low because of the attached or included earthy matter. These figures are much higher than the 7·441 given by Sachs. The crystal form is hexagonal;

$c=1{\cdot}6642$ (mean of Schaller's and Sachs' values). The habit is short prismatic, rarely equidimensional. Single crystals seldom exceed one millimeter in length, but masses of crystalline material may exceed one centimeter. Five forms have been observed, namely, $c\ \{0001\}$, $m\ \{10\bar{1}0\}$, $a\ \{11\bar{2}0\}$, $p\ \{10\bar{1}1\}$, and $x\ \{10\bar{1}2\}$ (new). Cleavage is good parallel to $\{0001\}$ and imperfect parallel to $\{10\bar{1}0\}$. Brittle. Luster adamantine to greasy on bright surfaces. Hardness apparently slightly over 3·5. Not radio-active (Boltwood), but Nutting reported faint evidence of helium on first warming the mineral in a vacuum.









The mineral being geometrically hexagonal, a basal section should remain dark under crossed nicols. But, as described by Moses, such a section does not remain dark but shows double refraction, and if thin enough will be seen to be composed of innumerable individuals, none of which is large enough to show interference figures. The double refraction is strong, the colors being of the third and higher orders. At about 130° the double refraction begins to decrease, as seen by the descending colors, until finally it becomes zero and the mineral remains dark under crossed nicols. The section now gives a uniaxial positive interference figure. After cooling, the section remains dark but after the lapse of many months is seen to be slowly returning to its doubly refracting condition. This phenomenon seems to show that kleinite is dimorphous and that the uniaxial optical state agreeing with its outward hexagonal form is stable only above 130° approximately, while below that temperature its stable condition is biaxial, probably triclinic. According to this the hexagonal crystals of kleinite must have been formed at a temperature not much if any below 130°. As is stated just below, it is at a point but a few degrees higher than this that the first permanent browning of the mineral become visible when it is heated, and that considerable loss of water has then taken place. What connection, if any, there may be between these two phenomena is not known.

Pyrognostic behavior.—When carefully heated in a closed tube, or better in one through which passes a slow current of air, the mineral loses a little water, begins to brown at 135°–150°, and as the temperature rises becomes still darker and yields more water, but gives no visible sublimate under 260° even after several hours. Between 260° and 280° mercury and calomel (not $HgCl_2$) sublime. When most of the calomel has passed off the residue begins to grow lighter colored, then yellowish and finally becomes nearly white. During the expulsion of the calomel some gas (Cl?) is evolved in minute amount that sets free iodine from solution of potassium iodide. On heating to 400° more of this active gas is evolved, but it is soon followed or accompanied by one that destroys the color of the free iodine (SO_2?). At 400°–420° appears a further sublimate less volatile than the calomel. If the test is made in a closed assay tube this last sublimate and the still unvolatilized residue may melt to a dark reddish liquid, which on cooling solidifies with a yellowish and then white color. Ammonia turns both sublimates black instantaneously, although the later one often contains mercuric as well as mercurous sulphate. Most of the nitrogen escapes in the elemental state during the formation of the calomel, but not quite all. There is not the least evidence of the formation of ammonia. If the heating is carried out in vacuo the evolution of the active gas is much more marked than at atmospheric pressure and if collected by a pump is seen to be of the color of chlorine. Under the vacuum this gas does not act on the mercury of the pump, but fouls that in the collecting tube strongly under atmospheric pressure. The scum on the mercury gives tests for chlorine. This liberation of free chlorine was at first supposed to indicate direct union of nitrogen and chlorine in the mineral, but since it is also given off on heating in vacuo a mixture of the artificial compound $NHg_2Cl.xH_2O$ with a sulphate of mercury ($3HgO.\ SO_3$ in the test) it is evidently a secondary reaction between one of the products of breaking up of the radical SO_4 and vapor of calomel or of the still undecomposed chlorine constituent of the mineral.

Behavior toward liquid reagents.—Soluble in warm hydrochloric as well as nitric acid without deposition of calomel. Also soluble in sodium sulphide and in ammonium bromide. The latter liberates as ammonia for every one part of nitrogen derived from the mineral itself three parts from the reagent. Fixed alkalies do not liberate ammonia. Hydrogen sulphide blackens speedily, ammonia not at all.

Additional data.—Several tests were made by decomposing the mineral in vacuo under varying conditions of treatment in order to get evidence as to the presence of either hydrogen in addition to that which was afforded as water or of oxygen other than that in the water and the SO_4 radical. For the evidence on these points reference must be made to the full report; suffice it to say here that no certain evidence was obtained in favor of the presence of one or the other of these elements other than in the combinations above named, though the proof is not absolute that there may not be small amounts of one or both (see also p. 268). If present, the hydrogen is in such small amount as to be unimportant in the formula of the mineral as a homogeneous unit, and oxygen must also exist in all probability as basic oxygen in a minor constituent of a mixture. The summation given on p. 267 is a strong argument against the presence of considerable percentages of either.

When, however, the mineral is fully decomposed by heat in presence of lime or sodium carbonate, oxygen is liberated in quantity. Theoretically the amount should be exactly equivalent to the SO_4 and Cl_2 found in a particular sample if the compound is normal and not basic, and this should afford an exact means for deciding the question of the presence of oxygen.

But as a matter of fact the oxygen never did equal the calculated amount by several tenths of one per cent. Of the various possible explanations to account for the deficiency the following, based partly on qualitative tests, seems the most probable. The oxygen is liberated partly in an active state and forms a chloroxy-salt of sodium or else nitrite or nitrate of sodium in small amount. It would require but little of one of these salts to bind enough oxygen to account for the observed deficiency. The evidence favors an oxy-salt of nitrogen in preference to one of chlorine. It is, of course, assumed that any such salt was formed by the act of decomposition and did not preëxist in the mineral.

Analytical methods employed and the results.—(1) Nitrogen. For nitrogen three methods were used: (*a*) expulsion as ammonia by sodium sulphide and gravimetric determination as the chlorplatinic salt; (*b*) expulsion as ammonia by ammonium bromide in a closed vessel, collection of the ammonia in titrated oxalic acid and determination of the acid left over; (*c*) direct determination as nitrogen gas expelled in vacuo, collected by the aid of a Töpler pump, and measured in a gas burette after freeing from other gases if present.

Numerous data are to be found in the full report relating to these methods, particularly the last. The second method was found to yield about two-tenths per cent more nitrogen than the first or than the second when sodium carbonate was used as a retainer for the chlorine and sulphur, the results by which agreed well.

This was probably in part if not altogether due to the action of the clayey gangue on the ammonium bromide with liberation of some ammonia (see p. 268). Were it not for this effect of the gangue the method would be an excellent one for obtaining proof as to the presence or absence of basic oxygen. The nitrogen found by the third method was finally tested by passing it over hot magnesium, which absorbed apparently the whole of it. It was also tested spectroscopically. The analytical results were as follows, calculated to gangue-free substance, the modes of decomposition employed being indicated at the heads of the several columns:

NITROGEN PERCENTAGES BY DIFFERENT METHODS.

		Gas-volumetric		
Na_2S	HCl	With Na_2CO_3	Without Na_2CO_3	NH_4Br
2·56	2·57	2·53	2·61	2·78
2·57		2·55	2·74	2·76
2·55		2·60	2·67	2·74
2·55		2·58	2·86	2·70
		2·43		
Av. 2·555				2·74
		2·54		

The single determination after solution of the mineral in hydrochloric acid and removal of the mercury as sulphide and of the SO_4 as the barium salt, is regarded with confidence, as also those by the sodium sulphide method. The greater variation among the results by the gas-volumetric tests with sodium carbonate is to be ascribed to the small amounts of mineral used—0·25–0·5 gram, the uncertainty in the burette readings in the upper section of the instrument and the greater chance for loss or gain during the numerous manipulations. The high results by the ammonium bromide method have been explained above. Those by the gas method without sodium carbonate are not clearly accounted for, but the results obtained in that way were always less satisfactory by reason of the fouling of the pump outlet and of the mercury in the collecting tube by the free chlorine that was formed.

(2) Mercury. Mercury was determined in several ways, almost always in connection with one of the nitrogen determinations: (*a*) As mercury by ignition with sodium carbonate and once as in organic combustion of mercury compounds. Most of the determinations were by this method. (*b*) As mercury by electrolysis from sodium-sulphide solution. (*c*) As the sulphide. The last method usually afforded higher and probably truer results than the first.

(3) Chlorine and sulphur. Since slight loss of chlorine and of sulphur as sulphide dioxide almost always resulted when the mineral was heated by itself, these components were determined in the sodium carbonate employed for the gas-volumetric determination of nitrogen. A greater variation among the few

chlorine results for the lighter colored crystals was observed than for the orange-colored ones, which latter afforded excellently agreeing results. But the results for the lighter crystals were in no case so markedly different from the others as to confirm Professor Sachs' conclusion that there was an appreciable chemical difference between the crystals of different shades, and they were in part affected by obvious errors.

(4) Water. None of the water afforded by the mineral is hygroscopic. About one-half comes off at 135°–150° and the total that is obtained by careful heating of the mineral by itself to complete decomposition, using a plug of gold leaf in the exit of the tube, is not clearly in excess of that obtained after the manner of organic combustion with copper oxide preceded by lead chromate and a roll of copper. Some of it comes from the clayey gangue, but most is beyond question given off by the mercury mineral. How much belongs to one and how much to the other it has been impossible to ascertain. The water determinations constitute the least satisfactory portion of the analytical results.

In the different specimens analyzed the gangue ran from 0·75 to 3 per cent in the dehydrated state, as obtained by ignition. In the full report the many analyses are given both as made and after recalculation to a gangue-free basis for both orange and light-colored crystals. We reproduce here only the averaged results for the deeper colored crystals since they were in best agreement, repeating that although the light-colored crystals afforded greater variations in chlorine and sulphur than the orange ones, this was in part due to obvious errors, and that the means for these constituents were slightly higher than for the orange crystals, rather than far lower as found by Sachs. To include them would hardly affect the general average.

AVERAGE COMPOSITION OF ORANGE CRYSTALS OF KLEINITE.

Hg	85·86	÷ 200	= 0·4293	= 2·34
Cl	7·30	÷ 35·45	= 0·2059	= 1·42
SO_4	3·10	÷ ½ 96·06	= 0·0646	
N	2·57	÷ 14·01	= 0·1834	= 1
H_2O	1·03	÷ 18·02	= 0·0571	= 0·311
	99·86			

In discussing the above ratios it must be borne in mind that the number for water is of doubtful value, so that it can receive little attention. The water can not exist in large part even as hydroxyl, for that would require an amount of basic oxygen entirely opposed to all the evidence, in which that of the summation is not of least import. The ratio shows at once that there is far too little nitrogen for a general formula of the type

$NHg_2X.xH_2O$, in which X represents Cl and SO_4. It is even insufficient for the chlorine alone in such a formula and we are therefore obliged to consider the possibility of the body being a mixture. Calomel as a constituent of such a mixture is excluded from consideration for the reason that but a trace is indicated on dissolving the mineral in warm hydrochloric acid and this appears to be derived from the gangue. Mercuric chloride would seem to be excluded by its solubility in water. As oxychlorides there would naturally be considered first terlinguaite and eglestonite, but both are excluded for the reason that they yield calomel on solution in hydrochloric acid. It remains to assume a mercuric oxychloride and then an oxysulphate, both of which might perhaps be formed simultaneously with $NHg_2Cl.xH_2O$ from a mercuric solution containing more mercury than is needed by the ammonia present to form a compound of this type. If, perchance, the oxychloride were Hg_2Cl_2O, or $HgO.HgCl_2$, and allowance were made for it on this basis in the ratio above given, the ratio of the residuals would show an oxysulphate with Hg to SO_4 as 4 to 3·23 and composition nearly $Hg_4O(SO_4)_3$, or $HgO.3HgSO_4$. The calculated amounts of these salts would demand 0·33 per cent of basic oxygen, an amount that happens to coincide almost exactly with that indicated by the nitrogen determinations according to the ammonium bromide method (p. 265), which as will be remembered gave more than was obtained by other methods. While the excess of ammonia obtained by the ammonium bromide method is with considerable reason believed to be in part due to the action of the aluminous gangue on the reagent, calculation shows that it can not well have all originated thus. If not, the only alternative, assuming that the tests were reasonably correct, is that an oxy-salt of mercury must have given rise to some at least of that excess of ammonia. The chief objection to accepting this alternative is the volume of oxygen corresponding to the required weight percentage, which if wholly given off as oxygen gas on heating the mineral itself ought not to have escaped detection and approximate measurement. Still, it is conceivable that in this method of operating, the basic oxygen might not all escape as gas. The evidence as to the presence of a little basic oxygen is conflicting, and further speculation would be profitless in the present state of our knowledge regarding this remarkable mineral. To assume that the nitrogen is very low and should be 2·885 per cent or exactly equivalent to the chlorine, is opposed by much evidence, including the fact that the sulphate would then be strongly acid.

It is regrettable that the long labor has resulted in nothing more definite than the fixing of this mineral as the first naturally occurring member of the so-called mercury-ammonium compounds and the untenableness of the possibility suggested by Professor Sachs. The question as to the structure of these mercury-ammonium bodies, whether they belong to one or other of the several types that have been suggested for them, is outside the scope of this investigation.

Montroydite.

Orthorhombic-holohedral, $a : b : c = 0{\cdot}6375 : 1 : 1{\cdot}1977$ (Schaller). Fifty-six forms observed, 45 new. Two crystal habits with all intermediate gradations: (1) Prismatic, flexible, dark red needles, commonly $1\frac{1}{2}^{\text{cm}}$, occasionally $2\frac{1}{2}^{\text{cm}}$ long, by less than 1^{mm} thick, often partially grayish from what appears to be a thin coating of some other (presumably mercury) mineral, or minute and orange in several forms, notably wormlike and (2) nearly equidimensional crystals of a few millimeters diameter. The larger needles occur also in curiously twisted and curved shapes, the minute orange ones in irregular rounded and loosely coherent masses. There are also hollow, irregularly shaped and bubble-like formations that in their interior resemble geodes, being lined with or nearly filled with one or both of the above mentioned types of crystals. A somewhat different form of bubble is found between large calcite crystals, smooth and somewhat glistening exteriorly, gray-black and partially filled with a spongy mass of crystalline material that is commonly very dark in color. Precise descriptions of these and other modes of occurrence are difficult to give in few words.

Color, dark red to yellow-brown or orange-brown. Streak yellow-brown. Transparent to translucent. Cleavage, perfect $\{010\}$. Hardness, 2–3, less than 2 (Moses). Brittle, also sectile, but the long needles, extremely flexible, can be rolled around a thin rod. Density not determined because of inability to separate completely from free mercury enough for a satisfactory test.

Completely volatile without fusing, yielding in a closed tube a sublimate of mercury only. Slowly blackened by hydrogen sulphide, but not equally over all surfaces.

Since the oxygen as given for montroydite by Professor Moses was assumed by difference, a direct determination was made by dissociating the mineral in vacuo, collecting, measuring and testing the gas evolved. The result was to confirm the identification of Professor Moses:

Analysis of Montroydite.

	Theory HgO	Found in 0·2213 g.	
Hg	92·59	92·74	weighed as metal
O	7·41	7·49	calculated from the volume.
	100·00	100·23	

Terlinguaite.

Monoclinic prismatic (holohedral), $a : b : c = 1{\cdot}6050 : 1 : 2{\cdot}0245$ (Schaller), $\beta = 74° \, 23'$. Of the 133 forms observed 102 are new. Crystals often extended in one direction and also equidimensional. The largest crystal measured $16 \times 4 \times 4^{mm}$, though faces over a centimeter broad are sometimes to be seen. Also occurs in powdery form impregnating the earthy gangue, to judge from the greenish color of some specimens of ore, and perhaps in a similar state admixed with eglestonite, in which case its identification is at least difficult. Much confusion seems to exist as to the original color of terlinguaite before it has been exposed to light. Moses writes of it as "sulphur-yellow with a slight greenish tinge, very slowly darkening on exposure to an olive green," but Mr. Hartley, in reply to our inquiry, wrote that the terlinguaite crystals were green ere they were touched by the sunlight, but that most of the terlinguaite occurs as a yellow powder changing to green. Sometimes brown crystals are seen and occasionally the green and brown colors appear in the same crystal. When brown they are difficult to distinguish at sight from eglestonite in one of its transitional color stages. Some of our earthy specimens that were yellow at first turned greenish on exposure and presumably contained terlinguaite. Beautiful spots of emerald-green reflected light appear when the crystals are examined with a lens as they occur on the specimen. If at times originally yellow the mineral is not in that state always distinguishable from kleinite, and perhaps not from eglestonite or even from the orange-red form of montroydite.

Streak yellow, turning greenish gray in light. Transparent or nearly so. Luster, brilliant adamantine. Cleavage, perfect $\{\bar{1}01\}$. Brittle to subsectile. Hardness 2–3. Density, 8·725 (Moses).

The effect of heating crystals in a closed tube differs somewhat according as this is done slowly or quickly. When quickly done there is violent decrepitation, continuing till the mineral has volatilized, the substance turning red-brown or almost vermilion in color (orange-yellow cold) and much of the resulting powder being projected up onto the sublimate of calomel and mercury above the assay. Eventually there is complete volatilization. With slow heat decrepitation is hardly noticeable. With the first burst of calomel sublimate there appears a little mercury, but then only calomel so long as there is any chlorine left in the residue. Sometimes at the last, when the flame is removed, brilliant short red needles of mercuric oxide form on the warm glass by recombination of some of the mercury vapor and oxygen.

In vacuo the color changes of the crystals as the heat increases are more marked, these being, after first appearance of a sublimate, red, black (without loss of luster), red-brown, orange-brown and dull. Before becoming completely orange-brown some faces are olive-green. When orange-brown the only visible sublimate is calomel and no trace of oxygen has been evolved. The residue then seems to be mercuric oxide, upon the decomposition of which partial recombination of its constituents occurs, to judge from the deposition on the warm glass near by of a slight orange-brown sublimate.

Hydrogen sulphide blackens the edges of a crystal, but further action is very slow; ammonia blackens only after some time. The second test serves to distinguish the mineral from eglestonite, which is at once blackened by ammonia. This difference in behavior of terlinguaite and eglestonite is in line with their chemical difference, the former being mercuric-mercurous, the latter wholly mercurous. Hydrochloric and nitric acids decompose terlinguaite with separation of calomel. The hydrochloric filtrate yields much bivalent mercury. Cold acetic acid slowly decomposes the mineral when in powder, also with separation of calomel, and in the filtrate hydrochloric acid produces no further precipitate, or but a very faint one. Eglestonite under similar treatment yields a heavy calomel precipitate, the filtrate from which is free from mercury.

Moses' empirical formula was confirmed by analyses in which the oxygen was measured directly and found to be wholly absorbed by phosphorus, thus showing its freedom from nitrogen.

ANALYSES OF TERLINGUAITE CALCULATED TO GANGUE-FREE SUBSTANCE.

	Theory Hg_2ClO	I	II	III	Ratio of III
Hg	88·65	88·92	88·31	88·61*	2·00
Cl	7·85			7·83	1·00
O	3·50			3·75	1·06
	100·00			100·19	

The high oxygen found in III is due probably more to error in measuring so small a volume as $2·67^{cm^3}$ than to the little montroydite that was present.

The only artificial mercuric-mercurous oxychloride hitherto prepared† has the formula of terlinguaite.

Eglestonite.

Isometric-holohedral. Crystals small, equidimensional, usually about and under one millimeter in diameter. They show two

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* Mean of I and II.

† Fischer, T., and von Wartenberg, H. Chem. Zeit., xxix, 308 (1905).

habits, one determined by the development of the rhombic dodecahedron and not particularly rich in forms, the other determined by development of the octahedron and with abundant forms. Of the 21 forms observed 17 are new. Whether eglestonite can be distinguished by its color in the mine or soon after removal therefrom from terlinguaite, with which it is sometimes closely associated, or from kleinite or the orange montroydite, we are unable to say, but from the confusion that existed in the minds of those who sent us our specimens it seems that it must be at least difficult to do so. The first specimens received were dark brownish and of dodecahedral habit, others were of octahedral habit and light brownish yellow. These last became darker in time. If sufficiently exposed the crystals turn black, but without losing their luster, as noticed by Moses. Streak yellow, turning black. Luster adamantine to resinous. Transparent to translucent. Brittle. Cleavage lacking. Fracture uneven and apparently sometimes conchoidal. Hardness, 2–3 (Moses). Density, 8·237 (Moses); not determined by us for the same reason as with terlinguaite, difficulty of freeing perfectly from mercury enough material for a satisfactory test.

When heated in a closed tube comports itself in almost every respect like terlinguaite. The residue, after expulsion of the calomel, seems to be mercuric oxide as with terlinguaite, formed in this case, however, from mercurous oxide at the expense of half the mercury of the latter, a reaction which accords with the observation that no oxygen escapes till all the calomel and some mercury have sublimed.

Hydrogen sulphide acts very much as upon terlinguaite and ammonia blackens at once, the latter reaction serving as a ready distinguishing test between the two minerals. Hydrochloric and nitric acids decompose it with separation of calomel. The hydrochloric acid filtrate contains no mercury. Cold dilute acetic acid acts more quickly on the powder of eglestonite than on that of terlinguaite, calomel is left and from the filtrate much more can be obtained by hydrochloric acid. The final filtrate is free from mercury. These tests, confirmed by the analysis, show clearly the mercurous nature of the compound, the first authentic instance of a mercurous oxychloride, native or artificial.

Analysis did not confirm the empirical formula $Hg_6Cl_3O_2$, deduced from J. S. McCord's analyses in the paper by Professor Moses, a formula which, in fact, is invalidated by the qualitative data above given, since it calls for mercuric as well as mercurous mercury. The analyses were made in the main as for terlinguaite, with the exception that the chlorine and mercury in the sublimate were each time determined, the separation being effected by sodium hydroxide, and the little mercury that goes into solution with the chlorine by this operation being recovered. Calculated to gangue-free substance the results were as follows:

ANALYSES OF EGLESTONITE CALCULATED TO GANGUE-FREE SUBSTANCE.

	Theory	I		II		III	
	Hg_4Cl_2O	0·1195 g.	At. ratio	0·1008 g.	At. ratio	0·1198 g.	At. ratio
Hg	90·21	88·33	4·11	88·94	3·86	89·73	3·99
Cl	7·99	8·32	2·18	8·23	2·02	8·12	2·03
O	1·80	1·72	1	1·84*	1	1·80	1
	100·00	98·37		99·01		99·65	

In all cases the mercury is probably low, and calomel was present to a slight extent in sample I at least. It is quite probable that the oxygen was less accurately determined than the chlorine, but the effect of low mercury and the presence of calomel are better brought out by the ratio based on oxygen than on chlorine as unity. The formula plainly indicated is Hg_4Cl_2O, or $Hg_2O.2HgCl$, one that is in full agreement with the qualitative behavior of the mineral. The variations in the analytical data reported by Moses are so wide that the excellent agreement of his averages with the formula $Hg_6Cl_3O_2$ can be due only to a balancing of large errors. The oxygen values of his table were indirectly determined and are affected by the errors involved in other determinations, which inspection shows were large.

The ammonium-bromide method, used with kleinite for determining nitrogen, might probably be employed successfully with eglestonite and terlinguaite and any other compounds of similar kind for the indirect but very accurate determination of the basic oxygen in them.

Two specimens of what was supposed to be eglestonite were analyzed, but with results indicative of a mixture of terlinguaite with calomel, though the appearance of both was decidedly against this. Possibly they represent a new species.

Calomel.

The crystals of calomel often reach a large size, some being $1\frac{1}{2}^{\mathrm{cm}}$ in diameter. They are very rich in forms, a total of 30 having been observed, of which 10 are new. The crystals are frequently twinned, twinning plane $e\{011\}$. The formula for calomel being well established, no chemical work was done on this mineral.

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* 1·90 by loss in wt. of ign. tube.

Native Mercury.

Native mercury occurs abundantly on nearly all of the specimens, except those of kleinite, on which we have not seen it. It is usually present as globular irregular masses associated directly with the other minerals. Globules often project from small cavities on the surfaces of crystals of terlinguaite, eglestonite and montroydite, and are sometimes to be seen in the interior of crystals of terlinguaite and montroydite, notably the latter. While much of it is in the form of a fairly pure liquid, a good deal is mixed with powdery oxychlorides as a sort of stiff paste having a gray or greenish color and irregularly associated with the plainly crystallized oxychlorides and montroydite. The proximate determination of this gray or greenish mass is almost impossible. Some of the mass has a yellowish, almost metallic sheen, which is perhaps largely an iridescent effect.

Summary.

Kleinite, as announced in 1905, belongs to the so-called mercury-ammonium compounds, but no probable formula can be deduced from the analyses. It may be a mixture of a mercury-ammonium chloride in great preponderance, $NHg_2Cl.\frac{1}{3}H_2O$, with an oxychloride and sulphate or oxysulphate of mercury.

Terlinguaite is a mercuric-mercurous oxychloride, $HgO.HgCl$, the formula of Moses being confirmed and the mixed nature ascertained by tests.

Eglestonite is a mercurous oxychloride, $Hg_2O.2HgCl$, the first authentic instance of such a compound, either artificial or native, and not $Hg_6Cl_3O_2$ as believed by Moses.

Montroydite is mercuric oxide, as supposed by Moses and proven now by direct determination of its oxygen content.

Laboratory U. S. Geological Survey, Washington, D. C., July.

ART. XXVII.—*Note on the Forms of Arkansas Diamonds;* by G. F. KUNZ and H. S. WASHINGTON.

DIAMONDS have recently been discovered in the peridotite stock of Murfreesboro, Pike County, Arkansas, the first having been found Aug. 1st, 1906, and about 140 in all up to the date of writing. A full description will be published later, but some preliminary notes on the forms and colors of the stones may be of interest.

The most commonly occurring forms are distorted hexoctahedrons, most frequently elongated, but occasionally flattened, and with always much rounded faces. The symbols of the hexoctahedrons have not yet been determined, but more than one form seems to occur, and in some cases they are merely vicinal to the octahedral face. A flattened, trigonal, lenticular form of spinel-twin, similar to fig. 4 in Dana's System (page 3), is rather common, especially among the yellow stones. Another form, also apparently twinned on 111, is shown by the largest diamond yet found, which in form, color, and effect somewhat resembles the well known "butterfly twins" of calcite from Cumberland. It is crescentic in shape, flattened in one direction of the twinning plane and elongated obliquely to it on either side.

There are a few regular and undistorted octahedrons, which show slightly rounded faces, though the center of these is usually flat. The edges are often replaced by the dodecahedron, and they are commonly further rounded by trigonal trisoctahedrons, with hexoctahedrons near the apices. The octohedral faces are commonly marked by small, shallow, triangular pits, which are most abundant toward the center; while a few show small, low, parallel ridges, the direction of which bisects the face angle. No cubes were seen, and tetrahexahedral and dodecahedral forms seem to be equally rare, except as replacing octahedral edges and angles.

White stones are common, the white being exceptionally pure and free from all tints of color, and usually absolutely pellucid, like the so-called "river stones" of South Africa. A considerable number are tinted brown or are a rich cinnamon-brown, while others are yellow, some of these being of a pure lemon color. Some of the stones are gray, and a number are very dark, almost black, bort; but none of the hard, amorphous carbonado seems to occur, though careful search was made for it, which should have revealed it had it been present.

The largest diamond weighs 6½ carats, and is 15·5^{mm} long, 7·75 high, and 4·2 thick, of an absolutely pure, pellucid white, free from inclusions. Its form was noted above. Another stone weighs $6\frac{1}{4}$ carats, several about 5, 4, or 3, and from this they run down to $\frac{1}{64}$ carat, the average being probably about one carat.

Inclusions are present in some of the stones, especially in the gray ones, and are apparently mostly of hematite, and in one case of what appear to be rutile needles. Several of the diamonds show rough and irregular indentations, as if they had formed or been attached to surfaces that were not smooth; while a very large proportion, possibly one half, are fractured.

While most of the diamonds have been found on the surface of the igneous area, a few have been found among the concentrates derived from washing the decomposed peridotite, which much resembles that of Kimberley, and one diamond was found embedded in the decomposed peridotite itself. The portion of this that is visible is $9{\cdot}1^{\mathrm{mm}}$ long and 3^{mm} wide, and the stone is apparently a distorted and elongated hexoctahedron, with much rounded faces, grayish in color. The evidence seems conclusive that the diamonds found are derived from the peridotite; and, if so, this is evidently the first occurrence of diamonds in place on either the North or South American Continent.

New York, Aug. 12, 1907.

ART. XXVIII.—*On a Method for the Observation of Coronas**; by C. BARUS.

1. *Character of the method.*—In the usual practical experiments with the large coronas of cloudy condensation (the largest types having angular diameter of nearly 60°), the small round source of light is placed in the equatorial (vertical) plane of the fog chamber and remote from it. The eye and goniometer are put as near it as possible, whenever sharp vision is essential. The diffracted rays in such cases come from the fog particles *a*, *b*, *c*, at the ends of the chamber *F*, as in figure 1*a*, and are liable to be seriously distorted by the refraction of the glass walls. The limit will be reached sooner or later, in which the fog particles to which the diffractions are due lie at or beyond the ends of the fog chamber, after which the features essential to the measurement will no longer appear. Moreover one eye only can be used in the measurements.

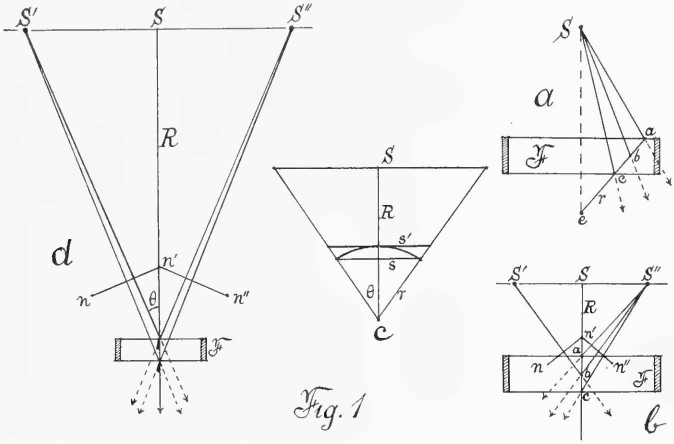

Fig. 1

It occurred to me, therefore, to invert the phenomenon by using two sources, which may be moved symmetrically towards or from the equatorial plane, as in figure 1*b*, and to observe the contact in this plane of the two identical coronas produced. In this way the oblique refractions are diminished as far as possible, the diffracting particles *a*, *b*, *c* lie in the middle, coronas of all sizes are observable, both eyes are available for observation, increasing sharpness of vision and lessening the eye strain. The contact method is in itself more sensitive,

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* Extract from a forthcoming report of the Carnegie Institution of Washington.

seeing that the eyes may be placed all but in contact with the fog chamber.

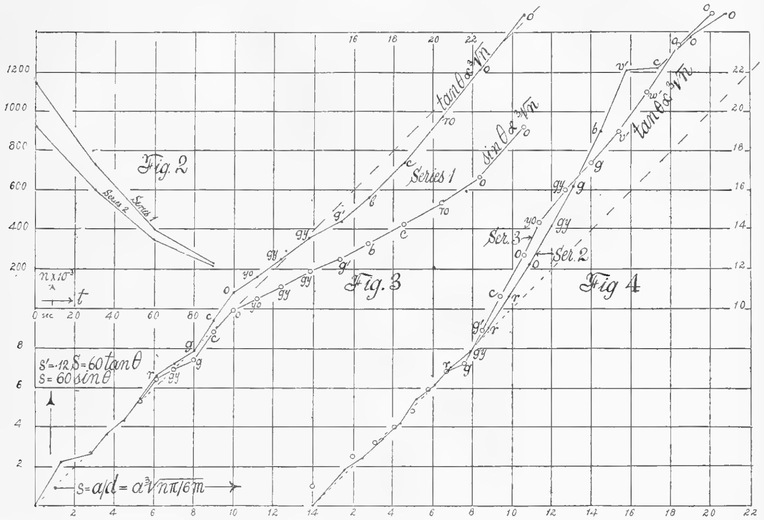
2. *Apparatus.*—Figure 1*b* and *d*, the latter drawn to scale, show a general disposition of the apparatus. S' and S'' are the two circular sources of light lying in the same horizontal, and movable in opposite directions in equal amounts, at the control of the observer sitting near at the fog chamber F. S' and S'' are therefore always symmetrical with respect to the vertical plane SR. The diffraction of rays due to the fog particles a, b, c, in F, produce coronas seen at nn' and $n'n''$, and the lamps S', S'' have been adjusted at a distance S, so that the selected annuli of the coronas are in contact at n'. The angular radii of the coronas, marked θ or shaded in the diagram, are nearly equal $2R \tan \theta = S$, where R is the distance of the axis of the fog chamber from the track S in parallel with it.

On a double track at S, the two carriages for the lamps, S', S'' are moved with sprocket and chain or in a similar manner and provided with a scale stretched between them, reading to centimeters. This is a lath of wood about 3 meters long with one end fastened at S', the other free, while the scale moves across an index at S''. A pole at R, with the end in the observer's hand, moves the two central sprockets and at the same time serves for the measurement of R, should this accidentally vary.

3. *Errors.*—The figure shows clearly that the angle of diffraction corresponding to the fog particles nearer and farther from the eye will not be the same and that this effect will vanish as the coronas are smaller, as the diameter or thickness of the fog chamber is less, and as the distance R from the source is greater. Slightly different annuli overlap; but the effect is much less here than in the case of a single source, where the active fog particles lie oblique to the axis. See figure 1*a* and figure 1*b* at a, b, c. In practice this effect is probably negligible if the dimensions of apparatus and disposition of parts are properly chosen, particularly so since the fog particles themselves are not usually so nearly of a size as to imply less overlapping. In fact the true corona, if large or even of moderate size, is seen but for an instant immediately after exhaustion. It therefore shrinks rapidly, as may be gathered from the following incidental data given in figure 2 and obtained with fog particles originally about $\cdot 00002^{\text{cm}}$ in diameter, belonging to the large yellow-blue corona.

The coronas shrink as the fog particles increase in number and decrease in size at an accelerated rate. This shrinkage begins as soon as the corona appears. The initial rates must be estimated at a decrement of number greater than 1·4 per cent per second, supposing that no water is added from other sources than the evaporation of smaller particles. In 100 seconds about 80 per cent have escaped. The case is much more serious for larger coronas, so that these are characteristically fleeting and must be observed at once. It may not be impossible that rapidity of evaporation itself sets a limit to the largest coronas producible. The nuclei, however, are not all lost, as a rule. They occur, at least in part, as water nuclei and are available for the next coronas, if not removed.

It follows then that for these cases the method of subsidence is not applicable, as the corona changes totally before measurable subsidence is recorded. Hence an instantaneous procedure like the former goniometer method or the present method is alone available.



4. *Data.*—Omitting the tables, I have constructed in figs. 3 and 4 results obtained by the method* of successive equal exhaustion with phosphorus nuclei in dust-free air, leaving out the initial fogs. It is seen at once that large coronal diameters are actually measurable; a result which was not possible hitherto. Reduced to the goniometer method (figure 1*c* shows the notation) the present results may be written $\cdot 12S = s'$ for small coronas; but for large coronas, if 2θ is the angular diameter, $S = 2R \tan\theta$, $s = 2r \sin\theta$ or $S = 8{\cdot}3s/\sqrt{1-s^2/r^2}$, $s = \cdot 12S/\sqrt{1+S^2/R^2}$; $R = 250^{\mathrm{cm}}$, $r = 30^{\mathrm{cm}}$. The letters on the curves refer to the colors of the discs and first annuli of the coronas.

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* This Journal, xiii, pp. 81–94, 1902.

Since the elementary diffraction equation may be put

$$\sin\theta = 1{\cdot}22\ \lambda/d$$

for the first minimum

$$\frac{S}{2\sqrt{R^2+S^2}} = 1{\cdot}22\lambda/d \text{ or } S = 2{\cdot}44\,R\,\frac{\lambda}{d}\Big/\sqrt{1-(2{\cdot}44\lambda/d^2}$$

and S would therefore appear to be less immediately adapted for the equation than s. It does not follow, however, that this s and the one observed at the goniometer work are the same. In fact they are not, the latter being larger for reasons involved in the more recondite theory of the experiment, or else due to irregular refractions at the remote ends of the chamber.

5. *Remarks on the results.*—Without entering at length into the details of the subject, it is clear that if $ds = a$ for normal coronas, where d is the diameter of particles and a an optical constant, $s = a(\pi n/6m)^{1/3}$, where m is the quantity of water precipitated per cm. and n the number of nuclei per cm. on which this water falls. I will add a few results showing the relation of the s computed in this way and the observed S or the s reduced from S.

Figure 3 contains data both for S, $\cdot 12S = s'$ and s and leads to a curious consequence. The computed chords of the coronas, $s = a(\pi n/6m)^{1/3}$ are here not proportional to $s = 2r\sin\theta$, but to $s = 2R\tan\theta$, where 2θ is the angular diameter of the coronas. This implies a diffraction equation reading $\tan\theta = 1{\cdot}22\lambda/\text{d}$.

In figure 3 $s\,a\,n^{1/3}$ is laid off as the abscissas and $\cdot 12 s\,a\tan\theta$ and $\cdot 12S\sqrt{1{\cdot}S^1R^2a}\ \sin\theta$, as the ordinates. If we confine our attention to values within $s = 14$, where the readings are more certain, and where there is less accentuated overlapping of coronas, the graph $.12S$ oscillates between two straight lines as the coronas change from the red to the green types. The slopes of these lines are respectively as $1{\cdot}08 = 73\lambda_1/a$ and $\cdot 99 = 73\lambda_2/a$, whence $\lambda_1 = \cdot 000047$ and $\lambda_2 = \cdot 000043$. These should be blue and violet minima.

The figure shows moreover that compared with the graph for $\cdot 12\,S = 60\tan\theta$, the curve for $\sin\theta$ is in series 1 quite out of the question, as already specified. The results for other independent series, 2, 3, are given in figure 4, in the same way. Curiously enough, series 2 and 3, which should be identical with 1, fail to coincide with it in the region of higher coronas. In these series the graph $s\,a\sin\theta$ (not shown) would more nearly express the results, though the agreement is far from satisfactory.

It is exceedingly difficult to account for this difference of behavior. As the abscissas $s = a(n\pi/6m)^{1/3}$, or $s\ a\ n^{1/3}$, and the ordinates, s (observed), are independent of each other, the equality of the two values of s will in a measure check the work apart from the constant a which determines n_1. This is actually the case for the lower series of coronas below $s = 10$, which are used in practice. It is the *observational* value of the aperture of the given coronas which varies. Very probably mixed coronas are being observed. To this must be added the subjective error or personal equation which enters into the determination of contacts. Finally the tendency of a corona to shrink at once after the formation of droplets, makes it difficult to catch the time at which coronas should be observed soon enough. Under other circumstances there is even liable to be an oscillation of the coronal aperture in the lapse of time. All these difficulties are accentuated as the coronas become larger, for here not only are the droplets more volatile, but the coronas overlap, and there is an unlooked for tendency for them to flatten at the point of contact. The dark rings are liable to invade the bright.

The green coronas in the series 1, 2, 3 show the following average values, the diameter d being given in cms.:

Ser.	Computed		Observed		Computed		Observed	
	s_3	s_2	s_3	s_2	10^6d_3	10^6d_2	10^6d_3	10^6d_2
1	8	16	8	14	400	200	400	230
2	8	14	8	15	400	230	400	210
3	8	13	8	13	400	250	400	260

Mean values are thus:

$$o_3 = 8\cdot0 \qquad 10^6d_3 = 400$$
$$s_2 = 14\cdot3 \qquad 10^6d_2 = 230$$

agreeing pretty well with my earlier data, where

$$s_3 = 8\cdot1 \qquad 10^3d_3 = 398$$
$$s_2 = 14. \qquad 10^6d_2 = 228$$

The subscripts here show the cycle to which the corona belongs, the 2d and 3d being producible here. The first cycle is very rarely obtainable; the fourth and fifth occur best in experiments with atmospheric air, not filtered, the coronas here being very crowded.

Brown University, Providence, R. I.

SCIENTIFIC INTELLIGENCE.

Miscellaneous Scientific Intelligence.

1. *Las Formaciones Volcánicas de la Provincia de Gerona;* by S. Calderon, M. Cazurro, and L. Fernandez-Navarro. Mem. R. Soc. Esp. Hist. Nat., vol. iv, 1907, pp. 159–489, 10 plates, 3 maps.—This is the report mentioned in the paper by the reviewer in the present number, and was received shortly after the final proofs had been returned. It is an excellent and detailed account of the volcanoes of Catalonia and will long remain the standard work on the subject. Cazurro gives a brief history and bibliography of the region, after which Calderon describes the general topographical and geological features of Catalonia and its volcanoes, and their relations to others in Spain. A list of Catalonian earthquakes is given by Cazurro, and the same writer describes in great detail the physical features of each volcano and flow, of which he enumerates more than fifty. Fernandez-Navarro describes the petrography of the rocks with much detail, finding them to be dominantly feldspar-basalts and nephelite-basalts, with some limburgites, tachylites, diabases, and others in very small amount. The work is illustrated by numerous cuts, with colored plates of rôck sections, and the maps add much to the value. The report is of great interest and is highly creditable to the Society and to the Commission to whom the investigation was entrusted. H. S. WASHINGTON.

2. *I Vulcani Attivi della Terra;* by G. Mercalli. Pp. 421, Milano, 1907 (U. Hoepli).—This volume gives a general account of the active volcanoes of the globe and, while intended primarily for Italian readers, it contains much matter of interest to foreign geologists. The author makes full use of his great knowledge and long study of Vesuvius, but also avails himself largely of others elsewhere. The structure and varied phenomena of active volcanoes are described systematically, the examples and illustrations being well chosen and widely scattered, and brief accounts are given of the most noteworthy eruptions. In a descriptive catalogue the author enumerates 415 active volcanoes. The causes of vulcanicity are briefly discussed and the author seems to favor the theory of Stübel. The volume is well and abundantly illustrated. H. S. W.

3. *Die Mineralien der Südnorwegischen Granitpegmatitgänge.* I. Niobate, Tantalate, Titanate and Titanonibate; von W. C. Brögger. Pp. 162, with 8 tables. Kristiania, 1906 (Jacob Dybwad).—The author's earliest studies on the minerals and rocks of Norway, and the extraordinary richness of the results which he has obtained, is so well known by all interested that it need not be discussed here. Mineralogists will rejoice that he has undertaken a comprehensive work describing the miner-

als occurring in the pegmatite veins of southern Norway. The first part has now been issued, which includes some of the rarest and most complex species,—namely, those belonging to the niobates, tantalates, titanates, and titano-niobates. The descriptions here given leave nothing to be desired and are accompanied by a series of plates, giving figures of the crystals of many species; there is also a map of the portion of Norway involved, showing the position of the localities.

4. *Das Problem der Schwingungserzeugung;* von Dr. H. BARKHAUSEN. Pp. iv + 113. Leipzig, 1907 (S. Hirzel).—The central idea of this book is that the production of oscillating electric currents may be regarded as due to the variation of resistance, inductance, or capacity in a circuit containing a steady E.M.F. In this way the author classifies all alternating current apparatus from the ordinary generator to the singing arc. He points out analogies between different forms of apparatus, and deduces some general conditions for stability and efficiency. The last section deals with mechanical oscillations and their relations to the electrical problem. H. A. B.

5. *Lehigh University, Astronomical Papers. Volume I. Part I. Results of Observations with the Zenith Telescope of the Sayre Astronomical Observatory from September 11, 1904, to September 1, 1905;* by JOHN H. OGBURN. Pp. 46 and Table. Published by the University, South Bethlehem, Pa., 1907.—This paper embraces the results of the first year of latitude observations with the new zenith telescope, the purchase of which was provided for in 1903 by Mr. R. H. Sayre with the general specification that it should be equal to the best in existence. The description of the telescope, its location, and the scheme of work are outlined in the preface. The instrument is located on the same meridian and 67·08 feet north of the instrument with which Professor C. L. Doolittle carried on his well-known variation of latitude work from 1876 to 1895.

The residuals from the adjusted latitudes show that the mean probable error of a single observation was $0''\cdot121$. The constant of aberration derived from the whole series for 1904–5 is $20''\cdot4645 \pm 0''\cdot01098$. The extreme variation of latitude shown is from $40° 36' 23''\cdot713$ on Feb. 21, 1905, to $40° 36' 24''\cdot007$ on Aug. 24, 1905. Plotting the final latitudes obtained at intervals of from three to five weeks and drawing a smooth curve between the points, it is seen that the final latitudes mostly lie not more than $0''\cdot01$ from the curve and in no case more than $0''\cdot04$ from it. When it is considered that these figures amount on the surface of the earth to but one foot and four feet respectively, the accuracy with which modern astronomy can follow the wanderings of the earth's axis within its body is perceived. The author is to be congratulated on the success of the arduous work of observation and reduction performed without assistance and in addition to the usual duties of college instruction. J. B.

OBITUARY.

ANGELO HEILPRIN, naturalist, explorer, and well-known writer and lecturer on geological and geographical subjects, died in New York City July 17th, after a long illness, in the 55th year of his age. A native of Hungary and a descendant of a cultivated and intellectual family, he was brought to this country while yet a small child by his father and received here his early education. In 1876 he went abroad and, in London, Paris, Geneva and other places, studied subjects chiefly of a geological and biological nature. In London he was awarded the Forbes medal for proficiency in geological work. In 1879 he returned to this country and the following year was appointed professor of invertebrate paleontology and geology at the Academy of Natural Sciences in Philadelphia and in 1883 executive curator of its museum, a post he held until 1892. He also filled the chair of geology in the Wagner Free Institute of Science, 1885 to 1890. During the last three years of his life he was lecturer on physical geography in the Sheffield Scientific School of Yale University.

Throughout his life, as opportunity offered, he engaged in active exploration in various parts of the world, making special studies of a geological and geographical character. Thus in 1886 he explored Lake Okeechobee, Florida ; in 1888 the Bermuda Islands ; in 1890 parts of South and Central America and Mexico, especially Yucatan, devoting attention particularly to the volcanoes. In 1891 he became interested in Peary's work and spent two summers in Greenland, leading the relief expedition in 1892. In 1896 he travelled in Morocco and Algeria studying the Atlas Mts. He also spent two summers in northern Alaska. His best known work is perhaps that connected with the eruptions of Pelée on Martinique in 1902, where he made a perilous ascent to see the volcano in activity. The results of his observations made during his travels he published in a number of books and magazine articles, and he also lectured extensively upon them. He was also a contributor to encyclopedic literature and wrote several popular works on geology. With his brother he edited Lippincott's New Gazetteer of the World.

During his life Heilprin accomplished a large amount of work and while this work was chiefly concerned with the popular rather than with the profounder aspects of science, it was none the less extensive and useful on this account. Men who have his ability to seize and present the essentials of scientific research and progress to the public in a clear and lucid manner by word and pen are uncommon, and this added to his energy and enthusiasm for exploration rendered him a man whose death, while still in the prime of life, is a serious loss in his chosen field of work. His wide knowledge, intellectual acquirements and varied talents, as well as his agreeable and friendly disposition, gained for him a large circle of friends, by whom he will be greatly missed. L. V. P.

Professor **JAMES MERRILL SAFFORD**, of Vanderbilt University, for many years state geologist of Tennessee, died on July 3 at the age of eighty-five years.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXIX.—*On the Corpuscular Rays produced in different Metals by Röntgen Rays;* by C. D. COOKSEY.

SAGNAC[*] has shown that when Röntgen rays fall on a substance this substance gives off rays very like the Röntgen rays producing them. Barkla[†] has investigated these rays and found that those from gases and light solids were almost identical in penetrating power with the primary rays producing them, while those from heavy solids such as lead, zinc, copper, etc., are much less penetrating than the primary. He also finds that the rays from gases and light solids vary in penetrating power as the primary varies, but those from the heavy solids vary very little for a large variation in the penetrating power of the primary. All these secondary rays are probably pulses in the ether like Röntgen pulses, though the secondary pulses may vary greatly in thickness from the primary producing them; heavy metals giving out much thicker pulses than the primary. Hereafter in referring to this type of rays we shall speak of it as "Secondary Röntgen Rays."

Beside this type of rays, Townsend,[‡] Dorn,[§] and Curie and Sagnac[‖] have shown that heavy metals, when Röntgen rays fall on them, give out a very absorbable type of radiation, consisting in part of negatively charged particles. The velocity of these particles is of the order of that of the cathode particles in a highly exhausted tube. Bestelmeyer[¶] has investigated by a photographic method the corpuscular rays produced when Röntgen rays fall on a platinum plate and found that they have velocities from 0·195 to 0·327 of the velocity of light. He shows

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[*] Annales de Chimie et de Physique, xxii, p. 493, 1901.
[†] Phil. Mag., xi, p. 812, 1906.
[‡] Proc. Camb. Phil. Soc., x, p. 217, 1899.
[§] Abhand. d. naturf. Ges. zu Halle, xxii, p. 39, 1900.
[‖] Journal de Physique (4), i, p. 39, 1902.
[¶] Ann. der Physik, xxii, p. 429, 1907.

that the velocity does not depend at all on the intensity, but does depend on the penetrating power of the primary Röntgen rays producing them; the harder or more penetrating primary rays producing higher velocities in the corpuscular rays. From some results published by Prof Bumstead* on the heating effects produced when Röntgen rays are absorbed by different metals, I was led to investigate this last type of rays, which

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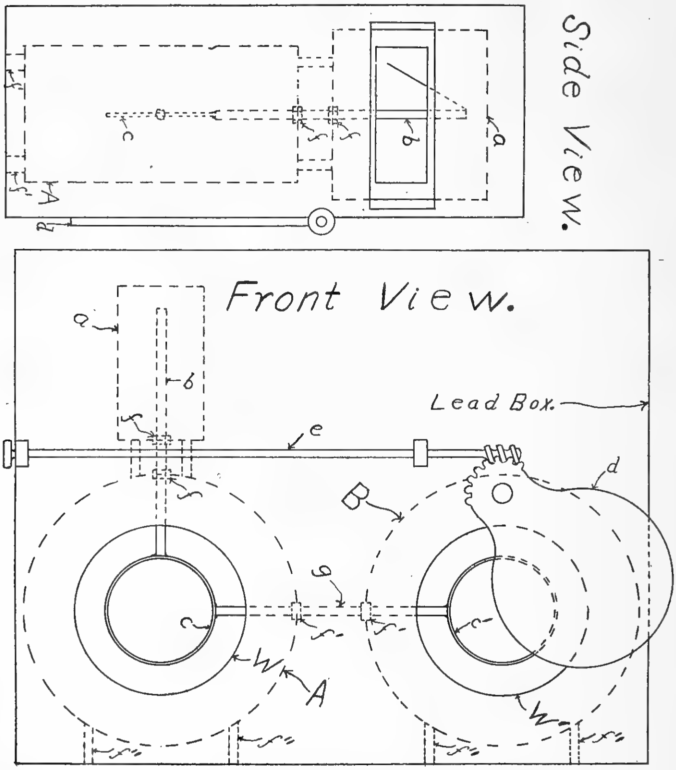

we shall refer to as "Corpuscular Secondary Rays." with a view to determining the relative number produced in different metals for equal absorptions of the same beam of Röntgen rays.

Apparatus.

It was decided to investigate these corpuscular secondary rays by means of the ionization which they produce, but owing to the great ease with which they are absorbed it was found that the thinnest aluminium which could be obtained would stop all but a few of these rays. It was necessary, therefore, to

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* This Journal, xxi, Jan., 1906.

let the metal to be examined form one end of the ionization chamber, and let the primary beam of Röntgen rays pass through the ionization chamber and fall on the metal. Then all the corpuscles coming from the metal would pass into the ionization chamber, producing ions in the air, and if the ionization due to the Röntgen rays was known, that due to the corpuscular secondary rays could be deduced. But it was found that the ionization due to the secondary rays was such a small fraction of that due to the primary, that this method was not accurate.

The apparatus as finally used and shown in fig. 1 was designed to eliminate the ionization due to the primary rays. Two ionization chambers, "A" and "B," were used, consisting of hollow brass cylinders about 5^{cm} long and about 10^{cm} in diameter, each encased in thick lead. The cylinders were mounted on vulcanite insulators, "f″," with their axes in a horizontal plane and parallel to each other and about 14^{cm} apart. Above the cylinder "A" and supported on it was a gold leaf electroscope consisting of a lead box, "a," with windows for observing the gold leaf, and a narrow strip of gold leaf hung from the upper end of a vertical brass rod, "b." The brass rod, "b," passed through the bottom of the electroscope box into the interior of "A," being insulated from "A" and "a" by vulcanite rings, "f," and its lower end terminating in a ring, "c," about 4^{cm} in diameter, made of fine brass wire. This ring was placed concentric with the axis of "A" and in a vertical plane parallel to and midway between the ends of "A." A brass rod, "g," insulated from "A" and "B" by vulcanite rings, "f′," connected "c" to a similar ring, "c′," similarly placed with respect to "B."

The Röntgen ray bulb was about 60^{cm} in front of the two ionization chambers with its target midway between their axes, so that the beam would pass through each cylinder longitudinally. The ends of "A" and "B" on the side toward the tube were covered with very thin aluminium leaf, and the rear end of "B" was covered in a similar manner. The rear end of "A" was left open, but provided with clamps by means of which disks of the metal to be tested could be clamped over this end.

Both cylinders stood in a thick lead box, open at the rear, and provided with windows in the side for observing the electroscope. In the front of the box were two circular openings, "W" and "W′," corresponding respectively with the ends of "A" and "B." Both openings were just small enough to prevent the beam of Röntgen rays from falling on the walls of either cylinder. Lead screens with different sized holes bored in them could be hung in front of "W" to control the amount of rays entering "A." A shutter, "d," placed over "W′" and controlled by a screw "e," gave a very fine adjustment to the size of this opening.

In use the lead box, chamber "A," and electroscope case were all connected to earth; the chamber "B" was kept at a constant potential of about 400 volts, and the gold leaf, rings "c" and "c′," and connections were brought initially to about 200 volts. This made a difference of potential between "A" and "c" of 200 volts, and between "B" and "c′" of minus 200 volts. The fall of the gold leaf due to the ionization in the chamber "A" could be read with a microscope having a micrometer eyepiece. If the Röntgen rays were turned on, and the size of the opening, "W′," properly adjusted so that there should be the same amount of ionization in "B" as in "A," the flow of electricity from "c" to "A" would be just equal and opposite to the flow from "B" to "c′," and there would be no motion of the gold leaf. In this way the ionization due to the Röntgen rays and any natural leak could be eliminated.

In order to test a given metal, a disk of the metal was made to fit over the rear end of the chamber, "A." This disk was then clamped over the end with a thin disk of aluminium interposed between it and the primary rays. (Aluminium was used because it gives off hardly any of the corpuscular secondary rays, and there do not enough of the secondary Röntgen rays come off from a thin sheet to produce any appreciable ionization.) The Röntgen tube was then excited, and the shutter, "d," adjusted till there was no motion of the gold leaf. The aluminium screen was then removed, and the time taken for the gold leaf to fall over a given number of scale divisions measured. The fall of the gold leaf was then due to the ionization produced by the secondary rays alone from the metal.

Preliminary experiments showed that an appreciable amount of the ionization in the chamber, "A," was due to secondary rays of the Röntgen type, and it was therefore necessary to find what proportion of the ionization was due to corpuscular secondary rays, and what due to secondary Röntgen rays. For this end the absorption of the secondary rays in thin sheets of aluminium leaf was measured: The primary rays were first eliminated by balancing the apparatus with a sheet of aluminium over the metal about 1^{mm} thick, sufficient to stop all the secondary rays from the metal, but not thick enough to give off any appreciable secondary rays itself that would be absorbed in the ionization chamber. The ionization was then measured which was due to the secondary rays from the bare metal and to those which got through successive sheets of aluminium leaf about ·001^{mm} thick. Curves were then plotted, having for abscissae the thickness of aluminium in millimeters, and for ordinates the ratios of intensity of ionization after absorption to the intensity before absorption.

Since the penetrating power of the secondary rays depends upon that of the primary rays, it was necessary to keep the Röntgen ray tube very constant, and to have some standard of the penetrating power of the primary rays. A self-adjusting tube was used which was found to be fairly constant. The standard of penetrating power or hardness of the primary rays was arbitrarily taken as the ratio of the ionization produced by the rays after passing through a sheet of aluminium 0·82^{mm} thick to that produced by the unobstructed rays. This ionization was measured in the chamber, "A," after connecting the chamber, "B," to earth, and entirely closing the opening, "W′." The hardness of the primary rays was varied by varying the length of the spark gap in the regulator, and by filtering out the soft rays by a thin iron screen.

Absorption curves were plotted for the secondary rays from lead, zinc, nickel, copper, tin, and silver for two different degrees of hardness of the primary rays. In the case of lead four curves were plotted for four different hardnesses of the primary rays. The curves are represented by the full lines passing through the circles and crosses. In every case the circles represent rays produced by soft, and the crosses rays by hard, primary rays. The following tables give the data from which the curves were plotted. Tables 1 and 2 refer to lead, 3 to zinc, 4 to copper, 5 to nickel, 6 to tin, and 7 to silver.

TABLE I.

Hardness=0·62				Hardness=0·89		
I	II	III	IV	II′	III′	IV′
0	1·00	1·00	0	1·00	1·00	0
·001	0·29	0·22	—0·66	0·49	0·45	—0·35
·002	0·15	0·07	—1·15	0·24	0·19	—0·72
·003	0·10	0·02	—1·70	0·11	0·06	—1·22
·004	0·09	0·01	—2·00	0·08	0·03	—1·52
·008	0·07	- -	- -	0·03	- -	- -

TABLE II.

Hardness=0·61				Hardness=0·95		
I	II	III	IV	II′	III′	IV′
0	1·00	1·00	0	1·00	1·00	0
·001	0·32	0·24	—0·62	0·44	0·40	—0.40
·002	0·19	0·11	—0·96	0·25	0·21	—0·68
·003	0·12	0·03	—1·52	0·12	0·11	—0·96
·004	0·10	0·02	—1·70	0·09	0·04	—1·40
·008	0·07	- -	- -	0·02	- -	- -

Table III.

	Hardness=0·66			Hardness=0·97		
I	II	III	IV	II′	III′	IV′
0	1·00	1·00	0	1·00	1·00	0
·001	0·55	0·31	—0·51	0·49	0·41	—0.39
·002	0·45	0·16	—0·80	0·33	0·19	—0·72
·003	0·37	0·05	—1·30	0·20	0·08	—1·10
·004	0·38	0·03	—1·52	0·21	0·04	—1·40
·008	0·29	--	--	0·11	--	--
·012	0·26	--	--	0·09	--	--

Table IV.

	Hardness=0·68			Hardness=0·78		
I	II	III	IV	II′	III′	IV′
0	1·00	1·00	0	1·00	1·00	0
·001	0·42	0·23	—0·64	0·52	0·44	—0·36
·002	0.33	0·11	—0·96	0·29	0·19	—0·72
·003	0·29	0·07	—1·15	0·19	0·07	—1·15
·004	0·29	0·04	—1·40	0·23	0·03	—1·52
·008	0·23	--	--	0·10	--	--
·012	0·22	--	--	--	--	--

Table V.

	Hardness=0·64			Hardness=0·82		
I	II	III	IV	II′	III′	IV′
0	1·00	1·00	0	1·00	1·00	0
·001	0·45	0·24	—0·62	0·33	0·32	—0·49
·002	0·40	0·11	—0·92	0·24	0·14	—0·85
·003	0·33	0·05	—1·30	0·13	0·04	—1·40
·004	0·30	0·02	—1·70	0·10	0·01	—2·00
·008	0·24	--	--	0·09	--	--
·012	0·19	--	--	--	--	--

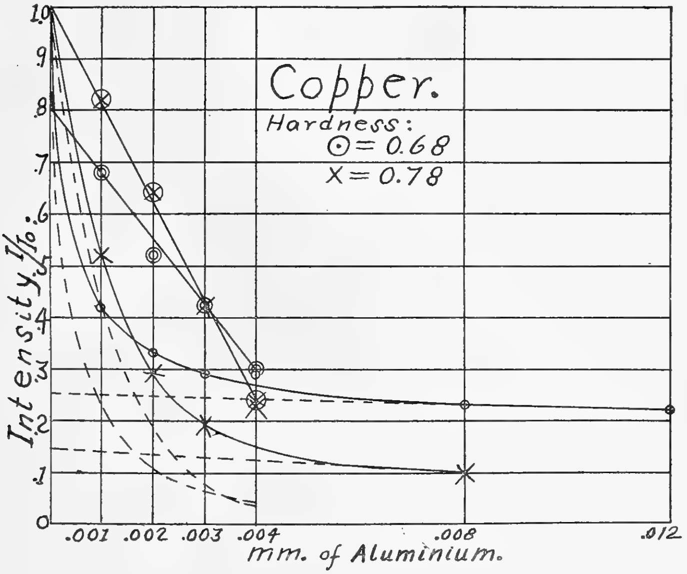
Table VI.

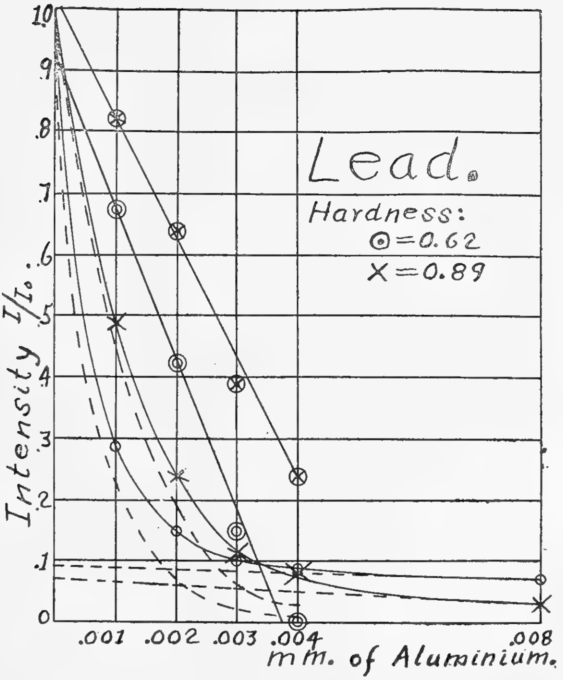
	Hardness=0·59			Hardness=0·95		
I	II	III	IV	II′	III′	IV′
0	1·00	1·00	0	1·00	1·00	0
·001	0·41	0·39	—0·41	0·50	0·43	—0·37
·002	0·18	0·15	—0·82	0·29	0·19	—0·72
·003	0·11	0·05	—1·30	0·19	0·08	—1·10
·004	0·04	0·02	—1·70	0·14	0·03	—1·52
·008	0·04	--	--	0·11	--	--
·012	--	--	--	0·10	--	--

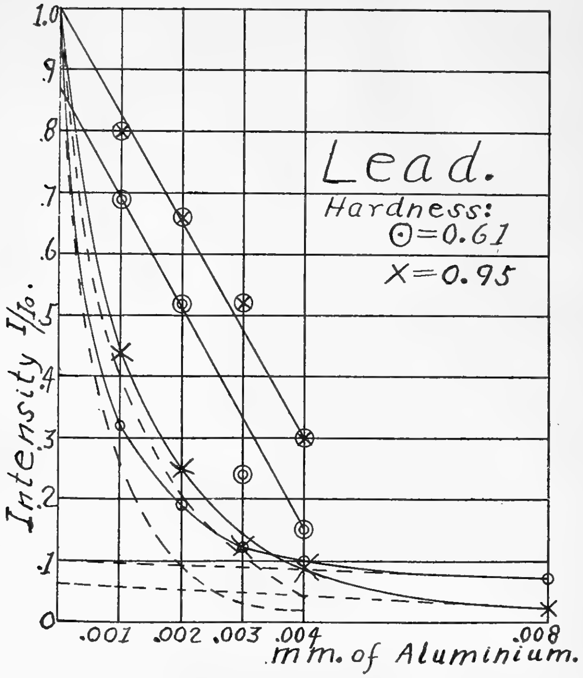
Table VII.

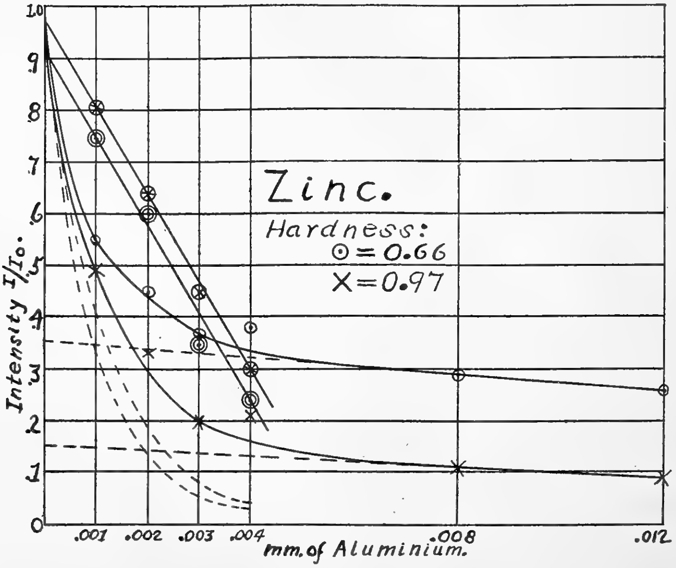
	Hardness=0·60			Hardness=0·90		
I	II	III	IV	II′	III′	IV′
0	1·00	1·00	0	1·00	1·00	0
·001	0·44	0·37	—0·43	0·52	0·41	—0·39
·002	0·17	0·10	—1·00	0·26	0·16	—0·80
·003	0·14	0·04	—1·40	0·20	0·07	—1·15
·004	0·12	0·02	—1·70	0·17	0·04	—1·40
·008	0·11	--	--	0·13	--	--
·012	0·09	--	--	0·12	--	--

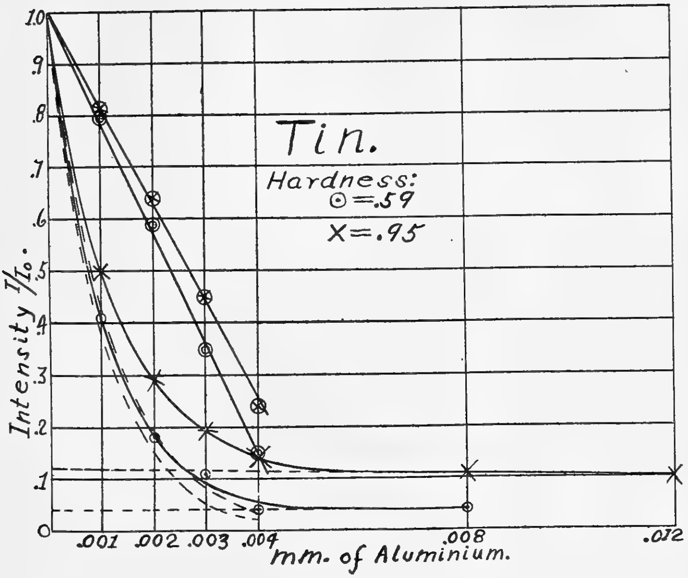
Column I of the tables gives the thickness of aluminium in millimeters; columns II and II′ give the intensity of the secondary rays after passing through the corresponding thickness of aluminium for the two hardnesses respectively, the intensity of the rays from the bare plate being always taken as unity.

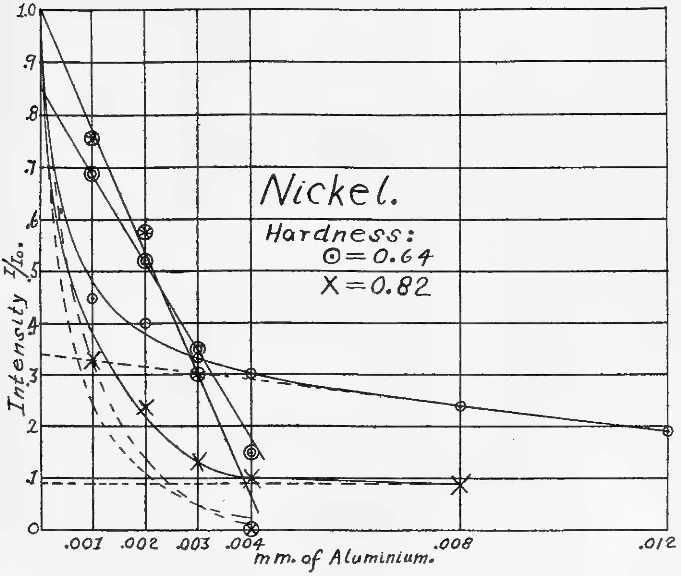




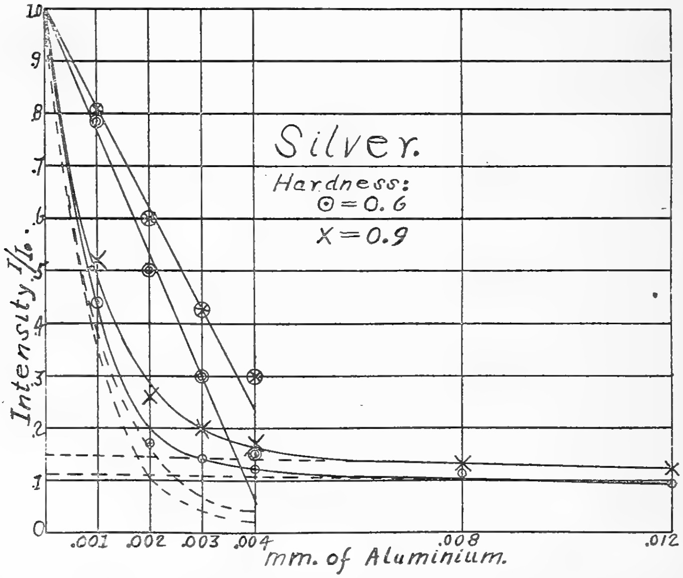

Lead.
Hardness:
⊙=0.61
X=0.95
Intensity I/I₀.
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
.001
.002
.003
.004
.008
mm. of Aluminium.


Zinc.
Hardness:
⊙=0.66
X=0.97
Intensity I/I₀.
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
.001
.002
.003
.004
.008
.012
mm. of Aluminium.


Tin.
Hardness:
⊙=.59
X=.95
Intensity I/I₀.
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
.001
.002
.003
.004
.008
.012
mm. of Aluminium.


Nickel.
Hardness:
⊙=0.64
X=0.82
Intensity I/I₀.
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
.001
.002
.003
.004
.008
.012
mm. of Aluminium.

In all the curves there is a very sudden drop up to the first three or four sheets of aluminium, and then the curves fall off more slowly. The first part of the curve up to the first three or four sheets of aluminium is undoubtedly due, for the most part, to the corpuscular secondary rays, while beyond this point the corpuscular rays are practically all absorbed and there remain only the secondary rays of the Röntgen type. As has been said before, these corpuscles come off with velocities comparable with the velocities of the cathode particles in a highly exhausted tube; say between 10^9 and $10^{10 \text{cms}}$/sec. Seitz* has investigated the absorption of cathode rays driven by 20,000 volts, corresponding to about $9 \times 10^{9 \text{cms}}$/sec., and finds that they will penetrate aluminium about $\cdot 002^{\text{mm}}$ thick, the fraction which gets through being about 0·16. A little further on we shall show that this is about the order of absorption for the rays constituting the first part of the curves under discussion. It is this agreement which leads us to believe that the first part of the curves is largely due to the corpuscular secondary rays.



With the exception of zinc and nickel the first part of all the curves due to the secondary rays produced by the hard primary rays lies above those produced by the soft primary rays. This would be expected from the results of Bestelmeyer, before mentioned, where the corpuscles produced by harder primary rays had higher velocities than those produced by the softer

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* Annalen der Physik, xii, p. 860, 1903.

primary rays. The fact that in the case of lead and copper the curves cross each other, and that in the case of zinc and nickel the harder lies below the softer, would seem to show that for these metals the harder primary rays produced less penetrating secondary rays. But there are several reasons to account for this. In the first place, for zinc, nickel, and copper a comparatively large proportion of the secondary rays consists of those of the Röntgen type which are much more penetrating than the corpuscular rays, and in the case of lead there is an appreciable quantity of these rays present. Owing to the shortness of the ionization chamber, "A," a considerable proportion of the secondary Röntgen rays doubtless passed entirely through the chamber, producing very few ions. If now the hard primary rays produce secondary rays of the Röntgen type more penetrating than those produced by the softer primary rays, a *larger* proportion of these penetrating secondary rays would pass through the chamber, without producing ions, than of the less penetrating ones. Thus the less penetrating rays would produce more ionization, and the curve corresponding to them would lie higher than the curve corresponding to the more penetrating secondary rays. This reasoning would not apply to the corpuscular secondary rays, since the most penetrating of these are absorbed by a few millimeters of air. But in all but two cases the part of the curve corresponding to the corpuscular rays shows greater penetration when the corpuscles are produced by hard primary rays than by soft. In the two exceptions, namely zinc and nickel, there are so many of the Röntgen type of secondary rays present that they would obscure the effect of the corpuscular type, and the above reasoning would again apply.

In order to show more clearly the variation of penetrating power of the corpuscular secondary rays for different hardnesses of the primary, I have subtracted from the whole curve the amount, shown by the broken straight lines, which seems to be about the proportion of secondary *Röntgen* rays present; and again plotted the curves after reducing the initial intensity to unity. These are shown by the broken curved lines. The intensities are given in columns III and III′ of tables 1 to 7. In every case the curve corresponding to hard primary rays lies above that for the soft, except in nickel and copper, where they cross very near the last point. This is probably due to not allowing enough for the secondary Röntgen rays.

If we consider the amount of the rays left unabsorbed after passing through $\cdot 002^{\mathrm{mm}}$ of aluminium, as shown by these latter curves, it is found to be between 0·10 and 0·20 of the total amount of corpuscular rays coming off. This agrees very well with the absorptions found by Seitz for cathode rays of high velocity, and leads us to believe, as mentioned above, that we are dealing with corpuscular secondary rays of velocities comparable with those measured by Seitz.

In subtracting the secondary Röntgen rays, where the points lie badly off the curve, the curve was taken in preference to the point. Attention should be called to the points for zinc and copper corresponding to the intensity of the rays after passing through four sheets of aluminium. These points lie as high or higher than the corresponding ones for three sheets, and it is due in all probability to an error in measuring the thickness of the fourth sheet of aluminium. A different sheet was used for the other metals, but I have not had time to repeat the two curves in question.

An attempt was made to see if the absorption of the corpuscular rays followed an exponential law. To this end the common logarithms of the points (given in columns III and III′ of the tables) were plotted. The origin was taken at the point on the axis of ordinates corresponding to unit intensity of the secondary rays, and the logarithms of the intensity plotted down, each tenth division for the intensity being equal to two tenths for the logarithms. The values of the logarithms are given in columns IV and IV′ of the tables.

For the more penetrating primary rays the points all lie pretty well on the straight line passing through the origin. This would seem to show that the corpuscular secondary rays produced by hard primary rays were very homogeneous in regard to velocities and were absorbed according to an exponential law. When we come to consider the soft rays we find that if we neglect the origin, the points lie fairly well on a straight line which cuts the axis of ordinates below the origin. This in connection with the absorption curves for the corpuscular rays leads us to the conclusion that the soft primary rays give rise to corpuscular rays between 70 per cent and 80 per cent of which are slow moving corpuscles which are almost all absorbed in the first ·001$^{\mathrm{mm}}$ of aluminium, and the rest faster moving corpuscles which are absorbed according to an exponential law; but in all cases, except nickel and copper, these corpuscles are slower moving than those produced by the hard primary rays. These exceptions, I am inclined to think, are again due to not taking sufficient account of the secondary Röntgen rays present.*

In the case of tin and silver the points for the rays produced by the soft primary rays lie on a straight line passing through the origin, showing that the corpuscular rays from these metals are very homogeneous even though produced by soft primary rays.

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* The writer hopes to investigate this question further by using a shorter ionization chamber.

TABLE VIII.

	0	·001	·002	·003	·004	·008	·012
I	3·4	6·8	1·8	2·6	3·8	4·8	5·2
II	3·8	7·8	2·0	2·8	3·4	5·0	5·4
III	4·0	7·6	2·0	3·2	4·4	5·8	6·6
Average	3·73	7·40	1·93	2·86	3·86	5·2	5·7
Ratio	1·00	0·50	0·29	0·19	0·14	0·11	0·10

Table 8 has been inserted to give an idea of the actual observations as taken. It is for tin for a hardness of the primary rays of 0·95. The numbers in the top row give the thickness of aluminium in millimeters. The next three rows give the three sets of observations of the time in seconds for the gold leaf to fall over a constant number of scale divisions; these values being inversely proportional to the intensity of ionization. The gold leaf moved so rapidly for the unabsorbed rays and so slowly after the rays had been partially absorbed that the same number of scale divisions could not be used for all thicknesses of aluminium. The times in the first two columns are for a fall of forty scale divisions, while in the remaining five columns the times are for a fall of five scale divisions from the same zero point. A separate observation showed that for a constant intensity of ionization the fall for forty divisions was to the fall for five in the ratio of 6·7 to 1. The last row gives the ratio of intensity of ionization to the initial intensity after reducing the times of fall to the same number of scale divisions. It was found that owing to asymmetry of the apparatus a very small change of hardness in the primary rays would disturb the balance enough to account for a large part of the errors, though great care was taken to see that the ionization due to the primary rays was properly balanced out before each separate observation. To show the magnitude of this error, suppose that the time observed for the secondary rays to produce a fall of five scale divisions was five seconds, it was sometimes found that after an observation the balance had been disturbed sufficiently for the primary rays alone to produce a fall one way or the other of five divisions in eighty seconds, which would tend to make the fall observed for the secondary rays too large or two small by about 6 per cent.

After this investigation of the character of the secondary rays coming off from different metals, the way was open to obtain some idea of the relative number of corpuscles produced in different metals for equal absorptions of the primary Röntgen rays. The method of procedure was nearly the same as that already described. The absorption curves showed that essentially all the corpuscles were stopped in the first ·003$^{\text{mm}}$ to ·004$^{\text{mm}}$ of aluminium, while practically all the secondary

Röntgen rays were able to get through. In order to compare two metals, say lead and zinc, the lead was covered with about $\cdot004^{mm}$ of aluminium and clamped to the chamber, "A". The Röntgen rays were then turned on and the leak balanced as before; but this time not only was the ionization due to the primary rays eliminated, but also that due to all the secondary Röntgen rays which got through the aluminium. After the system was balanced, the aluminium was removed, and the ionization measured which was due to all the copuscular secondary rays which escaped from the lead. Then the zinc was tested in the same way, care being taken to keep the intensity and hardness of the primary rays constant throughout the comparison. This method was pursued with all the metals; lead was taken as the standard, and all the other metals compared to it separately in order that the intensity and hardness of the primary rays might be the same throughout the comparison. Hardnesses were used as nearly as possible the same as those used in the first experiments.

It might be well here, by the way of parenthesis, to give some idea of the hardness of the tube used. The softest rays obtainable were those equal to a hardness of about 0·4 in the arbitrary scale, the vacuum being down to about the point where Röntgen rays begin, the green fluorescence on the walls of the tube just beginning to show. It was found impossible to keep the tube as constant as necessary with so low a vacuum, the vacuum changing very rapidly at this point; therefore a hardness of about 0·6 was the softest used, and this could be kept very constant. A thin iron screen was always used when hard rays were wanted, but this does not really make the rays harder, only cutting out the softer pulses in the beam, and making the *proportion* of hard pulses greater. As well as using the iron screen, the tube was run for a while with a longer spark gap in the regulator and with higher potential from the coil. This did make the rays harder, as the cathode particles producing them traveled faster in the tube.

To resume: the above comparison of different metals gave only the relative ionization due to the corpuscles which escaped from the metals, but not the number of corpuscles produced in the metal by the primary Röntgen rays. This latter can be roughly calculated as follows:

The intensity of the primary rays after passing through a thickness x of the metal, if we assume that for thin layers the rays are absorbed exponentially, is $I_0e^{-\lambda x}$, where λ is the coefficient of absorption of the primary rays in the metal. The number of corpuscles produced per cm. of path of the primary rays is proportional to the intensity of the primary. The number produced in a layer of the metal between x and $x+dx$ is proportional to $I_0 e^{-\lambda x} dx$. If k' be the coefficient of absorption of the corpuscular rays in the metal, the number which emerge from this layer will be proportional to $I_0 e^{-\lambda x} e^{-k'x} dx$, and if we call the total number of corpuscles emerging from the metal N′, we have that

$$N' \propto I_0 \int_0^\infty e^{-(\lambda+k')x} dx$$

$$\propto \frac{I_0}{\lambda+k'}$$

If we let the total number of corpuscles generated in the metal be N, then

$$N \propto I_0 \int_0^\infty e^{-\lambda x} dx$$

$$\propto \frac{I_0}{\lambda}$$

Therefore

$$N \propto \frac{\lambda+k'}{\lambda} N'$$

or

$$\propto \left(1+\frac{k'}{\lambda}\right) N'$$

Since the corpuscular rays are much more easily absorbed than the Röntgen rays producing them, the quantity $\frac{k'}{\lambda}$ will be very large compared to unity, and we can say

$$N \propto \frac{k'}{\lambda} N'$$

N′ is not, however, directly proportional to the intensity of the ionization measured in the ionization chamber. To find what relation the ionization measured bears to N′ we must take into consideration the absorption of the corpuscles in air, and the number of ions produced by a corpuscle per cm. of path for different velocities. For the range of velocities encountered in these experiments, however, I think we are justified in assuming that the corpuscles from all the metals produce the same specific ionization, for the following reason.

Durack* has measured the specific ionization produced by Lenard rays having velocities of about 4×10^9 cms./sec., and that produced by the deflectible Becquerel rays having velocities of from $2{\cdot}4 \times 10^{10}$ to $2{\cdot}8 \times 10^{10}$ cms./sec. In the first case he finds the specific ionization equal to about 0·4 and, in the second, to about 0·17 ions per corpuscle per cm. of path; a fall of about

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* Phil. Mag. (6) iv, 29, 1902; and v, 550, 1903.

57 per cent for an increase of velocity of about 78 per cent. Considering the slight variation in velocity with which the corpuscles come off from the different metals in our experiments, as shown by the variation in absorption, it seems safe to assume that the specific ionization due to the corpuscles from the different metals under consideration is approximately the same for all the metals.

To find the relation between N′ and the ionization measured let n be the number of ions produced by one corpuscle per cm. of path, and let K be the coefficient of absorption in air for the corpuscles from any metal. Then the number of ions produced in a layer of air between x and $x+dx$ is $n\,N'e^{-Kx}dx$, and the total number of ions produced is

$$nN'\int_0^{\infty} e^{-Kx}\,dx=\frac{nN'}{K}$$

This is proportional to the quantity measured, say Q. Therefore

$$N'\propto\frac{K\,Q}{n}$$

In comparing the number of corpuscles produced in any metal with the number produced in lead, we have:

The ratio of the number of corpuscles produced in any metal to the number produced in lead for equal absorptions and equal intensities of the primary rays is equal to

$$\frac{\frac{k'}{\lambda}\,K\;Q}{\frac{k'_l}{\lambda_l}\,K_l\;Q_l}=\frac{N}{N_l}$$

The coefficient of absorption for the corpuscular rays in passing through any substance is proportional to the density of the substance. We have found the absorption of the corpuscular rays in aluminium; let the coefficient of this be called k. Let ρ be the density of any substance, and ρ' the density of aluminium; then the above reduces to

$$\frac{N}{N_l}=\frac{\lambda_l\;k^2\;\rho\;Q}{\lambda\;k^2_l\;\rho_l\;Q_l}$$

The values of λ were measured for the different metals used. The values of k for the different metals are proportional to the slopes of the straight lines plotted with the curves in the cases where the lines pass through the origin. In the case of the secondary rays produced by the soft primary rays, where the straight lines do not pass through the origin, the following method for finding k was used. The slope of the straight line passing through the origin and the first point was multiplied by the percentage of rays absorbed by the first layer of aluminium, and the slope of the line passing through the first and remaining points was multiplied by the percentage of rays remaining unabsorbed by the first layer, and the sum of the two numbers thus found divided by 100. This seems to me to give the fairest value of *k* when the rays are not homogeneous.

TABLE IX.

Metal	Hard	k	$\frac{\rho}{\rho_l}$	$\frac{\lambda_l}{\lambda}$	$\frac{k}{k_l}$	$\frac{k^2}{k_l^2}$	$\frac{Q}{Q_l}$	$\frac{N'}{N_l'}$	$\frac{N}{N_l}$
Lead	0·61	5·9	1·00	1·00	1·00	1·00	1·00	1·00	1·00
"	0·92	3·7							
Silver	0·52	4·6	0·93	2·0	0·78	0·61	0·52	0·41	0·59
"	0·90	3·8		2·0	1·03	1·10	0·77	0·79	1·60
Nickel	0·59	5·5	0·79	1·4	0·93	0·87	0·36	0·33	0·35
"	0·94	4·9		1·5	1·30	1·70	0·35	0·46	0·70
Tin	0·59	4·2	0·65	1·1	0·71	0·51	0·64	0·55	0·23
"	0·95	3·6		1·0	0·97	0·94	0·75	0·73	0·46
Zinc	0·66	4·5	0·63	1·5	0·76	0·58	0·41	0·31	0·22
"	0·80	3·7		1·9	1·00	1·00	0·35	0·35	0·42
Copper	0·63	5·5	0·79	1·3	0·93	0·87	0·39	0·36	0·35
"	0·82	3·7		1·6	1·00	1·00	0·33	0·33	0·42

Table 9 gives the values of the ratios of the different quantities in the formula. The absolute values of *k*, given in the second column, are not the true coefficients of absorption, but the absorption per $0·01^{\mathrm{mm}}$ of aluminium calculated from the common logarithms and not the natural logarithms; but as *k* comes into the formula only as a ratio, the other constants cancel. The numbers after the metals in the first column denote the hardness of the primary rays used on the metal and on lead when the two were compared. The seventh column gives the ratio of intensity of ionization produced by the corpuscular secondary rays from the different metals to that which was due to the rays from lead, as measured experimentally for the different hardnesses given. The numbers in the eighth column are the ratios of the number of corpuscles which get out of the different metals to those which get out of lead. The numbers in the last column of the table represent the ratios of the total number of corpuscles produced in the metals to the number produced in lead for equal absorptions of the primary rays of equal intensity, as calculated from the formula.

It will be seen at once that, in all cases, this ratio is larger for the harder primary rays, in fact in silver the harder primary rays produce more corpuscles than in lead. For both hard and soft primary rays fewer corpuscles are produced, the less dense the metal. In the case of copper and nickel, which have the same density, the ratios are the same in the case of the soft primary rays; for the hard primary rays the ratio is much smaller for copper than for nickel, but it will be noticed that the hardness of the primary rays used on copper was considerably less than for the rays used on nickel. In the case of tin and zinc, which have nearly the same density, and on which primary rays of nearly the same hardness were used, we find the corresponding ratios nearly equal. In the case of silver, which is only slightly *less* dense than lead, there are much fewer corpuscles produced than in the lead by the soft primary rays, but the hard primary rays seem to produce more in the silver than in the lead.

It will be noticed in the case of nickel, zinc, and copper for the hard primary rays, and in silver for both soft and hard rays, that N/N_l is larger than N'/N_l'. This means that of the total number of corpuscles produced a less proportion escapes from these metals than from lead, which would not be expected since the corpuscles should be more absorbed in lead, owing to its greater density, than in the other metals. But reference to the values of $\frac{\lambda_l}{\lambda}$, the ratio of the absorption of the primary rays in lead, to that in the other metals, will show that the hard, and in the case of silver also the soft, primary rays are absorbed to a much greater extent in the lead than in the above mentioned metals; while the corpuscular rays coming from lead for hard primary rays possess nearly the same penetrating power as those from zinc and copper, and greater penetrating power than those from silver and nickel, as can be seen from the values of k/k_l. Therefore for equal absorptions of the primary rays the corpuscles must be produced much nearer to the surface in lead than in the other metals, and consequently a greater proportion of the number produced will escape from the lead than from the other metals, notwithstanding the fact that the corpuscles are more easily absorbed in lead owing to its greater density.

In the case of the soft primary rays, except for silver and nickel, the value of N/N_l is less than the value of N'/N_l'. But the *soft* primary rays are absorbed nearly as much by the other metals as by lead, and therefore the corpuscles will come from as near the surface in one as in the other, and, the density of lead being the greatest, more will get out of the other metals in proportion to the number produced than out of lead. In the case of silver we see that the absorption of the primary rays in lead is again much the greater. Nickel is the only other exception to the above, while zinc, which is more transparent to the primary rays in comparison to lead than nickel is, follows the rule; but a comparison of the absorption coefficients for the corpuscular rays will show that the corpuscles from lead, due to soft primary rays, are nearly as penetrating as those from nickel and much less penetrating than those from zinc. This should easily account for the exception.

Summary.

The results from these experiments may be summarized as follows:—

1. The velocities found from the absorption in aluminium of the corpuscular secondary rays produced when Röntgen rays fall on heavy metals are in good agreement with the velocities found by other investigators, for all the metals considered.
2. The more penetrating primary rays produce more penetrating corpuscular secondary rays.
3. For the more penetrating primary rays used the corpuscular rays from all the metals tested, with the exception of nickel, possessed nearly equal penetrating power; while for the less penetrating primary rays the penetration of the corpuscular rays varied considerably for the different metals, those from lead being the least penetrating.
4. The corpuscular rays produced by hard primary rays are very homogeneous and are absorbed according to an exponential law. Those produced by soft primary rays are not homogeneous, except for tin and silver, but consist of a large number of corpuscles which are absorbed in the first $\cdot 001^{\mathrm{mm}}$ of aluminium, and a smaller number which are not so easily absorbed.
5. In all the metals tested, with one exception, the ratio of the number of corpuscles produced in the metal to the number produced in lead for equal absorptions of the primary rays was greater for metals of greater density. In silver, however, the hard primary rays produced more corpuscles than in lead, which has the *greater* density.
6. The ratio N'/N_l' depends partly on the penetrating power of the corpuscular rays and to a great extent on the ratio of the absorption coefficients of the primary rays in lead and the metal compared with it. Where the primary rays are absorbed to a much greater extent in lead than in the other metal, the corpuscles will be produced much nearer to the surface in lead, and consequently more will escape from the lead, if the corpuscles from the lead are not too much less penetrating than those from the other metal. A good instance of this is silver, where more corpuscles are produced than in lead by the hard primary rays, but yet more get out of the lead than the silver.

If the energy of the corpuscular secondary rays is due, as Prof. J. J. Thomson* has suggested, to an explosion of the atom and not directly to the energy in the primary pulse, it is hard to explain why the more penetrating primary rays give rise to corpuscles of higher velocity than the softer rays do; while the intensity of the primary rays makes no difference in their velocity. The author has been unable to explain this variation in velocity with the nature of the primary pulse, but hopes that further experiments, with modifications in the apparatus, may throw more light on the subject of these corpuscular rays.

It gives me great pleasure to close by expressing my thanks for the valuable advice received from Prof. H. A. Bumstead, at whose suggestion this work was begun.

Sheffield Scientific School of Yale University,
New Haven, July, 1907.

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*Conduction of Electricity through Gases, 2d ed, p. 320.

Art. XXX.—*Description of a New Species or Sub-species of Hercules Beetles from Dominica Island, B. W. I., with notes on the habits and larvæ of the common species and other beetles. Brief Contributions to Zoology from the Museum of Yale University, No. LXVII;* by A. Hyatt Verrill.

While collecting a very large series of *Dynastes Hercules*, consisting of several hundred specimens, during the past two years in Dominica, my attention has been frequently attracted by the wide variation in coloration and markings exhibited by this species. As a general rule, however, the shade of ground-color, as well as the extent, shape and number of markings, vary so interminably and so grade into one another that it is impossible to separate any distinct color varieties which are constant. Moreover, the ground-color of the elytra is almost always of the same general color—a sort of straw or yellowish olive—only variable in depth of color, or at the most, varying from olive-ochre to greenish olive.

A few specimens have been obtained, however, which are so very distinct from all others and so remarkable in their variation from the normal color of *Hercules* that I have deemed it advisable to describe them as a new and distinct species or subspecies. In fact, if coloration alone constitutes a specific character among the coleoptera, then this *Dynastes* should be considered as a new species peculiar to Dominica.

Dynastes argentata, nov. *Silvery Hercules Beetle.* Male. Size, general shape, processes of thorax and head, etc., indistinguishable from *Dynastes hercules.* Head, thorax, lower parts, legs, etc., deep jet-black, instead of dark brown or purplish as in *Hercules.* Elytra pale plumbous, silver gray or grayish white, with a silvery metallic sheen. Edges of elytra all around, as well as a few large, circular scattered spots, intense jet-black. Hair on the posterior extremity of the abdomen, tibiæ, along edges of ventral segments and dorsal segments of thorax, pale silvery gray or whitish. Velvet hairs on lower surface of thoracic process deep orange brown or ferruginous when viewed from below, but silvery white or pale creamy white when seen from above or viewed in profile. Hair on ventral surface of head and thorax deep ferruginous or vandyke brown.

Length (type), including thoracic process, 6 inches. Length of thoracic process, 3 inches.

Habitat, interior mountain ranges of Dominica Island, Antilles.

The species formerly described by me* as *Dynastes tricornis* (fig. 1) should be referred to the allied genus *Strategus*, of which it is probably the largest known species. Its habits are similar to those of *Dynastes*.

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FIG. 1. *Strategus tricornis*, about nat. size. Phot. A. H. Ver.

Note on the habits and larvæ of the common Hercules beetle (Dynastes Hercules), and other beetles.

The Hercules beetle is common in the forests of inland mountains, where it is found in bunches of a dozen or more, clinging to the branches and trunks of the "La Glui" tree, on the sap or gum of which it feeds. As they usually congregate on the branches at a considerable elevation, they are seldom seen by the casual observers. In order to secure specimens it is usually necessary to shoot them, thus spoiling a large proportion for scientific purposes. Occasionally it is possible to secure a regular supply of beetles by cutting down a tree and scoring the trunks so that the sap runs freely. If any beetles are in the vicinity they are soon attracted to the felled tree and can be picked off by hand. Lights seem to have no attraction for the Hercules beetles of Dominica. The larva (fig. 2) is a huge grub, in general appearance resembling

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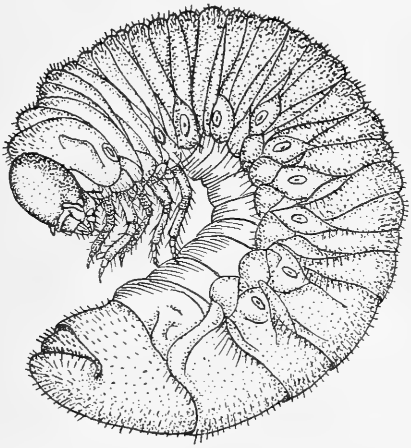
* This Journal, vol. xxi, p. 317, 1906.

a gigantic New England June-beetle larva. It feeds on dead and rotten wood of the La Glui tree, and requires several years to reach maturity. The pupa case is formed from rotten wood and the tough fibers of the bark. The imago when first emerged has the thoracic and occipital appendages but partly developed. They rapidly increase in size, however, and by the time the elytra and other horny parts are hard, the appendages have attained their full size.

2



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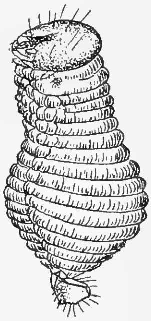

Fig. 2. Larva of *Dynastes Hercules.* Nat. size.
Fig. 3. Gru-gru Worm, the larva of Palm Weevil. ½ nat. size.

Of the two other new species, *Dynastes vulcan* and *D. Lagaii* (loc. cit., fig. 2), the latter is by far the rarest, only four specimens having been obtained by the writer during three years residence on the island.

D. vulcan (fig. 1, *b*) is rarer than *D. Hercules* (fig. 1, *a*), but far more common than *D. Lagaii*, while of *D. argentata* only one specimen is known.

Another noteworthy beetle of the island is the great Palm-Weevil (*Rhynchophorus palmarum*). It is of interest mainly because the larvæ are eaten by the natives. These larvæ (fig. 3), which are locally called "Gru-gru worms," feed on the decaying wood of the mountain Cabbage Palm and Gru-gru Palm. They attain a length of 2·15 to 3 inches when fully grown. They are fat, firm, legless grubs, and are considered a great delicacy by the natives, as well as by many foreigners who, having sufficiently overcome their natural repugnance, have ventured to taste them. The larvæ, after having been spitted on the slender midribs of palm leaves, are roasted over hot coals. Treated in this manner they pop open like roasted chestnuts, and taste much the same. From personal experience the writer can testify to the fact that they are excellent eating.

Of the other large coleoptera, *Philemus didymus*, a large black Rhinoceros-beetle, and *Neleus unicornis* are the most likely to be observed. The larvæ of *Philemus* live in decaying wood and other vegetable matter. The adult beetles have the peculiar habit of rolling balls of rotten wood and leaves, in which the eggs are deposited, much in the manner of the northern "Tumble-dung Beetles."

The *Neleus* larvæ live in rotten wood exclusively, and the beetles at certain seasons become exceedingly abundant. This beetle is remarkable for the peculiar loose-appearing manner in which the head and thorax are joined to the body. Even when living, the thorax wobbles about as if broken and entirely beyond the control of the insect.

A large undescribed species of Stag-beetles was also obtained by the writer.

Most of the remaining beetles are small or so scarce as to be but seldom met with, but special mention should be made of the huge "Fireflies" of the Elater group. These are abundant in the forests of the interior, and to one who has never seen them, the stories of their brilliancy seem incredible. One of these insects flying about an ordinary room renders most objects clearly visible at night, and fine print can be easily read by holding one near the page. The light emanating from these Firebeetles is continuous and issues from various portions of the body, especially from between the abdominal segments and from underneath the elytra.

ART. XXXI.—*On the Successive Cycles of Coronas;* by C. BARUS.

1. *Introductory.*—Using the method of successive identical exhaustions or withdrawal of nuclei, by which the nucleations left in the fog chamber should decrease in geometrical progression* from the high initial value given to dust-free air by the emanations of phosphorus, I have recently attempted to gain an estimate of the trustworthiness of the results, by using drops of pressure (δp from atmospheric p) of widely different values. These range from one extreme $\delta p = 10^{\mathrm{cm}}$ to the other $\delta p = 20^{\mathrm{cm}}$. Leaving the data, for which there is no room here, for publication elsewhere,† it appears that if the diameter of particle d of a given type and order of corona, worked out from the variables and constants of the experiment, agree reasonably well, the general method of reduction is assured.

The whole of the work was done in time series. Thus the exhaustion cock between the vacuum and fog chambers was kept open five seconds after exhaustion, only, and the time between two successive exhaustions was one minute. Other intervals were also tested without modifying the results. The time during which the cock remained open is of special importance, for the exchange of air between the two chambers depends upon it, and hence also the rate at which nuclei are removed per exhaustion. These details were determined in preliminary experiments. The isothermal pressure in the fog chamber after five seconds of communication between the chambers, obviously differs in marked degree from the isothermal pressure if the chambers are permanently left open in communication.

Additional correction was made for subsidence of fog particles during the short time, in all about fifteen seconds, needed for the observation of the coronas. They were then at once dispelled by opening the filter cock, evaporating the fog particles and restoring the nuclei left behind to their original size. Other losses, as for instance the evaporation loss which occurs when fog particles are precipitated on ions or on the vapor nuclei of dust-free air, or the time loss (decay), were found to be negligible. The amount of water precipitated, however, varies both with the adiabatic drop of pressure and with initial temperature, all of which was carefully allowed for. The ratio of sections of the fog chamber and the exhaust pipe was about 6/1, sufficient to reach the highest coronas. In fact the large red type of the first series was certainly obtained.

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* This Journal, xiii, pp. 81–94, 1902.

† To be given in a forthcoming Carnegie publication.

2. *The violet and green coronas.*—As has been suggested, the object of the series of experiments made at very low exhaustions (drop of pressure $\delta p = 10^{\text{cm}}$) and compared with a series for high exhaustions ($\delta p = 20{\cdot}5^{\text{cm}}$) was an estimation of the importance of the time effect and of the convective effect in causing loss of nuclei. If the latter series be reduced to the former by modifying the constants in terms of pressure and temperature, the coincidence of the graphs was found to be complete. This indicates that the method of reduction is reliable.

To determine in how far the results themselves are trustworthy, it will be necessary to find the computed values in the different independent series of measurements, of the diameter of the fog particles producing a given corona. For this purpose the violet (v) and green coronas (g) are suitable, the red (r) less so. There are three of the green coronas, the two upper being very brilliant. In a former paper the diameters of particles were estimated as $d = {\cdot}000460^{\text{cm}}$ for the middle green corona. Ratios of 4, 3, 2 were usually apparent, the data being multiples of a diameter something larger than $d = 00015^{\text{cm}}$, the corona for which is not producible in the fog chamber. In the present experiments the values of the diameter of fog particle d and s, the aperture of the green coronas, still show considerable fluctuation; but the data approach closely to a common mean, remembering that the color itself has a certain latitude, necessarily, and wide differences of exhaustion are involved in the tests. The ratio 2, 3, 4 of diameters of fog particles is not as well suggested in the present results as in the former, while the absolute sizes themselves are throughout smaller. It is nevertheless convenient to retain these ratios for the division of coronas into successive cycles. If these may be considered as beginning with deep red and ending with violet, the following cycles may be postulated, the subscripts denoting the order:

v_1,	($d =$ ·00011)	v_2,	$d =$ ·00019	v_3,	$d =$ ·00033	v_4,	$d =$ ·00044$^{\text{cm}}$
g_1,	($d =$ ·00013)	g_2,	23	g_3,	40	g_4,	52$^{\text{cm}}$
r_1,	($d =$ ·00016)	r_2,	32	r_3,	48	r_4,	64$^{\text{cm}}$

Only the red and crimson of the first series are certainly observable in any apparatus known to me. Their aperture, $s/30$, is about 40 degrees, their rings diffuse and their disc filmy, so that in a small apparatus they might be mistaken for clear air. The second series is producible and vivid throughout, and the same is even more true of the third. The fourth is already closely packed, while the fifth and subsequent series merge into each other too rapidly for separation.

Cycles 3 and 4 were obtained in great number in my work with atmospheric nucleation. Selecting some twenty or more cases, the mean ratio $1/s_3 : 1/s_4 = \cdot146 : \cdot206 = d_3 : d_4$. Hence the ratio of $3:4$ is very well sustained. The goniometer distance from the fog chamber was nearly a meter in this case. Hence it is probable that the cycle 1 is actually the first occurring, although the smallest active particles (violet) must exceed $\cdot0001^{\text{cm}}$ in diameter. The same terminal conditions are suggested by the axial colors of the steam jet. It seems curious that the diffraction phenomenon should begin with particles of the order of three times the wave length of light.

Using the method of contact of coronas from two sources described elsewhere,* the ratio of diameters of the four first series is again very nearly as 1, 2, 3, 4, for the green coronas, for instance.

3. *Wilson's*† *data and conclusions.*—The table contains Wilson's exhaustions (v_1/v) at 18° to 19° C. and the corresponding disc colors, as I interpret them. It also contains the equivalent relative drop of pressure $\delta p/p$ used above. From these and the colors of diameters of fog particles (d) may be estimated, very roughly of course, provided the cycle in which these colors lie is known; hence $d_{3,2}$ refers to the probable case of the occurrence of the third and second series, $d_{2,1}$ to the very improbable case of the occurrence of the second and first series. If the values m be found for the corresponding temperature and expansions ($\delta p/p$), the nucleations $n_{3,2}$ and $n_{2.1}$ respectively follow. Wilson gives but a single cycle between green coronas. There are two such series and three definite large green coronas producible, and I shall assume that the very vivid upper one is meant. The first cycle is not producible by any means known to me, except in its lower red coronas. Ignoring $n_{2,1}$ and taking $n_{3,2}$, the data are dis-

Estimate of the diameter of nuclei d and their number n per cm³ corresponding to Wilson's colors of cloudy condensation in wet dust-free air. Temp. 18°–19°.

v_1/v	$10^3 \times$ $\delta p/p$	Disc color	$10^5 \times$ $d_{3,2}$	$10^5 \times$ $d_{2,1}$	10^{-6} $n_{3,2}$	10^{-6} $n_{2,1}$
1·410	384	green	40	23	·17	·900
1·413	386	"	--	--	--	---
1·419	390	violet	33	19	·27	1·5
1·420	390	"	--	--	--	--
1·426	394	red	32	16	·32	2·5
1·469	418	greenish white	23	12	·90	7·0

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* This Journal, xxiv, p. 277, 1907.

† Phil. Trans. Royal Soc., vol. 189, pp. 265, 1897; cf. p. 285.

tributed similarly to my own so far as the slope of the curves for the vapor nucleation of dust-free air is concerned.

There is another way in which the estimate in question may be made. Let the nucleations corresponding to the colors be taken and reduction be made for the different drops of pressure in question. This is merely a corroboration of the method of computation. The coincidence is as close as may be expected, seeing that the methods of approach are widely different and that the nucleation varies as the cube of the inverse diameter of particle.

Wilson's views of the nature of the phenomena are quite different and lead to enormous nucleations, even as compared with the improbable $n_{2,1}$. He says (1c: p. 301) "When all diffraction colors disappear and the fog appears white from all points of view, as it does when (the expansion) v_2/v_1 amounts to about 1·44, we cannot be far wrong in assuming that the diameter of the drops does not exceed one wave length in the brightest part of the spectrum, that is, about $5x10^{-5}$ centim. That the absence of color is not due to the inequality of the drops is evident from the fact that the colors are at their brightest when v_2/v_1 is only slightly less than 1·44, and from the perfect regularity of the color changes up to this point.

Taking the diameter of the drops as 5×10^{-5} centim., we obtain for the volume of each drop about 6×10^{-14} cub. centim., or its mass is 6×10^{-14} grm.

Now, we have seen that when the expansion is such as produces the sensitive tint (when $v_2/v_1 = 1{\cdot}42$), the quantity of water which separates out is about $7{\cdot}6\times10^{-6}$ grm. in each cub. centim. With greater expansion rather more must separate out. We therefore obtain as an inferior limit the number of drops, when $v_2/v_1 = 1{\cdot}44$, $7{\cdot}6\times10^{-6}/6\times10^{-14} = 10^8$ per cub. centim."

In my data the smallest green coronas correspond to a diameter of particles of about $d_4 = {\cdot}00052^{\text{cm}}$, the next to $d_3 = {\cdot}00040^{\text{cm}}$, the next to $d_2 = {\cdot}00023$; the first (which I have not been able to produce by any means whatever, however large the nuclei) should correspond to $d_1 = {\cdot}00013^{\text{cm}}$, and even this calls for particles nearly three times as large as Wilson's estimate, ${\cdot}00005^{\text{cm}}$. In a small tube but 2^{cm} in diameter, like Wilson's test tube apparatus, it is improbable that the d_2 green corona, which is about twenty-seven degrees in angular diameter, could look otherwise than greenish white, whereas the filmy disc of the large crimson coronas (the largest producible $d_1 = {\cdot}00016$ with an angular diameter of about 39 degrees) would be regarded colorless. I shall venture to believe therefore that Wilson's large greenish-white coronas corresponded to about ${\cdot}9\times10^6$ rather than to 10^8 nuclei per cubic centimeter, that the maximum nucleation would not exceed 10^7 even if colors of the unapproachable first order were produced.

ART. XXXII.—*The Behavior of Molybdic Acid in the Zinc Reductor;* by D. L. RANDALL.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—clxiv.]

THERE has been a difference of opinion in regard to the degree of reduction obtained when molybdic trioxide, in sulphuric acid solution, is passed through the column of amalgamated zinc as applied in the Jones reductor. Jones,* who first determined molybdenum by this method, considered that the reduction goes to the condition represented by the formula $Mo_{12}O_{19}$, the same degree of reduction that Wernke† obtained with zinc and sulphuric acid in a closed flask. Doolittle‡ and Eavenson found that, by varying the strength of the acid and the speed at which the molybdenum was passed through, different degrees of reduction might be obtained. They calculated no formula corresponding to the degree of reduction obtained by them which was lower than that represented by $Mo_{12}O_{19}$. W. A. Noyes and Frohman,§ by taking pains to replace the air in the reductor flask by carbon dioxide, were able to obtain a reduction to the form of Mo_2O_3. Blair‖ and Whitfield, however, were unable to press the reduction below the condition represented by the symbol $Mo_{24}O_{37}$. Miller¶ and Frank in repeating the experiments of Blair and Whitfield obtained in general the same results, though by taking extraordinary precautions they were able to get a reduction to a point a little below midway between the conditions represented by the symbols $Mo_{24}O_{37}$ and Mo_2O_3.

The ease with which the reduced molybdenum solution is oxidized by the air has been noted and suggests the possibility of charging the reductor flask with some oxidizer unaffected by air, which shall anticipate the oxidizing effects of the air as the reduced molybdenum compound comes through the reductor and register the oxidation.

In the first experiments an excess of a standard solution of potassium permanganate was used in the receiver. But it was found, by running blanks, that somewhat more than the theoretical amount of permanganate was used up. Table I shows the results of experiments made by charging the reductor flask with 20^{cm^3} of approximately tenth normal standard potassium permanganate, passing 300^{cm^3} of warm dilute (2·5 per cent) sulphuric acid through the reductor, adding 20^{cm^3} of standard ferrous sulphate solution and titrating with permanganate to color.

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* American Institute Mining Engineers, xviii, 705.
† Zeitschr. Anal. Chem., xiv, 1.
‡ Jour. Amer. Chem. Soc., xvi, 234.
§ Jour. Amer. Chem. Soc., xvi, 553.
‖ Ibid., xvii, 747.
¶ Ibid., xxv, 919.

TABLE I.

$FeSO_4$ cm³.	$KMnO_4$ used cm³.	$KMnO_4$ theory cm³.	Difference cm³.
20	24·45	23·25	1·20
20	23·88	23·25	·63
20	25·40	23·25	2·15
20	24·90	23·25	1·65

This excessive reducing action on the permanganate must be due either to impurities in the zinc, to small particles of zinc worked through the asbestos layer at the bottom of the reductor, or possibly to the hydrogen formed in the reductor. That the last mentioned possibility is a sufficient cause of the effects obtained was shown by passing hydrogen, formed by the action of hydrochloric acid on zinc in a Kipp generator and washed with water and caustic potash, through 23^{cm^3} standard permanganate diluted with 300^{cm^3} of hot dilute (2·5 per cent) sulphuric acid, adding 20^{cm^3} of a solution of standard ferrous sulphate and titrating back with permanganate. The results obtained by such action of hydrogen during fifteen minutes is shown in Table II.

TABLE II.

$FeSO_4$ cm³.	$KMnO_4$ required cm³.	$KMnO_4$ theory cm³.	Reduced by hydrogen cm³.
20	24·6	23·1	1·5
20	24·7	23·1	1·6
20	23·6	23·1	·5

Having seen that potassium permanganate could not be used in the reductor flask, ferric alum was next tried as an oxidizer. The only objection to the use of this salt, that at the usual dilution of $500–600^{cm^3}$ an excess of ferric alum colors the solution strongly and makes the end point in the titration somewhat difficult to recognize, is overcome by the addition of a few centimeters of phosphoric acid which renders the solution colorless.

For the work with the ferric oxidizer the C. P. ammonium molybdate of commerce was recrystallized and found to contain 81·55 per cent of molybdenum trioxide by treating weighed portions in a platinum crucible with nitric acid and evaporating to dryness on the steam bath and igniting gently and weighing the molybdic anhydride formed. The ferric iron solution for use in the reductor flask was prepared by dissolving 100 grams of the crystalized salt in one liter of water. The column of zinc in the reductor was 36^{cm} in length. The procedure was to charge the reductor flask with 20 or 30^{cm^3} of the iron solution and 4^{cm^3} of phosphoric acid and to pass through the reductor in succession 100$^{cm^3}$ of hot dilute sulphuric acid (2·5 per cent), the ammonium molybdate dissolved in 10$^{cm^3}$ of water and acidified with 100$^{cm^3}$ of the hot dilute acid (2·5 per cent), 200$^{cm^3}$ of the hot dilute acid and finally 100$^{cm^3}$ of hot water. The solution was titrated while still hot with approximately tenth normal permanganate standardized against ammonium oxalate.

The molybdenum as it passed through the lower part of the reductor was green, but on coming in contact with the ferric salt was changed to a bright red color. The results in the following table are calculated on the assumption that the molybdenum was reduced to the form of Mo_2O_3. The close agreement with theory indicates that the reductor is able to reduce molybdenum to that form and that the reduction does not stop at a point represented by the formula $Mo_{24}O_{37}$ or $Mo_{12}O_{19}$.

TABLE III.

Ammonium molybdate taken grams.	Iron sol. cm^3.	H_3PO_4 cm^3.	$KMnO_4$ used cm^3.	MoO_3 found grms.	MoO_3 theory grms.	Error grms.
·2000	20	4	30·38	·1628	·1631	—·0003
.2000	20	4	30.45	·1632	·1631	+.0001
·2000	20	4	30·33	·1626	·1631	—·0005
·3000	30	4	45·65	·2447	·2447	±·0000
·3000	30	4	45·80	·2455	·2447	+·0008
·3000	30	4	45·73	·2451	·2447	+·0004
·3000	30	4	45·76	·2453	·2447	+·0006
·3000	30	4	45·68	·2448	·2447	+·0001
·3000	30	4	45·64	·2446	·2447	—·0001
·3000	30	4	45·71	·2449	·2447	+·0002

It having been shown that molybdenum may be successfully and uniformly reduced to the condition of Mo_2O_3 by anticipating any previous action of air and registering the oxidation by the action of a ferric salt, the method was then applied to the determination of phosphorus in ammonium phosphomolybdate precipitated in the usual manner.

For this work a solution of microcosmic salt was made up 1·2 grams to the liter and the phosphorus content determined by evaporating 50$^{cm^3}$ in a platinum crucible and igniting to form the sodium metaphosphate.

With the exception of using an equivalent amount of ammonium molybdate instead of molybdic anhydride, the method given by Blair* was used for making up the molybdate reagent. According to this method, 100 grams of pure molybdic anhydride and 400$^{cm^3}$ cold distilled water are thoroughly mixed and the mixture is treated with 80$^{cm^3}$ of strong ammonia (0·90 sp. gr.). When the solution is complete, the liquid is filtered

* Chem. Analysis of Iron, vi ed., p. 97.

slowly and with constant stirring into a mixture of 400^{cm^3} of strong nitric acid (1·42 sp. gr.) and 600^{cm^3} distilled water. Then 50 milligrams of microcosmic salt dissolved in a little water are added, the mixture is agitated thoroughly, the precipitate is allowed to settle for twenty-four hours and the solution is filtered before using.

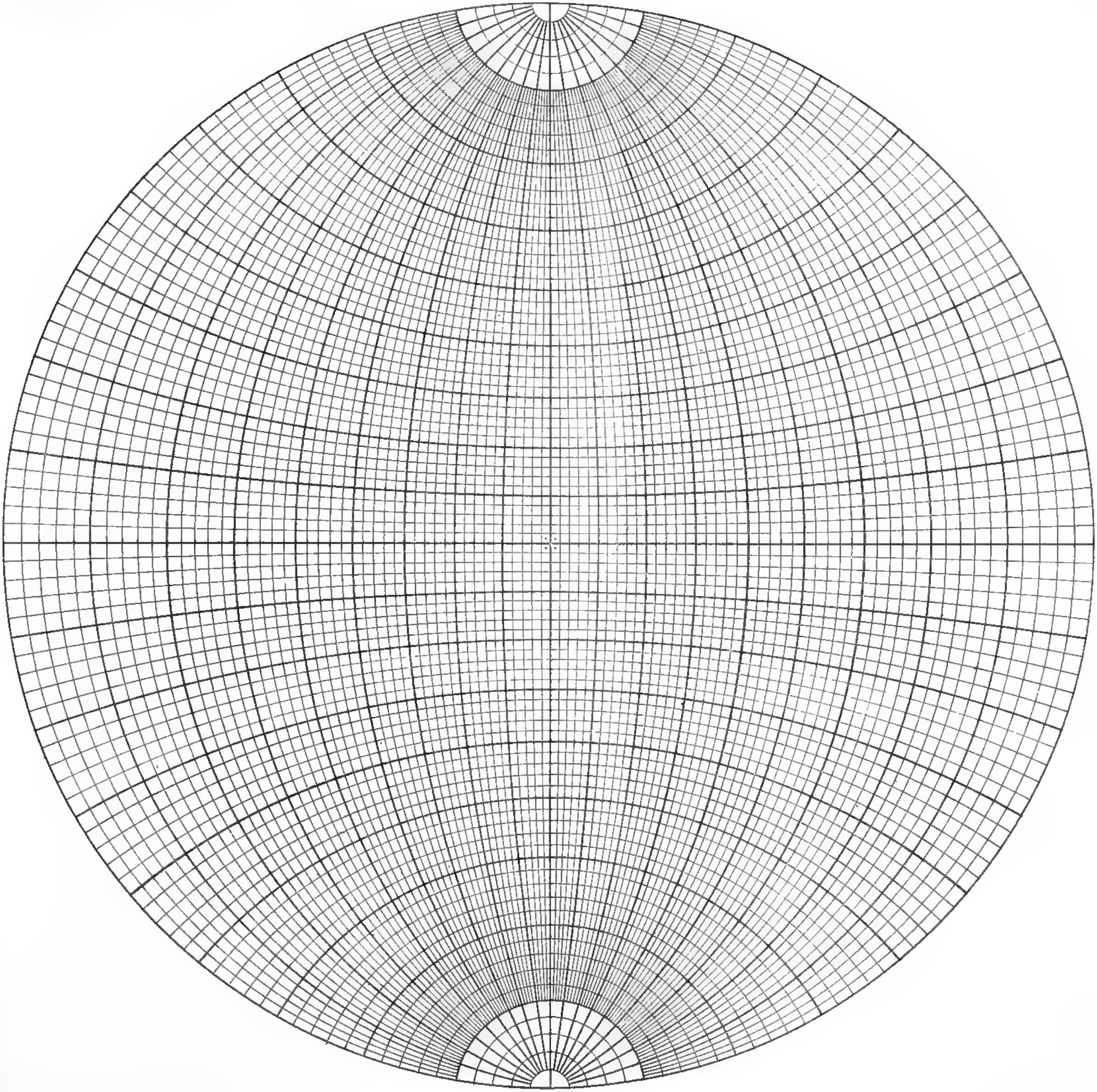
In order to have iron present during the precipitation of the phospho-molybdate, a solution of ferric nitrate was prepared and used in each experiment. A solution of the C. P. ferric nitrate of commerce, $Fe(NO_3)_3 9H_2O$, was made up to contain 150 grams to the liter, with enough nitric acid added to give the solution an amber color. To free the iron solution from traces of phosphorus, 400^{cm^3} of the molybdenum solution were added to the ferric nitrate and the whole well shaken and allowed to stand for twenty-four hours.

To measured portions of the phosphorus solution, in a 300^{cm^3} Erlenmeyer flask, were added 150^{cm^3} of the iron solution filtered and warmed to 35° C. The flask was stoppered with a rubber stopper and shaken for five minutes. The precipitated phospho-molybdate was allowed to settle, and was then filtered on asbestos in a perforated crucible and washed with a solution of ammonium acid sulphate (15^{cm^3} ammonia, 25^{cm^3} sulphuric acid, 1 liter water). The Erlenmeyer was washed out with a solution of 20^{cm^3} of water and 5^{cm^3} of ammonia, and this was poured on the asbestos in the crucible. The molybdenum solution was acidified with 10^{cm^3} of strong sulphuric acid and was passed through the reductor into the ferric alum solution. The molybdenum solution was preceded by 100^{cm^3} of hot water and followed by 200^{cm^3} of the hot dilute acid and 100^{cm^3} of water. The reduced solution was titrated immediately with approximately tenth normal permanganate. In the following table are shown results thus obtained in precipitating phosphorus as the phospho-molybdate, passing the acidic solution through the reductor into a solution of ferric alum, and titrating the ferrous salt which is formed.

TABLE IV.

P taken grms.	P found grms.	Error grms.
·003645	·003673	+ ·000028
·003645	·003697	+ ·000052
·003645	·003638	− ·000007
·003645	·003726	+ ·000081
·003645	·003630	− ·000015
·003645	·003661	+ ·000016

These results are calculated on the assumption that the ammonium phospho-molybdate contains phosphorus and molybdenum in the proportion given by the symbol $(NH_4)_3 12MoO_3 PO_4$, and that the reduction proceeds to the condition represented by the symbol Mo_2O_3.



ART. XXXIII.—*The Measurement of the Optic Axial Angle of Minerals in the Thin Section;* by FRED EUGENE WRIGHT. (With Plates I and II.)

DURING the past few decades the development of the petrographic microscope and petrographic methods has been exceedingly rapid and has now attained a state of such high efficiency that nearly every optic constant of a rock mineral in the thin section can be ascertained with ease and some degree of certainty. In many instances, in fact, the petrographer has at present at his disposal two and even more methods for the determination of a single optical constant under the microscope. The results obtained by these different methods are, however, often not of the same value, nor are all methods equally applicable to a given mineral section. Comparative and critical studies of the relative merits and accuracy of such methods under different conditions are not abundant in petrographic literature. It has therefore seemed to the writer desirable that such a study should be undertaken, and the microscopic examination of the artificial mineral aggregates produced in the Geophysical Laboratory has furnished a favorable opportunity. It has been found necessary in this work to use most of the available petrographic microscopic methods and to test them under different conditions.

Minerals are determined under the microscope by means of their crystallographic and optic properties; the more accurately such properties or constants can be ascertained for any given mineral, the more reliable and satisfactory is the determination. Of the several optical constants which are thus made use of in the identification of minerals, the optic axial angle, and with it the optical character, whether positive or negative, are among the most important. Different methods have been suggested, from time to time, by means of which the optic axial angle of any given biaxial mineral can be measured with greater or less accuracy and more or less rapidly; certain of these methods are of general application and can be employed on all mineral sections, while others can be used only on sections of fixed orientation. In microscopic work, however, all possible sections are to be encountered, and in each particular case, that method is the best and should be selected which not only gives the most accurate results, but also requires the least time. This is particularly true of extremely fine-grained preparations where it is frequently difficult to obtain results of any value whatever. In the following pages, the methods for measuring optic axial angles of minerals in thin section are to be described briefly, together with several novel methods which have been found serviceable, and a summary given of the results of comparative tests of all these methods on mineral sections of known and measured optic axial angles. As many of these methods have not been described in English, it has seemed desirable to introduce the general discussion by a mention of their underlying principles and an outline of their mode of application to different sections.

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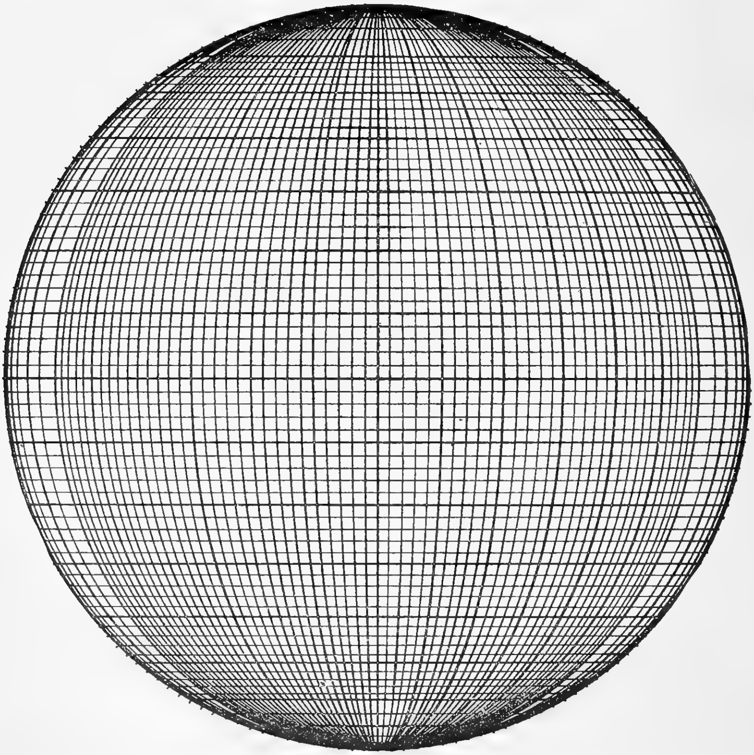

Several of the methods are in part graphical methods and involve the use of stereographic, orthographic or gnomonic projection plats. (Plate I and fig. 1.)* A few paragraphs,

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* Plate I is a photolithographic production of the stereographic projection plat by Professor G. Wulff (Zeitschr. f. Kryst., xxxvi, 14-15, 1902). Both great circle and small circle arcs are located two degrees apart in the projection plat, the great circle arcs having a radius R_1 for a given angle ρ, $R_1 = \frac{r}{\sin \rho}$, r being the radius of the projection plat; the small circle arcs, a diameter, $R_2 = r \cot \rho$. In the projection plat, these arcs have been con-

therefore, on these different methods of projection, their essential characteristics, and their application to microscopic work, are inserted at this point because of the important rôle they play in the theoretical consideration and elucidation of the optical methods to be given below.

The spacial relations between the optic and morphologic properties of a crystal are frequently complicated and extremely difficult of correct conception and description without the aid of special models or projections of the same. Both observation and theory have shown that for any crystal the optical phenomena which it presents can be ascertained for a particular color of light, both in direction and length, by reference to an ellipsoid, either triaxial ellipsoid or ellipsoid of rotation, or sphere in the limiting case. Having once determined the exact position and character of this ellipsoid within the crystal and the relative lengths of its axes, it is possible to figure mathematically and to represent graphically the optical properties of the crystal for light waves of the specified length transmitted in any given direction. In the general treatment of the optical properties of crystals, the source of light is considered to be located at a central point within the crystal and the light waves to emerge in all directions from that central point along the radii of an inscribed sphere of unit radius. In space any radius can be represented accurately by its intersection with the surface of the unit sphere, and like any point on the earth's surface, its position can be fixed accurately by two angles equivalent to those of latitude and longitude.

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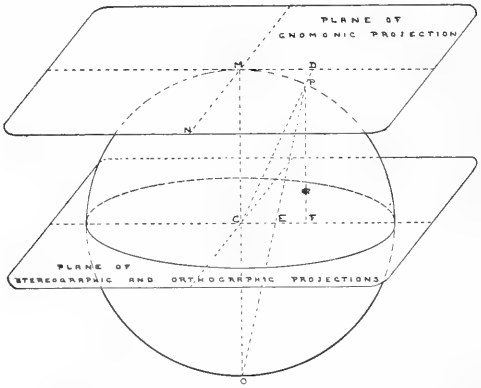
structed with great accuracy and measurements can be made directly by their use with errors of less than ¼°. Having given the stereographic and orthographic plats of Plate I and fig. 1, the process of plotting angles from them graphically and measuring angular distances is rendered easy and certain by the use of tracing paper, as first suggested by Professor Wulff. With the plat as a base, the measured angles, obtained from the microscope, are plotted directly on tracing paper from the projection plat underneath, and the various necessary operations of passing great circles through given points and measuring angular distances, etc., accomplished by revolving the sheet of tracing paper about the center of the projection plat as a pivot, until the required great or small circle of the projection plat beneath is found. The circle is then sketched with sharp pencil point on tracing paper and is sufficiently accurate for practical purposes, the slight errors produced by using tracing paper and stereographic plat being of the same order of magnitude as those of observation and therefore negligible. The amount of time and energy, moreover, expended in this method of free-hand sketching, is much less than that necessary for constructing accurately the required small and great circles. In actual practice it has been found expedient to draw with colored ink, on both stereographic and orthographic projection plats, radii and circles 2° apart, and thus greatly facilitate the ease with which observed data can be plotted. To incorporate these radii and circles in the original plats did not seem advisable because of the great complexity of lines which arises when radii, circles and great and small projection arcs are all superimposed in black ink. By the use of colored ink, no confusion arises and the radii and circles can be added at any time with little effort by the aid of rule and compass.

As a general rule, it is neither convenient nor feasible to work with actual models in the study of optical phenomena. Several different types of projection have been devised to overcome this difficulty by representing the spacial relations on a plane. In all cases the relation of the object to its projection plot is one of definite construction, and is dependent on the method of projection adopted.

In optical work, any one of three different methods of projection, the gnomonic, the orthographic, and the stereographic, may be used, each of which possesses certain favorable and certain unfavorable features. In each projection, the points on the sphere are pictured in a fixed plane.

In the *gnomonic* projection,* the plane of projection is the horizontal tangent plane passing through the crest of the unit sphere. (Fig. 2.) The point of intersection of the radius drawn through any given point on the sphere with the tangent plane is the projection point for that direction. In this projection, the great circles of the sphere become straight lines in the plat, and are small circles, hyperbolae. In the following pages, however, the gnomonic projection will not be used to any extent and will not therefore be described here in greater detail. It is particularly well suited to crystallographic work,

2



In this figure, the point D is the gnomonic projection point of the point P on the sphere, or of the direction CP in the crystal. The distance MD is evidently $r.\ \tan \rho$, r being the radius of the sphere and ρ the angle MCD. Similarly, the distance CE in the stereographic projection is $r \tan \frac{\rho}{2}$ and CF in the orthographic projection, $r \sin \rho$.

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* For a comparative study of projections, see V. Goldschmidt, Ueber Projektion und graphische Krystallberechnung, Berlin, 1887.

since by its use all crystal faces are reduced to points and zones to straight lines.

In the *orthographic* (also called orthogonal or parallel or ocular) projection, the eye of the observer is supposed to be at an infinite distance above the plane of projection and to look directly down upon the sphere. The lines of sight are then parallel and the points on the sphere are vertically above their projection points on the central diametral plane (figs. 2 and 3). In this projection, great circles appear as ellipses and small circles as straight lines. This projection is especially important since all interference phenomena observed in convergent polarized light under the microscope appear to the eye of the observer as they would were the actual interference phenomena plotted in this projection. The serious drawback to its general application in optical work lies in the rapid decrease of its sensitiveness to differences in angular distances near its outer margin. The interference figures below are all represented in orthographic projection, although their construction was accomplished in part by using the stereographic projection. In fig. 1, the ellipses represent great circles with a common diameter of intersection and drawn at intervals of 2° apart; while the straight lines are the projections of small circles, also 2° apart and corresponding to small circles of latitude. As on the sphere itself, the angular distance between any two points in projection can be found by passing through the two points the common great circle (ellipse in projection) and counting directly the distance in degrees by means of the small circles.

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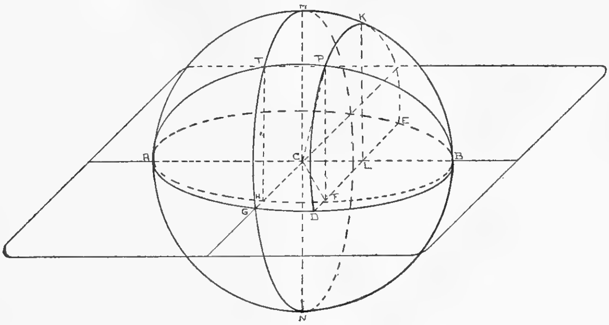

In fig. 3 the point P of the sphere, which is located in this case by the intersection of the great circle ATP and the small circle DPK, in the orthographic projection F and is there located by the ellipse AHF, the orthographic projection of ATP, and the straight line DFL, the projection of DPK. F is also the point of intersection of the diametral plane CGB with the line PF, normal through P to that plane.

The actual modus operandi of this and the stereographic projection will appear more clearly later when actual data of observation are plotted.

In the *stereographic* projection,* the eye of the observer is considered at the lower extremity of the vertical radius, the lines of sight being directed toward the points of intersection of given radii with the surface of the sphere. The intersection of the line of sight for a given radius or direction of light wave propagation with the central horizontal plane determines then the stereographic projection point of that radius. (Plate I and figs. 2 and 4.)

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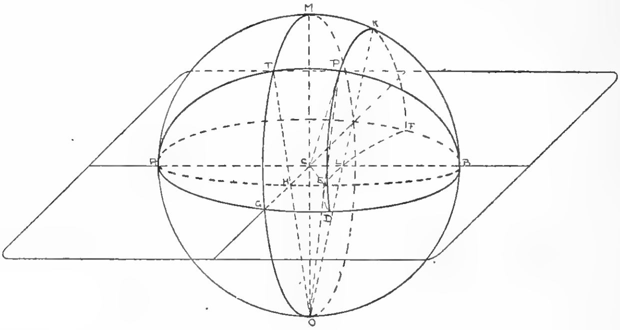

In this figure the point P of the sphere, corresponding to the direction CP within the crystal and located in this instance by the great circle ATP and the small circle DPK, becomes E in the stereographic projection plat and is there located at the intersection of the great circle arc AHE, the stereographic projection of ATP, and by the small circle arc DEL, the stereographic projection of DPK. E is also the point of intersection of the line OP with the horizontal diametral plane CGB.

The stereographic projection is unique in that all circles, whether great or small, appear in the projection as circles instead of ellipses, as might be supposed at first thought. The angle, moreover, which two great circles make with each other, is preserved unaltered in the projection. The projection is thus angle-true. In Plate I, the portions of great circles of the upper half of the sphere are represented by the circular arcs of which the horizontal radius is the limiting case, and the small circles by the arcs of which the vertical radius is the limiting case.

Biot's or Fresnel's rule.—In several of the optic methods to be described, frequent use is made of a rule first formulated

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* S. L. Penfield, this Journal (4), xi, 1,115; E. Fedorow, Zeitschr. Kryst., vols. xxvi, xxvii, xxix, and G. Wulff, Zeitschr. Kryst., xxi, 249, 1893; xxxvi, 14–15, 1902, have given complete descriptions of the stereographic projection.

by Biot[*] by which the directions of extinction for any section of a birefracting mineral can be found. Some ten years before Biot announced this general rule, Malus[†] had found that the light waves emerging from a calcite rhomb were plane polarized and that for any given section of calcite the lines of extinction were parallel and at right angles with the trace of the plane containing the optic axis and the normal to the section; in other words, the orthogonal projection of the optic axis on any given section of a uniaxial mineral determines its lines of extinction which are parallel with and normal to this projection line. By modifying the wording of this rule slightly, it is possible, as Biot proved experimentally and Fresnel[‡] demonstrated theoretically, to make it of general application to all birefracting substances; thus, the directions of extinction of a biaxial mineral[§] cut after any section are parallel to the traces, on that section, of the planes bisecting the angles between the two planes containing the normal to the section and the optic axes (or optic binormals); in other words, the lines bisecting the angles between the lines of orthogonal projection of the optic binormals on any given section of a biaxial mineral are the directions of extinction for that section for the particular color of light employed. It should be noted that this rule applies to optic phenomena within the crystal itself, and that for oblique incidence of light, as in convergent polarized light, the apparent angles observed in air must be reduced to true angles by means of the average refractive index of the mineral in question; by the formula $\sin V = \frac{\sin E}{\beta}$, E being the observed angle, V the required true angle, and β the mean refractive index of the mineral.

The above methods of projection, together with the Biot-Fresnel rule of construction for finding the directions of extinction on any plane, constitute the basis on which several of the methods described below rest. With practice, these projections become working models for the observer and aid him very materially in grasping and picturing the optical phenomena presented by different minerals under varying conditions.

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[*] Biot, J. B., Mém. de l'Acad. de l'Inst. de France, iii, 228, 1820.

[†] Malus, E. L., Théorie de la double réfraction de la lumiére dans les substances cristallisées, Mém. prés à l'Inst. Sc. math. et phys., ii, 303, 1811.

[‡] Fresnel, Second Mémoire sur la double réfraction, Pogg. Ann., xxiii, 542, 1831.

[§] The uniaxial minerals may for the moment be considered the limiting case of biaxial minerals for which $2V = 0$.

PART I. THEORETICAL.

In this part of the paper, the attempt has been made to describe briefly the methods, at present known to the writer, for measuring the optic axial angle of mineral sections under the microscope and to emphasize particularly their modus operandi and the principles on which they are founded. In the preparation of these descriptions constant use has been made of the Mikroskopische Physiographie, I, 1, by Rosenbusch and Wülfing, and of the original papers in which the methods were first mentioned, especially those by Becke and Fedorow. Several of the text-figures below have, in fact, been derived, with slight modifications, from these sources.

Convergent Polarized Light.

Optical phenomena in general can be observed and be measured by use of either convergent or plane polarized light. The study of optic axial interference figures has, however, until recently, been effected solely in convergent polarized light, and the methods applicable thereto are better known and more fully developed than those for plane polarized light. We shall, therefore, begin with the methods for measuring the optic axial angle of minerals in convergent polarized light.

There are several different lens combinations which can be used to advantage for obtaining and observing interference figures under the microscope in convergent polarized light; and of these, the one suggested by Amici* in 1830 has been found to be the best suited for optical measurements. With this method, the primary interference image, which is formed directly above the high power objective, is magnified and reproduced as a secondary image in the upper part of the microscope tube, where it can be observed either with magnifying glass or ocular with cross hair and micrometer scale. The small Amici-Bertrand lens by means of which this change of microscope to conoscope is effected must be inserted at such a point between ocular and objective that the secondary interference image observed through the ocular is as sharp and clear as possible.

Both theory and observation show, however, that all parts of the interference figure thus formed are not in perfect focus† at one and the same time. Fig. 5 illustrates the path of a light beam from condenser lens to eye of observer. From this figure, it is evident that the surface of focus for light waves entering in all possible directions is not a plane but roughly

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* Ann. Chim. Phys. (3), xii, 114, 1844.

† Rosenbusch-Wülfing, Mikroskop. Phys., I, 1, 215, 1904.

a sphere. It is necessary, therefore, to focus sharply on points about midway between the center and margin of the

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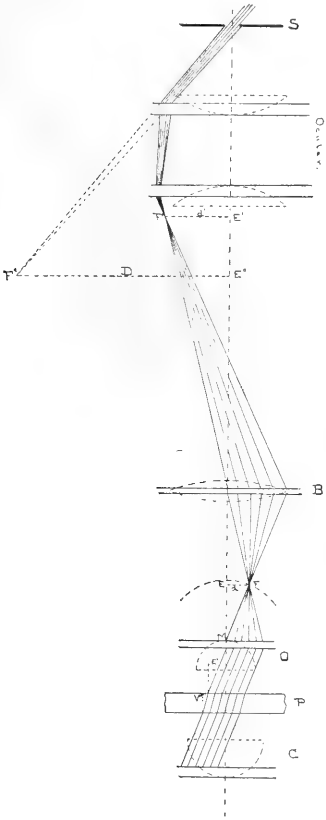

Fig. 5. In this figure, C represents the condenser lens system; O that of the objective, B, the Bertrand-Amici lens, P, the mineral plate and Oc, the ocular of the Ramsden-Czapski type. The primary image EF (*d*) is reproduced as a secondary image at E′F′ (*d*′) and later still more magnified by the ocular at E″F″ (D), where it is observed by the eye back of the small aperture S. In the writer's microscope with Fuess No. 9 objective, of equivalent focal length, $2{\cdot}7^{mm}$, and numerical aperture 0·97, the diameter of the primary interference figure measures about 5^{mm} and this is magnified very considerably by the Bertrand lens and by the ocular in the secondary interference figure as shown in the figure. By choosing a Bertrand lens of suitable focal length and inserting the same at the proper point between objective and ocular, it is possible to increase the magnification of the secondary interference figure and thus to enhance the accuracy of the measurements, providing the interference figure is sufficiently sharp and distinct to permit magnification to such an extent.

field (F of the figure) and to adjust the lenses for these points in order that the remainder of the field be as distinct as possible under the circumstances.

In order to minimize the error due to the slight parallax of rays near the margin of the field, a small stop, S, may be placed above the ocular as shown in the figure.

The exact position of any point in a given interference figure can be determined with considerable accuracy by using either a micrometer ocular with fixed scales or movable screw micrometers, or by means of a projection by camera lucida on paper. The actual position in space of any point thus fixed in the projection can then be stated if the relation between projection and object be known.

In 1882, Mallard* proved theoretically that the interference figure observed in the microscope is approximately an orthographic projection of the optic phenomena in space. To take the simplest case, let both condenser lens and objective consist each of a simple hemispherical plane convex lens, C and O, fig. 5. The rays which in the objective lens are parallel come to a focus at F, where they can be viewed directly by the unaided eye. Assuming the radius of the lens to be r, the radius R (MF, fig. 5) of the focal circle is evidently $\frac{r}{n-1}$, where n is the refractive index of the objective lens glass. It should be noted that under the microscope the optic phenomena are observed as they appear in the objective itself, i. e., modified by their refraction in the glass. The distance

$$\mathrm{EF} = d = \mathrm{R} \sin \measuredangle \mathrm{EMF} \tag{1}$$

Replacing ∡ EMF by its corresponding angle in air, E, the relation between which is expressed by $\sin \mathrm{E} = n. \sin \measuredangle \mathrm{EMF}$, equation (1) can be written

$$\mathrm{EF} = d = \frac{\mathrm{R}}{n} . \sin \mathrm{E}. \tag{2}$$

By fixing rigidly the relative positions of objective, Amici-Bertrand lens and ocular (fig. 5), the distance d for all angular values E, which can be measured in the microscopic field, bears a constant relation to D of the secondary interference figure

$$\mathrm{D} = k\, d \tag{3}$$

This distance D can be measured accurately with the movable screw micrometer ocular. Substituting D for d, equation (2) becomes

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* E. Mallard, Bull. Soc. Min. Fr., v., 77-87, 1882.

$$D = \frac{R}{n \, . \, k} \, . \sin E,$$

an equation which can be simplified to

$$D = K \sin E \qquad (4)$$

by replacing $\frac{R}{n \, . \, k}$, an expression consisting entirely of constants, by K, the Mallard constant of the microscope for the given fixed position of microscopic lens system. The constant K can be determined once for all by ascertaining the D for any known angle E. The method usually employed to determine this constant K is to measure, on a section of a biaxial mineral of known optic axial angle and cut normal to the acute bisectrix, the distances between the apices of the dark hyperbolic bars of the interference figure in the diagonal position; this distance is 2D, and the optic axial angle measured is 2E.

This method, however, does not furnish a check on the value of K, thus obtained, and its validity verified for other angles E, unless many similar sections of different biaxial minerals be taken and the K of the microscope for each angle E be ascertained. The formula, $D = K \sin E$, of Mallard assumes that the loci of the focal points of waves entering in all directions lie on a perfect spherical surface, an assumption which actual microscopic objective lens systems in the strict sense of the word do not fulfill.

To test the validity of the formula for the microscopic field of a given objective (No. 9, Fuess, with Amici-Bertrand lens, system 7–9, and movable screw micrometer ocular with Ramsden ocular), two polished plates of calcite were used, the one cut after 0001 and the second at an angle of 23° 17′ with 0001 as measured on a two-circled goniometer, the adjustment on the goniometer having been accomplished by means of fresh cleavage faces along the edge of the plate. These plates were placed successively on a carefully adjusted Fedorow-Fuess universal stage (large model) and the positions of the optic axis measured on the micrometer ocular screws as the stage was turned about its horizontal axis from degree to degree on both sides from the horizontal position. By means of the two plates, a continuous set of readings was obtained for D for angles E ranging from 0° to 47°. These values were ascertained for both scales (horizontal and vertical) of the double screw micrometer ocular described on page 336, and are listed in Table I.

The values for D listed under the heading "calculated" in this table were figured by Mallard's formula by taking the average value of K for both the horizontal and vertical scales of the double micrometer ocular; for the vertical micrometer

TABLE 1.

	Observed		Calculated			Observed		Calculated	
E	Dv	Dh	Dv	Dh	E	Dv	Dh	Dv	Dh
0°	0	0	0	0	26°	181	186	----	----
1	8·5	8	----	----	7	187·5	192·5	----	----
2	16·5	16	----	----	8	194·5	199·	----	----
3	23	22·5	----	----	9	199	206·5	----	----
4	29	30	----	----	30°	205·5	212·5	206·1	211·2
5	36·5	37·5	35·9	36·8	1	213·5	218·5	----	----
6	44	44	----	----	2	219	225	----	----
7	52	51	----	----	3	225	230·5	----	----
8	58·5	57·5	----	----	4	230·5	237·5	----	----
9	65	65·5	----	----	35	236·5	243·5	236·5	242·3
10°	71·5	73·5	71·6	73·4	6	243	250·5	----	----
1	78·5	80	----	----	7	249	256·5	----	----
2	85	87·5	----	----	8	254	261·5	----	----
3	92·5	94·5	----	----	9	259	266·5	----	----
4	100·5	102	----	----	40°	264	272	265	271·5
15	107·5	109·5	106·7	109·3	1	269	277	----	----
6	113·5	117	----	----	2	273	283	----	----
7	119·5	124·5	----	----	3	279·5	288	----	----
8	125·5	131·5	----	----	4	286·5	293·5	----	----
9	132	138	----	----	45	290	299	291·5	298·7
20°	139·5	144·5	141·0	144·5	6	295	303·5	----	----
1	146·5	152·5	----	----	7	300	308	----	----
2	154	158·5	----	----	8	----	----	----	----
3	160	164·5	----	----	9	----	----	----	----
4	166	171	----	----	50°	----	----	316·6	323·6
25	173	179	174·2	178·5					

scale, $K_v = 421·3$; for the horizontal, $K_h = 422·4$. The curves of fig. 6 express these relations graphically, the zero line of each succeeding curve being one division above the preceding curve, to prevent confusion. For the objective in question (No. 9, Fuess), and with the precautions observed to avoid parallax by placing a fine stop diaphragm S (fig. 5) above the Ramsden ocular, the agreement between theory and practice is remarkable.* The screw of the horizontal (H, fig. 11, p. 336) micrometer

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* In the Mikroskopische Physiographie I, 1, p. 330, by Rosenbusch and Wülfing, the latter gives a series of measurements with an a-monobrom-naphthaline immersion objective of R. Winkel and finds disagreements as high as 8° between observed and calculated values, as indicated in the following table :

	H	D	K	H_1
Aragonite ----------	11°33′	0·325	1·623	10°59
Muscovite ----------	24°43	0·700	1·674	24°14
Topaz---------------	39°05	1·075	1·705	(39°05)
Calcite -------------	60°51	1·590	1·821	68°50′

The angles under H are half the axial angles for these minerals obtained scale registered ·005^{mm} for each division on the head, while the vertical (V, fig. 11) scale screw, which was constructed at a later period and on a different lathe, was a trifle coarser and registered a slightly greater movement for one division on its head. For this reason the values K_v and K_h are slightly

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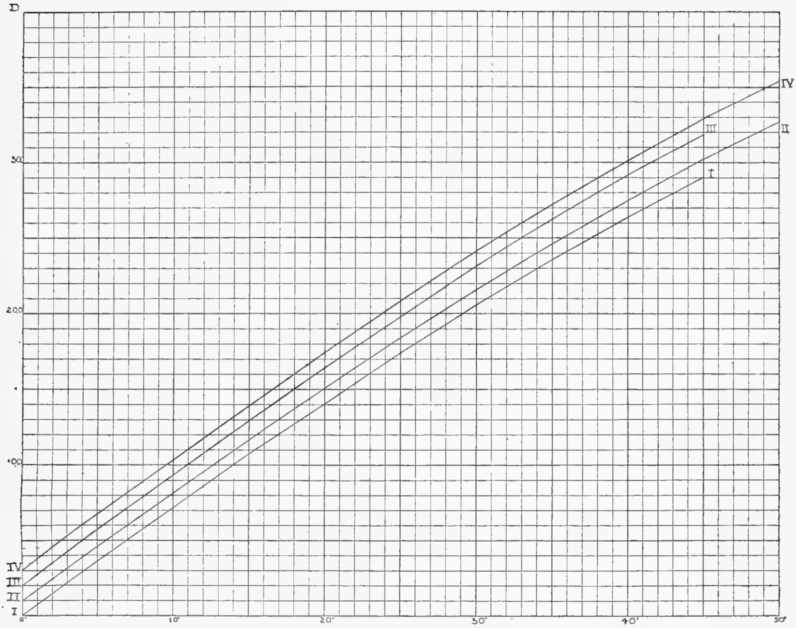

FIG. 6. Curve I of this figure contains the observed values of D_v for the vertical (V) micrometer screw of the double micrometer ocular (fig. 11, p. 336) for the different values of E from 0–47°; the values of D in Curve II were calculated from Mallard's formula for the same micrometer screw scale; Curve III in like manner was plotted from observed values of D_H, the horizontal micrometer screw for values of E from 0–47°; while Curve IV was plotted from values of D_H calculated from Mallard's formula, $D_h = K_h . \sin E$.

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from measurements on an optic axial angle apparatus while the angles under H_1 were calculated by Mallard's formula on the assumption that the K obtained for topaz (1·075) is valid for all angles. The differences between observation and calculation are large and indicate that the determination of the positions of optic axes near the periphery of the field is less accurate than that for more centrally located points; on comparison of this series of results with those obtained by Fuess, No. 9 objective, it is evident that objectives vary considerably in this particular and that for accurate work the constants K of each microscopic objective and lens system should be determined for a number of directions, either by using minerals of known optic axial angles or a uniaxial mineral as calcite in conjunction with the universal stage.

different. On an average, a movement of 6 divisions or $\cdot 03^{mm}$ corresponded to one degree, so that with this method of special refinement, the probable error for E remains at least ± 10′, and in wide hyperbolic bars, differences of 1° and over should be expected.

If only a single screw micrometer ocular be used, the section should be cut very nearly normal to the acute bisectrix, otherwise the values become much less certain. With a double screw micrometer ocular, however, this error can be eliminated directly and equally good values obtained on sections only approximately normal to the acute bisectrix, as will be shown later (page 336).

In place of solving the above equations $D = K \sin E$ and $\sin E = \beta \sin V$ by logarithms, it is possible to use a graphical method which is sufficiently accurate for the purpose and which Fedorow appears to have been the first to use.* An accurate drawing (Plate II) is made once for all which serves for all possible angles and all refractive mineral indices to be encountered. To solve the equation $D = K \sin E$, or $\sin E = \frac{D}{K}$, draw the circle with radius K (Plate II, preferably in colored ink); the intersection of the ordinate D with this circle makes then the angle E in degrees, as is evident from the right angled triangle. To solve the equation $\sin E = \beta \sin V$, or $\frac{\sin E}{1} = \frac{\sin V}{\frac{1}{\beta}}$, find the intersection of radius E° with the circle for the given refractive index and pass horizontally from this point to intersection with outer circle of drawing, which point indicates V in degrees.

Examples.

(1) $K = 54\cdot 0$ $D = 21\cdot 1$

Intersection of ordinate D with K-circle is at radius 23°.

(2) $E = 42°$ $\beta = 1\cdot 65$

Pass along radius 42° to intersection with circle labelled $\beta = 1\cdot 65$, and then horizontally to outer circle and read $V = 24°$.†

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* Fedorow, Zeitschr. f. Kryst. xxvi, 225–261, 1896. F. E. Wright, this Journal, xx, 287, 1905.

† The drawing of Plate II can also be used to solve the birefringence formula of Biot, $\frac{\gamma' - \alpha'}{\gamma - \alpha} = \sin \alpha_1 \sin \alpha_2$, which is very approximately correct and has been used frequently in optical work and in which $\gamma' - \alpha'$ denotes the measure of birefringence for any given section of a mineral, $\gamma - \alpha$, that of the maximum birefringence of the mineral, α_1 and α_2 the angles included between the normal to the section and the two optic axes respectively. This formula can be solved graphically at once by noting the length of the ordinate of the point of intersection of the radius α_2 with that circle whose radius is equal to the ordinate of the point of intersection of the radius α_1 with the outer circle. This graphical solution gives directly the relative birefringence of the section in per cent of the absolute birefringence $(\gamma - \alpha)$ as represented by the radius of the outer circle.

Mallard's method for measuring the optic axial angle is one of the most satisfactory of the microscopic methods and if available sections are at hand which show the required phenomena, Mallard's method should be adopted without question, especially if the measurements can be made with a double screw micrometer ocular. The limits of error of measurements of 2V by the Mallard method should not exceed 1°–2° on clear interference figures.

Methods of F. Becke.—In place of the single screw micrometer ocular which in itself is of very limited application, F. Becke* has substituted a graphical method in which the observed optical phenomena are projected by a camera lucida on a revolving drawing table fixed in position relative to the microscope. Accurate drawings of the interference phenomena are thus prepared and serve in place of the actual interference figure. This method has been fruitful in its results and with practice the necessary manipulative skill can be acquired to obtain trustworthy axial angle values. The accuracy of the method is dependent on several factors—the accuracy with which the drawing is prepared, the exactness with which the drawing table is centered, and the care with which measurements are made on the finished drawing.

The actual field of the projection does not measure over 25^{mm} in diameter, and a difference of 1° of E corresponds to a difference in D of about $\cdot 25^{mm}$, a distance which is easily measurable. With unusually sharp axial bars and nice adjustment of the optical system, it is theoretically possible to obtain an accuracy of about $\frac{1}{3}$–$\frac{1}{2}$°; in practice, however, a greater accuracy than 1–2° cannot be claimed for the method.

The writer has not seen the revolving drawing table described by Professor Becke, and has used in his work a small revolving disk D, graduated in degrees and supported by an arm E attached to the microscope stand by the collar F, as shown in fig. 7. This device was constructed in the mechanical workshop of the Geophysical Laboratory, after specifications furnished by the writer. The results obtained with it have proved satisfactory and the manipulation with the same convenient.

Having once fixed the position of this table so that its axis of revolution coincides after reflection in the camera lucida with the optical axis of the microscope and is also at the proper distance from the eye for distinct vision, its constant K, corresponding to the K of the microscope in the formula $D = K \sin E$, must be determined by one of the methods described above.

With the drawing of an interference figure thus properly prepared, it is possible to determine the angular distance,—polar

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* F. Becke, Tschermak's Min. petr. Mittheil., xiv, 563, 1894; xvi, 180, 1896.

angle ρ and longitude angle ϕ, of any point in the projection,—and to plot the same in stereographic or orthographic or gnomonic projection and thus to measure the angular distance between any two points, as those between optic axes occurring in the field of vision.

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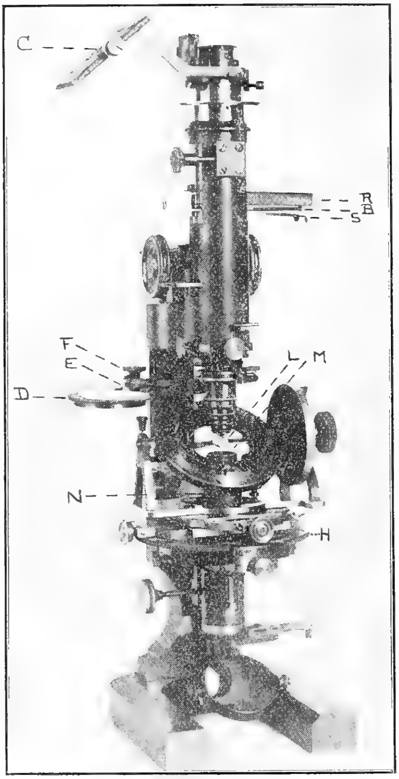

Fig. 7. In this figure, C is the camera lucida; D, revolving disk of drawing table graduated into degrees and supported by the arm E, which in turn fits into the collar F clamped to the stand of the microscope at the proper distance from C; R, axial angle reflector; B, Bertrand-Amici lens; S, sliding stop diaphragm; L, upper lens of condenser system fitted in brass ring in horizontal circle H_3 of universal stage (page 343); N, brass cylinder extension to hold lower portion M of condenser lens system (page 342).

In a recent article,* Professor Becke has described an ingenious method by which any section, in which only one optic axis appears in the field, can be used for the measurement

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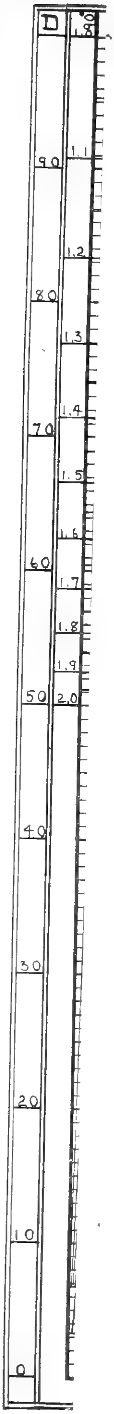
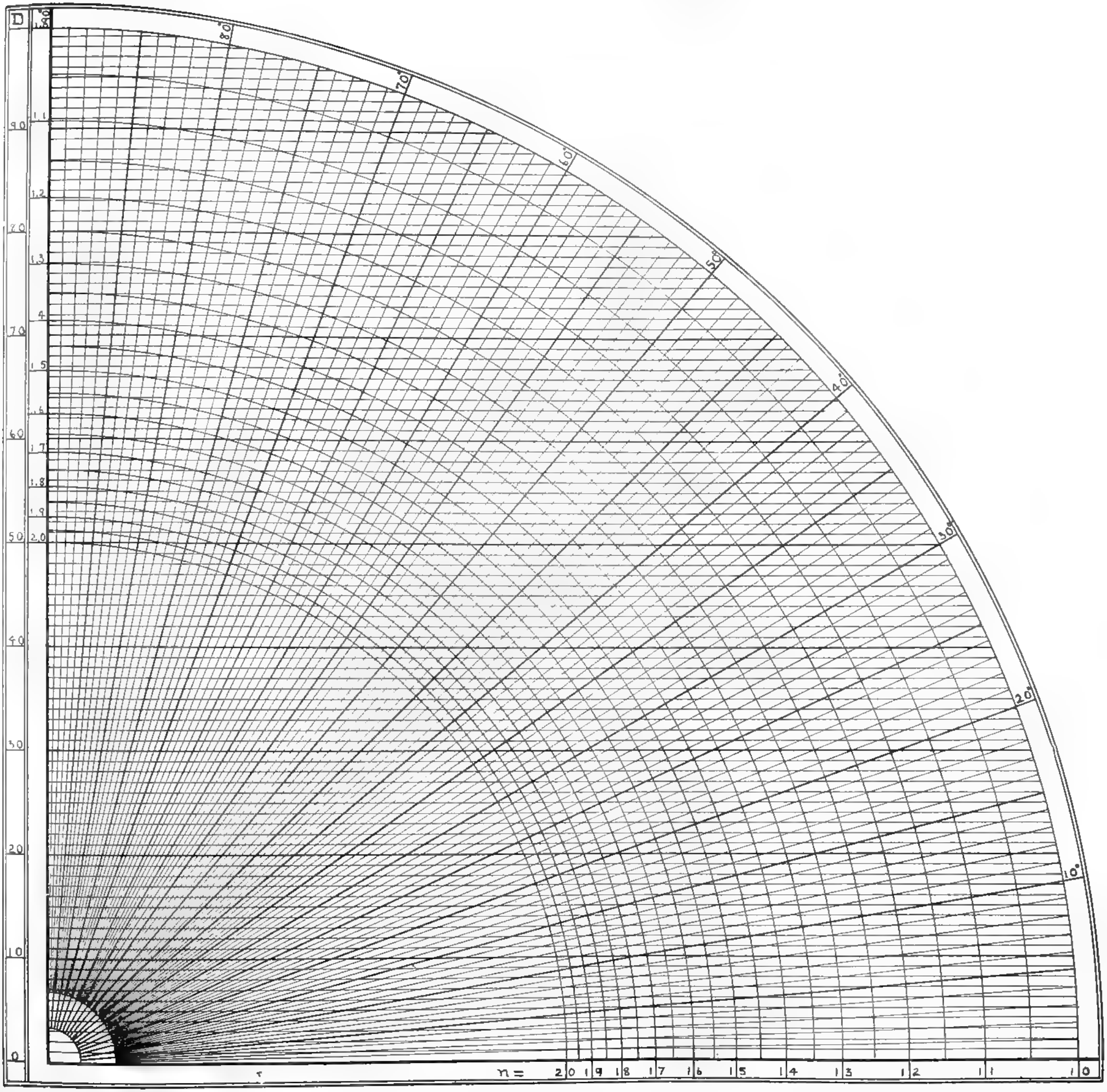
*F. Becke, Tschermak's Min. petr. Mitth., xxiv, 35-44, 1905.

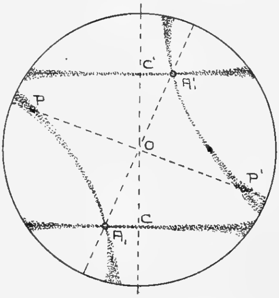

D
1.80
1.1
90
1.2
80
1.3
1.4
70
1.5
1.6
60
1.7
1.8
1.9
50
2.0
40
30
20
10
0


D
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
90
80
70
60
50
40
30
20
10
0
80°
70°
60°
50°
40°
30°
20°
10°
n = 2.0 1.9 1.8 1.7 1.6 1.5 1.4 1.3 1.2 1.1 1.0

of the optic axial angle, although the values obtained are only close approximations to the true value of the 2V. He utilizes the fact that sections of biaxial minerals, cut approximately normal to an optic axis, exhibit, in convergent polarized light, dark axial bars which resemble hyperbolas in the diagonal position and whose degree of curvature is dependent on the optic axial angle 2V. For any given position of the stage, the points along the dark bar of the interference figure correspond to those directions of light wave propagation in space whose planes of vibration coincide with the principal plane of the lower nicol (polarizer) and for which the extinction angle is zero.

To measure graphically the optic axial angle of a given mineral from the degree of curvature of its dark axial bar (zero isogyre) on a section about normal to an optic axis by this method, the axial bar is first drawn when in a position parallel to the horizontal cross hair (fig. 8, the straight line A_1 C in this position being the trace of the plane of optic axes); the microscope stage and drawing table are then revolved in the same direction about some convenient angle 30° or 45° and the axial bar drawn in the new position (A_1 P of fig. 8).* These drawings are repeated after revolution of the microscopic stage or drawing table alone through 180° (A_1' C′ and A_1' P′).

8



The point P in the projection is any convenient point on the dark curve or zero isogyre, and is therefore a direction in the crystal in its given position relative to the nicols along which light waves are propagated without changing their original plane of vibration. The plane of vibration for the point P is thus known, and the law of Biot can be applied directly to find by construction the second optic axis A_2.

A convenient form of construction is shown in fig. 9, the details of which are the same in every case. After plotting the observed points P and A_1 on tracing paper above the projection plat, the great circle $A_1'CA_2'$, of which P is the pole, is first found by revolving the tracing paper about the center O until P coincides with the vertical diameter of the under-

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* In his work the writer has found it more convenient and accurate to revolve the nicols instead of the stages, which remain stationary except for revolutions of 180°.

lying plat, and then finding and sketching that great circle whose intersection C with the vertical diameter is at 90° from P (to be counted from P, each of the great circles of the projection being 2° apart). Similarly, the great circle A_1A_2, containing A_1 and the extremities of the horizontal diameter DE, is located and drawn. The great circle which indicates the plane of vibration for P, can be found by either one of two methods: (*a*) it is that great circle containing P and tangent at P to the small circle, GPL (fig. 9), which parallels the trace GOF in projection of the principal plane of the lower nicol; (*b*) it is that great circle passing through P and the intersection C of the polar great circle $A_1'A_2'$ C with the trace of the principal plane FOC of the lower nicol.* In actual work, however, it is not necessary to draw this great circle PC, since the point C is the point sought and determines at once the direction of extinction for the given section. The simplified construction is illustrated in fig. 10, where C is

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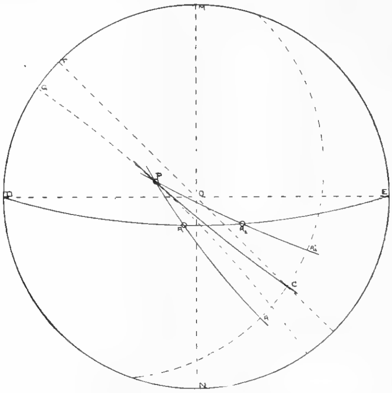

FIG. 9. In this figure the points P and A_1 are the two points obtained from the original drawing. The plane of vibration for the point P in its position of darkness is indicated by the great circle PC tangent at P to the small circle GPL, which is parallel to FOC, the trace of the plane of vibration of the polarizer when the zero isogyre passes through P. Further details of construction are added under fig. 10.

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* In his paper, Professor Becke determines this great circle as the one which is tangent at P to the straight line parallel to the trace in projection of the principal section of the lower nicol. This method does not facilitate the finding of the great circle in any degree, and introduces an error, as Professor Becke himself recognizes, which decreases the accuracy of the method to just that extent. It seems advisable, therefore, to use one of the new methods described above which are theoretically correct and equally simple.

the intersection of the great circle $A_1'A_2'$, and the diameter OC, the trace of the plane of vibration of the lower nicol.

Having thus determined the point A_1' and C, the projection of the second optic axis A_2 is found by making $A_2'C = A_1'C$ (Biot's law). The intersection of the great circle PA_2' with the plane of optic axes A_1A_2 determines then the position of A_2, and the angle A_1A_2 in projection is 2V, the angle between the optic axes.

The actual time consumed in this operation is not great, and the values obtained are approximately correct. The objection to its use lies chiefly in the subjective factor involved, namely, the skill required in drawing accurately the phenomena observed, and also in the nice adjustment of all parts of the instrument.

10

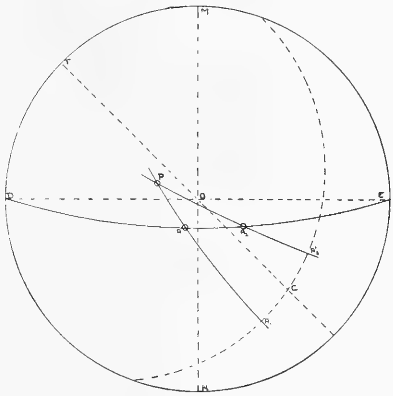

FIG. 10. In this figure the operations of actual construction are given which are required to measure A_1A_2 from the data in the drawing. The points A_1 and P are first located accurately in the drawing, reduced to angular values and plotted directly on tracing paper in stereographic projection; the great circle $A_1'A_2'$ polar to P_1, and the horizontal great circles A_1A_2 are then sketched; the point A_1' is the intersection of the great circle, containing P and A_1 with great circle $A_1'A_2'$, while the line OC is the trace of the plane of vibration of the lower nicol (polarizer) as it appears on the drawing after the revolution of 30° or 45°; the angle MOF indicating directly the angle of revolution. By definition $A_2'C$ is equal to $A_1'C$, and the intersection A_2 of the great circle PA_2' with the great circle A_1A_2 determines A_2, the second optic binormal, the angle A_1A_2 being the desired optic axial angle.

The location of the optic axis A_1 is at all times more accurate and trustworthy than that of P, owing to the indistinctness and width of the black axial bars near the margin of the field in consequence, chiefly, of elliptic polarization.

New Methods with Double Screw Micrometer Ocular.—In seeking for more accurate and at the same time simpler methods than those of Professor Becke described above, the writer has substituted in place of the usual single screw micrometer ocular, with a movement in one direction only, a double screw micrometer ocular with movements in two directions normal to each other. By the use of this double screw micrometer ocular, which was constructed in the workshop of the Geophysical Laboratory (fig. 11)* it is possible to determine the position of any point in the interference figure accurately by means of two micrometer screw readings, which correspond to rectilinear coördinates in the orthogonal projection and small circle coördinates in the stereographic projection. By means of the constant K of the microscope for each of these micrometer movements, K_V and K_H, which must have been determined previously by means of known angle values (table 1, page 328), each of these readings is reduced as usual to its angle value for the crystal by means of K and the average refractive index of the crystal,

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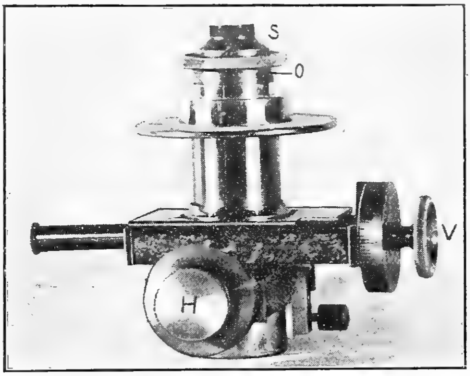

$$\sin V = \frac{D}{K \cdot \beta}$$

Having given the interference figure from a section of a biaxial mineral, cut so that one axial bar is visible, the course

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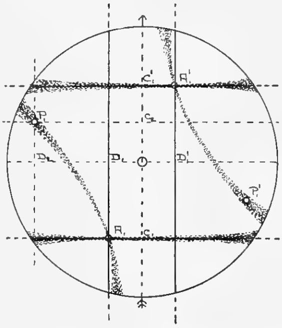
* The double screw micrometer ocular is fitted to microscope of fig. 7. The two movements, H horizontal and V vertical, are effected by fine micrometer screws, reading accurately to ·005mm. The construction of this ocular is similar to that of the single screw micromoter oculars with the exception that here two screws with corresponding movements are used in place of the single screw. O = Ramsden ocular ; S, small stop aperture to reduce errors of parallax.

of procedure in measuring the optic axial by means of the double screw micrometer ocular consists in: (*a*) revolving the microscopic stage until the dark axial bar is parallel to the horizontal cross hair of the ocular; (*b*) moving the horizontal cross hair by means of the vertical micrometer screw V until it coincides precisely with the center of the dark axial line (fig. 12, A_1C_1); (*c*) revolving the nicols (not the stage as may be done in the Becke method) about a suitable angle (usually 30 or 45°), the exact position of the optic axis A_1 then being the intersection of the axial bar with the horizontal cross hair (fig. 12, A_1C_1 with A_1P_1); (*d*) moving the vertical cross hair by means of the horizontal micrometer screw until it coincides with this intersection and recording both vertical and horizontal micrometer screw readings; (*e*) the stage is then revolved about an angle of 180°, and similar readings for A_1 taken in its new position, A_1'. This last step is necessary in order to locate accurately the center of the field O. The position of A_1 is thus fixed accurately and can be plotted directly, after proper reduction to true angles within the crystal, in stereographic (small circles) or orthographic (coördinates) projection. Any point P of the dark curved axial bar can now be determined by two micrometer readings (coördinates from the center) and, after reduction to angles within the crystal, plotted in the projection. From this point on the method does not differ from the foregoing methods. The optic axial angle is determined by construction from the projection plat thus obtained.

12



In plotting the angles corresponding to the coördinate readings of the double screw micrometer ocular, it should be noted that these angles apply to small circles, the angle for each micrometer screw indicating the position, from the center of the projection, of a certain horizontal or vertical small circle. The intersection of the horizontal and vertical small circles thus obtained from the two micrometer screw readings for a particular point of the interference figure determines the location of that point in the projection.

Measurements with the double screw micrometer ocular are more delicate, and therefore more accurate, than those with the Becke drawing table, and the values for 2V correspondingly more trustworthy. This method is of general application to all sections cut in such a way that either one or both optic axes appear in the microscopic field. By using projection plats, either stereographic or orthographic, results of a fair degree of accuracy can be obtained in a very few minutes.

On sections in which both optic axes of the interference figure are visible, the exact position of A_1 and A_2 can be measured directly, and after plotting, the value 2V obtained from the projection by direct reading. Such values should be accurate to ± 1°.

To form an idea of the relative degree of curvature of the axial bar in the diagonal position for sections of biaxial minerals cut at different angles with an optic axis (binormal) and for the optic axial angles 2V = 0°, 15°, 30°, 45°, 60°, 75° and 90°, the writer has constructed by graphical methods the following figures:

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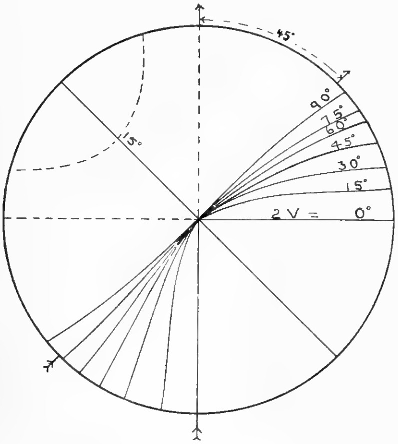

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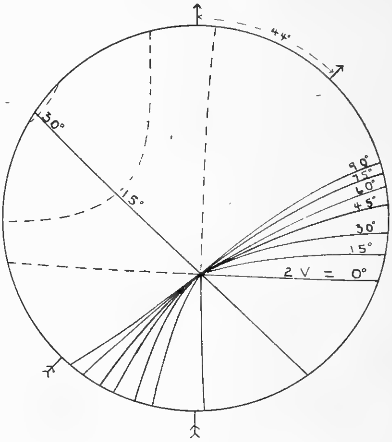

Fig. 13. This figure illustrates the positions in the interference figure of the dark curves of no extinction (axial bars) as they would appear in the field were observations made in air on a series of biaxial minerals having a mean refractive index of 1·60 and the optic angles indicated, and cut normal to one of the optic axes (binormals). From the figure it is evident that the radius of curvature of the axial bar increases with the optic axial angle, so that for 2V = 90°, the axial bar is practically a straight line.

Fig. 14. The conditions of construction for this figure were similar to those of fig. 12, except that the section is considered cut at an angle of $\lambda = 10°$, $\mu = 10°$ (small circle coördinates from the center) with one of the optic binormals.

In these figures, the dark lines represent the curves of 0° extinction (zero isogyres or axial bars) of the interference figure in orthographic projection, the plane of the optic axes making angles of about 45° with the plane of vibration of light waves from the lower nicol.

The curves of figs. 13, 14 and 15 are constructed for minerals with a refractive index $\beta = 1{,}600$, while in those of figs. 16–19 orthographic projections of the actual positions of the directions of 0° extinction within the crystal are given (refractive index of mineral and medium in which the phenomena are observed, being considered equal). It is evident from the figures that the differences in curvature of the axial bars for the different values of 2V are sufficient to warrant their use in measuring optic axial angles approximately. The accuracy of the method depends on the accuracy with which the points A_1 and P (fig. 12) can be determined. The positions most favorable for these points are located one-half to two-thirds the distance from center of field to its margin. Near the center of the field, the errors of construction increase rapidly, while near the margin, errors due to imperfections in the lenses and to elliptical polarization tend to modify the interference figures, and decrease the accuracy to be attained.

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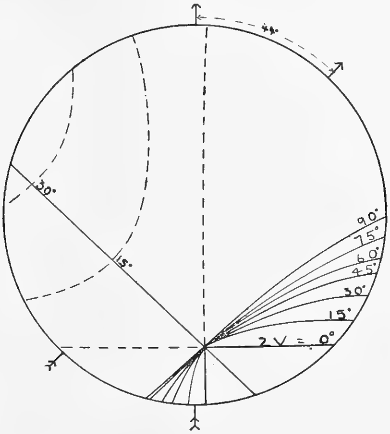

Fig. 15. This figure differs in construction from figs. 12 and 13 only in the fact that the section is considered cut at an angle $\lambda = 20°$, $\mu = 20°$ with one of the optic binormals.

The actual diameter of the field covered by the micrometer screw movements of the writer's microscope measures about 600 micrometer screw divisions. The distance covered by the extremes of the curves for 0° and 90° is less than 200 divisions, or on an average, about 2 divisions for one degree. Taking into consideration the indistinctness and width of the axial bars, it is easily possible to make an error of three or four divisions of the micrometer scale in these readings, so that an

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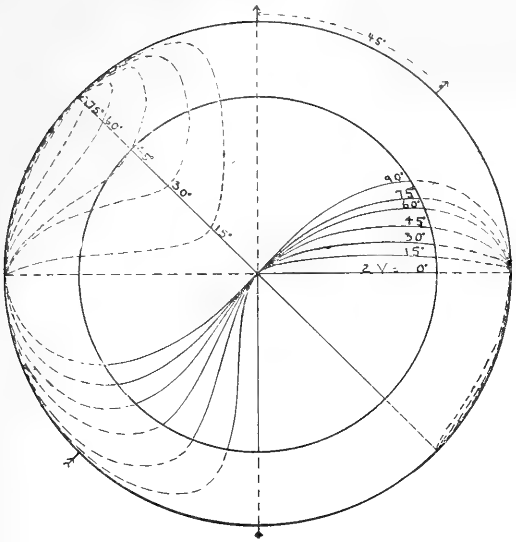

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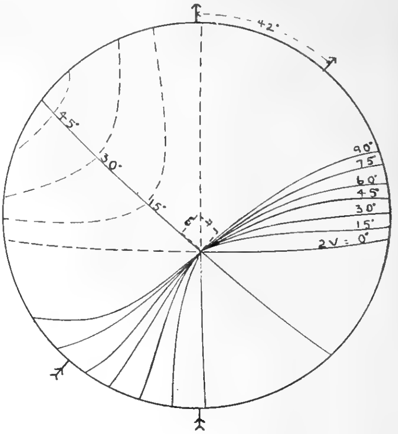

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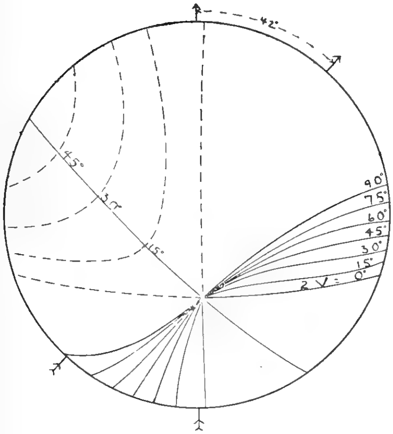

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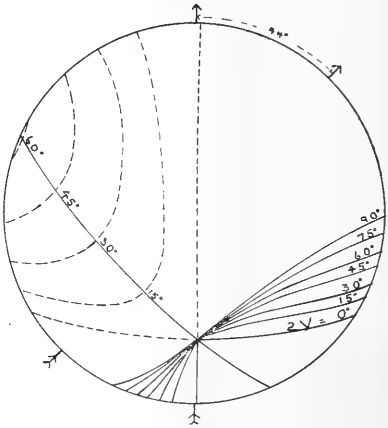

FIGS. 16, 17, 18, 19. In figs. 16–19 the axial curves (zero isogyres) are constructed under the assumption that the mean refractive index of both the mineral and the medium in which its interference phenomena are observed, are identical; in short, an orthographic projection of the phenomena as they appear within the crystal is given. In fig. 16, the section is normal to an optic **axis**; in fig. 17, the section makes angles, $\lambda = 5°$, $\mu = 6°$ (small circle coördinates) with the optic binormal; in fig. 18, the angles are $\lambda = 12°$, $\mu = 13°$, while in fig. 19, the section makes angles $\lambda = 20°$, $\mu = 20°$ with the optic axis; the angle of revolution of the stage and consequent new position of the trace of principal plane of lower nicol in each case is indicated by the arrows. The area included by the inner circle of fig. 16 indicates the relative field of vision of ordinary microscopes.

accuracy of more than ± 2° cannot be claimed for this method. With the drawing table, this probable error increases about ± 5° under the same circumstances.

In place of the expensive double screw micrometer ocular, the writer has had constructed a simpler, although slightly less accurate ocular, consisting of a Ramsden ocular with finely divided cross section scale in its focal plane (arrangement similar to that in ocular of Czapski). (Ocular of fig. 5.) After insertion of the Amici–Bertrand lens, the secondary image of the interference figure is brought to focus in the focal plane of the ocular, where the location of any point can be read off directly in coördinates, which in turn are to be reduced, just as the readings of the double micrometer screw ocular, to angle directions within the crystal, and then plotted in suitable projection. The coördinate scale employed in this ocular is a photographic reproduction on thin glass of a greatly reduced drawing.

Klein's lens, which was first described by Becke, can also be changed to fit the new conditions by simply introducing the above fine cross-grating or coördinate micrometer scale in place of the single micrometer scale.

By the use of such oculars with fine coördinate scales, one has the entire field of the interference figure under control, and, by use of projection plats, can readily measure optic axial angles on all sections which are so cut that one optic axis at least is in the field. If two optic axes appear within the field of vision, their positions can be read at once from the coördinate scale of the ocular and after proper reduction plotted in stereographic or orthographic projection where their angular distance can be determined directly.

Michel-Lévy Method.—For sections normal to an acute bisectrix of a mineral with large optic axial angles, Michel-Lévy has suggested a method which, although interesting theoretically, is not of great practical value, owing to the indistinctness of the phenomena to be observed. His method consists in reading the angle of revolution of the stage necessary to bring the interference figure from the crossed position to that in which the emerging axial bars of the interference figure are tangent to a given circle.* Actual practice with this method has shown that it is not sufficiently accurate and of such general application as to warrant a more detailed description at this point.

Method with Universal Stage.—In practice, it frequently happens that a given section is not favorably cut to show the

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* Michel-Lévy, et Lacroix, Les Mineraux d. Roches, 94-95, 1888. For a modification and simplification of his formula, see F. E. Wright, this Journal, xxii, 289, 1905.

optical phenomena to the best advantage, and that by tilting it a certain angle, the interference figures can be improved materially. This is particularly the case with fine-grained artificial preparations where, although individual crystals and cleavage can frequently be obtained, they do not rest in the section in the most advantageous position. Such crystals and crystal plates can be tilted either by means of an axial angle apparatus for the microscope, as that described by Bertrand* many years ago, or by use of the glass hemisphere of Schroeder van der Kolk,† or by the new upper condenser lens of ten Siethoff.‡ The last two methods are qualitative methods only, while that of Bertrand, although quantitative, permits of revolutions only in one plane. To supply the want of a universal condenser lens on which angular movements can be accomplished and measured in any direction, the writer has modified the Fedorow-Fuess universal stage by having a brass disk, L, constructed in the workshop of the Geophysical Laboratory to fit in the Fedorow-Fuess stage (large model) in place of the inner ring bearing the glass with cross hair (see fig. 7, page 332). Into this ring the upper lens of the ten Siethoff condenser lens system is inserted. The partially bevelled upper surface of this condenser lens has a radius of $1{\cdot}5^{mm}$, and permits, even with a No. 9 Fuess objective, angular movements of about 30° on either side of the normal. By means of a proper cylinder, N, of brass (fig. 7, page 332) resting on the cylinder containing the lower nicol, the remaining lenses of the condenser system are raised to the required distance from the upper lens. This type has proved extremely useful for work with artificial preparations, since by its use sections may be so placed that the most favorable measurements possible can be accomplished with the double micrometer ocular, and in certain cases even, where the optic axial angle is small, the same can be measured directly by means of the universal stage angles in convergent polarized light.

Although the measurements accomplished by the universal stage methods of Fedorow are made in parallel polarized light and with low power objectives, the same objectives can be used for weakly convergent polarized light with Bertrand lens and the position of the optic axes thus determined if it be possible to bring them within the field of vision and provided they are sufficiently distinct for accurate location under these conditions.

For general work, however, with thin sections in convergent polarized light, the methods requiring the double screw micrometer ocular are the most accurate and easy of application.

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*E. Bertrand, Bull. Soc. Min. Fr., iii, 97-100, 1880.

† Schroeder van der Kolk, Zeitschr. f. wiss. Mikroskopie, viii, 459-461, 1891, and xii, 188-189, 1895.

‡ E. G. H. ten Siethoff, Centralblatt f. Min., 657, 1903.

The methods for determination of the plagioclase feldspars, rich in lime, which have been developed by F. Becke* by using Klein's lens and Czapski ocular, also by means of revolving drawing table, can be applied directly to the two screw micrometer ocular and more accurate data obtained by its use.

PARALLEL POLARIZED LIGHT.

The introduction of the universal stage methods by Fedorow in 1893† and succeeding years placed a powerful instrument of attack in the hands of petrologists. With his methods, it is now possible to obtain the optic properties of mineral sections which before were considered practically useless. The universal stage (fig. 20) can be attached securely to any suitable petrographic microscope; parallel polarized light only is used. By means of horizontal and vertical axes of revolution, a crystal section can be brought to any given position and revolved about any axis for optical examination.

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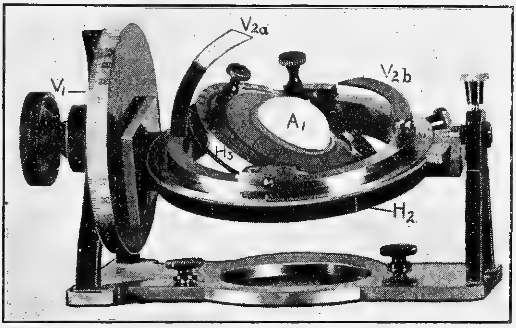

FIG. 20. In its present form the universal stage comprises, when attached to the microscope stage, five graduated circles; H_1, the horizontal circle of the microscope stage, H_2, the large horizontal circle of the universal stage, with H_3, the inner and thin section bearing circle, V_1, the large vertical circle, and V_2, an inner circle consisting of two segments V_{2a} and V_{2b}, and placed to measure the angles of revolution of the inner disk H_3 about a horizontal axis. Two glass hemispheres (A_1 being the upper) are usually employed with the stage to increase the angle of vision of the microscopic field.

In plane polarized light an optic axis is recognized by the fact that when placed parallel to the axis of the microscope it remains uniformly dark during a complete revolution about

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* F. Becke, Tschermak's Min. petr. Mitth., xiv, 415-442, 1895.

† E. Fedorow, Zeitschr. Kryst., xxi, 574-678, 1893; xxii, 229-268, 1894; xxv, 225-261, 1895; xxvii, 337-398, 1897; xxix, 604-658, 1898.

that axis. By plotting these directions graphically in projection, and by determining extinction angles in given zones, it is possible not only to measure the optic axial angle, but also to determine the exact position of the optic axes with reference to the crystal plate, even though it may happen that neither optic axis appears within the field of vision.

The values for 2V thus obtained on different sections, however, are not all of the same order of exactness, as will appear later in the more detailed discussion of the different sections. It should be noted that in the Fedorow methods, as in the preceding, the measured angles are reduced by means of the average refractive index β to true angles within the mineral before plotting in stereographic projection. Here also the combination of tracing paper with stereographic projection plat as a base, as suggested by Wulff, is to be recommended as the best and most efficient scheme for obtaining results rapidly and accurately.

In these methods the rule of construction of Biot-Fresnel, that the planes of vibration of light waves propagated in any given direction bisect the angles between the two planes containing one of the two optic axes and the given direction, is used constantly, since the two factors, on which the universal stage methods are practically based, are the directions of the optic axes, as they may be determined directly, and extinction angles for certain zones and directions. Fedorow has also shown how it is possible with his methods to measure the refractive indices and also the birefringence approximately of a mineral from any section. These methods are not, however, germane to the purpose of this paper, and will not be discussed further. It may be stated that, although the methods of Fedorow involve the use of a stereographic projection plat and are in part graphical in nature, they are not difficult of application and often furnish results where other methods fail. In ordinary microscopic work, it frequently happens that one method will yield more accurate data in a shorter time than a second, and that particular method should then be chosen in preference to all others.

In general, the Fedorow methods are indirect methods and frequently involve a large expenditure of time to complete the observations on a single plate. For these reasons chiefly, petrologists have not adopted them so rapidly and generally as might have been anticipated, particularly as the old tested methods accomplish about what is desired by the busy petrologist who uses the microscope simply as a means to an end—to aid him in interpreting geological phenomena and relations.

When attached to the microscope, the Fedorow-Fuess stage (fig. 20) possesses, when in the 0° (primary) position, three horizontal circles, H_1 (microscope stage), H_2 and H_3, each circle graduated into degrees with verniers attached to H_1 and H_2; each of these circles is revolvable about a vertical axis; the horizontal axes of revolution and equivalent vertical circles are V_1 and V_2 also divided into degrees and V_1 with vernier attached. On the original stage described by Fedorow and made by Fuess, the partial scales V_2 are wanting and have been attached by the writer. These scales were constructed in the workshop of the Geophysical Laboratory, and have been found of practical service in several methods, especially those involving the principal sections of the triaxial ellipsoid of any mineral (page 353). Each partial scale of V_2 is accurately divided and carefully adjusted to the instrument. When not in use, the scale segments of V_2 can be inclined to a horizontal position V_{2b} and are then entirely out of the way. Measurements given below will be referred to this modification of the Fedorow-Fuess universal stage.

To increase the angle of vision of the field, two glass hemispheres, A_1 and A_2 (in fig. 20 A_1 only appears, A_2 being hidden by H_2), are usually employed; between these the preparation is placed, either cedar wood oil or glycerine being used to stick the same together and to reduce the effects of total reflection. For general work with the universal stage, it is advisable to follow the suggestion of Fedorow and use special circular (2^{cm} diameter) object glasses on which to mount the preparations in place of the ordinary rectangular (26×46^{mm}) thin section object glasses.

With the universal stage of this type, it is possible not only to bring a crystal section in any given position, but also to revolve that section about any axis; in short, by its use one has control over all possible directions and zones or axes of revolution of a crystal.

The Determination of the Crystal System of a Given Mineral by Means of the Universal Stage Method.—The fact that the universal stage allows the observer to study the different effects of a given mineral section on light waves transmitted through it in different directions, enables him to determine at once the crystal system to which the crystal belongs. This is accomplished most readily by means of extinction angles along certain directions, since the term extinction angle implies a definite relation between a given crystallographic and a given optical direction in any mineral. These relations vary with the crystal system of the mineral, and in fact are such definite functions of the same that, as Brewster* was the first to show, it is possible from extinction angles alone to determine definitely the crystal system of a given mineral. Briefly, an iso-

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* Brewster, D., Phil. Trans., 1814, 187-218; 1818, 199-272.

metric mineral is isotropic for all directions of light wave propagation. Uniaxial minerals (hexagonal and tetragonal) appear isotropic for light waves passing along the principal crystallographic axis. For all other directions, they are anisotropic, but even then can generally be distinguished from biaxial minerals at once by the fact that every section of a uniaxial mineral contains the ω ellipsoidal axis, parallel with and normal to which it extinguishes. If the section be placed, therefore, in the position of darkness between crossed nicols and be revolved about a horizontal axis, V_1, it will continue to remain dark, if the ellipsoidal axis ω coincides with the axis of revolution, while if the ellipsoidal axis ω be normal to the latter, the crystal will exhibit interference colors of polarization on revolution except for sections of the prism zone. Biaxial minerals, on the other hand, do not in general remain dark for either axis revolution, and only do so for sections in the principal zones of the optical ellipsoid. Biaxial minerals show, moreover, two directions of apparent isotropism, those of the optic axes or optic binormals. To trace out the relations obtaining for orthorhombic, monoclinic and triclinic minerals and their distinguishing features, is not a difficult matter, but one for which space is not here available. They are in effect those which are used for the same purpose with ordinary methods.

The Accurate Determination of the Position of an Optic Axis when in the Field of Vision.—Although the underlying principles of determination by means of the universal stage are the same for all sections of a mineral, it has been found by experience that for certain sections, certain courses of procedure for measuring the optic axial angles are best adapted to produce the best results. Fedorow has divided the possible sections of any biaxial mineral into four convenient groups, each of which has its special characteristics and to each of which certain methods are best suited. The relative positions of the optic axes to and in the field of vision have been made the criteria for distinguishing these different groups; thus, in group (1) both optic axes are within the field of vision; (2) one optic axis is within the field of vision and makes an angle of less than 20° with the normal to the section; the second optic axis cannot be brought within the field of vision by any revolution of the stage; (3) one optic axis only appears in the field and makes an angle of over 20° with the normal to the section, the second optic axis lies entirely outside the field; (4) both optic axes lie outside of the microscopic field, the section in question being cut more or less nearly perpendicular to the optic normal, or about parallel to the plane of the optic axes; or about normal to the obtuse bisectrix of a mineral with small optic axial angle.

In case one or both optic binormals of a biaxial mineral section can be brought by revolution to coincidence with the axis of the microscope, it is necessary to determine these angles of revolution with the greatest possible accuracy. In all cases, an approximate determination is first effected by revolving the section about V_1 and H_2 until it is dark and remains dark during a complete revolution of the microscope stage H_1. In weakly convergent polarized light the optic axis can be seen in the center of the field. In ordinary microscopes, where absolutely plane parallel polarized light cannot be obtained, the section in such a position will not be perfectly dark, owing to internal conical refraction, but will preserve the same degree of slight uniform illumination for all positions of the microscope stage.

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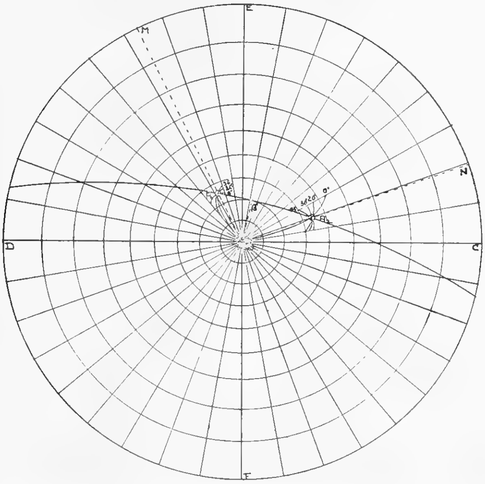

Fig. 21. In this figure, the method for locating the position of the optic axes by means of optical curves is illustrated. The figures 0°, 20°, 30° and 45° opposite the curves indicate the angles which the plane of vibration of the polarizer at the time of observation made with the plane of symmetry of the microscope.

More accurate determinations of the position of an optic axis can then be made by means of extinction angles along definite directions, which, when plotted in projection, give rise to curves all of which pass through the optic axis. The average point of intersection of a set of such curves is then the true position of the optic axis in projection. (Fig. 21.)

Such curves have been called optical curves by Fedorow and are obtained most readily by first placing the crossed nicols in any given but fixed position, then turning H_2 through angles of 5° respectively, and for each position of H_2 determining the angle of inclination about V_1 for which the section is in the darkest position (0° extinction) (fig. 21); the same results can also be attained by first turning the preparation about V_1 a specified angle and then about H_2 until darkness ensues. By this method, those directions in the crystal are obtained (after proper reduction of observed angles to crystal directions by means of the refractive index) for which the extinction is zero for a given position of the nicols. The curve uniting these directions in projection is the optical curve for the particular position of the nicols to the axes of revolution. Analogous curves for other and different positions of the nicols are to be obtained and plotted in similar manner. All such curves pass through the optic axes and also the center of the projection. Their points of intersection in the projection determine, therefore, with considerable accuracy, the exact position of the optic axis or of both axes, in case both axes can be brought within the field of vision. Since such optical curves are intended solely to increase the accuracy of the determination of the positions of the optic axes, their approximate positions being known from the preliminary determination, it is necessary, in actual practice, to take readings of H_2 only 5° or 10° on either side of the approximately correct position of the optic axis as determined by the preliminary direct observations. Convenient positions of the nicols for optical curves are at 0°, 45°, 15° and 30° from the V_1 axis of revolution. If both optic axes appear within the microscopic field of vision, the most satisfactory method of measuring the optic axial angle by means of the universal stage is to determine the exact position of each axis by the above method and to plat the same in stereographic projection, in which the angle can be measured directly by graphical methods rather than by calculation, from the cosine formula, $\cos 2V = \cos V_{1a} \cdot \cos V_{1b} + \sin V_{1a} \sin V_{1b} \cos (H_{1a} - H_{1b})$ in which $2V$ designates the optic axial angle; V_{1a}, H_{1a}, the readings for the one optic axis; and V_{1b}, H_{1b}, those for the second.

The results obtained by the use of optical curves can be checked and verified by several of the methods described below, which are of general application and can readily be applied to this special case.

Fedorow has shown that in actual practice with minerals of weak to medium birefringence, the errors can be disregarded which are due to the reduction of all observed angles by means of the average refractive index of the crystal in place of the true refractive indices for each given direction; and likewise those errors which may arise from slight deviations in planes of vibration (extinction angles) due to refraction from steeply inclined plates and consequent elliptical polarization, are small quantities of a low order of magnitude and can be disregarded in general.

The method of measuring the optic axial angle by means of opti-

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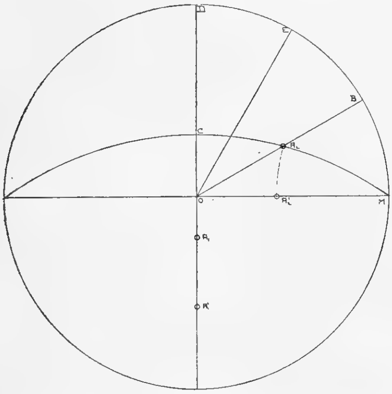

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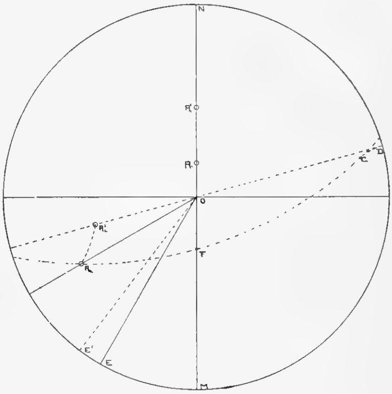


Fig. 22. In the method illustrated by this figure, the visible optic axis A_1 is brought to coincide with the plane DCO and the extinction angle DOE measured while the stage is in the horizontal position. A_2 must lie then in the plane OB, the angle BOE having been made by construction equal to DOE. The section is then revolved about OM (axis V_1) until the extinction angle becomes 45°, in which case the plane OM contains A_2, since A_1 has remained during this revolution in the plane DCO; on turning the specimen back to its original position, the line OM becomes the great circle CA_2M and the intersection of this great circle with the plane OB fixes A_2 definitely in the projection. In practice, the great circle CA_2M need not be drawn, since on placing the tracing over the plat it is only necessary to find that small circle A_2A_2', the arc of which intercepted between OB and OM is equal to the angle of revolution.

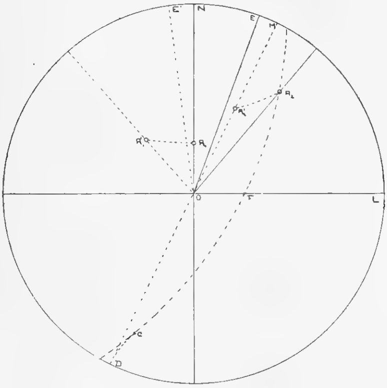
Fig. 23. The general method of extinction curves shown in this figure is applicable to all sections in which one optic axis A_1 can be brought to coincidence with the axis of the microscope. After the determination of the exact position of A_1 by means of optical curves the specimen is revolved about H_3 until A_1 coincides with the plane NO normal to the axis V_1 of the universal stage. The extinction angle MOE of the specimen in horizontal position is then determined; by construction EOA_2 is made equal to MOE; the specimen is then revolved about V_1 a convenient angle (apparent angle observed to be reduced to true angle), and the new extinction angle MOE′ ascertained. In the new position, the optic axis is contained in the plane OA_2', angle $E'OA_2'$ having been made equal to MOE′. The exact position of A_2 is then determined on the drawing on tracing paper by noting the small circle of the underlying projection plat, whose arc A_2A_2' intercepted between OA_2 and OA_2' is equal to the angle of revolution. This determination can be checked by drawing the great circle CF, which marks the position which the plane OA_2' would assume were the specimen turned back to its original position. In practice the position of A_2 is determined for different angles of revolution about V_1 and the mean position of all determinations taken as the most probable and correct location of A_2.

cal curves can be used only when both optic axes appear within the field of vision. In other cases, other methods are to be employed which involve either the measurement of extinction angles in zones or the determinations of the position of the principal planes of the ellipsoid, these latter to be plotted in appropriate projection. In most cases, however, one optic axis can be determined directly by optical curves, while the second optic axis makes a large angle with the normal to the section, and must be determined indirectly. A simple but comparatively accurate method to accomplish this consists in first turning the stage about H_2 until the known optic axis comes to lie in the plane normal to the axis V_1 (OCD, fig. 22), and in determining the extinction angle ($\sphericalangle$EOD) when the stage is in horizontal position and also at such an inclination about V_1 that the extinction angle is 45°; this can be recognized most readily by placing the nicols in the 45° position and then revolving the preparation about V_1 until darkness ensues. By thus ascertaining the angle of revolution necessary to attain the required 45° extinction angle, the great circle CA_2M is fixed with reference to the horizontal diameter, the plane in which the unknown optic axis A_2' must rest when the extinction angle is 45°. The intersection A_2 of the great circle CA_2M with the radius OB drawn at an angle, with the vertical line, of twice the angle of extinction ($\sphericalangle$EOD) for the plate in the horizontal position, fixes the position of the second optic axis in the projection. This method, however, is not always applicable owing to the indistinctness of extinction phenomena in steeply inclined sections (effect of elliptical polarization), and a second method of extinction curves, of which the above is only a special case, can be used to advantage. Having first placed the known optic axis in the plane normal to the axis V_1 as in the above method, measure the extinction angles for different inclinations of the stage about V_1 (the angles, as usual, to be reduced to real angles within the crystal by means of its average refractive index), and plot these directions of extinction in stereographic projection. (Fig. 23.) Under these conditions the radii, which make an angle with the vertical diameter OM_1 equal to twice the extinction angles, are evidently the planes containing the second optic axis A_2 whose exact location can be readily found by noting for two given radii, as OA_2 and OA_2', the small circle, whose arc A_2A_2' intercepted between the radii is equal to the angle of revolution of the stage. In practice it is advisable to repeat the determinations of the extinction angles and to take as angles of inclination those equivalent to 0°, 10°, 20°, 30°, 40° and 45° in the crystal on both sides of the normal to the section.

In actual work with this method, it happens occasionally that the determination of the location of A_2 is not accurate because of the acute angle between the radius and the small circle A_2A_2'. In such cases the writer has been able to apply with favorable results one of the two following new methods, which, like the preceding method, are based on the measurement of extinction angles for different angles of inclination about one of the horizontal axes of revolution of the universal stage. The new circle V_2 may render hereby valuable assistance.

In the first of the new methods, the horizontal position of the section is exactly that of the above method (fig. 24); A_1, having been previously located accurately, is brought to coincidence with ON, and the extinction angle of the specimen in the horizontal position ascertained; and then instead of being revolved about the horizonal axis V_1 (the line OL in projection), it is revolved about V_2 (or ON in the projection) as an axis,* a given angle (apparent angle in air equivalent to true angle in crystal). A_1 travels during the revolution of stage to A_1' in the projection, the direction of extinction wanders from OE to OE′ and the plane OA_2 containing A_2, from OA_2 to OA_2', the angle $E'OA_2'$ being by construction $= E'OA_1'$. By recording the angle of revolution of the stage about ON (V_2) required to bring the section to its new position, it is not difficult to find in the projection that small circle, parallel to OL, whose arc A_2A_2' intercepted by the lines OA_2 and OA_2' is equal to the above angle of revolution and thus to locate A_2.

24



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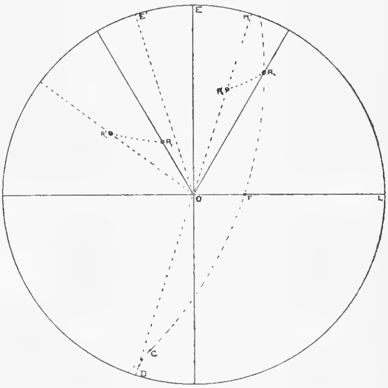

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* The same effect can be produced by revolving the specimen 90° about H_1 and about V_1 as an axis.

To insure accuracy, this measurement should be repeated for several different angles of revolution and A_2 determined in each case. As in the first method, the great circle CF, indicating the original position of the plane OA_2', can be constructed and should pass through A_2 on the line OA_2.

The second new method differs from the first only in the fact that instead of placing the optic axis A_1 in the plane OE (fig. 25), and then measuring the extinction angle of the section in the horizontal position, the actual direction of extinction OE is brought to coincidence with the axis of revolution of the universal stage (V_1 or V_2); the section is then revolved a given angle about this axis and from the extinction angles the lines OA_2 and OA_2' determined whose arc is equal to the angle of revolution. The point A_2 is then the desired direction of the second optic axis.

26

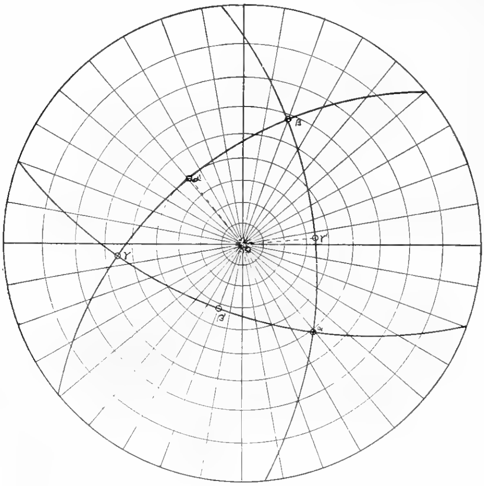


Fig. 26. In this figure, the great circles $\alpha\beta'\gamma$, $\alpha\beta\gamma'$ and $\alpha'\beta\gamma$ of the stereographic projection denote the traces of the principal planes of the optical ellipsoid within the crystal. They are fixed in position by determining the positions of H_3 and V_2 for which the section remains dark for all positions of inclination about the horizontal axis V_1 (V_2 being normal to V_1); the lines $O\beta'$, $O\gamma'$ and $O\alpha'$ are thus fixed both in direction and length and also the great circles $\alpha\beta'\gamma$, $\alpha\beta\gamma'$ and $\alpha'\beta\gamma$, the planes of symmetry of the ellipsoid, the intersections α, β and γ of which are in turn the ellipsoidal axes.

In both new methods the determination can be varied by inclining the specimen first about V_1 as an axis and then determining a series of extinction angles for different angles of inclination about V_2 (V_2 in this case being normal to V_1) and thus locating A_2 afresh with each extinction. By establishing a set of observations about V_2 for each new position of V_1 it is possible to extend the number of observations indefinitely and thus to locate A_2 with the greatest possible accuracy. In fact, the position of A_1 in the projection is immaterial so long as this position be definitely known with respect to the axes of revolution (V_1 and V_2), since with A_1' located at any point in the projection it is still possible to locate A_2 by means of extinction angles for different angles of inclination about V_1 and V_2. This method, involving the use of both V_1 and V_2, is therefore a method of general application and is capable of furnishing reliable data on all sections so cut that one optic axis at least falls within the field of vision.

Still another method which furnishes trustworthy results and is of general application, consists in determining first the positions of the planes of symmetry and the axes of the ellipsoid within the crystal. (Fig. 26.) In this method, practically all of the graduated circles of the stage are brought into play, since not only must extinction angles be observed, but also the section revolved about the ellipsoidal axes and the exact position of each axis noted. The method of procedure consists in first placing the stage in the zero (primary) position, H_3, H_1, H_2, and V_1 in zero position, and V_2 normal to V_1; the section having any orientation and position. The section is then inclined about V_2 until darkness between crossed nicols ensues; if this be not the case, it is turned about H_3 a small angle, and the attempt made a second time, and so on until at a definite angle of inclination about V_2 darkness is observed. The preparation is then revolved about V_1, and if by chance the correct position be obtained, darkness will continue for every angle of inclination about V_1. This is usually not the case, and by repeated trial that position of H_3, H_2 is to be found for which the preparation remains dark for every angle of revolution about V_1. The angle of inclination V_2 and the directive angle H_3 determine then the position of one of the planes of symmetry of the ellipsoid within the crystal, e. g., the plane $\alpha\beta'\gamma$ of fig. 26, this being fixed by the line $O\beta'$; in similar fashion the planes $\alpha\beta\gamma'$ and $\alpha'\beta\gamma$ are located and plotted in the stereographic projection. This method of locating the planes of symmetry of the ellipsoid within the crystal is comparatively rapid and sensitive, and a fair degree of accuracy can be attained by its use. The new circles V_2 (fig. 20) which were attached in the Geophysical Laboratory to the large Fedorow-Fuess universal stage, have proved extremely serviceable and time savers in this method.

Having once determined the position of either α or γ by this method, and that of one optic axis A_1 by optical curves, the position of second optic axis A_2 is readily obtained, since the angle A_1a or $A_1\gamma$ is by definition equal to A_2a resp. $A_2\gamma$.

After some practice, the exact relative positions of H_2, H_3 can be found without difficulty for which darkness remains for all angles of inclination about V_1. To insure accuracy, however, the fact of remaining dark should be scrutinized very sharply, since the correct position is not always that of absolute darkness but rather that for which the same degree of darkness or intensity of uniform lighting obtains throughout.

From the complete determination by this method of the positions of a, β and γ, which should be mutually 90° apart, Fedorow has shown that the average refractive index of the mineral can be derived approximately, although the determination is not of sufficient accuracy to be of great practical value.

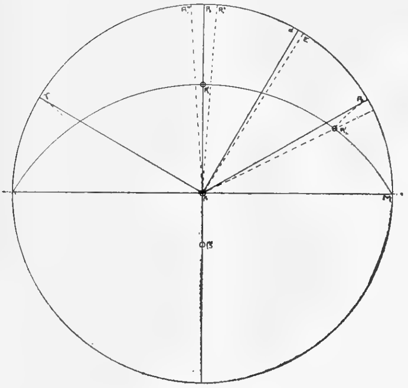
By this method of determining the positions of the principal sections of the ellipsoid, the distinction between uniaxial and biaxial minerals is greatly facilitated and the general problem solved for all possible sections. In case the position of neither optic axis can be determined directly, both optic axes lying outside the field of vision, the methods for measuring the optic axial are based solely on the determination of extinction angles along certain directions, and are of such a nature that by their use only very rough approximations to the true value of 2V can be obtained, errors of ± 10° and over being easily possible within the range of possibility. Fedorow has suggested one principal method applicable to such cases and the writer has had occasion to use several others. They are not so satisfactory, however, as the above methods, and are not of equal practical value. For the sake of completeness, they are described briefly in fine type below.

Section nearly perpendicular to the optic normal β.

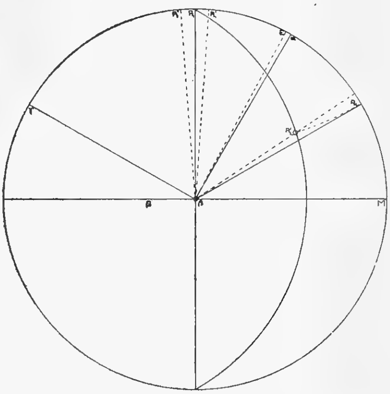
In case the section of a mineral is so cut that it makes an angle of 30° or less with the plane of the optic axes, neither optic axis appearing, in consequence, within the field of vision, the above method places the observer in a position to measure the optic axial without even seeing either optic axis. The exact position of β can first be determined by this method, and then brought to coincidence with the microscopic axis, in which case the plane of the optic axis is horizontal. In this position the circles V_1 and H_1 are free and the section can be revolved about V_1 and extinction angles determined on H_1. (Figs. 27 and 28.)

Since the exact positions of a and γ have been determined and the two optic axes make equal angles with these bisectrices, it is possible by trial to bring one of the optic axes A_1 to coincidence with the normal to V_1 (fig. 27), and to test the accuracy of its position by means of extinction curves for different inclinations of the section about V_1. Thus let α be the acute bisectrix (fig. 27) and assume that one optic axis A_1 coincides precisely with the normal to axis V_1; A_2 is then the second optic axis and angle $A_1\beta\alpha$ equal to angle $A_2\beta\alpha$, and $A_1\beta\alpha$ is the extinction angle. On revolving, now, the section about V_1, the optic axial point A_1 is brought to A'_1 and the extinction angle $A'_1\beta E$ for the new position of the section should bisect exactly the angle $A'_1\beta A'_2$. If this be not the case and the extinction angle be too large or too small, the section should be revolved about H_2 either counter clock wise (A''_1 to A_1) or clock wise, A'''_1 to A_1, through a small angle and a new set of measurements made, until after repeated trials the corrected position is to be found for which observation and construction agree precisely. The angle $A_1\beta\alpha$ is then half the desired optic axial angle.

27



28



In certain cases this method of placing the one optic axis A_1 in the plane normal to the axis of revolution V_1 has been found unsatisfactory, and a new method used which consists in first bringing by trial the one optic axis to coincidence with the axis of revolution and then measuring the extinction angles for different angles of inclination about V_1 (or V_2) and testing the results of observation and construction until they coincide. The method is shown in fig. 28 and is so similar to the foregoing method (fig. 27) that further description is unnecessary.

For a section nearly normal to the obtuse bisectrix of a mineral, both optic axes lie again outside the field of vision and the optic normal β cannot be brought to coincidence with the axis of the microscope. The above methods do not apply, therefore, and new ones are required to meet the new conditions and of these the following has been found practicable by the writer.

Place the universal stage in the primary position, the axis of V_2 normal to that of V_1 and the circles H_1, H_2, and H_3, all in the horizontal position; determine the exact position of the obtuse bisectrix (α or γ, as the case may be) by the method of principal ellipsoidal planes (page 353), and bring it to coincidence with the axis of the microscope, the plane of the optic axes being then parallel to the vertical cross hair. (Fig. 29.) Revolve section some convenient angle about axis V_2 and then about V_1 (as shown in fig. 29), also through any suitable angle. Measure accurately the extinction angle of the section in its new position. Plot data in stereographic projection after proper reduction of observed angles to true crystal angles; and find those two points A''_1 and A''_2 contained in the optic axial plane and equidistant from the obtuse bisectrix α'', which are so located that the observed extinction angle OE_1 bisects the angle $A''_2OA''_1$ (fig. 29). The angle $A''_1A''_2$ is then the desired optic axial angle, 2 V.

29

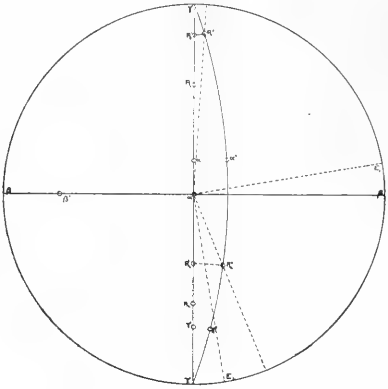


Fig. 29. To use the method indicated by this figure, turn the section so that its obtuse bisectrix coincides with the axis of the microscope (center of the projection plat), and the optic axial plane is parallel to the vertical cross hair; turn preparation about axis V_2 a convenient angle (reduce to true crystal angle equivalent to apparent angle observed in air or glass), and then about axis V_1 (normal to V_2) any suitable angle, and measure extinction angle of section in its new position. Plat these data in stereographic projection and find those two points A''_1 and A''_2 equidistant from the obtuse bisectrix and contained in the plane of optic axes in its new position, for which the observed line of extinction OE bisects the angle included between OA''_1 and OA''_2.

With the universal stage in its present form it is not always possible to execute the movements indicated in the above method, since when the obtuse bisectrix is brought to coincide with the axis of the microscope, the axis of V_2 is in general no longer horizontal and the revolution about V_2 is therefore along an inclined axis. In plotting the observed data, this fact should be carefully noted, otherwise errors may occur and nullify the results.

With the universal stage, it is thus possible to measure the optic axial angle of any grain of any transparent birefracting substance and to distinguish the biaxial and uniaxial minerals. The degree of accuracy of this measurement, however, is not of the same order of magnitude for all sections, but differs very materially with different sections. As a matter of experience it has been found that the most accurate results can be obtained on sections in which both optic axes appear within the field of vision; that good results can be had from sections which show only one optic axis within the field, while for sections in which neither optic axis appears within the field the determination is uncertain and at best only a rough approximation.

To summarize briefly the different methods best applicable to the four different possible cases cited above:

(1) The optic axes are both within the field of vision and inclined between 15°–55° with the normal to the section. Determine approximate position of the two optic axes by bringing each one, by means of H_2 and V_1, into the vertical position. Determine position of each more accurately by means of optical curves in projection and check by means of extinction curves and exact location of principal planes of ellipsoid, especially the plane containing the optic axes.

(2) Section is nearly normal to an optic axis; one optic axis A_1 inclined less than 20° to section normal. Place stage in horizontal position,—H_2 and H_3 in horizontal position and V_1 normal to V_2—turn H_3 and incline about V_2 until optic axis coincides with the axis of the microscope; then revolve about V_1 and turn H_2 until darkness is attained, and thus determine plane of optic axes and β'. Incline V_2 back to 0° position, revolve about H_2 until the optic axis coincides with plane normal to V_1 and determine extinction curve, the intersection of which with plane of optic axes in projection fixes the position of the second optic axis accurately. Check by determining α and γ both from projection and observation; also by extinction curve for revolution about V_2.

(3) One optic axis inclined between 20°–55° within the crystal to the normal of the section, the second entirely out of the field of vision. Determine visible optic axis by optical curves and second optic axis by means of extinction curves, both about V_1 and V_2. Verify results by determination of α, β and γ.

(4) Both optic axes are entirely without the field of vision, i. e., are inclined at an angle of more than 65° in air with normals to the section. In such instances the location of the optic axes is accomplished by means of extinction angles alone and the values obtained are not accurate, since a slight error of 1° in the determination of the extinction angle may affect the

value of optic axial angle up to 30°. For accurate work, therefore, such sections are of little value in general at the present time for measuring the optic axial angle by the universal stage methods. In case, however, the section be about normal to the obtuse bisectrix, the measurement of the optic axial angle is much more certain and satisfactory.

As noted previously, experience has shown that the best and most rapid method of projection is that of Wulff, who uses an accurate stereographic or orthographic plat as a base and tracing paper on which to sketch the great circles and to execute the actual measurements.

Since the accurate measurement of the optic axial angle can be accomplished only on sections in which at least one optic axis is within the field of vision, it is of interest to note the probable relative frequency of occurrence of such sections in a rock section. The microscopic field of the universal stage fitted with glass segments includes an angle of about 60°, and the area on the surface of the unit sphere thus covered for a biaxial crystal is evidently $s = 4\pi.2\,(1-\cos\phi) = 4\pi.4\ \sin^2\frac{\phi}{2}$, 2ϕ being the angle of vision of the field reduced to the true value within the crystal; if the observed angle 2ψ be used, the average refractive index of the mineral β and that of the glass segments n should be introduced into the formula $s = 4\pi.2\frac{n^2}{\beta^2}\sin^2\frac{\Psi}{2}$. The probability, P_1, that a section showing an optic axis is evidently measured by the relative surfaces s to S, the surface of the sphere itself:

$$P = \frac{s}{S} = \frac{4\pi.4\ \sin^2\frac{\phi}{2}}{4\pi} = 4\ \sin^2\frac{\phi}{2} = 4\frac{n^2}{\beta^2}\sin^2\frac{\psi}{2}.$$

In case the areas covered by the two optic axes overlap, the formula should be changed, as Césaro has shown,* to

$$P = 4\ \sin^2\frac{\phi}{2} - \frac{2}{\pi}\left(\text{arc cos}\left(\frac{\sin V}{\sin\phi}\right) - \cos\phi\ \text{arc cos}\left(\frac{\tan V}{\tan\phi}\right)\right)$$

in which 2V denotes the angle between the optic axes.

Assuming an average refractive index of 1·65 for ordinary biaxial minerals, and 1·52 for the glass hemispheres, the probability of encountering a proper section ranges under these conditions from 4 to 10, in unaxial crystals, to 8 to 10 in biaxial crystals for which the fields for the optic axes do not overlap. The degree of probability is high and one should be able to find suitable sections in every slide for the measurement of the optic axial of each mineral present.

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* G. Césaro, Mem. de l'Acad. Roy. d. Sci. d. Belgique, liv, 1895.

Fedorow* has also shown how it is possible to measure the birefringence $\gamma - \beta$ and $\beta - \alpha$ by use of the universal stage and the Fedorow mica-comparator and thus to ascertain the optic axial angle from the approximate formula $\cos^2 \frac{V_g}{2} = \frac{\gamma - \beta}{\beta - \alpha}$, either by graphical means or by calculation.

Lane† has also used the birefringence of different sections as a rough measure for the optic axial angle, but his methods are even less exact than those of Fedorow and can only give first approximations to the true optic axial angle of a given mineral. In cases of parallel intergrowths of different amphiboles and pyroxenes they have, nevertheless, rendered valuable service. Both his methods and the one of Fedorow will not, however, be discussed further in this paper.

Extinction angles of faces in zones whose axes lie in the plane of the optic binormals.

This method is particularly adapted to monoclinic minerals, as amphiboles and pyroxenes, and may be of service to secure a rough estimation of the optic axial angle of such a mineral. The underlying principle of this method is again the rule of Biot-Fresnel (page 322), and mathematical formulae suitable for its solution have been developed by Michel-Lévy,‡ Césaro,§ Harker,‖ Lane,¶ Daly,** and others. These formulae show that for the exact determination of the optic axial angle, the method of extinction angles on different faces in the same zone is not well adapted to optic axial determinations, especially when the optic axial angle of the mineral is small. In certain cases, it is possible to express this relation, as Lane has shown, in a slightly different form which is better adapted for measurements. Lane's method, as applied to the pyroxenes and amphiboles, consists in measuring the angle between the clinopinacoid and that face of the prism zone which shows the same extinction angle. For this case, in which the plane of the optic binormals contains the zonal axis, the formulæ of Césaro and Michel-Lévy reduce to the form,

$$\tan 2x = \frac{(\tan \lambda + \tan \mu) \cos v}{1 - \tan \lambda \tan \mu \cos^2 v} \qquad (1)$$

λ and μ being angles between the zonal axis and the two optic

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* Feodorow, E. von, Zeitschr. f. Kryst., xxv, 349–356, 1896.

† A. C. Lane, this Journal (3), xliii, 79, 1892.

‡ Michel-Lévy et Fouquée, Minéralogie Micrographique, p. 368.

§ A. Césaro, Mem. de l'Acad. Roy. d. Sci. d. Belg., liv, 26, 1895.

‖ Harker, A., Miner. Magazine, x, 239, 1894.

¶ See Daly, Proc. Amer. Acad. Arts and Sci., xxxiv, 314, 1899.

** Daly, R. A., Proc. Amer. Acad. Arts and Sci., xxxiv, 314–323, 1899.

binormals respectively; and v the angle between a plane of the zone and plane of optic binormals. For the plane containing the optic axes $v = 0$ and the extinction angle becomes

$$\tan 2x = \frac{\tan \lambda + \tan \mu}{1 - \tan \lambda \tan \mu}.$$

For that plane which shows the same extinction angle, the equation

$$\frac{\tan \lambda + \tan \mu}{1 - \tan \lambda \tan \mu} = \frac{(\tan \lambda + \tan \mu) \cos v}{1 - \tan \lambda \tan \mu \cos^2 v} \qquad (2)$$

or

$$\cos v = - \cot \lambda \,.\, \cot \mu \qquad (3)$$

is evidently valid. In order that equation (3) be valid, $\cot \lambda \cot \mu$ must be less than unity, or

$$\lambda + \mu > 90^\circ.$$

But the values 2V, the optic axial angle, and $2x$, twice the extinction angle on the plane of optic binormals are related to λ and μ by the equations

$$\lambda + \mu = 2x$$
$$\lambda - \mu = 2V$$

Substituting these values in (3), we find

$$\cos v = \frac{\cos 2x + \cos 2V}{\cos 2x - \cos 2V}. \qquad (4)$$

or

$$\cos 2V = \cos 2x . \frac{\cos v - 1}{\cos v + 1} \qquad (5)$$

In table 2, the values of v are given for different optic axial angles (2V) and different extinction angles (x), the extinction angle being considered taken invariably to the acute bisectrix of the optic binormal angle. It is evident from this table that for small optic axial angles this method has no practical value for even rough measurements. The larger the axial angle, however, the more sensitive the method becomes.

Table II.

x_1	50	55	60	65	70	75	80	85
x_2	40	35	30	25	20	15	10	5
2V								
10	134°27′	118°58′	109°03′	102°08′	97°10′	97°37′	91°21′	90°00′
20	133 29	117 47	107 47	100 49	95 50	92 10	90 00	88 39
30	131 45	115 42	105 32	98 31	93 31	90 00	87 40	82 23
40	129 05	112 30	102 08	94 01	90 00	86 29	84 10	82 50
50	125 04	107 47	97 10	90 00	85 59	81 29	79 11	77 52
60	118 58	100 49	90 00	82 50	77 52	74 28	72 13	70 57
70	109 03	90 00	79 11	72 13	67 30	64 18	62 13	61 02
80	90 00	70 57	61 02	54 56	50 55	48 15	46 31	45 33

Measurement of the optic axial angle on the total refractometer.

Pulfrich,[*] Soret,[†] Viola,[‡] Cornu[§] and Wallérant[‖] have shown that it is possible on a single section of a biaxial or uniaxial mineral to determine not only the three principal refractive indices α, β and γ, but also, by observing the planes of polarization of each wave corresponding respectively to $\alpha\beta$,$\beta\gamma$ and $\gamma\alpha$, to determine accurately the relative position of the principal planes of the ellipsoid to the given section; and from the accurate refractive indices thus ascertained to figure the optic axial angle with great exactness. These methods, however, require specially ground and polished sections and are not, in general, microscopic methods, although the total refractometer of Wallérant is attached directly to the microscope and is employed on thin uncovered and polished sections of rocks. Unfortunately, the writer has had practically no opportunity to work with the total refractometer of Wallérant, and is, therefore, not in a position to judge personally of its fitness for optic axial angle determinations. Viola and others have shown that on the Abbe total refractometer results of great accuracy and certitude can be obtained rapidly and without difficulty. The mineral plates should measure then $1^{\mathrm{sq\ mm}}$ or over to furnish sufficiently intense reflexion signals for nice adjustment and measurement.

Measurements.

So much space has been devoted above to the theoretical considerations and descriptions of methods that in this section only a part of the available observational data can be enumerated and a brief résumé of the results presented. Enough data will be offered, however, to indicate certain inferences bearing on the relative accuracy and applicability of the different methods under test.

Different minerals, as aragonite, topaz, muscovite, etc., were first chosen and oriented sections cut to show the different phenomena required by the several methods. The correct optic axial angle for each mineral was then measured in sodium light on a Wülfing-Fuess axial angle apparatus, the angle obtained thereby being adopted as the standard of comparison for all methods. For each mineral a series of measurements of the optic axial angle for different sections and by the different methods was taken and the relative degree of accuracy of each method judged, not only by the results obtained, but also

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[*] Pulfrich, C., Das Total reflektometer, Leipzig, 1890.

[†] Soret, Zeitschr. Kryst., xv, 43, 1899.

[‡] Viola, C., Zeitschr. Kryst., xxxi, 40–48, 1889; xxxvi, 245–251, 1902.

[§] Cornu, Compt. Rend., cxxxiii, 125; Bull. Soc. Min., xxv, 7.

[‖] Wallérant, F., Bull. Soc. Min., xx, 12–26, 1898.

by the factors on which the method itself is dependent and their relative exactness under the conditions of observation.

Measurements with Axial Angle Apparatus.

The optic axial angles obtained in sodium light on the Wülfing axial angle apparatus varied slightly and the average of five determinations of each angle is given below:

Topaz, Willard Co., Utah.
  2E = 126° 13′. 2V = 66° 42′.
Aragonite, Bilin, Bohemia.
  2E = 31° 09′. 2V = 18° 22′.
Muscovite (*a*)
  2E = 71° 40′
Muscovite (*b*)
  2E = 59° 42′.

Measurements with the Becke drawing-table.—To economize space, the results are given below in their reduced form ready for plotting directly in projection, the angle θ denoting the longitude from the horizontal E–W line of the projection and ρ the polar distance; A_1 as usual denotes the visible axial point and P_1 any point on the dark axial bar.

Topaz.

(*a*)	ϕ	ρ
A_1 - - - - - - - -	0°	5°·0
P_1 - - - - - - - -	+65	20 ·5

In projecting these angles and performing the requisite mechanical operations, the optic axial angle thus determined on this section was 2V = 62°·5. For a second section the values were:

	ϕ	ρ	
A_1 - - - - - - - -	— 8°	3°·8	2V = 70°
P_1 - - - - - - - -	—72	19 ·6	

For a third section:

	ϕ	ρ	
A_1 - - - - - - - -	+27°	8°·8	2V = 63°
P_1 - - - - - - - -	—58	23	

The average of these three values is 65°·2.

Aragonite.—In aragonite the optic axial angle is so small that both axial bars A_1 and A_2 are visible and the direct determination of $2V_{A_1A_2}$ should in all cases be accurate within one degree. The birefringence is so strong, however, that the measurements involving a point P_1 or P_2 on the dark axial bar and consequent introduction of the refractive index β for that point, may be decidedly incorrect. The use of the refractive index β presupposes only slight differences between the refractive indices of the mineral in order that the errors thus caused may not be too large.

(1)

	ϕ	ρ	
A_1	−80°	17°·5	$2V_{A_1A_2}$ = 17°·4
A_2	−130	23	$2V_{P_1A_1}$ = 17 ·5
P_1	+15	18 ·4	

(2)

A_1	−10°	8°	$2V_{A_1A_2}$ = 18°·3
A_2	−17 ·1	10 ·6	$2V_{P_1A_1}$ = 21
P_1	+42	21	

(3)

A_1	+44°	28°·3	$2V_{A_1A_2}$ = 18°·0
A_2	+85	19 ·5	$2V_{P_2A_2}$ = 17 ·6
P_2	−15 ·5	18 ·4	

(4)

A_1	−56°	11°·2	
A_2	−140	14 ·3	$2V_{A_1A_2}$ = 17°·5
P_1	+29	23 ·4	$2V_{P_1A_1}$ = 16
P_2	+158	26 ·0	$2V_{P_2A_2}$ = 23

The values for $2V_{A_1A_2}$ do not differ over 1° from the true value, while those for $2V_{P_1A_1}$ differ as much as 5° from the true value.

Muscovite. (b)

	ϕ	ρ	
A_1	0°	35°·6	$2V_{A_1A_2}$ = 71°·2
A_2	0	−35 ·6	

Double Screw Micrometer Ocular.—The data given below appear also only in corrected form ready for plotting in projection, the actual scale readings having been reduced to equivalent angles in air and these in turn figured to true angles within the crystal, by means of the refractive index β. The errors observed above in aragonite sections because of strong birefringence apply equally well here. In the following tables H indicates the horizontal and V the vertical micrometer screw of the ocular.

Topaz.

(1)

	H	V	
A_1	3°·5	0°	2V = 64°·5
P_1	5 ·5	17 ·5	

(2)

A_1	5°·3	·3	2V = 65°·5
P_1	7 ·6	17 ·2	

Aragonite.

(1)		H	V	
	A_1	7°	9°·8	$2V_{A_1A_2} = 18^\circ{\cdot}0$
	A_2	−10 ·8	9 ·8	$2V_{P_1A_1} = 18\ {\cdot}5$
	P_1	17 ·8	6 ·8	$2V_{P_2A_2} = 14$
	P_2	−17 ·5	6 ·8	

(2)				
	A_1	4°·6	20°	
	A_2	−13 ·20	20	$2V_{A_1A_2} = 17^\circ{\cdot}9$
	P_1	5	3	$2V_{P_2A_2} = 19$
	P_2	−23 ·5	3	$2V_{P_1A_1} = 23$

(3)				
	A_1	7°·3	1°·8	
	A_2	−11 ·5	1 ·8	$2V_{A_1A_2} = 18^\circ{\cdot}5$
	P_1	20 ·6	18 ·8	$2V_{P_1A_1} = 18$

Muscovite. (*a*)

(1) *a*		H	V	
	A_1	35°·5	0°	2E = 71°
	A_2	−35 ·5	0	

(1) *b*				
	A_1	0°	36°	2E = 72°
	A_2	0	−36	

Muscovite. (*b*)

	H	V	
A_1	30°·1	0°	2E = 60°·2
A_2	−30 ·1	0	
A_1	0°	30°	2E = 60°
A_2	0	−30	

Measurements with the Fedorow-Fuess universal stage.—The angles given below were read directly on the different circles of the universal stage and before plotting in projection require reduction to true crystal angles by means of the refractive index β of the mineral and μ (=1·5239) of the glass hemispheres used. The letters H_1, H_2, H_3 and V_1, V_2 designate the different circles of the universal stage (see fig. 11) on which the angles were read. The angles after the letter N designate the angle made by the principal plane of the lower nicol with that of the microscope.

Topaz. Section after 001 (acute bisectrix).—A direct preliminary determination of the position of the optic axes in parallel polarized light was first made and the approximate location of each axis determined. These values were later corrected by means of optical curves.

Direct preliminary determination.

	H_1	H_2	H_3	V_1	V_2	
A_1	180°	90°	294°	35°	—·5°	2V = 66°·6
A_2	"	"	"	36°	—·5°	

Corrected by method of optical curves.

				N = 0° V_1		N = 30° V_1		N = 45° V_1	
H_1	H_2	H_3	V_2	A_1	A_2	A_1	A_2	A_1	A_2
180°	80°	294°	1°	33·5	—33·5	37	—39·5	33	—37
"	85	"	"	35	—36	36	—38	33·5	—37·5
"	90	"	"	35·5	—36	34	—37	34	—36·5
"	95	"	"	34	—34·5	33	—36	34	—37
"	100	"	"	33	—34·5	33	—34	35	—37

After proper reduction of these angles, the corrected angle, obtained directly from the stereographic plat, is 2V = 66°·5.

Topaz. Section nearly normal to an optic axis.—The determination in this case can be most readily accomplished by first locating A_1 accurately by optical curves and then fixing the position of A_2 in projection by means of the principal ellipsoidal planes.

Optical curves for A_1.

				N = 0°	N = 30°	N = 45°
H_1	H_2	H_3	V_2	V_1	V_1	V_1
180°	80°	225·5	—1	4·5	4·5	5
"	85	"	"	5	5	5·5
"	90	"	"	6·5	6	5
"	95	"	"	7	6	5
"	100	"	"	8	5	4

After reduction to true angles, the position of A_1 in projec- on was found to be: H_1, 180°, H_2, 90°, H_3, 225°·5, V_1, 6° and V_2, 1°. The $\gamma\beta$ ellipsoidal plane was located by: H_1, 180°, H_2, 0°, H_3, 315°, V_1 —, V_2, 26°, while for the $\alpha\gamma$ ellipsoidal plane, the readings were: H_1, 180°, H_2, 90°, H_3, 225°·5, V_1, —, V_2, —1°. The optic axial angle thus determined in projection plat is 2V = 64°. In such cases, where the section is nearly normal to an optic axis, the method of extinction curves is not of practical value, owing to the difficulty of determining extinction angles with requisite accuracy.

Topaz. Section nearly normal to obtuse bisectrix.—Optic axial angle was found by first locating the principal ellipsoidal planes $\alpha\beta$ and $\alpha\gamma$ and then measuring the extinction angle of the section when α coincided with the microscope axis and after revolution of the section from that position through known angles about V$_1$ and V$_2$.

For the ellipsoidal planes the readings were:

	H$_1$	H$_2$	H$_3$	V$_1$	V$_2$
$\alpha\beta$ plane	180°	90°	236°·5	--	0°
$\alpha\gamma$ plane	"	"	326·	--	—17·5

For α in coincidence with the microscope axis, the readings were found from the projection to be: H$_1$, 185°, H$_2$, 90°, H$_3$, 326°, V$_1$, 30°, V$_2$, 22°·5. After the revolution about V$_1$ and V$_2$, the angles recorded were: H$_1$, 189°·5, H$_2$, 90°, H$_3$, 326°, V$_1$, 40°, V$_2$,–15°.

From these angles 2V was measured in projection and found to be 66°.

By direct observation of the optic axis, the same angle was also obtained. This method may in favorable instances give reliable results, but in general it cannot be considered an accurate method, owing to the undue influence in projection of slight deviations of the extinction angle on the value of the optic axial angle.

Second Section:

	H$_1$	H$_2$	H$_3$	V$_1$	V$_2$
$\alpha\beta$ plane	180°	90°	140°	--	+ ·5°
$\alpha\gamma$ plane	"	"	234	--	—32·5
Optic axis A$_1$	"	"	140	4°	+ ·5

The optic axis A$_1$ was determined by direct readings. After proper reduction to true angles the value 2V=63° was obtained from the projection plat.

Topaz. Section about perpendicular to the optic normal.—In this instance the principal elliposoidal planes were first determined and ellipsoidal axis β brought to coincide with the microscope axis and the extinction angle measured in that position. By trial that position of H$_2$ was found for which A$_1$ coincided with the principal plane of the lower nicol, and the optic axial angle thus ascertained by measuring the extinction angles of the section in different positions of V$_1$ and comparing the data of observation with those obtained by graphical methods from the projection plat on the assumption that A$_1$ did actually coincide with the principal plane of the lower nicol. In like manner, the section was revolved about V$_2$ and extinction angles measured until theory and observation furnished identical results.

The principal ellipsoidal planes of the section were determined by the readings:

	H$_1$	H$_2$	H$_3$	V$_1$	V$_2$
$\beta\gamma$ plane	180°	90°	333°	--	+16°
$\beta\alpha$ plane	"	"	241·5	--	— 1

For the different positions of H_2, the extinction angles for a given angle of revolution about V_1 were:

H_1	H_2	H_3	V_1	V_2
145°	123°	333°	17°	31°
145·5	122	"	"	"
144·5	124	"	"	"
144·3	123·5	"	"	"

On plotting these values in projection, it was found that 2V was about 64°–67°, but a more decisive result was not attainable. The method is not accurate and can only furnish very rough approximations.

In the second method, which involves revolution about an axis normal to that of the above, the values observed were:

H_1	H_2	H_3	V_1	V_2
148°·5	33°	332°	17°	31°
148 ·5	34	"	"	"
149	32	"	"	"

and from these angles, 2V was found to lie between 64 and 68°.

The determination cannot be termed satisfactory and this method, like the above, can furnish only rough approximations to the true values of 2V.

Summary.

(1) The optic axial angle of minerals in the thin section can be determined under the microscope in either convergent or parallel polarized light.

(*a*) In convergent polarized light, methods for the measurement of the optic axial angle are available for all sections in which at least one optic axis appears within the field of vision. Of these the method requiring the use of the Becke drawing table is of general application and furnishes results of a fair degree of accuracy—the usual probable errors being about ± 1° if both optic axes be visible, and ± 5° if only one optic axis be visible. More accurate and somewhat simpler in manipulation and of the same general application is the method involving the new double screw micrometer ocular, described above. This ocular combined with the method of projection of Professor Wulff, is a general extension of the Mallard method, and, like the Becke method, utilizes the rule of Boit and Fresnel which defines the planes of vibration for any direction of wave propagation. With this ocular the probable errors of determination on sharp interference figures should not exceed 1° if both optic axes are visible, nor 3° if only one optic axis appears in the field.

(*b*) In parallel polarized light, the methods involving the Fedorow-Fuess universal stage are used and furnish satisfactory results, provided the position of one optic axis can be determined directly. If both optic axes are outside of the field of vision, the results obtained are usually unsatisfactory and inaccurate. Theoretically, it is possible to measure the optic axial angle of any biaxial transparent mineral on any section by means of the universal stage. If both optic axes appear within the field of vision, the error of determination should not exceed 1°, and if only one of the optic axes be visible, the accuracy may decrease to ± 5°. The exact location of a visible optic axis is assisted somewhat by use of the method of optical curves. Having once fixed the location of one optic axis, that of the second is determined by the method of extinction curves. If both optic axes lie entirely outside of the field, special methods must be resorted to, but in general without marked success, owing to the great difference in the value of 2V caused by a very slight deviation in the measured extinction angle.

The range of the field of vision of the universal stage is greater than that of any possible interference figure; the Fedorow universal stage methods are, therefore, applicable to a greater number of sections than the methods with convergent polarized light and may furnish results on sections otherwise useless for ordinary methods. Both experience and theory show that for all these methods the accuracy of the determination varies considerably with the section and mineral in question. The most accurate results can be obtained on sections for which both optic axes appear within the field of vision; less accurate but still satisfactory measurements can be made when only one optic axis appears, particularly when it is situated about midway from the center to the margin of the field.

For convergent polarized light, the general extension of the Mallard method by means of the new double screw micrometer ocular is the most satisfactory and accurate method available, but good results can be had by use of the Becke drawing table.

The readings in both methods require to be reduced to equivalent crystal angles and plotted in stereographic projection. The optical axial angle is then measured upon the plot by graphical methods.

(2) For the purpose of plotting and measuring observed and calculated angles, the stereographic projection is without doubt best adapted to optical work in general. The stereographic plot of Plate I is a photographic reproduction of the accurate drawing by Professor Wulff published in the Zeitschrift für Krystallographie.

(3) Since the interference figures are roughly orthographic projections of the phenomena in space, an accurate ortho-

graphic plat (fig. 1) has been added with the standard stereographic plat to serve as a base for future plotting of similar phenomena.

(4) Plate II is intended to serve as a graphical base by which to solve Mallard's formula, K sin E=D; also $n_1 \sin a_1 = n_2 \sin a_2$; also $\gamma' - a' = (\gamma - a) \sin a_1 \sin a_2$, a_1 and a_2 being the angles included between the given direction of wave propagation and the two optic axes respectively.

(5) The Mallard formula and method were tested by a new method and the agreement of the formula with fact for the special objective used and the particular precautions observed found to be remarkable. It was evident that for each microscopic objective similar tests should be made at intervals across the entire field in order to insure accuracy and certainty in the results obtained.

(6) A disk-shaped type of the Becke drawing table was constructed in the Geophysical Laboratory and found satisfactory in practice.

(7) An improvement was made in the Fedorow-Fuess universal stage, consisting in the addition of two hinged graduated circles on which to read the inclinations of the second vertical circle V_2, and found to be of service in several methods.

(8) A new form of condenser lens system which combines the advantages of the ten Siethoff qualitative adjustable condenser system with the exact movement of the universal stage, was also described and applied to the examination of minute mineral sections, especially of artificial preparations.

(9) A set of accurate drawings of the position of the dark axial bar of the interference figure in convergent polarized light for sections cut at various angles with one optic axis but always so that the optic axis is still visible, has been prepared, and the theoretically probable limits of error of determinations of the optic axial angle by the different methods and for the different sections established graphically.

(10) In the course of the investigation, several methods, based solely on extinction angles for different faces, were tried, but without exception they were discarded because of the difficulties in the measurement of the extinction angle and the undue influence of small differences in extinction angle on the value of the optic axial angle.

Geophysical Laboratory,
Carnegie Institution of Washington, May 15, 1907.

ART. XXXIV.—*Note on a New Radio-Active Element;* by BERTRAM B. BOLTWOOD.

IN an earlier paper[*] the results of some experiments were described which indicated the separation of the parent of radium from a solution of a uranium mineral. Some pure thorium nitrate was added to a solution obtained by treating a kilogram of carnotite ore with dilute hydrochloric acid and, after the removal of the substances precipitated by hydrogen sulphide, the thorium was precipitated as oxalate. The oxalates were converted into nitrates, the precipitation with oxalic acid was repeated and the substances were converted into chlorides. Measurements of the amount of radium emanation produced by the solution of these chlorides showed that in a period of 193 days the amount of radium present had more than doubled, and it was therefore evident that the process described had separated the immediate parent of radium from the uranium mineral.

From a number of earlier experiments I had found that after this treatment the thorium salt contains a radio-active body which retains its activity without apparent alteration in the course of several years. As it was easily proved that this substance was not radium, uranium or polonium, it was therefore assumed to be actinium, Debierne[†] having stated that the chemical properties of actinium are similar to those of thorium. Moreover, it had been found that small amounts of an emanation which completely lost its activity in less than half a minute were evolved from the oxides of the thorium treated in this manner. I therefore suggested that actinium was the parent of radium and the intermediate product between uranium and radium.

Rutherford, using a commercial preparation of actinium, has recently obtained results[‡] which prove that the immediate parent of radium is distinct from actinium itself although it is present in his actinium preparation. He states that the parent substance can be separated from actinium by precipitation with ammonium sulphide.

For the past ten months I have been continuing my experiments with the object of determining definitely the radio-active properties and chemical behavior of the radium parent. As sources of material I have used carnotite, Joachimsthal pitchblende, gummite, uranophane and a specimen of very pure uraninite from North Carolina.

In confirmation of Rutherford's statement it has been found

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[*] This Journal, xxii, 537, 1906.

[†] C. R., cxxx, 906, 1900.

[‡] Nature, lxxvi, 126, 1907.

that the rate of production of radium in solutions of the parent is not affected appreciably by the presence of radio-actinium and its products. Continued observations of the growth of radium in my original solution indicate that the rate of production of radium has been constant, within the limits of experimental error, for a period of over 500 days. Using one of my own preparations, I have been unable to repeat the separation of the radium parent from actinium by the ammonium sulphide treatment which Rutherford has described. With pure, freshly-prepared ammonium sulphide no separation could be detected. The radium parent can, however, be quite completely separated fron actinium by precipitation with sodium thiosulphate, under the conditions usual for the precipitation of thorium. As ammonium sulphide readily changes into ammonium thiosulphate, it would appear probable that the separation noticed by Rutherford was due to the latter compound.

An interesting and important relation has been observed between the growth of radium and the activity of the substances other than thorium in my solutions containing the radium parent. This proportionality is most striking in those solutions containing the more completely purified salts. More significant still is the fact that this radio-active constituent does not appear to possess any of the characteristic properties af the recognized radio-active elements. Less than half a gram of thorium oxide containing an amount of this new body having an activity about equal to that of five grams of uranium did not produce sufficient actinium emanation to permit its detection in a sensitive electroscope, although under the conditions of experiment the thorium emanation evolved could be detected and measured without difficulty.

That the active substance is not actinium was also demonstrated by the fact that from a solution over five months old, containing about 3 grams of thorium and a quantity of the new substance with an activity equal to that of about 35 grams of uranium, no active substances other than thorium products could be separated by precipitation of the earths with ammonia, by the formation of finely divided sulphur from sodium thiosulphate or by the precipitation of considerable quantities of barium sulphate in the solution. The first process should have separated actinium X and the last two should have separated radio-actinium had these products been present.

The behavior of the oxides obtained by strongly igniting the hydroxides precipitated by ammonia from a solution similar to the above is also significant. The activities of these oxides remain nearly constant for long periods, showing only a slight initial rise corresponding to the formation of thorium X in the thorium present. No rise corresponding to the formation of actinium X can be observed, but if actinium were present a separation of this product would be expected.

The most conclusive proof that the substance described is a new radio-active element is furnished by the properties of its α-radiation. The α-rays which it emits are much more readily absorbed by aluminium than the α-rays from polonium, with which it has been directly compared. Their range in air as determined by the scintillation method appears to be less than 3 centimeters, which is less than the range of the α-particle from any other known radio-active element. The new substance also gives out a β-radiation which is less penetrating and more easily absorbed than that from uranium, the value found for the coefficient of absorption being about 1·8 aluminium.

Experiments which have been carried out with a view to obtaining a quantitative separation of this new element from small quantities of very pure uraninite have given results which are in good agreement with one another and which indicate that the activity of the new element in equilibrium with radium is about 0·8 of the activity of the radium itself with which it is associated. This is about the value to be expected if the new substance is intermediate between uranium and radium when the range of α-particles in air is taken into consideration. It is very likely that this radio-active element is present in Debierne's actinium preparations and in some of Giesel's "emanium" compounds which have been put on the market by the Chininfabrik, Braunschweig, especially in the former, and its presence may perhaps explain the confusion which has resulted from Debierne's earlier assertions that actinium accompanied thorium as opposed to Giesel's positive statements to the contrary.*

Strong evidence has, therefore, been obtained of the existence in uranium minerals of a new radio-active element, which emits both α and β radiations, which produces no emanation and which resembles thorium in its chemical properties. It is without doubt a disintegration product of uranium and is in all probability the immediate parent of radium. The name "Ionium" is proposed for this new substance, a name derived from the word "ion". This name is believed to be appropriate because of the ionizing action which it possesses in common with the other elements which emit α-radiations.

Further experiments are in progress which it is hoped will afford additional information as to the properties and chemical behavior of this new body.

Sloane Laboratory, Yale University,
New Haven, Conn., Sept. 21, 1907.

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* Chem. Berichte, xl, 3011, 1907.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Action of Ozone upon Metallic Silver and Mercury.*—The blackening of bright silver by ozone is generally given as one of its characteristic reactions, particularly in distinguishing it from hydrogen peroxide. It would seem, therefore, that the reaction should take place easily under any conditions. However, Manchot and Kampschulte have found that when a piece of silver is held at the mouth of a Siemens' ozone tube, there is little blackening when the ozone is dry, and even when the silver is moistened the reaction is uncertain and not characteristic. They have found, on the other hand, that if the silver is heated to near redness and then is exposed to ozone as it cools, a beautiful coating is quickly obtained, but the reaction becomes indistinct when the metal has cooled to a temperature still considerably above that of the room. By a series of experiments at known temperatures it was shown that the reaction with very dilute ozone is scarcely appreciable at 100°, but becomes more distinct as the temperature rises, until it becomes best and very beautiful at 220–240°. The intensity of the reaction decreases gradually at still higher temperatures, on account of the decomposition by heat of the silver oxide, and it does not occur at all at 450°. The experiments just described were carried out with carefully dried gas, but it was found that moist ozone gives the same results. The handbooks of chemistry say, on the contrary, that completely dry ozone does not oxidize dry silver. The interesting fact was observed that a great number of substances adhering to the surface of silver, even in exceedingly minute quantity, impart to it the property of being instantly blackened by ozone, even in the cold. For instance, silver polished with emery paper, or etched with nitric acid and carefully washed and dried, shows this property. Many metallic oxides give this catalytic effect. Curiously enough, certain silver surfaces which were susceptible to the action of ozone in the cold lost this property after standing for some time at ordinary temperature. In the case of mercury it was found that the temperature of greatest action of ozone is 170°. Similarly to silver, the action is gradually less below and above this temperature.—*Berichte*, xl, 2891.

H. L. W.

2. *The Separation of Tellurium from the Heavy Metals.*—Brauner and Kuzma have made a useful contribution to the analytical chemistry of tellurium. They find that when this element is precipitated in the customary manner by means of sulphur dioxide, other metals, such as mercury, lead, bismuth, copper, cadmium, arsenic, antimony, and thallium, tend to come

down with the tellurium to some extent. They find this to be the case particularly with copper. As a means of separating tellurium from some of these metals they convert the tellurium into telluric acid and then precipitate the other metals as sulphides, leaving the telluric acid in solution, since hydrogen sulphide does not act upon this compound at all until after a long time. Their method in detail is as follows: The tellurium contaminated with a heavy metal (Cu, Bi, Sb) is collected on a Gooch filter, dissolved in nitric acid, the solution is evaporated, the residue is dissolved in potassium hydroxide (1 : 5), and in a well covered vessel (Erlenmeyer flask) is oxidized by the gradual addition of ammonium persulphate (about $4-6^{g}$). After the excess of the latter has been removed by boiling, the liquid is acidified with sulphuric acid, and to the cold liquid 100^{cc} of hydrogen sulphide water are added. The excess of hydrogen sulphide is then removed by means of a rapid stream of carbon dioxide. The sulphide is then filtered off and brought into a weighable form by an appropriate method. The telluric acid may be reduced to tellurous acid by adding hydrochloric acid and boiling down to 25^{cc}, as has been shown by Gooch and his co-workers, and then the tellurium may be precipitated by means of sulphur dioxide water. The authors collect this precipitate on a Gooch filter and dry it at 120° in a stream of carbon dioxide.—*Berichte*, xl, 3362.

H. L. W.

3. *The Rays from Thorium Products.*—The assumption by HAHN of the existence of a product, mesothorium, intermediate between thorium and radiothorium, was noticed in the July number of this Journal. Hahn now considers the existence of mesothorium as fully established by further experiments. He has found also that mesothorium, at first considered to be rayless, gives off β-rays, and he reaches the conclusion, in an indirect manner, that thorium itself gives off α-rays of a peculiar kind. He gives the following list of the radio-active thorium products and the kind of rays given off by each :

Thorium	α-rays.
Mesothorium	β- “
Radiothorium	α- “
Thorium X	α- “
Emanation	α- “
Thorium A	slowly β-rays.
Thorium B Thorium C	α, $\beta+\gamma$-rays

—*Berichte*, xl, 3304.

H. L. W.

4. *The Decomposition of Gaseous Hydrocarbons by Ignition with Powdered Aluminium.*—KUSNETZOW has found that the hydrocarbons, methane, ethane, ethylene and acetylene, are completely decomposed when they are passed several times through a tube containing aluminium powder and heated to the melting

point of the aluminium. In each case pure hydrogen was produced in the theoretical amount, while the carbon was partly deposited in the free state on the surface of the metal, and partly formed a carbide. The latter by the action of water gave off methane which was contaminated with other hydrocarbons.—*Berichte*, xl, 2871. H. L. W.

5. *Studies on the Mode of Growth of Material Aggregates.* II (*Addendum*) *Distribution of Variations*;* by A. J. LOTKA.—It was pointed out in the body of the paper, under the above heading, that the distribution of the molecules amongst the three classes: stable, metastable and transitional, must bear a close relation to reaction velocity and equilibrium, and the influence of temperature on the same.

A perusal of Arrhenius' paper on the influence of temperature on reaction velocity, published in the Zeitschr. f. phys. Chem, 1889, iv, 226–234,† suggests that his "inactive" and "active" molecules correspond to the "stable" and "metastable" molecules of our presentation. We may then directly apply Arrhenius' theory.

If we denote

by N the total number of molecules of A

by N_σ the number of stable molecules of A

by N_μ the number of metastable molecules of A

by N_τ the number of transitional molecules (of $A \longrightarrow B$)

then, by Arrhenius,

$$N_u = \mathfrak{K} N_\sigma \tag{1}$$

where $\mathfrak{K}$ is very small and follows Van't Hoff's relation

$$\mathfrak{K}_T = \mathfrak{K}_0 e^{\frac{\mathfrak{Q}}{R} \cdot \frac{T_0 - T}{T_0 T}}$$

On the other hand we have

$$\begin{aligned} N_\tau &= kN(t'-t) \\ &= kN_\sigma (t'-t) \text{ very nearly.} \end{aligned}$$

Hence, $N_\sigma : N_\mu : N_\tau :: 1 : \mathfrak{K}_T : k(t'-t)$

This proportion then expresses the distribution of the molecules amongst the three classes at a given temperature T, in those cases in which Arrhenius' theory is applicable, viz: in reactions whose velocity coefficient varies with the temperature according to the relation:

$$k_T = k_0 e^{\frac{\mathfrak{Q}}{R} \cdot \frac{T_0 - T}{T_0 T}}$$

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* See this Journal, Sept., 1907, p. 214.

† Compare also Arrhenius, loc. cit., 1899, v. xxviii, p. 317, et seq. and Rothmund, loc. cit., 1896, v. xx, pp. 168–179.

Similar considerations apply to the molecules of A′. The relation between the temperature and the equilibrium constant then follows immediately from

$$K_T = \frac{k_T}{k'_T}.$$

6. *On a Method for the Observation of Coronas;* by C. Barus.—The following corrections are called for in the above article, as printed in the September number (pp. 277–281).

§3, line 17 ; for $\cdot 00002^{cm}$ read $\cdot 0002^{cm}$.
§4, line 16 ; for $(2\cdot 44\lambda/d^2$ read $(2\cdot 44\lambda/d)^2$.
§5, lines 15, 16, 30, 34 ; for α read "varies as."
§5, line 16 ; for $\cdot 12\sqrt{1}\cdot S^1 R^2$ read $\cdot 12 S/\sqrt{1+S^2/R^2}$.
§5, line 61 ; for o_3 read s_3.
§5, line 13 ; for tan read tan θ.

II. Geology.

1. *United States Geological Survey.*—Recent publications of the U. S. Geological Survey are included in the following list (continued from p. 83):

Folio, No. 150. Devils Tower Folio, Wyoming; by N. H. Darton and C. C. O'Harra. Pp. 9, with 5 charts.

Professional Paper, No. 53. Geology and Water Resources of the Bighorn Basin, Wyoming; by Cassius A. Fisher. Pp. 72, with 16 plates and 1 figure.

Bulletins.—No. 300. Economic Geology of the Amity Quadrangle, Eastern Washington County, Pennsylvania; by Frederick G. Clapp. Pp. 145, with 8 plates and 7 figures.

No. 304. Oil and Gas Fields of Green County, Pa.; by Ralph W. Stone and F. G. Clapp. Pp. 110, with 3 plates and 17 figures.

No. 308. A Geologic Reconnaissance in Southwestern Nevada and Eastern California; by Sydney H. Ball. Pp. 218, with 3 plates and 17 figures.

No. 311. The Green Schists and associated Granites and Porphyries of Rhode Island; by B. K. Emerson and Joseph H. Perry. Pp. 74, with 2 plates and 6 figures.

No. 312. The Interaction between Minerals and Water Solutions, with Special Reference to Geologic Phenomena; by Eugene C. Sullivan. Pp. 69.

No. 317. Preliminary Report on the Santa Maria Oil District, Santa Barbara County, California; by Ralph Arnold and Robert Anderson. Pp. 69, with 2 plates and one figure.

No. 318. Geology of Oil and Gas Fields in Steubenville, Burgettstown and Claysville Quadrangles, Ohio, West Virginia and Pennsylvania; by W. T. Griswold and M. J. Munn. Pp. 196, with 13 plates.

No. 320. The Downtown District of Leadville, Colorado; by

S. F. Emmons and J. D. Irving. Pp. 72, with 7 plates and 5 figures.

Water-Supply and Irrigation Papers—No. 190. Underground Waters of Coastal Plain of Texas; by Thomas U. Taylor. Pp. 73, with 3 plates.

No. 195. Underground Waters of Missouri, their Geology and Utilization; by E. M. Shepard. Pp. 224, with 6 plates and 6 figures.

No. 197. Water Resources of Georgia; by B. M. Hall and M. R. Hall. Pp. 342, with 1 plate.

No. 199. Underground Water in Sanpete and Central Sevier Valleys, Utah; by G. B. Richardson. Pp. 63, with 6 plates and 5 figures.

No. 201. Surface Water Supply of New England, 1906 (Atlantic Coast of New England drainage); by H. K. Barrows. Pp. 120, with 5 plates and 2 figures.

No. 203. Surface Water Supply of Middle Atlantic Water, 1906 (Susquehanna, Gunpowder, Patapsco, Potomac, James, Roanoke and Yadkin river drainages); by N. C. Grover. Pp. 100, with 4 plates and 2 figures.

No. 204. Surface Water Supply of Southern Atlantic and Eastern Gulf States, 1906 (Santee, Savannah, Ogeechee and Altamaha rivers and eastern Gulf of Mexico drainages); by M. R. Hall. Pp. 110, with 5 plates and 2 figures.

No. 206. Surface Water Supply of Great Lakes and St. Lawrence River Drainages, 1906; by H. K. Barrows and A. H. Horton. Pp. 98, with 3 plates and 2 figures.

No. 208. Surface Water Supply of Missouri River Drainage, 1906; by R. Follansbee, R. I. Meeker and J. E. Stewart. Pp. 190, with 5 plates and 2 figures.

2. *Carnivora from the Tertiary Formations of the John Day Region;* by John C. Merriam. Univ. of Calif. publications. Bull. of the Dept. of Geol., vol. v, No. 1, pp. 1–64, pls. 1–6.—This valuable paper is based upon a collection made by the University of California parties in 1899 and 1900 in the John Day Valley of eastern Oregon, supplemented by further collections made during the fall of 1900, in the region of Crooked River and Logan Butte, south of the John Day Basin. The illustrations are reproduced from the first rough proofs, as the original plates and drawings were destroyed in the great fire of San Francisco.

The sequence of formations in the John Day region is as follows:—

John Day River terraces	Quaternary
Rattlesnake formation	Pliocene
Mascall formation	Miocene
Columbia Lava formation	Miocene
John Day series	Miocene to Oligocene
Upper John Day	
Middle John Day	
Lower John Day	
Clarno formation	Eocene
Upper Clarno	
Lower Clarno	

The John Day and Mascall formations are almost entirely ash and volcanic tuff in various forms. The mammal remains are from the John Day, Mascall, Rattlesnake, and Terrace deposits. The John Day consists for the most part of evenly stratified beds containing a characteristic dry land fauna; the higher strata, however, are crossbedded and contain fresh-water types.

The lower Mascall is composed of fresh-water sediment containing fresh-water fishes, molluscs, and fossil plants, while the upper portion consists of evenly stratified ash beds like those of the John Day.

The carnivora of the Tertiary faunas of the John Day region are known through numerous types, but the actual number of specimens is not large and may be counted among the rarities. It is probable that the fauna is still only imperfectly represented in the collections. Carnivora are known as yet only from the John Day and Mascall formations of this series, the distribution of species being as follows:

Middle John Day 11 species, 23 specimens.
Upper John Day 6(?) species, 12 specimens.
Mascall 2 species, 2 specimens.

There is also a considerable number of species of which the geological range or occurrence is unknown.

Canidæ.—There is a remarkable variety of canid types compared with those of other formations in America, nearly all from the John Day beds; as but two of the eighteen species are from the Mascall. Most of the types exhibit primitive characters though much variation in structure is shown, and in some cases differentation has led to the development of considerably specialized forms.

Compared with the canids of other Tertiary formations in America, the John Day dogs represent a stage of evolution which does not correspond to that of any other formation. Of the nine generic types but one, *Cynodictis* is considered identical with a White River genus; the type is, however, much more advanced than the White River species. The genera have all advanced along lines of specialization laid down in the White River epoch.

The Mascall is separated from the John Day by at least one period of erosion and by the epoch of the accumulation of the Columbia Lava. The relationships of the Mascall Canidæ and the stratigraphic relations taken together indicate that the epoch of the Mascall beds is not far from that of the Deep River. The position of the John Day below these beds puts it into a division much earlier than the Loup Fork.

Felidæ.—Though fairly well-known from skulls and teeth, the John Day cats have, as a whole, presented some of the most puzzling features of this fauna. The most common and best known forms included in the genera *Archælurus* and *Nimravus* have been generally considered as representing the most primitive division of the machærodont group of the Felidæ. In the

White River beds, held to be older than the John Day, there appeared to be among the felines no forms so primitive as these. As the other elements of the John Day fauna are nearly all more advanced than the corresponding forms of the White River, the evidence regarding the age of the beds which is furnished by these cats seemed to contradict that of the remainder of the fauna. The persistence of the primitive running type of feline seems due to the fact that the country was in the main open and ill suited to the development of the larger, slower animals upon which the more specialized saber-toothed cats preyed.

The nine species of Felidæ described are entirely confined to the John Day, none being known from the Mascall. In the Loup Fork, however, the species of true *Felis* and of *Machærodus* represent a more advanced stage of development and a closer approximation to the recent fauna than is found in either the John Day or the White River.

Conclusions.—Taken together the Canidæ and Felidæ of the John Day represent a stage of evolution somewhat more advanced than that reached in the White River, and less advanced than that of the Loup Fork. Compared with the known faunas of Europe, they appear to be not older than the Middle Oligocene of Fontainbleu, and not as young as the Middle Miocene of Sansan. R. S. L.

3. *A Lower Miocene Fauna from South Dakota;* by W. D. MATTHEW. Bull. Amer. Mus. Nat. Hist., vol. xxiii, art. ix, pp. 169–219.—In this bulletin Dr. Matthew announces the discovery of a fossil fauna which links the latest of the White River with the earliest of the so-called Loup Fork faunæ of the western plains. This gap had been filled in part by the John Day of Oregon, but this is much more nearly allied to the White River than to the Loup Fork.

Matthew and Gidley have given the name Rosebud Beds to the Lower Miocene formation of South Dakota lying between the White River and Loup Fork. These beds are divided by a white, flinty, calcareous layer lying about half way up, into an upper and a lower series, each with its characteristic animal forms.

In the Lower Rosebud Matthew has identified five new species of Carnivora, nine species of Rodentia, of which six are new, three species of Perissodactyla, and six of Artiodactyla, one of which he describes as new. The Upper Rosebud fauna is almost entirely distinct, few species passing through. It contains four new species of Carnivora, one of which is the type of a new genus, a new genus and species of Insectivora, four new species of Rodentia and one form representing an undetermined genus, five species of Artiodactyla of which three are new, and one new genus and at least three species of Perissodactyla. The Rosebud fauna is derived from the John Day, there being but one immigrant, the antilocaprid *Blastomeryx.* The species are in advance of those of the John Day, though the great majority can be referred to John Day genera.

A comparison with the Middle and Upper Miocene faunæ is much more difficult on account of our imperfect knowledge of so many of the species. These appear, however, to be a further outgrowth of the Rosebud, but contain new elements which cannot be derived from this source, such as the Proboscidea, the Pecora (modern ruminants), Protohippinæ (horses with long-crowned, cemented teeth and reduced lateral metapodials but retaining a vestigial pollex), and probably certain Carnivora (Lutrinæ, etc.). Aside from these foreign elements of the later Miocene, the Rosebud fauna presents two stages in the evolution of the Miocene fauna fairly intermediate between the John Day and the Deep River–Pawnee Creek beds; the remainder are sufficiently more primitive for generic separation or represent phyla which have not survived. If the John Day represents the Upper Oligocene of Europe and the Deep River–Pawnee Creek the Middle Miocene, the Rosebud represents an earlier and a later phase of the Lower Miocene.

The discovery of these intermediate stages will enable us to clear up the relations of most of the Oligocene and Upper Miocene genera and to trace the descent of the various phyla and subphyla much more exactly than has hitherto been possible. The more elaborate studies and extensive collections of the past few years in the American Tertiaries have shown that the simple phyletic series, based upon more fragmentary and imperfect data than are now available, are true only in a general and approximate way. Recent phylogenetic study has tended quite as much to negative as to positive results—to break up accepted phyla as to reinforce them by more complete knowledge of the genera. It is peculiarly satisfactory, therefore, to find a fauna which is intermediate between two stages hitherto disconnected, and enables us to perceive the exact relationship between genera which could until now be connected only in a general or provisional way. The preliminary results here presented are very incomplete and various additions and modifications may be needed when the collections are more completely prepared and studied. R. S. L.

4. *Points of the Skeleton of the Arab Horse;* by H. F. OSBORN. Bull. Amer. Mus. Nat. Hist., vol. xxiii, art. xiii, pp. 259–263.—In this brief article Professor Osborn discusses the distinctive features of the Arabian horse as shown in the skeleton of the horse "Nimr" recently mounted at the American Museum of Natural History. It is interesting to compare these points with those of the Arab mare, "Esnea," the skeleton of which is preserved in the Yale University Museum. "Esnea" was a pure bred Arabian, imported from Damascus by Mr. John W. Garrett in 1852. Some of the points are as follows:

(1.) Arab horses possess but five lumbar vertebræ. This is true of "Nimr," of "Lexington" in the U. S. National Museum, and also of a thoroughbred in the British Museum. "Esnea," however, has six lumbars, the last three being cöossified.

(2.) The characteristic elevation of the tail due to the upturned sacral and anterior caudal vertebræ together with the remarkable horizontal position of the pelvis "Esnea" would show were the skeleton properly mounted. As it is, the back is so highly arched that the zygapophyses are pulled apart.

(3.) The short tail is a distinctive feature, "Nimr" having sixteen vertebræ compared with the eighteen of a draught horse, while "Esnea" has but thirteen and the tail is seemingly complete.

(4.) The fourth character, that of a complete shaft to the ulna, "Esnea" does not show, for with her the shaft is discontinuous for about 65^{mm}, although a fractured end implies that the actual break in the continuity of the bone may have been less.

(5.) The Arab skeleton is noted for the great density of the bone. This is not especially true of "Nimr." Whether or not it is true of "Esnea" has not been ascertained.

(6.) The skull of "Nimr" has a large brain case, prominent orbits, a broad forehead, and a "dish profile." That of "Esnea" agrees except that the profile is not dished.

(7.) The development of the sagittal crest in "Nimr," as well as the fossæ for the insertion of the masseteric muscles in the angular region of the jaw, are probably more exaggerated than in "Esnea" as a sexual character. The slender, tapering jaw is characteristic of both individuals.

(8.) "Esnea" shows the slight depression in the malar region in front of and below the eyes, to which Lydekker calls attention as characteristic of the skulls of several thoroughbreds. This "Nimr" does not show.

Finally, Osborn says: "Altogether in my opinion these osteological characters justify the separation of the Arab as a distinct species (*Equus africanus* Sanson), of distinct origin and from wild ancestors very different from those of the northern horse."

R. S. L.

5. *Eiszeit und Urgeschichte der Menschen;* von Dr. HANS POHLIG. Pp. 141. Leipzig, 1907 (Quelle & Meyer).—This is a valuable little book recently published by the well-known authority on the Pleistocene faunæ of Europe.

6. *Physikalische Kristallographie vom Standpunkt der Strukturtheorie;* von ERNST SOMERFELDT. Pp. vi, 131, mit 122 Abbildungen im Text und auf eingeheften Tafeln. Leipzig, 1907 (Chr. Herm. Tauchnitz).—This compact volume will be found useful and interesting by those desirous of obtaining a knowledge of the modern theory of molecular structure and the crystallographic and physical relations connected with it. The matter is presented after the manner of Sohncke, and is liberally illustrated by photographs from models, which will be helpful to the student. The application of the theory of structure to the different aspects of crystallographic physics, as the etching figures, the phenomena of rotatory polarization, etc., are well presented in the latter part of the work.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Carnegie Institution of Washington.*—Recent publications of the Carnegie Institution are noted in the following list (see earlier, p. 87, July, 1907 :

No. 5. A General Catalogue of Double Stars within 121° of the North Pole ; by S. W. BURNHAM. Part I. The Catalogue, 4to, pp. lv. Part II. Notes to the Catalogue. Pp. viii, 259–1086.

No. 54. Research in China. Volume One in Two Parts: Part Two. Petrography and Zoology ; by ELIOT BLACKWELDER. Syllabary of Chinese Sounds; by FRIEDRICH HIRTH. 4to, pp. iv, 367–528.

No. 62. Condensation of Vapor as induced by Nuclei and Ions ; by CARL BARUS. 8vo, pp. v, 164, with 55 tables and 66 figures.

No. 64. Variation and Correlation in the Crayfish, with Special Reference to the influence of Differentiation and Homology of Parts; by RAYMOND PEARL and A. B. CLAWSON. 8vo, pp. 70, with 32 tables.

No. 68. Further Researches on North American Acridiidæ ; by ALBERT P. MORSE. 8vo, pp. 54, with 9 plates.

No. 71. Atlas of Absorption Spectra ; by H. S. UHLER and R. W. WOOD. 4to, pp. 59, with 26 plates (102 figures).

No. 72. Investigation of Inequalities in the Motion of the Moon produced by the Action of the Planets ; by SIMON NEWCOMB, assisted by FRANK E. ROSS. 4to, pp. v, 160, with 49 tables.

No. 84. The Proteins of the Wheat Kernel ; by THOMAS B. OSBORNE. 8vo, pp. 119.

2. *A Laboratory Manual of Invertebrate Zoölogy ;* by GILMAN A. DREW, Ph.D. Pp. xii, 201. Philadelphia, 1907 (W. B. Saunders Co.).—The manual is based on laboratory directions which are the result of the experience of the last six years in teaching the class in general zoölogy at the Marine Biological Laboratory of Woods Hole, Mass. In addition to the particularly satisfactory directions for dissecting a large number of invertebrate types, special emphasis is placed upon such facts as lead the student "to an appreciation of adaptation." B. W. K.

OBITUARY.

Dr. WILBUR OLIN ATWATER, Professor of Chemistry in Wesleyan University, Middletown, Ct., since 1873, died on Sept. 22 at the age of sixty-three years.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXXV.—*On the Electric Arc between Metallic Electrodes;*[*] by W. G. Cady and H. D. Arnold.

First Paper.—*Introduction.*

§1. Up to the present time most investigations on the electric discharge between metals have been confined either to the glow discharge,—chiefly at low gas pressures,—or else to the arc discharge at relatively high current densities, where a pronounced volatilization of both electrodes takes place. No systematic examination of the transition from one of these forms of discharge to the other, for various metals, seems to have been carried out. The present paper has to do with this transitional region, having regard particularly to the phenomena observed with the electric arc at relatively small currents.[†]

The starting-point of the investigation was the observation made by one of the writers, that the iron arc at a certain critical value of current undergoes an abrupt change somewhat similar to the well-known "hissing point" of the carbon arc. The similarity was so strong that in our preliminary reports we used the terms "quiet state," "hissing state," and "hissing point" to denote the phenomena observed. More recent observations have shown that the effect is not to be compared to the hissing point of the carbon arc, but that it is a different phenomenon, casual reference to which has been made by various observers in the past. Thus Maisel[‡] notes that the iron arc

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[*] This investigation is being carried on with the aid of a grant of $200 from the Elizabeth Thompson Science Fund, grateful acknowledgment of which the writers desire to make here.

[†] Brief reports on these experiments have appeared in Nature, lxxiv, 443, 1906; Electrician, lviii, 816, 1907; Phys. Rev., xxiv, 381 and 446, 1907.

[‡] Phys. Zeitschr., v, 550, 1904.

ceases to hiss at a current somewhere below two amperes; Steinmetz* mentions an unlooked-for change in voltage at about one ampere; and as we shall show later, the darkening of the arc in the neighborhood of the anode† and the appearance of striations in the arc,‡ which several experimenters have noted, may also be referred to the same common cause. Among the names mentioned, Stark and Cassuto seem to have been the only ones who recognized the nature of the phenomenon.

Hence it seems better to use the term *critical point* in referring to the effect described in this paper, and to substitute for "quiet state" and "hissing state" the terms *first stage* and *second stage* respectively.

I. *The Critical Point of the Iron Arc.*

§2. *Apparatus.*—Among the metals that have been tried in air at atmospheric pressure, iron shows the critical point by far the most easily. No essential difference in any of the phenomena was noticed whether the arc was horizontal or vertical, anode above or below. The effects here described are, however, best obtained with the anode down, probably because the anode, which as will be seen is the seat of the critical point, is then free of disturbing influences from the heated vapors.

Most of the observations on the iron arc were obtained with a lamp constructed for the purpose, in which each terminal could be raised and lowered by means of a rack and pinion. Horizontal adjustments permitted the alignment of the terminals, which were inclosed in a wooden box with glass sides, to protect the arc against air currents. Current and voltage were measured by means of Weston instruments. The direct current mains yielded a supply at either 120 or 240 volts, which could be raised to 475 volts by connecting a storage battery and small dynamo in series.

The appearance and length of the arc were observed by projecting an image, magnified about ten times, by means of a small lens, onto a mirror, from which it was brought to a focus on a vertical paper scale graduated in millimeters. The scale was mounted close beside the arc, thus enabling one observer to control the arc and record lengths, while a second observer recorded voltage and current.

The following method of determining length of arc also gave good results in cases where it was desirable not to darken the room. A telescope was focused on the image of the arc

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* Tr. Elec. Cong. St. Louis, vol. ii, p. 710, 1904.

† Matteucci, C. R., xxix, 263, 1849; Arons, Ann. Phys., i, 700, 1900; Stark, Phys. Zeitschr., v, 81, 1904; Stark and Cassuto, Phys. Zeitschr., v, 264, 1904.

‡ Gassiot, Pogg. Ann., cxix, 133, 1863; de la Rue and Müller, Phil. Tr., clxxi, 65, 1879; Child, Phys. Rev., xx, 369, 1905.

as partially reflected from a piece of plate glass. Back of the glass, at the same distance as the arc, was a vertical paper scale, brightly illuminated. The arc was then seen superposed upon the scale.

Beside German silver rheostats, a large carbonate of soda resistance was used to secure a finer regulation of current.

§3. *The Iron Arc in free Air.*—In order to make the transition from the second to the first stage it is of prime importance that the arc shall have settled into a normal state. When the arc has just been struck, with fresh electrodes, oxidation immediately commences, resulting in the formation of a mass of molten magnetic oxide on each terminal. Owing to the comparatively rapid consumption of the cathode, the molten oxide here presents a flat or even concave surface; at the anode on the other hand the oxide forms a rounded globule of continually increasing size, due to the transportation of matter from the cathode. It was found best to touch the terminals together from time to time, thereby transferring a part of the positive globule to the cathode and causing the discharge to take place between convex surfaces. When cold, the oxide tips are easily detached from the iron electrodes, leaving generally a blunt point of iron at the anode and a slight concavity at the cathode.

Thus the normal iron arc in free air is in reality one between terminals of magnetic oxide of iron. A test for iron nitride in the globules gave negative results. Air-holes of considerable extent are often found in the cooled positive globule. The origin of these is not certain, but an examination of the globules indicates that air finds an entrance at points around the edge between the globule and the metal, making its way to the neighborhood of the arc, where owing to the highly liquid state of the globule it emerges, leaving a cavity behind. The same is true of copper (see §18) and of iron when the arc has been burned in nitrogen. When the vapors from the iron arc condense, brown oxide forms in a copious powder. Most of these details are doubtless familiar to all who have worked with the iron arc, but it seems worth while to refer to them in view of the important relation borne by the oxidation to the critical point.

§4. In free air, with iron terminals from three to six millimeters in diameter, the arc is generally on the first stage as long as the current is below one ampere. The arc proper has then a bluish-white color at the negative end, which gradually shades into dark blue as the anode is approached. At the anode is a layer that seems almost completely dark. A thick yellowish-green mantle surrounds the arc, apparently due to the oxidation of the iron in the arc itself. This mantle seems to avoid touching the anode. Outside the mantle is a thin second mantle or shell, springing from the cathode and probably due to oxidation of the negative globule.

The arc starts from an intensely bright spot on the cathode, but the anode end is very dim and diffuse. As the current is increased by diminishing the external resistance, the various parts of the arc brighten in intensity, and the terminal voltage decreases in the usual manner. Fig. 5 (p. 403) shows a group of characteristic curves for iron, for various lengths of arc. The curve for 8^{mm} may be taken as a typical case. Here the part *MA* is on the first stage, with large external resistance. In this, as in the other diagrams, full lines represent those regions where the discharge is stable, broken lines those where no steady discharge can be maintained.

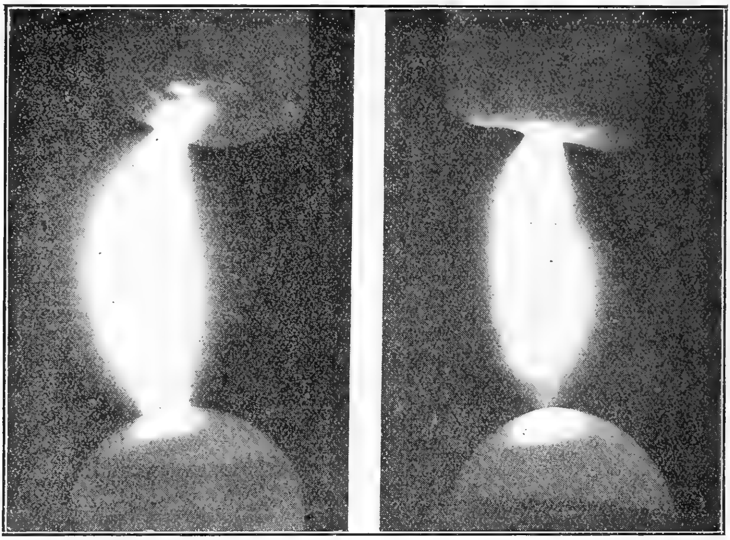

Fig. 1. The Iron Arc. The positive terminal is below in each case.
Right: 1st stage, $l = 4{\cdot}5^{mm}$, $I = 1{\cdot}3$ amp., $E = 74{\cdot}5$ volt.
Left: 2d stage, $l = 4{\cdot}5^{mm}$, $I = 1{\cdot}3$ amp., $E = 61{\cdot}0$ volt.

When the current reaches a value a little over one ampere, a very small decrease in external resistance causes an abrupt change to take place. The potential difference drops about 12 volts, the current increases slightly, a distinct hissing sound is heard, and the blue-white light of the cathode extends nearly uniformly to the anode, where a small bright spot appears. At the same time the mantle and shell surrounding the arc increase greatly in brightness.

This sudden change is represented in fig. 5 by the broken line *AB*. Between the points *A* and *B* no readings can be taken. As the current is still further increased, the portion *BN* on the second stage is obtained. This is, of course, the stage on which the iron arc is usually operated for spectroscopic or other purposes, and it constitutes the final state of the arc.

The energy expended at the beginning of the second stage is always less than that at the end of the first stage, owing to the great decrease in voltage, together with the fact that the increase of current is limited by the external resistance.

The photographs, fig. 1, give a fair idea of the appearance of the arc, though it was impossible to reproduce the surrounding mantle. When the arc is viewed directly through dark glasses, the change in appearance between the two stages is much more striking than in the photograph. The bright spot seen on the front surface of the positive globule in each photograph is the reflection of the light from the arc.

If one begins taking observations on the second stage and decreases the current, it is usually found that the change back to the first stage does not take place along the line *BA*, but that a smaller value of current can be reached. Thus in the observations shown in fig. 5, as the external resistance was gradually increased, the break took place along the line *CD*. The value of the current for the critical points *A* and *C* is subject to variation, but in general it may be said that the longer the arc, the wider is the parallelogram. In the observations shown in fig. 5, no difference was observed between the lines corresponding to *AB* and *CD* for lengths of 1^{mm} and 2^{mm}, though even here on other occasions wide differences have been found. Thus at least for long arcs there may exist two values of voltage for the same current. As would be expected, the lines *BA* and *CD* cut the axis of ordinates at a point corresponding to the supply voltage. These characteristic curves are discussed more fully in §30.

§5. The first step was to see how far these two stages are analogous to the quiet and hissing states of the carbon arc. The experiments described by Mrs. Ayrton* were repeated, with the following results: When the arc is on the second stage, the first stage can be precipitated by (1) decreasing the current, (2) drawing the electrodes farther apart, or (3) lengthening the arc by an air-blast or by a magnet. Also, as with the carbon arc, the largest current that will maintain the first stage is greater the longer the arc.

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*The Electric Arc, p. 279.

§6. *The Drop in Potential at the Anode.*—Mrs. Ayrton* found for the carbon arc, that of the change in voltage in passing through the hissing point, about two-thirds occurs at the anode, the rest in the gas. There are serious difficulties in the way of carrying out this test with iron, for although the iron arc when undisturbed burns steadily enough, still the approach of an exploring pencil, especially when the current is small, causes the arc to be repelled and to burn with great irregularity.† Indeed, the sources of error in the use of exploring electrodes mentioned by Pollak‡ in connection with the mercury arc and by Child§ seem to be particularly dangerous with the metallic arc in free air.

Carbon was first tried as an exploring electrode, but it was soon abandoned for fear of error from the vapor which it introduced into the arc. It did, indeed, change the arc voltage by about five volts.

Then a rod of iron was employed. A small diameter could not be used, as the rod then melted too rapidly. Platinum melted almost as readily as iron. When an iron pencil $2{\cdot}5^{mm}$ thick was introduced into the arc, a globule of oxide formed on its extremity, which was so large in comparison with the length of arc that any thought of accurate exploration of the field was out of the question. Still, it was possible to show at least qualitatively by means of a quadrant electrometer that the change in voltage when passing through the critical point was chiefly, if not wholly, on the anode side of the exploring electrode.

When the arc is formed between a cathode of carbon or copper and an iron anode, the critical point occurs practically the same as between iron terminals. But when iron is the cathode and carbon the anode, no sudden change takes place until the hissing point for carbon is reached. With an iron cathode and copper anode no critical point occurs (unless it be the critical point for copper, which is discussed farther on) until a deposit of iron has formed on the copper; then the normal change for iron takes place.

The Iron Arc in Nitrogen.

§7. Pursuing the analogy with the carbon arc, the question arose whether oxidation plays a part in producing the observed effect. Some preliminary tests in which oxygen had been excluded from the arc as far as possible indicated that either a very small trace of oxygen is still capable of precipitating the

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* The Electric Arc, p. 288.

† Child observed the positive and negative drop in the case of the metallic arc, but he used a current of six amperes. See Phys. Rev., xii, 149, 1901.

‡ Ann. Phys., xix, 218, 1906.

§ Phys. Rev., xxiv, 498, 1907.

change in the iron arc, or else it is possible to obtain both first and second stages between terminals of magnetic oxide of iron even when no free oxygen is present in the surrounding gas.*

The question was settled conclusively by starting an arc between carefully cleaned iron terminals in pure nitrogen.

The apparatus shown in fig. 2 was used for this purpose. The terminals *A* and *K* were located inside a glass bulb *B* 15^{cm} in diameter. They were made from iron rod $4{\cdot}5^{mm}$ thick, and the ends from which the discharge took place were turned down to a diameter of 3^{mm}. They extended into the bulb through vertical glass tubes about 80^{cm} long, which were provided with ground joints at *D* and *E*. The glass tubes dipped into vessels of mercury, which rose to barometric height when the air was exhausted. It was possible to raise and lower each electrode independently, as well as to rotate it about a vertical axis in order to secure exact alignment. The rod *K* was jointed at *F*. The short portion beyond *F* was bent outward by a suitable device when *K* was to be taken from the bulb or intro-

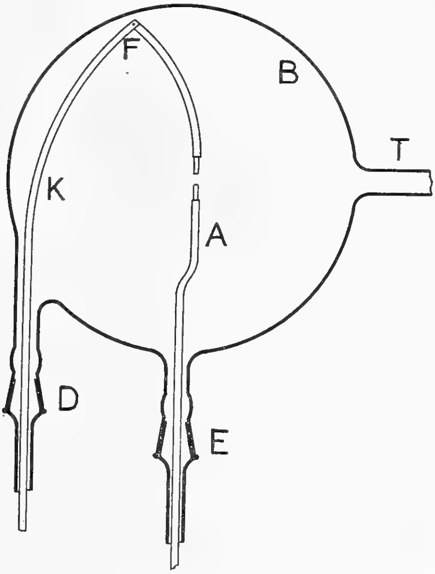

Fig. 2. Apparatus for the arc in nitrogen.

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* When the iron arc was formed under a bell-jar containing nitrogen in which only a small trace of free oxygen can have been present, a surprisingly large quantity of nitric acid was produced. Traces of moisture or other impurities from organic substances in the jar may have contributed toward this.

duced into it. The curvature of the rod was such that it could just be slipped in through the neck of the bulb. *T* was a side outlet leading to the manometer, Geryk pump and nitrogen generating and purifying apparatus.

This construction was chosen in order to exclude from the arc all substances that might introduce traces of oxygen, and at the same time to permit as much freedom as possible in manipulating the electrodes. Great precautions were taken in purifying and drying the nitrogen, which was generated chemically. The bulb was carefully heated to drive off occluded gases. Several sets of observations were made, in each case the apparatus having been exhausted and filled with nitrogen several times. In some cases a trace of oxidation was noticed at the start, which soon ceased, leaving the tips of the electrodes bright and silvery in appearance.

In agreement with an observation of Arons* we found that the black metallic dust from the arc became deposited more densely on the negative than on the positive electrode. This would seem to indicate that the dust particles on leaving the arc carry a positive charge. It is not what one would expect in view of the fact that it is chiefly the negative electrode that disintegrates.

§8. The following results were noted. As long as a trace of black oxide remained on the electrodes both stages could be obtained, in nitrogen as well as in air. But when the discharge took place between terminals of metallic iron, it presented the appearance of the second rather than the first stage, even when the current was reduced until the arc went out. Only in the last instant before the arc ceased, when it was flickering irregularly, was there any indication of the appearance of the first stage. This alone is enough to show that oxidation is *not* the cause of the second stage in the iron arc.

§9. *Observations in a Partial Vacuum.*—We shall show in §23 that in the case of certain metals the critical point can easily be obtained at reduced gas pressures, although it does not appear in free air. With unoxidized iron and platinum it is almost impossible to get the first stage at any pressure. With a supply of 475 volts, and iron terminals in nitrogen, using the apparatus of fig. 2, a glow discharge could be obtained at any pressure, but when the current was sufficiently increased the glow persisted in changing to the second stage of the arc, provided the pressure was high enough to make the formation of an arc possible.

A careful examination was made at various pressures, but no stable first stage could be found. At a pressure of 60^{cm} and with very short arc there was what seemed to be an exceed-

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* Ann. Phys., i, 700, 1900.

ingly unstable first stage, but it could not be established with certainty.

A very unstable region was found at pressures between 10 and 30^{cm}. Here the discharge changed back and forth from glow to arc so rapidly that it looked like both simultaneously.

The Critical Point due to Vaporization.

§10. After it had thus been proved that the difference between the first and second stage of the iron arc cannot be attributed to oxidation, the thought suggested itself that perhaps in the first stage we have, even in free air without artificial cooling, an anode that is below the temperature of vaporization. The observation that the positive globule appears in a more agitated condition on the second stage, as well as the glow-like appearance of the arc in the neighborhood of the anode on the first stage, tend to strengthen this view. This means, of course, that on the first stage the discharge has the character of an arc at the cathode, but of a glow at the anode.

Such a possibility was mentioned several years ago by Stark,* and more recently Stark and Cassuto† have carried out observations with an arc in which the anode was not even incandescent. The mercury arc with iron anode belongs also to this class of phenomena. What made the case less obvious with the iron arc was, first, the incandescent state of the positive globule on the first stage, and second, that any characteristic of the glow discharge was hardly to be anticipated with ordinary electrodes in free air with a supply voltage as low as 110.

§11. Several methods of testing this hypothesis at once suggested themselves. The first was, to test for vaporization by measuring the *loss in weight* of the positive globule on the two stages. Even to the eye it was apparent that the positive globule grew somewhat more rapidly on the first than on the second stage.

In order to avoid the growth of the globule from oxidation of the anode or from matter transported across from the cathode, a small globule of magnetic oxide was placed as anode in a cavity in the end of an electric light carbon, while another carbon served as cathode. The arc was allowed to burn long enough for the globule to absorb all the carbon it could, and the globule was taken out and weighed. The loss in weight was then observed after the arc had burned a certain number of minutes on the second stage, then again for the first stage.

Table I contains a summary of the results :

TABLE I.

Stage	Current	Voltage	Arc Length	Watts	Loss per Min.
1st.	1·15	61	2^{mm}	70·1	$0·82^{mg}$
2d.	1·4	48	2^{mm}	67·2	$5·75^{mg}$

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* Die Elektr. in Gasen, 1902, p. 154.

† Phys. Zeitschr., v, 264, 1904.

Thus although more energy is expended on the first than on the second stage, still the loss in weight of the positive globule is seven times as great on the second as on the first. The loss on the second stage, according to this theory, is due to vaporization of the globule; that on the first, in so far as it cannot be accounted for by errors, is due in part perhaps to ionic bombardment, and in part to local heating from the arc itself.

Strictly speaking, the energy considered should have been that expended at the surface of the anode, and not that for the whole arc. Still, since the change in voltage occurs chiefly at the anode, it follows that if the true anode drop were known and multiplied by the value of the current, the ratio of the energies for the first and second stage would be even greater than is indicated in Table I, thus making the argument even more conclusive.

§12. *Spectroscopic Evidence.*—The arc was formed between a carbon cathode and iron anode; its image was then projected onto the slit of a spectroscope. On the first stage, the spectrum of iron was faintly visible, owing to traces of iron in the carbon and probably to a small amount of iron set free from the anode, as indicated in the preceding paragraph. At the instant when on decreasing the external resistance the critical point was reached, the iron spectrum flashed out with great brilliancy. The same is true of the arc between a carbon cathode and silver anode (§24). This indicates that even if vaporization is taking place on the first stage, it is exceedingly small in comparison with that on the second.

§13. *Evidence from Temperature of Positive Globule.*—A series of tests was made with a thermo-electric junction imbedded in the positive globule. A junction consisting of a platinum wire $0{\cdot}13^{mm}$ in diameter and a wire of platinum and 10 per cent rhodium $0{\cdot}25^{mm}$ in diameter, held by an arm that could be controlled by slow-motion screws, was thrust into the globule after the arc had been formed. It was connected to a d'Arsonval galvanometer, and scale deflections were noted as the arc current gradually increased. According to the vaporization theory, the positive globule on the first stage, with the exception perhaps of a small region immediately under the arc, is at a temperature below the boiling point. At the critical point, copious vaporization suddenly sets in, and from then on the temperature of the globule would remain practically constant if it were not for losses by conduction and radiation. Owing to these losses, and to the diminution of energy on passing through the critical point, changes in the mean temperature of the globule cannot be taken as a sure indication of its physical state in the neighborhood of the arc.

It was found, however, in spite of the great decrease in energy at the beginning of the second stage, that the galvanometer deflection decreased but little. In so far as the junction can be considered as giving the mean temperature of the globule, this means that the globule temperature is not proportional alone to the energy expended, but tends to become constant when the second stage is reached.

§14. *Heating the Positive Globule.*—Anything that raises the temperature of the positive globule should cause the critical point to be reached at a smaller current. This we have found to be the case. With thin electrodes, which conduct the heat away less readily, the critical point comes at a slightly smaller current than with thick electrodes. Also, the smaller the positive globule, the sooner is the critical point reached. Thus with the same anode, we have recorded within a few minutes values of the critical current from 1·1 to 1·7 amperes, depending on the size and curvature of the positive globule.

The experiment was also tried of heating the positive terminal, an iron rod 3^{mm} in diameter, by means of a blast lamp. A large mica shield fitted closely around the rod about a centimeter below the arc, to protect the latter from the direct effects of the flame. When the positive terminal was heated to redness, the critical current was 1·4 amp. Without artificial heating, the critical current was 1·7 amp. The globule was of approximately the same size in each case, and the blast lamp was kept burning throughout the experiment in order that the nature of the gas surrounding the arc might be constant.

Stark and Cassuto (l. c.) have shown that heating the anode causes the positive drop to increase slightly, owing probably to increased thermal electromotive-force. This, by increasing the expenditure of energy at the anode, would also tend to cause the critical point to come at a smaller current.

When it was attempted to cool the anode by surrounding it with snow, anomalous results were obtained, which we found to be due to the effect of the water vapor. For example, when steam was allowed to flow freely into the inclosure surrounding the arc, the break from the first to the second stage took place at a much higher voltage and smaller current than when the air was not thus saturated with moisture. The difference—amounting to about ten volts in the case of the potential difference—is too great to be accounted for by change in the heat conductivity of the air due to the presence of moisture. It is more likely that the water vapor, which as the experiments of Merritt and Stewart* indicate becomes highly ionized in the arc, gives to the arc quite different characteristic curves from those prevailing in ordinary air.

* Phys. Rev., vii, 147, 1898.

II. *Observations with Various Metals.*

§15. *Change from Glow to Arc with Iron and Platinum Terminals.*—Mention has already been made (§9) of the glow discharge in nitrogen between iron terminals with a supply e.m.f. of 475 volts. This has been observed in free air with terminals of iron, copper, and platinum, but only when the electrodes were nearly free from oxidation. In each case, almost the whole supply e.m.f. was used up in the arc. The effect could only be obtained with an arc less than 1·5^{mm} long.

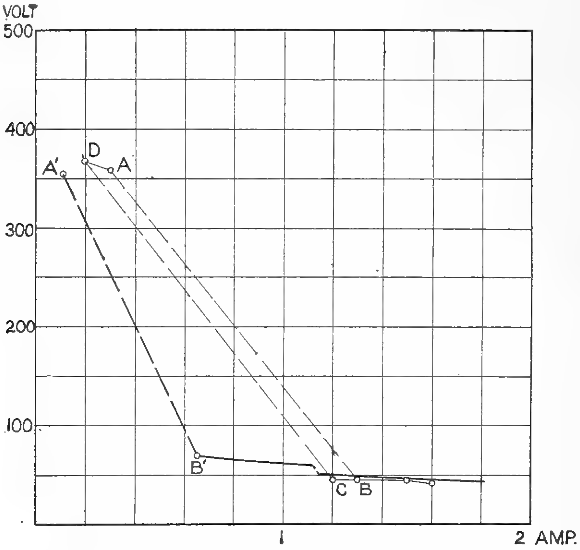

Fig. 3. Change from glow to arc in free air. Heavy lines, iron. Light lines, platinum.

The space between the electrodes looked entirely dark, but the discharge remained in this state only a few seconds, for the cathode rapidly became incandescent, causing the glow to change to an arc, with the accompanying drop in voltage and increase in current.

With iron electrodes on which there were only small particles of oxide, the arc at small currents burned irregularly, and at the positive end it sprang wildly from one particle to another, while its negative end was concentrated on one particle. If the wandering of the arc caused the negative end to leave its minute globule of oxide, the discharge instantly changed to a glow. Then as soon as the whole cathode had become incandescent, the arc formed again, concentrating itself upon an oxide particle as before. This may be due simply to the loose particles having a higher temperature than the electrode itself, but it may indicate also that the oxide of iron, like that of calcium, emits negative corpuscles more readily than does the metal itself. When the electrodes have become completely tipped with oxide, no glow discharge can be obtained.* A similar spontaneous change back and forth between glow and arc was also observed with terminals of copper, and of platinum.

§16. Fig. 3 shows the limiting values of current and voltage for the change from glow to arc, with platinum and iron electrodes. The length of arc is about 1^{mm}. In the case of platinum, AB is the line along which the change takes place in going from glow to arc. The arc current can then be decreased so that the change back to glow is along CD. This is analogous to the "parallelograms" referred to in §4, and is similar to an observation of Kaufmann's.† No such overlapping was detected in the case of iron. The platinum arc is very irregular, but as nearly as can be judged it is on the second stage.

When the glow between iron electrodes changes along $A'B'$ to an arc, the latter is on the first stage. Further decrease in external resistance results farther on in the change to the second stage, as shown in fig. 3. Points based on observations made during this experiment are represented by circles. The lines representing the first and second stages of the iron arc in air are based on other data.

The close agreement of the curve for the platinum arc with the second stage of the iron arc is noticeable. It looks as if the higher boiling point of platinum allowed the glow to persist until the current was greater than is possible with iron electrodes, so that when the change to arc occurred, the initial arc current as determined by the slope of the line AB was too great for the first stage to exist. In other words, cathode and anode begin to volatilize at the same instant. If a higher supply e.m.f. had been available, it is quite probable that the first stage could have been maintained with the platinum arc. With the arc between platinum terminals in nitrogen, no better success in reaching the first stage was obtained, even at reduced gas pressures.

After the platinum electrodes had cooled, an examination under the microscope revealed a system of grooves or striae on their surfaces, somewhat like those mentioned by Arons.‡ A similar structure, apparently crystalline in nature, can be seen

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* Stark (Phys. Zeitschr., v, 81, 1904) found that the glow did not change to an arc when the electrodes were clean.

† Ann. Phys., ii, 158, 1900.

‡ Ibid., i, 705, 1900.

sometimes on the surfaces of the iron globules. After cooling, the platinum rod which had served as cathode looked perfectly bright at the tip, but the platinum anode showed a discoloration, apparently the same as that which de la Rive* took for a sign of oxidation.

§17. *Magnetite-Copper.*—The two electrodes belonging to a magnetite arc lamp were used. When the magnetite was positive, the critical point was observed just as with the iron arc. The large size of the electrodes made observations at small currents very irregular.

§18. *Copper.*—After some difficulty, the critical point in free air was found. For comparison with iron, the observations have been plotted in fig. 5. They were obtained with a 475 volt supply, length of arc 4^{mm}, diameter of electrodes 6^{mm}. In fig. 5 only the "parallelogram" *mnop* corresponding to *ABCD* for iron is shown, so that *pm* is a part of the characteristic curve on the first, *no* on the second stage. The cause of the parallelograms for copper and iron is explained in §30. The change in appearance of the copper arc between the first and the second stage in air is in a general way similar to that for iron, though less pronounced.

The arc takes place between molten globules of copper oxide, which shrink considerably on cooling. Air cavities are sometimes found inside these globules, probably of the same nature as those in the case of iron.

§19. *Aluminium and Zinc.*—The only observations were in free air. The formation of oxides made the arcs so unsteady that no accurate observations could be made. Over a wide range of current no evidence of anything other than the second stage could be found.

§20. *Mercury, Cadmium and Tin.*—Arcs were formed in air between these metals as anodes and carbon as cathode. The discharge was very unsteady, and no certain indication of the first stage was found. This is not surprising, owing to the low boiling points of the metals.

§21. *Bismuth.*—A piece of bismuth was placed as anode in a brass receptacle, with a carbon cathode. Much oxide formed, but it became reduced in the neighborhood of the arc. The arc burned normally on the second stage, but as the current was decreased, the bright spot on the anode disappeared and the first stage seemed to have set in. Unfortunately the arc could not be kept burning steadily on this stage, and no readings could be taken owing to the irregularity of the discharge.

§22. *Lead.*—In free air about as much evidence of the first stage could be found as with bismuth.

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* Pogg. Ann., lxxvi, 270, 1849.

To get rid of the oxidation, an apparatus was constructed for forming in nitrogen arcs with anodes of various metals. This consisted of a bell-jar about 27x12^{cm} cemented onto a brass base. The substance serving as anode, in the form of a small pellet, was laid in a cavity in the top of a massive brass block, in order that the heat might be conducted away as rapidly as possible. The upper (negative) electrode was a carbon 8^{mm} in diameter held by a small brass rod, which passed up into a glass tube. The latter was cemented with ceiling wax into the neck of the bell-jar. At the upper end of the brass rod was an iron button. By means of a strong electro-magnet whose poles approached close to the tube on each side, the weight of the carbon was sustained and it could be raised and lowered at will.

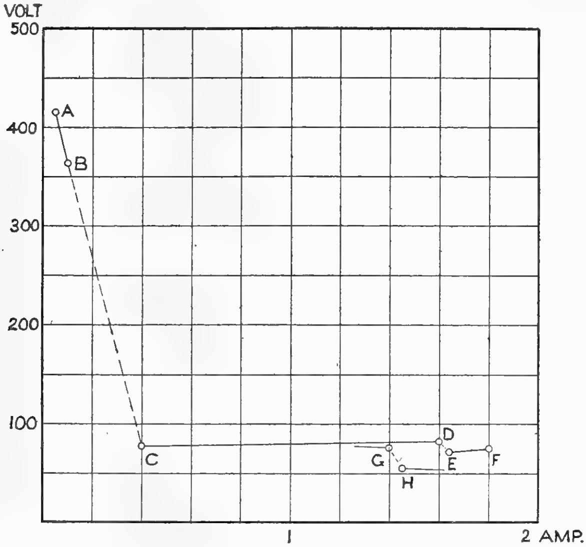

Fig. 4. Points A to F, glow and arc with silver anode. Points G and H, arc with lead anode.

§23. It was thought that at low pressure in nitrogen the critical point might be observed more readily than in free air. This we found to be the case. With a lead anode, in nitrogen up to 12^{cm} pressure, only the glow discharge was observed. The cathode glow formed a mantle covering the negative terminal to an extent depending on current and gas pressure. The dark space extended from this to the positive column, which formed merely a thin coating over the surface of the anode.

At 30^{cm} the change from second to first stage was easily observed. This is shown in fig. 4, points *G* and *H*. To the left of *G* the arc is stable on the first stage; to the right of *H*, on the second stage.

At 55^{cm} and over only the second stage could be maintained. When on the first stage, there is a soft diffused positive glow over the anode and the arc is very dark except close to the cathode. On the second stage the usual bright spot appears at the anode and the whole arc becomes luminous.

§24. *Silver.*—In free air with a carbon cathode the silver anode always melted, though there was no troublesome oxidation. Only the second stage could be observed.

Observations in nitrogen were begun at a pressure of about a millimeter, using the apparatus described in §22. An e.m.f. of 460 volts was applied. The chief observations are shown in fig. 4. *A* and *B* are on the glow discharge, *C* and *D* on the first stage of the arc, and *E* and *F* on the second stage. The length of arc was 3^{mm} except for the point *F*, where it was somewhat greater. The change from *B* to *C* took place spontaneously when the pressure had increased to $4{\cdot}5^{cm}$, and from *D* to *E* when it had increased to 31^{cm}. It was not found possible to get both changes at the same pressure. The lines *AB*, *CD* and *EF* are what would result if the external resistance were gradually diminished and at the same time the gas pressure increased.

The appearance in the neighborhood of the anode on the two stages of the arc was similar to that in the case of lead, but a decided tendency to the formation of striations was manifest.

There can be but little doubt that most metals would yield curves similar to those in fig. 4. In other words, between a carbon cathode and metallic anode three distinct forms of discharge are possible, for each of which a separate characteristic curve must be drawn; the glow, the arc with non-volatilizing anode, and the arc with an anode that is giving off vapor. With electrodes of iron or copper, all three stages may be seen in free air by merely decreasing the external resistance (fig. 3).

§25. *The Striated Arc.*—When the nitrogen pressure was in the neighborhood of 6^{cm}, the arc with non-volatilizing silver anode (first stage) showed several exceedingly distinct striations, sometimes as many as six or seven. This occurred with a length of arc from 10 to 15^{mm} and with current ranging from 0·3 to 1·5 amp. The discharge began at an incandescent spot on the carbon cathode, from which a luminous column 2 or 3^{mm} long extended. At this point the bluish striations began, growing more distinct and nearer together as the anode was approached.

The stratified discharges mentioned by Gassiot,* de la Rue and Müller,† and Child,‡ were doubtless manifestations of the same phenomenon. From some of the beautiful photographs published by de la Rue and Müller it is clear that they had to do with an arc discharge in which the anode was not heated to boiling. In fact they express the view that the arc may be regarded as a modified stratified discharge. This, as we have now seen, is strictly true only of the arc on the first stage.

The small size of the striations would render the experimental determination of the distribution of potential between the electrodes very difficult. An approximate value of the potential drop for each striation may be estimated on the assumption that the cathode drop is about 10 volts, the anode drop, judging from the observations of Skinner,§ on the order of 30 volts. In a typical case, with 164 volts across the arc, current 0·42 amp., and length 15^{mm}, with six striations, a simple computation gives about 20 volts as the average potential drop necessary for ionization in each striation. This is less than the drop per striation usually found in the glow discharge, and is probably to be accounted for by the high temperature of the gas.

§26. *Carbon.*—We have seen that three characteristic curves may be drawn for the discharge between metals. For carbon terminals still another stage exists, namely the hissing arc, in which the oxidation of the anode causes a further decrease in voltage.

We have succeeded, by suitably varying the current and the surrounding gas, in obtaining all four types of discharge between carbon electrodes. The experiment was begun in nitrogen with a 460 volt supply. Under certain conditions striations were visible on both the glow and the first stage of the arc. After the current had been increased until the second stage had arrived, air was slowly substituted for the nitrogen and the current further increased up to the hissing point. Owing to the heating of the bell-jar, observations had to be made rapidly, so that no systematic series of readings could be taken. The change from first to second stage was not well marked, for the volatilization of the carbon anode seemed to set in gradually as the current increased. Child‖ mentions

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* Pogg. Ann., cxix, 133, 1863.

† Phil. Trans., clxxi, 65, 1879.

‡ Phys. Rev., xx, 364, 1905.

§ Wied. Ann., lxviii, 752, 1899.

‖ Phys. Rev., xx, 373, 1905.

these forms of discharge, referring to them merely as "arcs." He also noted still another modification when cored carbons were used.

Theory of the Change in Voltage at the Critical Point.

§27. Among the agents that influence the anode drop may be mentioned (1) material and temperature of the anode, (2) nature, degree of ionization, and temperature of gas in the neighborhood of the anode, (3) ultra-violet light from the cathode.

In passing from first to second stage, these factors are affected as follows:

(1) The change in temperature of the anode may be neglected, since, according to the theory that has been advanced, the critical point is characterized by the arrival of the material of the anode at its boiling point.

(2) On the first stage the gas at the anode is chiefly that of the surrounding space, with some vapor from the cathode. On the second stage the current passes mainly through vapor supplied by the anode. The contraction of the arc at the anode on the second stage indicates a considerable rise in temperature of this vapor over that of the gas on the first stage.

(3) Since the change does not affect the cathode, the ultra-violet light is unchanged, unless itbecomes partly absorbed by the vapor before reaching the anode. On the other hand, ultra-violet light from the anode itself on the second stage may compensate for this.

It is probably that a thermal e.m.f. exists at the anode on the first stage in a direction opposed to the current, on account of the high temperature of the anode, and, with iron and copper in free air, perhaps also the fact that the oxides of metals emit negative ions with comparative ease. When vaporization of the anode begins, the increased temperature and density of the vapor in contact with the anode, and its identity with the anode in substance, conspire to reduce this thermal e.m.f. and thereby to lower the anode drop.*

Great experimental difficulties would stand in the way of measuring the counter electromotive-force at the anode by the method used by Duddell for the carbon arc,† which so far is the only method capable of yielding reliable results. It seems most probable to the writers that the observed decrease in voltage at the critical point is due partly to this change in thermal electromotive-force, partly to the increased conductivity of the vapor in the arc. The theory would require modification

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* Cf. Stark, Retschinsky and Schaposchnikoff, Ann. Phys., xviii, 213, 1905.

† Electrician, p. 918, 1901.

if it were shown that at the temperature in question the anode emits not negative but positive ions.*

§28. A test for ionization in the neighborhood of the iron arc was made after the method of Child.† No perceptible excess of positive over negative ionization could be detected, either on the first or second stage. In this connection it would be of interest to measure the rate of emission of charged particles from iron oxide at different temperatures.

As for the absolute value of the anode drop on the first stage, this cannot be assumed to be the same as on the glow discharge, on account of differences in temperature, current and composition of the gas in the neighborhood of the anode, as well as the presence of ultra-violet light from the cathode. Observations made by means of a platinum exploring electrode in an arc with a silver anode indicated that the anode drop is less on the first stage of the arc than on the glow discharge. This would be expected, in the light of Skinner's observations on the conditions that control the drop at the anode.‡ In our experiments it was not possible to obtain voltage readings of more than relative value.

§29. *Melting Point and Heat Conductivity.*—Much weight has been laid by Grandquist and others on the importance of the parts played in the mechanism of the electric arc by the heat conductivity and melting point of the electrodes. It is of interest to examine the connection between these quantities and the occurrence of the critical point. For purposes of comparison, of still greater importance than the melting points would be the boiling points of the substances used as anode; but we have practically no data on this subject.

The only metals showing the critical point well in free air were iron and copper. Of these, copper has the lower melting point and the better heat conductivity. Heat conductivity of the metal, however, does not play the controlling part here, for in the case of iron it makes but little difference in the occurrence of the critical point whether the globule is formed on an iron rod or placed in a poorly-conducting carbon holder. This is due perhaps partly to low heat-conductivity of the oxide globule itself, partly to its somewhat loose connection with the metal behind it.

We have found by tests with a blowpipe that copper oxide melts at a lower temperature than magnetic oxide of iron. In accordance with this, the critical point for copper comes at smaller current and less expenditure of energy than that for iron.

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* Cf. Polak, Elektrot. Zeitschr., xxiv, 599, 1907; Gehrke and Reichenheim, Verh. d. Deutschen Phys. Ges., v, 76, 1907.

† Phys. Rev., xii, 137, 1901.

‡ Wied. Ann., lxviii, 752, 1899.

For other metals, the data are too meager to afford comparison between any except carbon and silver, and lead and silver. With each of these as anode, the cathode consisted of carbon. Among the observations recorded, the following are suitable for comparison:

TABLE II.

Anode		Arc				
Material	Mass	Gas Pres.	Length	Voltage	Current	Watts
C	1·3 gr.	18^{cm}	7^{mm}	214	0·35	75
Ag	3·0	21	5	100	1·4	140
Pb	4·8	30	8	75	1·4	105
Ag	3·0	31	3	82	1·6	131

In Table II, the voltage and current are those on the first stage, just before the critical point. The last column gives the total number of watts expended in the arc. The anode was of approximately the same size and shape in each case, and supported in the same way in the apparatus described in §22. For each pair of observations the gas pressure is nearly the same. In the case of silver, the bell-jar contained air; with lead and carbon, nitrogen. Still, the silver did not oxidize perceptibly, and unless the oxygen changed the electrical conditions through catalytic action, the comparison holds good.

Comparing silver with carbon and also with lead, the expenditure of energy is less for the substance of lower heat conductivity. Lead also melts at a lower temperature than silver. The constants of prime importance here are, of course, the boiling points of silver and lead. The comparatively small current at which the critical point occurs in the case of carbon in spite of its high boiling point can only be explained by its low conductivity and on the assumption that the nature of the surface of the anode, as regards roughness and the presence of impurities, plays a very large part. It may be said of the arc in general that far too few trustworthy data have been assembled for sweeping conclusions to be drawn as to the effect of the physical properties of the electrodes.

III. *The Characteristic Curves of the Iron Arc.*

§30. In fig. 5 is shown a system of curves connecting current with voltage across the arc for various lengths. The supply e.m.f. was 240 volts, electrodes 4^{mm} in diameter. For the sake of distinctness, the observations for 1, 4, and 8^{mm} are represented by dots, those for 2 and 6^{mm} by crosses.

The meaning of the lines *AB*, *CD* was referred to in §4, in which the overlapping of the curves on the two stages was pointed out. The cause of this overlapping can now easily be understood. Beginning with point *B*, if the current is decreased, the change back to the first stage does not take place at once along the line *BA*, because the arc on the second stage is very contracted at the anode, so that the high temperature of the positive base of the arc is maintained until a smaller value of current, represented at *C*, has been reached. Here the expenditure of energy at the anode is so small that vaporization is no longer possible, and the first stage enters in.

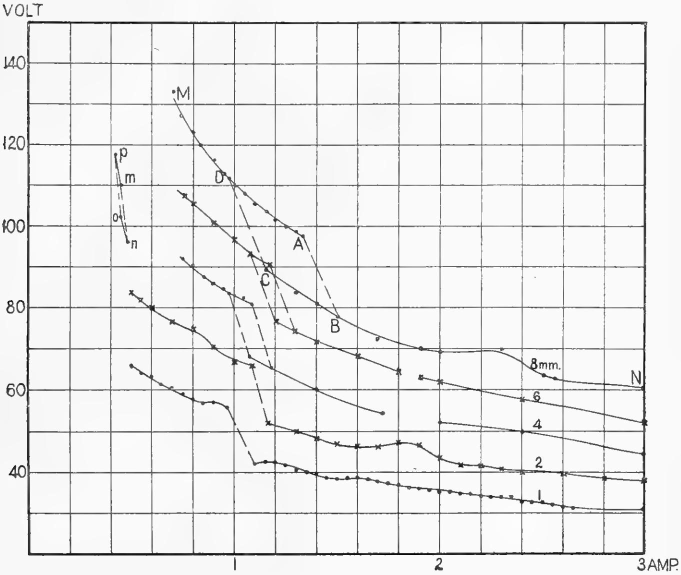

Fig. 5. Characteristic curves, iron arc.

For an analogous reason the change from first to second stage occurs along *AB*, not *DC*.

It will be noticed that the change *AB* occurs with a larger current for long than for short arcs, and that the change in voltage is also greater for long arcs. The probable explanation is that with a long arc on the first stage the anode is comparatively cool, so that the current has to increase farther before evaporation sets in. If the rate of vaporization increases with the current, the change in current, and therefore also in voltage, must be greater the longer the arc. This is the opposite to what occurs at the hissing point of the carbon arc.*

If the arc burns with the electrodes almost in contact, the

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* Mrs. Ayrton, The Electric Arc, p. 288.

first stage cannot be observed, because the anode is kept at a high temperature from its proximity to the cathode.

In the curves for 2 and 8^{mm} the maxima corresponding to the "rotating stage" of the arc are evident (see §33). So unsteady was the arc during this stage at lengths of 4 and 6^{mm} that no readings could be taken. The maxima are presumably due to increased voltage caused by a bending or lengthening of the arc.

§31. Up to the present time, no satisfactory mathematical expression for the mechanism of the metallic arc has been produced. Steinmetz (l.c.) has derived a formula for the potential difference across the iron arc as a function of current and length, which is in fair agreement with observation over the range experimented on. This formula is open to criticism, however, in that it takes no account of the drop at the anode, and assumes the temperature throughout the arc to be that of the boiling point of the electrodes.

As for the curves in fig. 5, their range is limited by the comparatively low voltage of the supply. The presence of the critical points and the irregularities due to the rotation of the arc also contribute toward making the observations worthless for analysis.

§32. Wide discrepancies exist between the values given by different observers as the "constants" of the metallic arc. Thus for the value of a in the equation

$$E = a + bl \text{ . ... } (1)$$

v. Lang[*] gives for iron 25 volts, Lecher[†] 20, and Child (l.c.) 25 volts. The value obtained from the experiments of Steinmetz (l. c.), who observed the potential difference the instant before the electrodes (magnetite rods) were brought together, is from 28 to 31 volts.

These differences are inherent in the different methods employed. When the arc approaches the length zero, the anode receives negative ions directly from the cathode and its drop is all but eliminated. Moreover, the resistance of the iron oxide from which the discharge takes place depends upon its temperature, and this forms a very appreciable source of error for which it is almost impossible to correct. The value of a obtained by this method cannot be compared with one derived, for example, by extrapolation from the E-l curve, nor with one obtained with the use of an exploring electrode. Differences in the currents used by various observers account also for a part of the discrepancies.

We have made a large number of observations in which the iron terminals were slowly brought together and the last volt-

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[*] Wied. Ann., xxxi, 384, 1887.

[†] Ibid., xxxiii, 609, 1888.

meter reading recorded before the electrodes touched. Little reliance is to be placed on the precision of these values, on account of the variable resistance of the globules themselves, as stated above. Taken all together, our observations indicate a value of from 21 to 23 volts as the critical potential difference for zero length of arc. Probably the best method would be to record the drop in voltage by means of an oscillograph, which would indicate the true residual drop after the globules had touched and before they had time to cool perceptibly.

Observations of the critical voltage for copper by the same method gave about 22 volts at 4 amp., in fair agreement with v. Lang's 23·9. Child (l. c.) found as the sum of the positive and negative drops for copper, using a carbon exploring electrode, at 6 amp., 25 volts.

From the observations represented in fig. 5, together with other data covering a wider range, we have constructed a system of curves connecting voltage with length of arc, for the arc between iron terminals. These make it evident that the linear law represented by equation (1) does not hold, especially for small lengths. The curves are convex upward, suggesting that an equation of the form

$$E = a + bl + c\sqrt{l}.$$

in which a, b, and c may be functions of the current, would be nearer the truth. We prefer not to assign numerical values to these constants until more complete data have been obtained.

For the iron arc in nitrogen, the E-l curves have the same general form as in air. For the same current and length of arc, the potential difference is about twelve volts less than in air, as was found by Arons.[*] The critical voltage (zero length) was perhaps two or three volts less than in air.

IV. *Electrical Oscillations in the Metallic Arc.*

§33. *Rotations in the Iron Arc.*—In the first of the preliminary papers already referred to, mention was made of an effect noted with the iron arc in free air. After the current has been increased on the second stage to a little below two amperes, the positive end of the arc begins to rotate, so that on the anode a ring instead of a spot of light appears. This is accompanied by a high-pitched whistling sound, which as the current is still further increased degenerates into a sputter, and this in turn into a steady, strong hiss, the ring meanwhile having disappeared. The arc is in great agitation, swaying about from side to side, and sometimes separating into several arcs. At the beginning of whistling, there is a curious tendency for

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[*] Ann. Phys., i, 706, 1900.

the arc to spring back on to the first stage, so that for an instant hissing ceases, current falls abruptly, and e.m.f. rises several volts.

If one begins to increase the external resistance immediately after one of these changes, the first stage can sometimes be maintained steadily for a short time, even though the current is far greater than that at which the critical point normally occurs. The reason evidently is that the anode becomes so far cooled that evaporation ceases. A maximum of the characteristic curve is often found in the neighborhood of this stage (cf. fig. 5).

The effect mentioned reminds one of Trotter's observation of rotations in the carbon arc at the beginning of hissing, but the cause can hardly be the same. It is more likely that it is a case of electromagnetic rotations. Opportunity has not yet been found to examine this more closely, but it is proposed to do so with the aid of an oscillograph. That marked oscillations in current are here taking place was shown by the fact that when the arc circuit included the primary of an induction coil whose secondary was connected to a quadrant electrometer, a large deflection ensued.

§34. *Tests for Continuity of Discharge.*—The following experiments were made with a view to testing the assertion of Lecher,* which has found general acceptance, that the arc between terminals of silver, copper, or of carbon on the quiet stage, is perfectly continuous, while that between terminals of iron, platinum, or of carbon on the hissing stage is discontinuous or intermittent.

The nature of the fluctuations between carbon terminals has been investigated by Duddell, who found that on the hissing stage the arc is not intermittent, but subject to irregular fluctuations.

Lecher's method was, to connect in parallel with the arc a condenser and stretched brass wire in series. Changes in potential difference between the arc terminals set up oscillations in the condenser circuit, thereby heating the wire and causing it to expand. Now, recent work on the "singing" metallic arc indicates the possibility of oscillations being set up in such a circuit as this, in spite of its small self-inductance, even though the arc of itself is not discontinuous. We decided to investigate this, and at the same time to study the oscillations in the neighborhood of the critical point.

§35. To measure the intensity of the oscillations, we used a bolometer similar to Fessenden's barretter, as this was easier to construct and more sensitive than Lecher's hot wire. A platinum wire about 4^{cm} long and $0{\cdot}024^{mm}$ in diameter, having

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* Wied. Ann., xxxiii, 609, 1888.

a resistance of about 12 ohms, was connected in series with a mica condenser of one-third m.f. capacity, the two forming a shunt across the arc. Recent experiments of Austin* call attention to the importance of having a low resistance in series with the condenser. Nevertheless, the resistance of our bolometer did not prevent the production of measurable oscillations as will be seen. The platinum wire was connected as one arm of a Wheatstone bridge.

At the beginning of the experiment the arc was struck and the bridge balanced with battery current flowing, the condenser circuit remaining open. When the condenser switch was closed, the resulting deflection of the galvanometer in the bridge was taken as a measure of the intensity of the oscillations. Current for the arc was taken from the 240 volt mains.

As a preliminary test, carbon terminals were employed. No deflection could be observed when the arc was quiet, but the light went violently off the scale when the arc hissed. On the quiet state of the carbon arc oscillations are not to be expected, on account of the small self-inductance and large resistance of the shunt circuit.

§36. *Iron terminals in free air* were next used. The self-inductance of our shunt circuit cannot have been appreciably greater than Lecher's. Yet we found it possible to make the iron arc "sing" audibly, even on the first stage, with the current a little below one ampere. The tone was a high-pitched squeak or whistle. Inserting a self-inductance of 0·000 04 henry caused a lowering of pitch, though not as much as would be expected, showing that under these conditions the simple formula for period,

$$T = 2\pi\sqrt{LC}$$

does not hold.

When the arc was singing, the heating of the bolometer threw the light off the scale; the arc current increased, while the voltage dropped several volts, as has been observed by Austin (l. c.).

Whether the arc sang audibly or not, the galvanometer was always found to be deflected, but in general much more on the second than on the first stage. As the oscillations were generally of too high frequency to produce an audible sound, no direct estimate of their period was made, nor could their dependence on current and length of arc be observed. The galvanometer deflections depend on the total quantity of electricity passing per second through the shunt circuit, and this is a function not only of frequency, but also of amplitude and wave-form. We found the deflections to increase as the cur-

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* Bull. Bur. Stand., iii, 325, 1907.

rent increased and also as the length diminished. This may have been due to increasing frequency, since Simon* has shown the frequency to vary in the same manner. Adding non-inductive resistance to the shunt circuit always greatly reduced the deflections.

The experiment of inserting in series with the condenser a small coil having a self-inductance of 0·000 04 henry was also tried. This always diminished the deflections when the current was over 2 amp., but as the current was decreased, its damping effect was reduced until at small currents it sometimes even caused an increase in the deflection. This points to the existence of a sort of resonance between the arc and the shunt circuit, and is probably related to the fact that a decrease in the arc current tends to reduce the frequency.

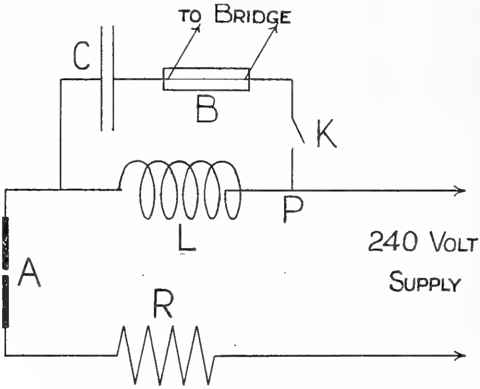

FIG. 6.

§37. *Experiments with the Copper Arc, Lecher's Method.*—With no self-induction in the shunt circuit, closing the switch of the latter always put the arc out unless the current was over three amperes. Galvanometer deflections were not large, and they grew smaller as the current increased. That Lecher found no effect with copper is probably due to the lower sensitiveness of his apparatus.

With 0·000 04 henry in series with the condenser, the current could be reduced to one ampere before the arc went out. Deflections increased with decreasing current, and before the arc was extinguished the light disappeared from the scale. This illustrates the effectiveness of the copper arc at small currents for the production of high frequency oscillations.

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* Phys. Zeitschr., vii, 433, 1906.

§38. It seemed desirable to test the continuity of the arc by some method less likely to set up disturbing oscillations. When the condenser-bolometer system was connected in parallel with a non-inductive resistance which was in series with the arc, no deflection whatever could be observed. But the connections shown in fig. 6 were found to give excellent results. A is the arc, R a regulating resistance, L the primary of a large induction coil whose iron core was removed, consisting of 200 turns of heavy wire, with a self-inductance of about 0·0012 henry. In parallel with L are the capacity C of 3·6 m.f., the bolometer wire B and the switch K.

When K is closed, the bolometer is not heated as long as the arc current remains constant. But any fluctuation of current, producing a varying potential difference between the terminals of L, sends an alternating current through the shunt circuit and causes a deflection of the galvanometer in the bridge. Correction was made for a slight deflection due to the passage of the commutator bars under the brushes of the generator.

With the iron arc in air, deflections of the order of 30 div. were found at the beginning of the second stage, which reached a maximum while the arc was rotating at about 2 amp. and then decreased again. There was no deflection on the first stage after the effect of the commutator had been eliminated. When a singing arc was produced on the first stage by connecting a second capacity and inductance in parallel with the arc, a large deflection resulted.

Sahulka* finds that a self-inductance connected in series with a singing arc oscillates with a frequency of its own, and not simply with the arc frequency. This point we have not tested.

A simple method of comparing frequencies is to insert an iron core in the coil L, fig. 6. When this was done, it was found that for a singing arc on the first stage the insertion of the core produced no perceptible effect on the galvanometer deflection. With the arc on the second stage, not singing, the iron core increased the deflections about tenfold, while the fluctuations due to the commutator of the generator gave a deflection that was multiplied about thirty times by the insertion of the core. Thus the oscillations due to the volatilization of the anode on the second stage are intermediate in frequency between those due to the commutator and those of the singing arc. The last are so rapid that the self-inductance of the coil is no longer increased on inserting the iron core.

Tests were also made with the iron arc in nitrogen at atmospheric pressure. The irregular sputtering condition of the arc gave rise to a continual heating of the bolometer, which

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* Écl. Électr., 1, 396, 1907.

was most pronounced in the unstable state just before the arc went out (§8).

§39. *Oscillations in the Silver and Copper Arcs.*—The copper arc was formed in air, the silver in nitrogen. The apparatus shown in fig. 6 was used, with 460 volt supply. In the case of copper, the galvanometer deflections at currents over 1·5 amperes were small, but they increased with decreasing current, and at a little below one ampere the light disappeared from the scale. This is similar to the effect found when the bolometer circuit was in parallel with the arc, and indicates that we have to do with a peculiarity of the arc itself, and not with oscillations imposed upon it from without. No special effect was noted on passing from the second to the first stage of the copper arc.

In the case of silver, the effect was even more pronounced, especially at low pressures.

A silver anode and carbon cathode were used. At two amperes and over the deflections were very small, but as the current was decreased, the deflections grew larger, becoming very pronounced on the first stage. With small currents at 7^{cm} pressure, the deflection was far too great to be observed. The tests with silver indicate that the cause of the effect lies chiefly at the anode. There are reasons for thinking that these oscillations may be due to an exceedingly rapid changing back and forth between the two stages of the arc, or perhaps between arc and glow: this point is to be investigated further.

It is possible that the sensitive condition of the arc in the neighborhood of its critical point may be such that this region will prove to be a particularly good one to select for the production of high frequency oscillations.

Summary.

§40. I. There exist between iron terminals in free air two types of arc, distinct from each other in appearance and in characteristic curves. To these types the terms first stage and second stage have been applied for the sake of brevity. The transition from one stage to the other is somewhat similar to the hissing point of the carbon arc, but the cause is not the same. Evidence from loss in mass of the electrodes, spectrum of the arc, and temperature of the anode, shows that the first stage is characterized by the absence of vaporization of the positive terminal.

II. Experiments are described on the change from the glow discharge to the arc in free air between terminals of iron, platinum and copper. Attempts were made at identifying the two stages for arcs between several different metals in air.

Both stages could be maintained steadily only in the cases of copper and of iron. In nitrogen at reduced pressures the glow and both stages of the arc were observed between a carbon cathode and anodes of lead, silver, and carbon. There is reason to believe that similar results can be obtained with most other metals. Platinum, and iron free from traces of oxide, did not show a stable first stage under any conditions.

The diminution in potential difference between the arc terminals in passing through the critical point from the first to the second stage is attributed partly to a decrease in the thermal e.m.f. at the anode, partly to increased conductivity of the arc vapor.

There is some evidence of a connection between the critical point and the melting temperature of the material of the anode, but it is not well marked, and is likely to be masked by effects due to the physical condition of the surface of the anode.

III. The characteristic curves of the iron arc are discussed, together with the probable form of the equation connecting voltage, current, and length.

IV. A series of experiments was carried out on electrical oscillations in arcs with iron, copper, and silver anodes.

At a current a little below two amperes, on the second stage, the iron arc rotates and emits a whistling sound. This is often attended by spasmodic changes back to the first stage.

The application of Lecher's test for continuity led to observations on the "singing" iron and copper arcs, the energy expended in the oscillations on both stages of the arc being observed by means of a bolometer. To test the continuity of arcs between various metals by a method more free from error, a new manner of connecting the bolometer was devised. A general agreement with Lecher's results for large currents was found. But the iron arc became continuous on the first stage, while in the case of arcs with silver or copper anodes, marked oscillations were detected as the current decreased.

Scott Laboratory of Physics, Wesleyan University,
Middletown, Conn., July, 1907.

ART. XXXVI.—*Gibbs' Geometrical Presentation of the Phenomena of Reflection of Light;* by ARTHUR W. EWELL.

IN his lectures at Yale upon the Electromagnetic Theory of Light, Prof. Gibbs briefly outlined a geometrical method of representing and interpreting the phenomena of total and metallic reflection, which, to the writer's knowledge, has never been published, and is not included in his collected papers. The writer has found this method so valuable in teaching and in experiments upon metallic reflection, that he believes others, outside the small number who were privileged to hear Prof. Gibbs, will find it a clear, simple and practical method of representing the relative amplitude and phases and optical constants, the analytical expressions for which are complicated.

The foundations of this paper are lecture notes of the years 1898–99. In place of Prof. Gibbs' vector notation, the more common scalar quantities will be used, and the writer has added

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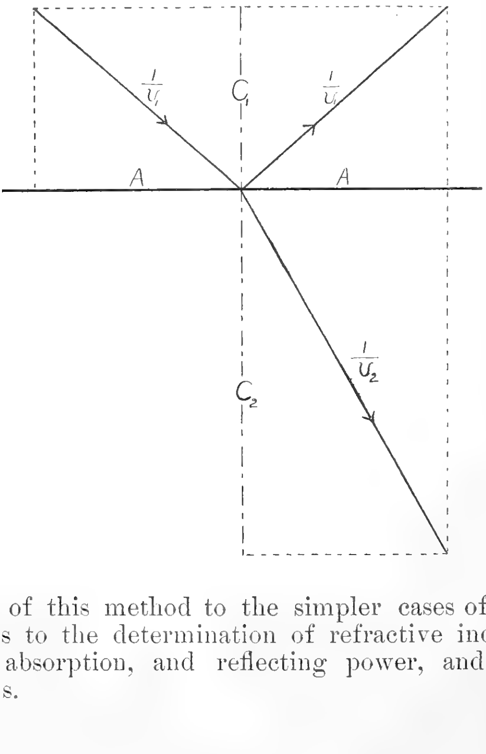

extensions of this method to the simpler cases of reflection, applications to the determination of refractive indices, coefficients of absorption, and reflecting power, and numerical illustrations.

The method, in brief, consists in representing by lines the reciprocals of the velocities of light in the two media between which reflection occurs, and also their components parallel and perpendicular to the surface. These lines are so chosen that very simple geometrical quantities represent Fresnel's Laws, which are assumed, together with the ordinary laws of reflection and refraction. As the lines and angles vary with the angle of incidence and the optical constants of the media, the relative amplitudes, phases, etc., are given by simple geometrical relations.

Light is reflected at the surface, separating medium (1) from medium (2). Let C_1 and C_2 be the components, normal to the surface, of the reciprocal velocities, $\frac{1}{v_1}$ and $\frac{1}{v_2}$ (fig. 1). Let i be the angle of incidence, or reflection, and r the angle of refraction. Since the angles of incidence and reflection are equal and since the ratio of the sines of the angles of incidence and refraction is $v_1 \div v_2$, the components, A, of $\frac{1}{v_1}$ and $\frac{1}{v_2}$, parallel to the surface, are equal.

For simplicity, we will take as unity the components of the incident light vibration, parallel and perpendicular to the plane of incidence (i. e., the light is polarized at 45°). Let the amplitude of the component of the reflected vibration, parallel to the plane of incidence, be R_p, and of the perpendicular component, R_s. Fresnel's Laws of Reflection are then:

$$R_s = -\frac{\sin(i-r)}{\sin(i+r)}, \quad \frac{R_p}{R_s} = -\frac{\cos(i+r)}{\cos(i-r)}, \quad R_p = \frac{\tan(i-r)}{\tan(i+r)}$$

From the above figure and notation,

$$\sin i = Av_1, \cos i = C_1v_1, \sin r = Av_2 \cos r = C_2v_2$$

Substituting:

$$R_s = \frac{C_1 - C_2}{C_1 + C_2}, \quad \frac{R_p}{R_s} = \frac{A^2 - C_1C_2}{A^2 + C_1C_2}$$

The latter is of course the more interesting and important. The product of the two will give R_p.

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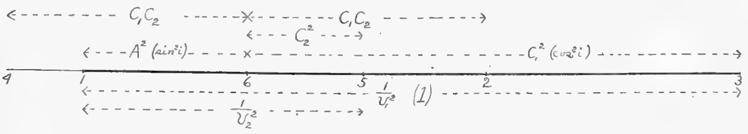

These quantities will be represented graphically. Horizontal distances we will consider real, and positive if to the right.

Vertical lines are imaginary. In fig. 2, let $\overline{13} = \frac{1}{v_1^{\,2}}$, $\overline{15} = \frac{1}{v_2^{\,2}}$, $\overline{16} = A^2$. Since $\frac{1}{v_2} = A^2 + C^2$, $\overline{63} = C_1^{\,2}$, $\overline{65} = C_2^{\,2}$. Let $\overline{62}$ be a mean proportional between $\overline{63}$ and $\overline{65}$. Then $\overline{62} = C_1C_2$, $\overline{64} = -\,\overline{62}$ and we have the simple formulæ:

$$R_s = \frac{C_1^{\,2} - C_1C_2}{C_1^{\,2} + C_1C_2} = \frac{\overline{32}}{\overline{34}}, \quad \frac{R_p}{R_s} = \frac{\overline{14}}{\overline{12}}$$

To apply these expressions to any case of reflection, take $\frac{1}{v_1^{\,2}}$ as unity, and lay off $\sin^2 i$ as $(A^2, \overline{16})$; $\cos^2 i$ as $C_1^{\,2}$, $(\overline{63})$; and $\overline{15}$ as $\frac{1}{v_2^{\,2}}$, $\left(\frac{n_2^{\,2}}{n_1^{\,2}}\text{, where } n \text{ is the refractive index}\right)$. Locate $\overline{62}$ and $\overline{64}$, the mean proportional, and find the above ratios. Fig. 2 is thus drawn for light, incident in air, at 48°, upon glass of refractive index 1·53.

$$\frac{R_p}{R_s} = \frac{\overline{14}}{\overline{12}} = -\,.237, \quad R_s\,\frac{\overline{14}}{\overline{34}} = -\,.334.$$

Both are negative, i. e., there is a difference of phase of π between R_p and R_s, and between R_s and the perpendicular component in the incident light.

As the angle of incidence increases, 6 moves to the right and therefore $\overline{14}$ decreases until, at the Polarizing Angle, it becomes zero and hence also $\frac{R_p}{R_s} = 0$. Near grazing incidence A and hence $\overline{16}$ is large, $\frac{R_p}{R_s}$ is now positive and both it and R_s are increasing with increasing angle of incidence.

Suppose the light is passing in the opposite direction, i. e., from a medium where the velocity is less to one where the

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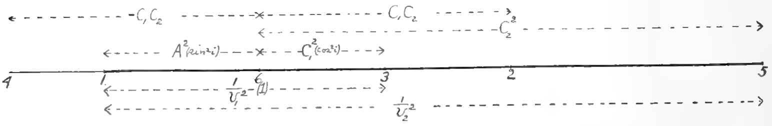

velocity is greater. The various quantities for small angles of incidence are represented in fig. 3. $R_s = \frac{\overline{32}}{\overline{34}}$ is positive, $\frac{R_p}{R_s} = \frac{\overline{14}}{\overline{12}}$ is negative and as the angle of incidence is increased, 6 moves to the right and as before, at the Polarizing Angle $\overline{14}$ becomes zero. Fig. 3 is drawn for light incident at 30° upon a glass (n=1·53) — air surface.

$$\frac{R_p}{R_s} = \frac{\overline{14}}{\overline{12}} = -.185, \qquad R_s = \frac{\overline{32}}{\overline{34}} = .528$$

As the angle of incidence is still more increased, $\overline{16}$ A^2 exceeds $\overline{15} = \frac{1}{v_2^{\,2}}$ and $\overline{65} = C_2^{\,2}$ becomes negative, and hence C_2 is imaginary. At the point where 6 is at 5, $A^2 = \frac{1}{v_2^{\,2}}$ or the emerging waves, travel parallel to the surface and the angle of incidence is the Critical Angle. Beyond this angle, conditions are represented by fig. 4, which may be taken as typical of total reflection. Since 62 ($=C_1C_3$) and $\overline{64}$ are mean proportionals of $\overline{65}$ and $\overline{63}$ and C_3 is imaginary, 2 and 4 must lie on a circle whose diameter is 53. Evidently numerically,

$\frac{R_p}{R_s} = 1 = R_s = R_p$, and the angle between $\overline{12}$ and $\overline{14}$ gives the phase difference between the two components and the angle between $\overline{32}$ and $\overline{34}$, the phase difference between R_s and the incident, perpendicular, component. The latter phase difference is evidently zero when total reflection begins and π at grazing incidence. The difference of phase between the two components, angle 412, is seen to be zero at both extremes and a maximum when $\overline{12}$ and 14 are tangents. For this case, by geometry,

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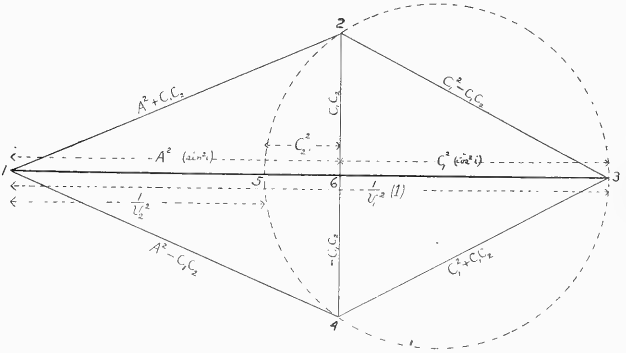

$$\overline{52}^2 : \overline{23}^2 = \overline{56} : \overline{63} = 15 : \overline{13} = \frac{1}{v_2^{\,2}} - \frac{1}{v_1^{\,2}} \therefore \overline{52} : \overline{23} = v_1 : v_2 \therefore$$

the maximum angle 412 $\doteq \pi - 4$ angle 235 $= \pi - 4\tan^{-1}\frac{v_1}{v^2}$

Fig. 4 is drawn for light incident upon a glass ($n=1{\cdot}53$) – air surface at 48°. The angles of phase difference are: angle 412 $\left(\frac{R_p}{R_s}\right) = 46{\cdot}^\circ$, angle 234 ($R_s$) $= 56^\circ$. The maximum difference of phase between the two components $= \pi - 4 \tan^{1-} \frac{1}{1{\cdot}53} = 47^\circ$.

We have hitherto considered perfectly transparent bodies. We will now consider the general case, so called Metallic Reflection. The general expression for the light disturbance may be written:

$$X = Ae^{-\frac{2\pi k w}{\lambda}} e^{2\pi i\left(\frac{t}{T} - \frac{w}{\lambda}\right)}$$

where X is the instantaneous force, A = amplitude, λ = wave length, T = period, t = time, w = coördinate for the direction in which the light waves are advancing, and k = Coefficient of Absorption, i. e., the amplitude is reduced to $\frac{1}{e}$ of its initial value in a distance $\frac{\lambda}{2\pi k}$. If we write the above equation in the form:

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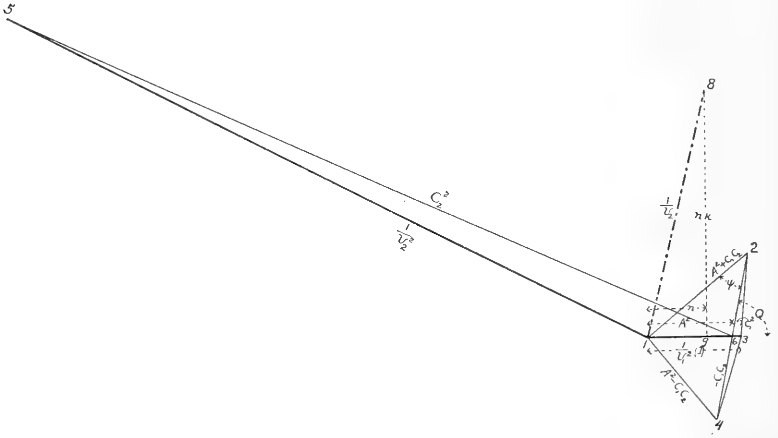

$$\overline{X} = Ae^{2\pi i\left(\frac{t}{\lambda} - \frac{w}{\lambda}(1-ik)\right)}$$

and determine the reciprocal velocity of the light waves, we obtain the complex expression: $\frac{T}{\lambda}(1-ik)$. The real part, $\frac{T}{\lambda}$, is the ordinary reciprocal velocity, $\frac{1}{v}$, or proportional to the refractive index, and the imaginary portion is proportional to the product of the refractive index and the coefficient of absorption. If we chose as unity the velocity in pure ether, the real part is the Refractive Index, n, and the imaginary portion is nk.

In total reflection, C^2, as we have seen, is a pure imaginary, i. e., no waves are propagated in the second medium perpendicular to the surface. In the general case of light meeting the surface separating two media, waves are propagated in the second medium with some absorption, i. e., C^2 is complex. Fig. 5 represents a typical case of so-called Metallic Reflection. We will suppose that the first medium has no appreciable absorption. As in previous figures, $\overline{13} = \frac{1}{v_1^2}$, $\overline{16} = A^2$, $\overline{63} = C_1^2$, $\overline{65} = C_2^2$, $\overline{15} = \frac{1}{v_2^2}$. C_2^2, $(\overline{65})$, being complex, the mean proportional between it and $\overline{63}$ will be $\overline{62}$, whose length is the arithmetical mean proportional and such that the angle 263 is half the angle 563.

Since $\frac{R_p}{R_s} = \frac{\overline{14}}{\overline{12}}$, the phase difference must decrease from π at perpendicular incidence (6 at 1), to zero at grazing incidence (6 at 3), while the phase of $R_s = \frac{\overline{32}}{\overline{34}}$ varies from zero to π. At the Principal Incidence, I, the phase difference is $\frac{\pi}{2}$ or $\overline{14}$ and $\overline{12}$ are at right angles. The numerical value of $\frac{\overline{14}}{\overline{12}}$ is the Principal Azimuth.

To determine the refractive index, n, and the coefficient of absorption, k, we extract the square root of $\frac{1}{v_2^2}$, $(\overline{15})$. The real part of the root is n $\left(\frac{1}{v_1}\text{ being unity}\right)$ and the imaginary portion is nk.

Fig. 5 represents reflection from copper in air, when the angle of incidence is 71° 35′, the Principal Incidence (Drude). The velocity of light in air, v_1, is taken as unity and $\frac{1}{v_1^2}$ is represented by $\overline{13}$. $\overline{16} = A^2 = \sin^2 71° 35'$, and $\overline{63} = C_1^2 = \cos^2 71° 35'$. The Principal Azimuth of copper is 38° 57′. Since at the principal Incidence, I, the difference of phase is $\frac{\pi}{2}$, $\overline{12}$

and $\overline{14}$ are drawn at right angles, in the ratio $\overline{14}:\overline{12} = \tan 38° 57'$, and such that $\overline{24}$ is bisected at 6. From the preceding, $\overline{62} = C_1C_2$ and $\overline{64} = -C_1C_3$. $C_2{}^2 = \overline{65}$ is now constructed. Since $\overline{62}$ is a mean proportional between $\overline{63}$ and 65, the angle 563 is made twice angle 263 and the length of $\overline{65}$ is such that $\overline{62}^2 = \overline{63} \times . \overline{65}$. $\frac{1}{v_2{}^2} = A^2 + C_2{}^2$ is then $\overline{15}$. The point 5 being determined, the relative amplitudes $\left(\frac{\overline{14}}{12}\right)$ and phases (angle 412) may be determined for any angle of incidence, i, since $\sin^2 i = 16$ and $62 = -\overline{64}$ is a geometric mean proportional between $\overline{63}$ and $\overline{65}$.

Let $\overline{18}$ be the geometric square root of $\overline{15}$ (or the numerical square root at an angle $816 = \frac{1}{2}$ angle 516). The real part, $\overline{19}$, is the refractive index, n, and the imaginary part, $\overline{98}$, is nk, where k is the coefficient of absorption. Fig. 5. gives, for copper, $n = {\cdot}62$, $nk = 2{\cdot}6$, hence $k = 4{\cdot}1$.

It is not difficult to show also that k is the tangent of twice angle 124, which is half the angle 263 (Drude's Q).

$R_s \left(= \frac{32}{34}\right)$ is numerically ·94 and the angular difference of phase (angle 234) is 167°.

The intensity of the reflected light is:

$$R_s{}^2 + R_p{}^2 = \left(\frac{32}{34}\right)^2 \left[1 + \left(\frac{14}{12}\right)^2\right]$$

(which equals 1·46 for the above illustration, the incident intensity being 2 or 73 per cent), and evidently increases rapidly with increase of the imaginary portion of $\frac{1}{v_2{}^2}$, i. e., of k, thus illustrating Selective Reflection.

Worcester Polytechnic Institute,
Worcester, Mass., August, 1907.

Art. XXXVII.—*The Decay of Ionized Nuclei in the Fog Chamber, in the Lapse of Time;* by C. Barus.

1. *Introduction.*—The attempt was made in an earlier paper to standardize the coronas by aid of the decay curves of radium. The method is apparently very simple and requires the knowledge merely of the coronas appearing under given circumstances when the radium tube is in place d on the outside of the fog chamber, in comparison with the coronas observed under the same circumstances when the radium has suddenly been removed for different lengths of time before condensation. From electrical observations with condensers, the equation

$$dn/dt = -bn^2 \text{ or } 1/n = 1/n' + b(t-t')$$

is found to be adequate if n and n' denote the ionizations occurring at the times t and t', and the same would appear to be the case with the corresponding nucleations. Moreover, if the relative nucleations for two coronas obtained at a given exhaustion are known (for instance by the earlier method of geometric sequences) the absolute values of the nucleations will follow. With a radium ionization at t and t' seconds after its removal

$$n' = \left(\frac{n'}{n} - 1\right) / b(t-t').$$

But the attempt to carry out this apparently straightforward method leads to grave complications. If n be reckoned in thousands per cubic centimeter, the electrical value of b may be taken as of the order of $b = \cdot 001$; while the value of b which I deduce from the decay of ions in the fog chamber, is more than two times as large as this, increasing moreover very rapidly as the nucleation is smaller. True it is possible that the method for finding the nucleations, absolutely, may be at fault. If relative values seem to be trustworthy, absolute data are not to the same degree substantiated; but even if this were granted, however improbable, the march in the values of b would be unaccounted for and seems to be a new phenomenon.

2. *Data. Exhaustion above the fog limit of air.*—In the first series of experiments the adiabatic drop of pressure δp was somewhat larger than the condensation limit of dust free wet air. The initial coronas were small as the radium was weak (10,000X, 100 mg).

When the values of b were computed from the means of successive pairs of measurements of nucleation n, at different times, t, a somewhat irregular increase of b, was observed as n decreased. When the first observation was combined with the fourth, etc., the values were, $x = {\cdot}29$ being the relative drop of pressure, $\delta p/p$,

$$\begin{aligned} b = {\cdot}0029 \\ 34 \\ 36 \\ 41 \end{aligned}$$

or a mean value, $b = {\cdot}0033$ (n reckoned in thousands), if the last observation is ignored, since the coronas are just visible here.

If the electrical datum, $b = {\cdot}0014$ be correct, the present nucleations n are to be increased on the average, ${\cdot}0003/{\cdot}0014 = 2{\cdot}3$ times. If the last datum for b were included much more. This is quite unreasonable. One must conclude therefore that b for nuclei is larger than b for ions or that an ion, acting as a nucleus in a saturated atmosphere, decays ($dn/dt = -bn^2$) several times as rapidly, as the same ion in a dry atmosphere when tested by the electrical conduction of the medium.

If but a part, n, of all the ions are captured, n' escaping, we may write

$$-dn/dt - dn'/dt = bn^2 + 2\,bnn' + bn'^2$$

so that both dn/dt and dn'/dt are larger than bn^2 and bn'^2; If $n = n'$

$$-2\,dn/dt = 4\,bn^2, \text{ or } -dn/dt = 2\,bn^2.$$

If but $1/3$ of all the ions, $3n$, are captured, $-dn/dt = 9\,bn^2$; etc. Hence, if but $1/m$ of all the ions are captured the coefficient of decay being as found should be about m times too large as compared with the true value.

This does not explain, however, why the coefficient b increases when t is larger and n is smaller; if it were additionally assumed that ions decrease regularly in size as they decay more and more, so that they withdraw more and more fully beyond the given range of supersaturation applied, the second part of these occurrences would also be accounted for; but the assumption is not probable.

3. *Exhaustion below the fog limit of dust free air.*—It would follow from what has just been stated that if the drop of pressure is lower, the values of b obtained must be larger. For not only are few of the ions caught but the diminution of bulk (virtually) which may accompany the decay would place them sooner out of reach of the given exhaustion as the interval of decay increases. But in experiments of this kind, the successive values of b again show an outspoken march into larger values as the time t increases.

If we combine the first observation with the fourth, etc., as before, and

$\delta p/p = x = \cdot 27, b = \cdot 0038,$
041,
057,
134, or a mean value of $b = \cdot 0045$

(when n is reckoned in thousands), if the last observation is ignored. But to ignore this value is here quite inadmissible, as the data for a parallel series where $x = \cdot 25$, viz.,

$b = \cdot 021$
$\cdot 177$

fully show.

4. *Data for weak ionization. Radium at a distance.*—In the above work the initial intensity of radiation was the same. It was suggested that the average size of a nucleus might decrease in the lapse of time. Thus a variety of further questions arise; 1, whether weak radiation produces a smaller average nucleus; 2, whether a stronger radiation does the reverse; 3, whether the limit of b decreases as the exhaustion increases and finally approaches $b = \cdot 001$ (counting n in thousands), etc. The experiments of the following work show that b varies with the number of nuclei present, no matter whether a given nucleation is due to weak radiation, or to decay from a stronger radiation, or finally to low exhaustion; or that the nuclei probably break to pieces as a whole.

The data, moreover, were investigated by the new method of two diffraction sources of light, S cm. apart, at a distance R from the fog chamber. The number of nuclei, n, found in the exhausted fog chamber, is corrected by multiplying by the volume expansion. Finally, b was computed from pairs of observations about 20 seconds apart. Water nuclei were always precipitated before each test. With the exhaustion slightly above the condensation limit of air, the data were constructed in comparison with cases for stronger radiation and of weaker radiation (by decay) in the above experiments. Together they formed a coherent series of curves, proving that it is the number n present which determines the value of b, no matter whether the small number is due to low exhaustion ($\delta p/p$ near the condensation limit), or to decay of ions in the lapse of time (exhaustion t seconds after removing the radium from the fog chamber), or due to lower radiation (radiation at some distance 40^{cm}, from the fog chamber.)

The results may be otherwise summarized, by giving $-b = (dn/dt)/n^2$ in terms of the nucleation n, from which the decay takes place. The rapidly increasing values of b when n is smaller and their tendency towards constant values when n

is larger (remembering always that the ionization is throughout *low*) are then apparent.

Exhaustions above the condensation limit of air fails to bring out the usual high values of b, for the ionized nucleation eventually emerges into the vapor nucleation of dust free air. These high values appear if the exhaustion is low enough to catch but few vapor nuclei while being high enough to insure large coronas due to ions.

Two series of experiments made with this end in view confirm the occurrence of large values of b associated with small values of n, no matter how the latter are obtained.

If the true equation of the decay curve, dn/dt, were known, it would then be worth while to reduce all the data to a common scale; but the graphs obtained show that the values of b rather suddenly increase below $10^{-3}n_0 = 10$, so that a simple relation is not suggested for the reduction.

The question arises incidentally whether the ions may not vanish by accretion, i. e., their number may be reduced because individual ions cohere; in such a case the fog limits should be reduced for which there is no evidence. There seems to be an independent second cause for decay entering efficiently when the nucleation becomes smaller. We may, therefore, pertinently inquire into its nature.

5. *Case of combined absorption and decay of ions.*—The most promising method of accounting for the above results has been suggested by the work done in connection with the behavior of phosphorus nuclei.* There may be either generation or destruction of ions proportional to the number n, present per cubic centimeter, in addition to the mutual destruction on combination of opposite charges. In other words the equation

$$-dn/dt = a + cn + bn^2$$

is now applicable, where a is the number generated per second by the radiation, c the number independently absorbed per second and bn^2 the number decaying by mutual destruction per second. Here c is negative for generation and positive for absorption. If a is zero

$$1/n = 1/n_0 + (1/n_0 + b/c)\,(\epsilon^{c(t-t_0)} - 1),$$

where the nucleation n and n_0 occurs at the times t and t_0 respectively. Hence, when c becomes appreciable

$$-\frac{dn/dt}{n^2} = \frac{c}{n} + b,$$

or the usual decay coefficient increases as n diminishes, becom-

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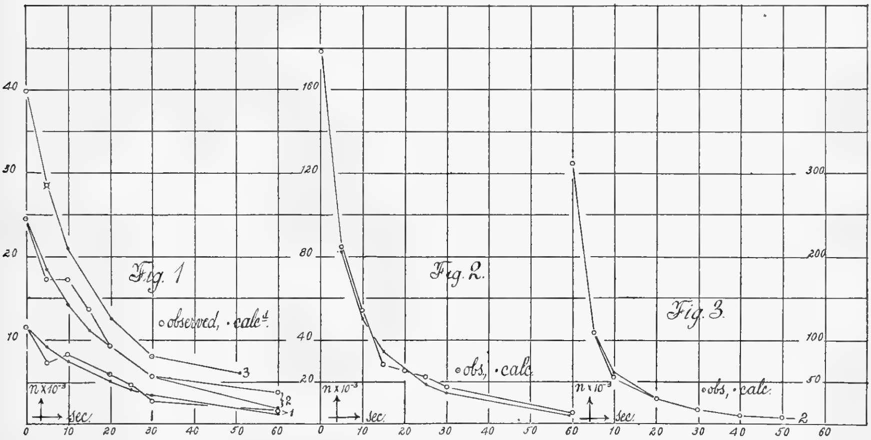
*Barus: Experiments with ionized air; Smiths. Contr., No. 1309, 1901, pp. 34 to 36.

ing infinite when $n = 0$. This is precisely what the above experiments have brought out. The value of b does not appear except when n is very large. Since b is of the order of 10^{-6}, if c is of the order of 3×10^{-2} (as will presently appear), c/n will not be a predominating quantity when n is of the order of 10^6 or $c/n = 3 \times 10^{-8}$; but it will rapidly become so as n approaches the order of 10^4 or $c/n = 3 \times 10^{-6}$, which again is closely verified by the above data.



Again, if $-dn/dt = -a + cn + bn^2$, the conditions of equilibrium are modified and become, since $dn/dt = 0$,

$$a = cn + bn^2$$

where a measures the intensity of radiation. It no longer varies as n^2, for

$$n = \frac{c}{2b}(1 + \sqrt{1 + 4ab/c^2}).$$

6. *Absorption of phosphorus nuclei in tubes.*—The method of the preceding paragraph, applied to the data obtained in the given paper with phosphorus nuclei, leads to striking results. It shows the possibility of computing nucleation by passing a current of highly ionized air through tubes of known length and section (absorption tubes) into the steam jet apparatus there developed. But there is no room for these results here.

7. *Further data and results.*—Experiments with special reference to the views just given were made at some length. Their general character is shown in figures 1, 2, 3, where the abscissas are the times elapsed since radiation was cut off and the ordinates the number of nuclei caught in thousands per

cubic cm. It is not possible, however, from results of the character of the present, to discriminate sharply between c and b, and the endeavor will have to be made to select the best values from inspection.

In these series the constants obtainable for different intervals of time separately for each series would be as follows:

Series	1	1	2	2	3	3	4
$10^6 b$	2·4	2·9	·82	·88	·61	·56	1·1
$10^3 c$	— 18	— 20	45	32	41	40	39

The mean data of series 2 to 4 would then be $b =$ ·000000,79, $c =$ ·039. There is a curious consistency in the constants separately determined, even when the compensating values of b and c are of different signs, as for instance in series 1. The reason is not apparent. The constants will necessarily be correct at three values of t, but the computed values of n are no better as a whole than will be the case if the first set of constants of series 2 for instance were used. In fact the constants b may be arbitrarily put at a reasonable estimate* $b =$ ·000,001 with $c =$ ·0356 and a fair reproduction of the observation is obtained. This is shown in the charts where these computed values ($b = 10^{-6}$) are incorporated. Close inspection, however, shows that in all cases the fall of computed curves, while not quite rapid enough at $t - t_0 < 10$, is somewhat too rapid for higher time intervals. Thus b should be less than 10^{-6} and c greater than ·035, to be adapted to the present results.

The question finally arises whether any systematic error in the standardization of coronas and hence in the values of n, could have produced an effect equivalent to the occurrence of a constant c. Suppose that $-dn/dt = bn^2$ for the true nucleation, and that $N = A + Bn$ as the result of systematic errors of standardization. Then $-dN/dt = b'N + c'N + d'$, an equation broader in form than the one accepted. The constants d' and c' both vanish with A, the former more rapidly. Hence, the possible introduction of c through the method of standardization is not excluded however how improbable, since the equation is conditioned by the occurrence of A.

8. *Conclusion.*—If the rate of decay of ionized nuclei be written bn^2, the coefficient b as found by the fog chamber increases as n decreases and may reach tenfold the order of the usual electrical value of the order of $b = 10^{-6}$. The endeavor to explain this by supposing that but $1/m$ of all the ions are caught and $dn/dt = -mbn$, is not satisfactory.

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* Townsend, McClung, Langevin, find $b = 1·1 \times 10^{-6}$ about, using the usual electrical method. See Rutherford's Radioactivity, pp. 41, 42, 1905.

It makes no difference how the small efficient nucleation is produced, whether by weak radiation, or by decay (time loss) from a larger nucleation, or by small exhaustion catching but few nuclei.

The data of the fog chamber may be explained by postulating the absorption coefficient c so that if a be the number generated per second $-dn/dt = -a + cn + bn^2$. In such a case, if b is 10^{-6} the order of the corresponding decay of ions as found by condenser, and if c is of the order of $3{\cdot}5 \times 10^{-2}$, the results of the fog chamber are closely reproduced for all values of nucleation.

A similar theory may possibly be extended to include the absorption of phosphorus nuclei, carried by an air current through thin tubes of different length and section (absorption tubes).

Finally it is improbable that the constant c should be introduced by a systematic error in the standardization of the coronas of cloudy condensation.

Brown University, Providence, R. I.

Art. XXXVIII.—*Some new Crystallographic Combinations of Calcite from West Paterson, N. J.*; by H. P. Whitlock.

The calcite crystals which furnish the material for this paper were found in the trap rock quarry one mile northwest of the village of Haledon, N. J. They were collected by Mr. H. H. Hindshaw in the summer of 1904 and are now in the collection of the New York State Museum. They are essentially different from any of the types described by Rogers* and present two forms which are new to the species. The interest attached to the remarkable crystallized datolite from the locality added to the above facts seems to justify a short crystallographic description of these crystals. The writer wishes to express his thanks to Mr. Hindshaw for the material to be described, as well as for facts relating to the location and geology of the locality.

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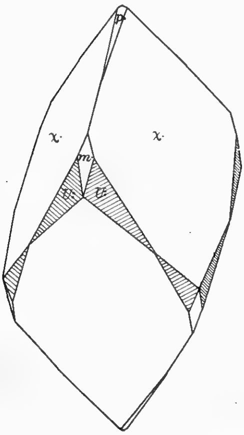

Type I. Crystals of type I occur isolated or in small parallel aggregates, immediately associated with the light greenish datolite previously described from an adjacent locality†. In several instances they were obtained from the casts left by the flat plates of some mineral of previous generation, presumably a mica, which has been dissolved out of the matrix of datolite. Minute rosettes of specular hematite accompany the crystals of this type, aa well as a thin coating of limonite.

These crystals are 3^{mm} to 8^{mm} in vertical length, transparent and colorless. They are rhombohedral in habit, the dominant form being the negative rhombohedron χ.$(0\cdot 9\cdot \bar{9}\cdot 4)$. This rhombohedron is modified on the polar edges by the positive rhombohedrons *p*. $(10\bar{1}1)$ and *m*. $(40\bar{4}1)$ in small development. The positive scalenohedron U: $(54\bar{9}1)$ is present as a series of small striated faces modifying the basal angles of χ. Fig. 1 shows this combination.

Type II. The crystals of this type occur implanted directly on the walls of the open seams and cavities in the diabase. They are quite uniform in size, averaging 5^{mm} in vertical length and are developed with the vertical axis in every instance nor-

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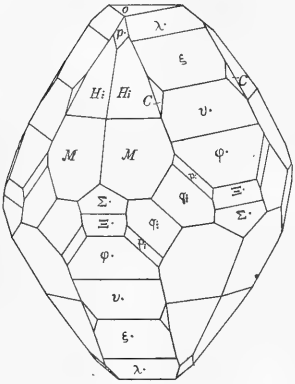
* A. F. Rogers, The crystallography of the Calcites of the New Jersey Trap Region. School of Mines Quarterly, xxiii, 336, 1902.

† Dana, E. S., On the Datolite from Bergen Hill, New Jersey. This Journal (3), iv, 16, 1872.

mal to the bounding surface. They are semi-transparent and contain numerous inclusions of specular hematite in minute aggregates. Hematite in microscopic, reddish, metallic plates in some instances fills the interstices between the crystals. The crystals of type II are rhombohedral-scalenohedral in habit. A well developed series of negative rhombohedrons characterizes this type, the planes in the rhombohedral zone being sharp and brilliant.

The two positive scalenohedrons noted, M $(8\cdot4\cdot\overline{12}\cdot5)$ and H: $(36\bar{9}5)$ in the zone $[0001\cdot21\bar{3}1]$, consist of smooth and somewhat dull planes but yielded fair reflections. The latter of these is new. Two negative scalenohedrons in the zone $[02\bar{2}1\cdot12\bar{2}0]$, 𝔭 : $(13\bar{4}1)$ and 𝔮 : $(24\bar{6}1)$, give sharp, brilliant reflections. A new negative scalenohedron $(1\cdot13\cdot\overline{14}\cdot10)$ lies close to the zone of negative rhombohedrons between $(05\bar{5}3)$ and $(04\bar{4}3)$. The planes are small but well developed and agree fairly well with theory as to the measured angles. The letter C has been assigned to this form. The forms observed on crystals of this type are:—

2



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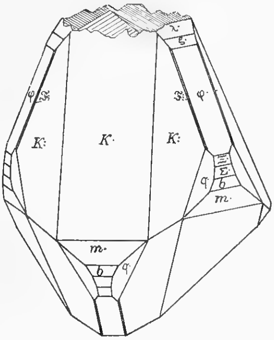

o (0001), *p*. $(10\bar{1}1)$, λ. $(0\bar{8}87)$, ξ. $(04\bar{4}3)$, *υ*. $(05\bar{5}3)$, *φ*. $(02\bar{2}1)$, Ξ. $(05\bar{5}1)$, Σ. $(0\cdot11\cdot\overline{11}\cdot1)$, 𝔭 : $(13\bar{4}1)$, 𝔮 : $(24\bar{6}1)$, H: $(36\bar{9}5)$ new, M $(8\cdot4\cdot\overline{12}\cdot5)$, and C $(1\cdot13\cdot\overline{14}\cdot10)$ new. Fig. 2 shows this combination.

Type III. Crystals of this type are translucent, milky white and average 20^{mm} in vertical length. They occur with considerable amethystine quartz implanted in irregular aggregates on the walls of partly filled seams in the diabase. In habit these crystals are distinctly scalenohedral, the dominant scalenohedron being K: ($21\bar{3}1$). No instance of a doubly terminated crystal was noted. A strongly developed zone of negative rhombohedrons connects this type with type II, the forms being identical in both types. Of these the negative rhombohedron φ.($02\bar{2}1$) is developed to a considerable habit. Broad but rough and irregular planes of K. ($50\bar{5}2$) replace the obtuse polar angles of K: . The negative scalenohedron q : ($24\bar{6}1$) of type II is present in small development. The positive scalenohedrons 𝔉 : ($4\cdot8\cdot\bar{12}\cdot5$) and 𝔇 : ($4\cdot16\cdot\bar{20}\cdot9$) in the zone [$21\bar{3}1\cdot02\bar{2}1$] are present as extremely narrow modifications. The termination in crystals of the type is rarely complete, the polar angle of the dominant scalenohedron ordinarily being replaced by a "built up" rim surrounding a slight depression, which latter is frequently partly filled with rosettes of hematite and prochlorite. The following forms were observed:

b ($10\bar{1}0$), *m.* ($40\bar{4}1$), K. ($50\bar{5}2$), λ.($08\bar{8}7$), ξ.($04\bar{4}3$), φ.($02\bar{2}1$), Ξ($05\bar{5}1$), Σ.($0\cdot11\cdot\bar{11}\cdot1$), K: ($21\bar{3}1$), q : ($24\bar{6}1$), 𝔉 : ($4\cdot8\cdot\bar{12}\cdot5$) and 𝔇 : ($4\cdot16\cdot\bar{20}\cdot9$). Fig. 3 shows this combination.

TABLE OF ANGLES.

Angle	Measured °	′	Calculated °	′	Angle	Measured °	′	Calculated °	′
$0001 : 10\bar{1}0$	90	25	90	0	$54\bar{9}1 : 45\bar{9}\bar{1}$	15	53	16	30
$10\bar{1}1 : 40\bar{4}1$	31	$10\frac{1}{2}$	31	$10\frac{1}{2}$	$13\bar{4}1 : 02\bar{2}1$	16	45	17	5
$10\bar{1}1 : 50\bar{5}2$	23	30	23	$19\frac{1}{2}$	$24\bar{6}1 : 42\bar{6}\bar{1}$	30	33	30	39
$0\bar{1}11 : 08\bar{8}7$	93	1	93	$1\frac{1}{2}$	$63\bar{9}5 : \bar{6}9\bar{3}5$	64	56	66	58
$0\bar{1}11 : 04\bar{4}3$	97	23	97	$21\frac{1}{2}$	$63\bar{9}5 : 9\bar{3}\bar{6}5$	32	$59\frac{1}{2}$	32	2
$0\bar{1}11 : 05\bar{5}3$	103	18	103	$17\frac{1}{2}$	$63\bar{9}5 : 36\bar{9}\bar{5}$	69	13	68	17
$0\bar{1}11 : 02\bar{2}1$	107	$44\frac{1}{2}$	107	$43\frac{1}{2}$	$63\bar{9}5 : 8\cdot4\cdot\bar{12}\cdot5$	7	11	6	58
$0\bar{1}11 : 09\bar{9}4$	109	39	110	20	$8\cdot4\cdot\bar{12}\cdot5 : \bar{8}\cdot12\cdot\bar{4}\cdot5$	71	22	72	22
$09\bar{9}4 : 9\bar{9}04$	104	$4\frac{1}{2}$	104	$17\frac{1}{2}$	$8\cdot4\cdot\bar{12}\cdot5 : 12\cdot\bar{4}\cdot\bar{8}\cdot5$	34	44	34	20
$0\bar{1}11 : 05\bar{5}1$	122	34	123	$8\frac{1}{2}$	$8\cdot4\cdot\bar{12}\cdot5 : 4\cdot8\cdot\bar{12}\cdot5$	55	$12\frac{1}{2}$	55	20
$0\bar{1}11 : 0\cdot11\cdot\bar{11}\cdot1$	129	13	129	$20\frac{1}{2}$	$4\cdot8\cdot\bar{12}\cdot5 : 02\bar{2}1$	16	$46\frac{1}{2}$	17	10
$21\bar{3}1 : \bar{2}3\bar{1}1$	75	$9\frac{1}{2}$	75	22	$4\cdot16\cdot\bar{20}\cdot9 : 02\bar{2}1$	9	50	9	$44\frac{1}{2}$
$21\bar{3}1 : 02\bar{2}1$	37	33	37	41	$1\cdot13\cdot\bar{14}\cdot10 : \bar{1}\cdot14\cdot\bar{13}\cdot108$	2	$16\frac{2}{3}$	83	31
$54\bar{9}1 : \bar{5}9\bar{4}1$	66	$28\frac{1}{2}$	66	$42\frac{1}{2}$	$1\cdot13\cdot\bar{14}\cdot10 : 14\cdot\bar{13}\cdot\bar{1}\cdot10$	4	50	5	54
$54\bar{9}1 : 9\bar{4}\bar{5}1$	52	13	52	11	$1\cdot13\cdot\bar{14}\cdot10 : 04\bar{4}3$	3	55	3	0

Mineralogical Laboratory, N. Y. State Museum, Albany.

Art. XXXIX.—*The Preparation of Acetamide by the Action of Ammonium Hydroxide and Ethyl Acetate;* by I. K. and M. A. Phelps.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—clxv.]

It has been stated by Hofmann* that the action of aqueous ammonia upon ethyl acetate at ordinary temperatures yields after several days' standing considerable amounts of acetamide, but that the amount of acetamide by no means corresponds to the amount of ethyl acetate taken. Hofmann further states that according to a communication from Dr. Bannow the yield of acetamide, even when formed in large quantities, is usually not much above 70 per cent of that theoretically demanded. In this same communication Hofmann makes a similar statement in regard to the action of ethyl formate.

In a former paper from this laboratory† conditions have been shown under which very nearly the theoretical yield of formamide by the action of ammonium hydroxide and ethyl formate is obtained. Now it has been found that conditions closely similar will give theoretical yield as well in the case of ethyl acetate and aqueous ammonia.

For the work given here ethyl acetate of commerce was treated in a separating funnel with sodium carbonate solution, and, after separating from this, was washed with distilled water. The ethyl acetate thus purified from acid impurities was separated as completely as possible from the water, dried over fused calcium chloride and then treated again with a fresh portion of fused calcium chloride before fractioning. Portions boiling between 77° and 77°·2 were taken as pure ethyl acetate.

Definite portions of the pure ethyl acetate were weighed, and, after chilling below zero in an ice and salt mixture, were mixed in a stoppered reagent bottle with definite volumes of ammonium hydroxide. In some of these experiments the ammonium hydroxide was the pure concentrated ammonium hydroxide of commerce; in others the ammonium hydroxide was made more concentrated by saturating at $-10°$ the pure concentrated ammonium hydroxide of commerce with dry ammonia gas obtained by heating concentrated ammonium hydroxide in a flask connected with a return condenser and drying further the ammonia by passing it through a lime tower; while in a third series of experiments the product obtained by mixing in the cold in a stoppered reagent bottle the ethyl acetate and ammonium hydroxide was saturated in the cold with dry ammonia gas obtained in the manner given

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[*] Berichte, xv, 977.

[†] This Journal, xxiv, 173.

above. In every case, after the solution had stood a sufficient time in the reagent bottle stoppered tightly so that the ammonia gas should not escape, it was transferred to a 250^{cm^3} distilling flask, connected with a 100^{cm^3} distilling flask in the usual way for a vacuum distillation, with the use of the least amount of absolute alcohol to rinse the sides of the bottle. The low boiling impurities, ammonia, alcohol, and water, were removed by fractioning in vacuo in the usual way, the 250^{cm^3} flask being heated in a bath of hot water finally at 60° for fifteen minutes after the pressure on the manometer registered 15^{mm}. The acetamide left in the flask was distilled by heating the flask in an acid potassium sulphate bath at 140° to 150°, and was collected in the receiver, cooled by a stream of cold water, and weighed.

The experiments of section A are those in which the pure ammonium hydroxide of commerce was used with the ethyl acetate, and after standing suitably the mixtures were distilled in vacuo as given above.

The experiments of section B were conducted in the same way as those in section A, except that the ammonium hydroxide used was saturated at $-10°$ with dry ammonia before mixing in the cold with the ethyl acetate.

The experiments of section C were conducted in the same way as those of A excepting that the entire mass of ethyl acetate and ammonium hydroxide after mixing in the cold was saturated with dry ammonia gas at $-8°$ to $-10°$.

From an inspection of the results recorded in section A it is seen that the volume of ammonium hydroxide taken for a given weight of ethyl acetate, as well as the time allowed for the interaction of the ethyl acetate and ammonia, influences the yield of acetamide. The theoretical yield can be obtained with the proportion and concentration of the reagents used here only on long standing. Two weeks' standing at ordinary temperatures with so large an amount as 75^{cm^3} of the ammonium hydroxide for 50 grm. of ethyl acetate will give the yield required by theory, although for smaller proportions of the ammonium hydroxide that time is not sufficient.

It is evident from the results given in section B that a solution of saturated aqueous ammonia tends to give a larger yield of acetamide in a given time than can be obtained by weaker aqueous ammonia.

In section C the results show that in shorter time than by the procedure in experiments given in A and B of the table the theoretical yield of acetamide may be obtained by saturating in the cold the mixture of ethyl acetate and ammonium hydroxide and allowing it to stand either four or six days according to the proportion of the aqueous ammonia present.

TABLE I.

A

Treatment with NH_4OH.

	Ethyl acetate	Ammonium hydroxide		Reaction time		Acetamide	
No.	grm.	cm^3	Sp. g.	Days	Hrs.	Theory grm.	Found grm.
(1)	50	50	0·90	3	22	33·57	21.70
(2)	50	50	0·90	6	19	33·57	25·60
(3)	50	50	0·90	13	--	33·57	29·00
(4)	45·4	50	0·90	126	--	30·80	30·36
(5)	50	75	0·90	3	23	33·57	26·89
(6)	50	75	0·90	6	--	33·57	30·15
(7)	50	75	0·90	8	--	33·57	31·18
(8)	50	75	0·90	13	--	33·57	34·10
B							
Treatment with NH_4OH saturated with NH_3.							
(9)	50	50	---	3	19	33·57	21·03
(10)	50	50	---	12	--	33·57	32·80
(11)	50	50	---	49	--	33·57	33·12
(12)	50	78	---	3	22	33·57	28·81
(13)	50	78	---	6	22	33·57	32·53
C							
Treatment with NH_4OH and saturation of the mixture with NH_3.							
(14)	50	50	0·90	3	16	33·57	25·78
(15)	50	50	0·90	6	--	33·57	33·71
(16)	50	50	0·90	12	6	33·57	33·82
(17)	50	50	0·90	20	--	33·57	33·47
(18)	50	75	0·90	--	23	33·57	17·72
(19)	50	75	0·90	2	--	33·57	30·08
(20)	50	75	0·90	3	--	33·57	31·63
(21)	50	75	0·90	4	--	33·57	33·62
(22)	50	75	0·90	4	6	33·57	34·00

It is evident that the time of completion of the reaction is dependent upon the concentration of the ammonia.

It was found that the mixture of ammonium hydroxide and ethyl acetate became homogeneous in the experiments of section A in about three days, in B in somewhat less time, and twenty-four hours in C. In experiment (18) the mass became homogeneous at the end of twenty-three hours, and in this single instance distillation was made as soon as this phenomenon appeared. It is evident that the formation of acetamide progresses slowly and is not at an end as soon as the mass becomes homogeneous.

It was found by experiment that a known weight of pure acetamide treated with 10^{cm^3} of water and fractioned in vacuo could be recovered with a loss of less than 0·05 grm. The acetamide tends to hold traces of water; and it was not found possible to remove it by fractional distillation in vacuo without danger of loss of very small amounts of acetamide.

The presence and amount of ammonium salt in the acetamide obtained in the procedure outlined above were tested for by the use of a solution of sodium cobalti-nitrite. An experiment showed that 0·0002 grm. of ammonium chloride could be readily detected in the presence of 0·50 gram of acetamide. The acetamide obtained directly by fractioning in vacuo, as given above, was found to contain traces of ammonia and ammonium salt. In experiment (8) the crude material was transferred after weighing the product obtained from the vacuum distillation to a watchglass and allowed to stand in a desiccator over sulphuric acid for twenty-four hours, and the loss sustained was 0·62 grm., presumably largely water with some ammonia. Some of this loss must have been acetamide also, for by a separate experiment with pure acetamide recrystallized from benzene it was found that acetamide continually lost in weight in a sulphuric acid desiccator. The acetamide from experiment (8) after being dried showed the presence of not more than 0·30 grm. of ammonium salt, estimated by the amount of precipitate produced with sodium cobalti-nitrite as compared with the amount of precipitate obtained under similar conditions with ammonium choride, pure acetamide and sodium cobalti-nitrite. The material obtained in experiment (22) was redistilled with an air condenser under ordinary atmospheric pressure and yielded 27·5 grm. of product boiling between 221° and 222°. This product showed on testing with sodium cobalti-nitrite no ammonium salt. Theoretically, more ammonium salt might be present in those cases where the standing is longest. But it was found on redistillation, under ordinary atmospheric conditions, of the acetamide obtained directly by the processes given above, that ammonium salt was not present in sufficiently large amounts in the different experiments to be noticeable.

It is clear from the work given that acetamide with only traces of impurity may be obtained in quantities barely less than quantitative for the amount of ethyl acetate taken, if ethyl acetate and ammonium hydroxide are mixed in the cold and allowed to stand a suitable length of time. Increasing the amount of ammonium hydroxide employed shortens the time of standing necessary for a theoretical yield, and increasing the concentration of ammonia by saturating the mixture of ethyl acetate and ammonium hydroxide in these proportions with ammonia gas further diminishes, by one-half or more, the time of standing.

Art. XL.—*On the Volumetric Estimation of Potassium as the Cobalti-nitrite;* by W. A. Drushel.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—clxvi.]

The use of sodium cobalti-nitrite for the qualitative detection of potassium is well known and its use as a quantitative reagent has been described by R. H. Adie and T. B. Wood,* whose results are fairly accurate and favorably comparable with results obtained by the platinic chloride gravimetric method. In the process worked out by these investigators a solution of a potassium salt containing the equivalent of 0·5 per cent to 1 per cent of K_2O is acidified with acetic acid and precipitated by an excess of sodium cobalti-nitrite. The mixture is allowed to stand at least a few hours, preferably over night, and is then filtered through a perforated crucible fitted with an asbestos felt. The precipitate is washed with 10 per cent acetic acid. According to Sutton it is important that the precipitation should be made in a solution containing the equivalent of 0·5 per cent to 1 per cent of K_2O, since in solutions of lower concentration the precipitate comes down in a condition in which it is apt to run through the filter in washing. The precipitate is then decomposed by boiling in dilute sodium hydroxide, and the cobalt is removed as the hydroxide by filtration. The nitrites, which are a measure of the potassium in the precipitate, are estimated by titrating with standard potassium permanganate. Adie and Wood found by analysis that the composition of the precipitated potassium salt is represented by the formula $K_2NaCo(NO_2)_6.H_2O$. According to their method a cubic centimeter of strictly $\frac{n}{10}$ potassium permanganate is equivalent to 0·000785 grm. K_2O.

The object of this investigation was to determine the best conditions for precipitating and filtering the potassium cobalti-nitrite, and to shorten the work of estimating the potassium by oxidizing directly with potassium permanganate without the preliminary decomposition of the precipitate and removal of cobalt recommended by Adie and Wood. In a series of preliminary experiments the precipitated cobalti-nitrite was oxidized by an excess of potassium permanganate, the excess of permanganate reduced by standard oxalic acid, and the remaining oxalic acid titrated to color. In this treatment trivalent cobalt is reduced to the bivalent condition, and from the formula of potassium sodium cobalti-nitrite it would appear that the oxygen thus made available should be equivalent to one-twelfth of that necessary to oxidize the nitrites. The results of these experiments are given in Table I.

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*Jour. Chem. Soc., lxxvii, 1076. Sutton's Vol. Anal., 9th ed., p. 62.

Portions of a potassium chloride solution of known strength were treated with an excess of sodium cobalti-nitrite* and filtered on perforated crucibles fitted with asbestos felts. The precipitates were first washed with a 10 per cent acetic acid solution, then once with water. In experiments 1 to 5 the precipitate was decomposed by boiling with sodium hydroxide and the nitrites estimated according to the method of Adie and Wood, giving the results in the second column of Table I. The cobaltic hydroxide filtered off on asbestos was reduced by heating nearly to boiling in a measured amount of standard oxalic acid containing a little sulphuric acid. The excess of oxalic acid was estimated by titrating with standard potassium permanganate, and from this the equivalent of the cobaltic hydroxide in terms of permanganate was found by subtraction, giving the results in the third column of the table. In experiments 6 to 10 the precipitated potassium salt together with the crucible and asbestos felt, after stirring the precipitate and felt loose from the crucible, was placed in a beaker containing a measured amount of standard permanganate, taking care to use an excess, diluted to about ten times its volume and heated nearly to boiling. After five to eight minutes, or when the manganese hydroxide formed gave the solution a dark color, it was acidified with 5^{cm^3} to 20^{cm^3} of sulphuric acid (1 : 7). After a few minutes a measured excess of standard oxalic acid was run in from a burette, the temperature being kept a little below the boiling point until the solution became clear, and then titrated to color with permanganate. The whole amount of permanganate used less the equivalent of the oxalic acid used is the amount necessary for the oxidation of the precipitate. The results are given in the fourth column.

Table I.

No.	K_2O taken grm.	$KMnO_4$ used in titration of nitrites after removal of cobaltic hydroxide cm³.	$KMnO_4$ equivalent to cobaltic hydroxide cm³.	$KMnO_4$ used in direct titration cm³.
1.	0·0235	32·4	2·5	——
2.	0·0235	32·25	2·5	——
3.	0·0235	32·65	2·55	——
4.	0·0353	48·35	3·88	——
5.	0·0353	49·	3·95	——
6.	0·0235	——	——	30·
7.	0·0235	——	——	29·65
8.	0·0235	——	——	29·4
9.	0·0353	——	——	43·65
10.	0·0353	——	——	44·4

* Prepared according to the directions given by Adie and Wood *loc. cit.*, also given in Sutton's Volumetric Analysis, 9th ed., p. 62.

From the results of Table I it appears that the oxidizing value of the cobaltic hydroxide in terms of permanganate is nearly one-twelfth of that required for the oxidation of the nitrites, while the amount of permanganate necessary in the presence of the cobalt is nearly eleven-twelfths of that required for the oxidation of the nitrites after the removal of the cobalt. The factor used, therefore, in calculating the results from the direct titration should be twelve-elevenths of that given by Adie and Wood; that is, in titrating the precipitate without first separating the cobalt one cubic centimeter of strictly $\frac{n}{10}$ potassium permanganate is equivalent to 0·000856 grm. K_2O.

Unless the potassium salt solution is of the proper concentration the precipitate is very difficult to filter and wash, and shows a tendency to pass through the felt. By repeated experiments it was found that this difficulty as well as the necessity for allowing the precipitate to stand over night is avoided by evaporating the mixture nearly to dryness on the steam bath after adding the sodium cobalti-nitrite solution in considerable excess. Upon cooling the pasty residue it becomes hard and dry. It is then treated with cold water to dissolve the excess of sodium cobalti-nitrite, and the insoluble portion is collected on the filter. This precipitate may be freely washed with cold water without showing a tendency to pass through the filter, and is so insoluble that less than 0·5 of a milligram of the dried precipitate will dissolve in a liter of water at the room temperature during 24 hours standing with occasional shaking. This mode of treatment was found to work well and was used in all the subsequent experiments.

The method as worked out and used in all the experiments except those of Table I is as follows: The solution of a potassium salt, containing not more than 0·2 grm. K_2O and free from ammonium salt, was treated with a rather large excess of sodium cobalti-nitrite solution acidified with acetic acid, and evaporated to a pasty condition over the steam bath. It was then cooled and treated with 50^{cm^3} to 100^{cm^3} of cold water and stirred until the excess of sodium cobalti-nitrite was dissolved. It was allowed to settle and decanted through a perforated crucible fitted with an asbestos felt. The precipitate was washed two or three times by decantation, after which it was transferred to the crucible and thoroughly washed with cold water. In the meantime a measured excess of standard potassium permanganate was diluted to ten times its volume and heated nearly to boiling. Into this the precipitate and felt were transferred and stirred up, after which the crucible was also put into the solution, since particles of the precipitate stick persistently to the sides of the crucible. After the oxidation had proceeded five or six minutes manganese hydroxide separated out and the color of the solution darkened. At this point 5^{cm^3} to 25^{cm^3} of sulphuric acid (1:7) were added, and the solution, after stirring, was allowed to stand a few minutes. Then a measured amount of standard oxalic acid, containing 50^{cm^3} strong sulphuric acid per liter, was run in from a burette, taking care to add an excess. The temperature was maintained a little below the boiling point until the solution became colorless and the manganese hydroxide had completely dissolved. It was then titrated to color by permanganate in the usual manner. From the whole amount of permanganate used the permanganate equivalent of the oxalic acid used was subtracted and the remainder multiplied by the factor calculated for the strength of permanganate used, 0·000856 being the factor for strictly $\frac{n}{10}$ potassium permanganate.

To make the $\frac{n}{10}$ oxalic acid solution, exactly 7·1066 grm. of pure recrystallized ammonium oxalate were dissolved in about 700^{cm^3} of cold distilled water contained in a liter flask. To this solution were then added 50^{cm^3} of strong sulphuric acid. The contents of the flask were cooled to 15° C. and made up to the mark with distilled water. The potassium permanganate solution was made approximately decinormal and standardized in the usual way. This standard was checked by standardizing under conditions as nearly as possible like those under which the solution was used. A measured portion was diluted ten times, heated nearly to boiling, acidified with dilute sulphuric acid and allowed to stand a few minutes. It was then bleached with a measured amount of oxalic acid, using it in slight excess, and titrated to color. The two methods agreed very well, the difference in permanganate seldom being greater than one-tenth to two-tenths of a cubic centimeter in 25^{cm^2}.

TABLE II.

	K_2O taken	K_2O found		Error in K_2O	
No.	As KCl grm.	Gravimetrically grm.	Volumetrically grm.	Gravimetrically grm.	Volumetrically grm.
1.	0·0237	0·0240	0·0238	0·0003 +	0·0001 +
2.	0·0237	0·0243	0·0242	0·0006 +	0·0005 +
3.	0·0354	0·0359	0·0355	0·0004 +	0·0000 ±
4.	0·0474	0·0478	0·0471	0·0004 +	0·0003 —
5.	0·0048	0·0048	0·0050	0·0000 ±	0·0002 +
6.	0·0024	0·0024	0·0023	0·0000 ±	0·0001 —
7.	0·0005	-----	0·0006	--------	0·0001 +
8.	0 0015	-----	0·0017	--------	0·0002 +
9.	0·0355	-----	0·0355	--------	0·0000 ±

In the first six experiments of this series the precipitate was dried at 115° C. and weighed. It was then treated with permanganate by the method previously described. Experiments 6, 7 and 8 show that very small amounts of potassium may be estimated with a fair degree of accuracy.

In Table III the effect of the presence of members of the calcium group was investigated. Calcium and magnesium apparently do not interfere, while barium and strontium tend to give high results.

TABLE III.

	$CaCl_2$	$MgCl_2$, taken	$BaCl_2$,	$Sr(NO_3)_2$	K_2O taken	K_2O found	Error
	grm.	grm.	grm.	grm.	grm.	grm.	grm.
1.	0·2000	0·2000	------	------	0·0005	0·0007	0·0002 +
2.	0·3000	0·5000	------	------	0·0237	0·0234	0·0003 —
3.	0·5000	1·0000	------	------	0·0829	0·0824	0·0005 —
4.	0·5000	1·0000	------	0·5000	0·0711	0·0737	0·0026 +
5.	0·5000	1·0000	0·5000	0·5000	0·0474	0·0493	0·0019 +
6.	0·5000	1·0000	0·5000	------	0·0237	0·0251	0·0014 +
7.	0·5000	1·0000	------	------	0·0711	0·0713	0·0002 +

The method may also be used in the presence of phosphoric acid and is therefore applicable to the estimation of K_2O in fertilizers. In Table IV are the results obtained in nine fertilizers by the platinic chloride method and the cobalti-nitrite volumetric method. In columns one and two are the duplicate results obtained by two analysts of the Connecticut Agricultural Experiment Station, and in column three are the results by the volumetric method. The water-soluble phosphoric acid present in these samples is given in the fourth column.

TABLE IV.

K_2O in Mixed Fertilizers.

	K_2O by platinum chloride method		K_2O by vol. cobalti-nitrite meth.	Water-soluble P_2O_5 in sample
No.	per cent	per cent	per cent	per cent
1.	5·22	5·18	5·18	4·16
2.	6·53	6·56	6·56	3·10
3.	2·23	2·24	2·24	7·82
4.	8·68	8·64	8·78	0·94
5.	6·37	6·42	6·38	6·62
6.	6·08	6·13	6·13	5·61
7.	4·08	4·02	4·02	3·15
8.	4·62	4·66	4·67	2·43
9.	1·68	1·67	1·77	6·03

Ten grams of the fertilizer were placed in a 500^{cm^3} flask and 300^{cm^3} of water were added. The contents were boiled for 30 minutes and ammonia water was added to slight alkalinity. Enough ammonium oxalate was added to precipitate all the calcium and, after cooling, the solution was made up to the mark on the neck of the flask and well shaken. The solution was then filtered through a dry filter into a dry flask. Two 50^{cm^3} portions of the filtrate were transferred with a pipette to platinum dishes, one portion being used for the gravimetric estimation by the platinum chloride method and the other for the volumetric estimation by the cobalti-nitrite method. After evaporating these portions to half their volume over the steam bath, 1^{cm^3} sulphuric acid (1 :1) was added and the evaporation was continued as far as possible over the steam bath, and finally over a low flame. After the danger of spattering was over the flame was increased and the charred organic matter was burned off, finally, over the blast lamp. The potassium sulphate was dissolved by adding a little water and heating over the steam bath, and the potassium was estimated as previously described.

The volumetric method may be summed up thus: The potassium is precipitated as potassium sodium cobalti-nitrite by an excess of sodium cobalti-nitrite and the mixture is evaporated on the steam bath. The precipitate is separated by filtration through asbestos and oxidized by hot standard potassium permanganate. The excess of permanganate is bleached by an excess of standard oxalic acid and the solution is then titrated to color by permanganate. The amount of potassium oxide is found by multiplying the oxygen value of the amount of potassium permanganate used by the factor 1·09.

This method has the advantages over the platinum chloride method that no expensive reagents are used and that the time required for a determination is materially reduced. The method is considerably shorter than that of Adie and Wood and does not require the potassium solution to be of any definite concentration to work well.

In closing, the author desires to acknowledge his indebtedness to Dr. R. G. Van Name for many helpful suggestions during the progress of the work.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Atomic Weights of Silver, Nitrogen and Sulphur.*—The masterly researches conducted by Prof. Theodore W. Richards are being continued with apparently still more wonderful precision than heretofore. RICHARDS and FORBES have studied the quantitative synthesis of silver nitrate. For this purpose they employed a bulb of fused quartz for evaporating and drying the silver nitrate produced by dissolving pure silver in pure nitric acid. They found that 100,000 parts of pure silver produce 157·479 parts of silver nitrate. If silver is assumed to be 107·93, nitrogen must be 14·037, while if silver is taken as 107·880, nitrogen must be 14·008. The question of the exact atomic weight of silver must be determined by further work, particularly upon the composition of the chlorates and the ammonium salts. RICHARDS and JONES have investigated the comparative weights of silver sulphate and silver chloride, carrying out the conversion in a tube of fused quartz. They found that 100·000 parts of silver sulphate gave 91·933 parts of silver chloride, and calculated, if silver is taken as 107·93, sulphur is 31·113, while if silver is 107·88, sulphur is 32·069. The final decision in regard to the atomic weight of sulphur must await further work upon that of silver.—*Carnegie Inst. Pub. 69* (1907). H. L. W.

2. *The Atomic Weight of Radium.*—MDME. CURIE made determinations of this atomic weight in 1902, using nine centigrams of radium chloride. With this small quantity the value 225 was obtained. Having now at her disposal a few decigrams of the salt, she has carefully purified it, and has obtained four decigrams of very pure radium chloride, upon which she has carried out three determinations under much more favorable conditions than before. The determinations were made by comparing the weights of anhydrous radium chloride with the weights of silver chloride produced from them. The results led to the conclusion that the atomic weight of radium is 226·2, where Ag is 107·8 and Cl is 35·4, with a probable error of less than half a unit. If the international atomic weights for silver and chlorine are used as a basis, the value is Ra=226·45. The radium salt was not absolutely free from barium, as shown by the spectroscopic test, but it is the author's opinion that the trace of impurity present had an inappreciable effect upon the results, and it is her opinion that the difference between the results of 1902 and 1907 should be attributed to the inferior accuracy of the experiments performed with only nine centigrams of radium salt, and with less pure reagents.—*Comptes Rendus*, cxiv, 422.

H. L. W.

3. *The Melting-Point of Pure Tungsten.*—In connection with the commercial application of tungsten filaments in electric lighting, it is well known that the melting point of this metal is very high, and in the neighborhood of 3000° C. WARTENBERG has now made some careful determinations of the melting point of pure metallic tungsten by heating it electrically in a vacuous bulb and employing a carefully calibrated optical pyrometer. He concludes that the true melting point of the metal is at least 2800° and probably not more than 2850°. For comparison the author measured the temperature of the positive crater of the arc lamp, which varies somewhat with the kind of carbon used, and determined this to be 3350°, while Reich had found 3430° with the same kind of pyrometer.—*Berichte*, xl, 3287. H. L. W.

4. *Solubilities of Inorganic and Organic Substances*, by ATHERTON SEIDELL. 8vo, pp. 367. New York, 1907 (D. Van Nostrand Company).—This is a useful and important book of reference which will be appreciated by all classes of chemists. It differs from Comey's well known dictionary in confining itself entirely to quantitative data, or in other words, it deals with solubilities only in the sense of the composition of saturated solutions. This limitation has made possible the introduction of the solubilities of organic compounds, as far as they have been determined quantitatively, and this addition has still left the book much smaller than Comey's. The latter admirable work will still be of use when qualitative data are sought, for instance, when we wish to know if an inorganic compound, whose solubility has not been studied quantitatively, is readily or sparingly soluble in water, or when we desire to find out how readily a substance dissolves in the ordinary acids. The new book is attractive in its mechanical details, and is a very convenient one for use, as the matter is arranged alphabetically, and besides it has a full index. The author has not made a mere compilation, but has devoted much labor to re-calculations, and to the selection of the most reliable results. H. L. W.

5. *Practical Chemistry for Army and Matriculation Candidates, and for Use in Schools*, by GEOFFREY MARTIN. 12mo, pp. 144. London, 1907 (Crosby Lockwood & Son).—This little book outlines a course of laboratory work covering a wide range of subjects. It starts with elementary chemistry, and takes up quantitative work, solubility determinations, volumetric analysis, blowpiping, melting- and boiling-points, etc. Necessarily, in so small a book, the various subjects must be treated very briefly. However, the experiments appear to be well selected and clearly described. The book does not deal with chemical theory, except that it gives numerous equations, and pays considerable attention to chemical arithmetic. H. L. W.

6. *The Elements of Physical Chemistry*, by HARRY C. JONES; Pp. 650, 8vo. New York, 1907 (The Macmillan Company).—The appearance of a third edition, revised and enlarged, indicates an extensive use of this well known, excellent text-book. Recent

advances in the science have been incorporated, many minor improvements have been made, and numerous new references to literature increase the value of the book for reference.

H. L. W.

7. *Canal Rays.*—A number of papers on this subject have recently appeared: and the conviction appears to be gaining that in these rays one has the best means of ascertaining the nature of the positive atom. F. **Paschen** (Ann. der Physik, No. 7, pp. 247–260) gives some remarkable photographs of the Doppler effect in the canal rays produced in hydrogen. In the main he substantiates Stark's investigation, but he differs from him in regard to the distribution in the light of the displaced lines or bands, in certain series of lines. In a second paper (pp. 261–206) Paschen gives an investigation of the Doppler effect in oxygen. He employed a concave grating of 10^{cm} diameter and 3·03 meters radius. The papers contain interesting reflections upon the relation of series lines and the Doppler effect. **Stark** (Ann. der Physik, No. 9, pp. 798–804) answers the objections of Paschen, and maintains that the latter's assertion that the series lines of oxygen do not show the Doppler effect is not correct. Paschen maintains his position in Ann. der Physik, No. 10, pp. 997–1000. The most suggestive paper on the subject of canal rays is one by J. J. **Thomson** (Phil. Mag., May, 1907, pp. 561–575). The vacuum tube employed by Thomson was terminated at the end of the tube in which the canal rays were formed, by a screen covered with powdered willemite. The canal rays falling on this screen produced a fleck of light and the deflection of this spot of light by electric and magnetic fields was studied in various gases. A variety of rays were discovered: for one kind $\frac{e}{m}$ has the value of 10^4, that of an atom of hydrogen; for another kind $\frac{e}{m}$ has half this value. A paper in Phil. Mag., Sept., 1907, p. 359–364) also by J. J. Thomson, shows that particles of positive electricity are shot off in all directions from the gas traversed by the canal rays.

J. T.

8. *Propagation of Plane Electromagnetic Waves over Plane Surfaces and their relation to Wireless Telegraphy.*—J. **Zenneck** gives a mathematical discussion of this subject, and its bearing upon the absorption of such waves by the atmosphere. Marconi has shown that the distance one can reach by wireless telegraphy is $2\frac{1}{2}$ times greater by night than by day and he attributes this phenomenon to the increased absorption of the waves due to ionization of the air by daylight. Zenneck's calculation shows that the layers of air less than 6,000 meters from the earth's surface cannot change their conductivity by daylight sufficiently to account for the absorption of the waves, and he believes that this absorption is due to the loss of energy from the antennæ due to daylight. It is probable also that the good effect of clouds and fog is due to the protection of the antennæ from this loss of

energy due to light. The waves employed in wireless telegraphy in passing from water to land and in the reverse direction must suffer partial deflection. The amplitude, therefore, of the wave depends not only upon the distance the waves have traversed over land and sea but also upon the shore form, or barrier between land and sea. On this partial reflection depends the fact that less distorted waves are received at a distance from the sender than at a station near the sender.—*Ann. der Physik*, No. 10, pp. 846–866. J. T.

9. *Influence of Magnetic Fields on the Resistances of Electrolytes.*—G. BERNDT shows that the change of resistance of metals in magnetic fields depends greatly upon temperature conditions and he gives a method for controlling temperature. He found that electrolytes in fields up to 3000 Gauss units, submitted to perpendicular lines of magnetic force and to parallel lines up to 1000 Gauss units, did not change in resistance more than $\frac{1}{250}$ per cent. Mercury showed with lines perpendicular to the layer no change greater than $\frac{1}{25000}$ per cent, and with lines parallel none greater than $\frac{1}{200000}$ per cent. A very small change in bismuth was attributed to an electro-dynamic effect. In general fluid bodies suffer no change in magnetic fields.—*Ann. der Physik.*, No. 10, pp. 932–950. J. T.

10. *Change of Resistance in Metal Wires with Occlusion of Oxygen.*—GUIDO SZIVESSY reviews the subject of occlusion of hydrogen by palladium and gives a formula which directs his work upon the occlusion of oxygen. He finds marked changes due to this cause in silver wires, and in platinum. Gold wires showed no increase in resistance. The results with palladium were doubtful.—*Ann. der Physik*, No. 10, pp. 963–974. J. T.

11. *Atlas of Absorption Spectra;* by H. S. UHLER and R. W. WOOD. Pp. 59, with 26 plates. Washington, 1907 (published by the Carnegie Institution).—This is a collection of more than one hundred photographic maps of the absorption spectra of solutions of various aniline dyes and also of some inorganic salts. The maps are so arranged as to show the variation of the width of the absorption bands with the thickness and concentration of the solution. The spectra comprise the visible and ultra-violet regions from about 0·61μ to nearly 0·20μ. The photographs are beautiful and accurate and reflect much credit upon the experimental skill of Dr. Uhler, who has devised novel and ingenious methods of experiment that cannot fail to be of service in future work on absorption spectra. H. A. B.

12. *Bulletin of the Bureau of Standards;* S. W. STRATTON, Director.—The third number of Volume III of the Bulletin of the Bureau of Standards has recently appeared. One of the papers by G. K. Burgess gives the following as the approximate melting points of metals of the iron group; the specimens examined ranged in purity from 98 per cent to 99·95 per cent:

Iron	1505° C.	Nickel	1435°
Chromium	1489°	Manganese	1207°
Cobalt	1464°		

The melting points of cobalt and nickel are regarded as correct to within 5°, while the possible error of the others is probably less than 10°. The method employed was based on the measurement of the intensity of a particular monochromatic radiation from platinum or other substance, as discussed in an earlier paper noted below. An atmosphere of pure hydrogen was found applicable in the case of these easily oxidized elements. For melting points above that of platinum, it is suggested that iridium, or perhaps tungsten, may be used.

The latter half of the same number (pp. 433–540) is occupied by a paper by E. B. Rosa and N E. Dorsey, describing the results of a new determination of the ratio of the electromagnetic to the electrostatic unit of electricity. In this the method of capacities has been employed but with a higher degree of accuracy than has been realized hitherto. The conclusion of the paper with the final results is held over for another number. In a preceding issue of the Bulletin, a paper by Waidner and Burgess describes the radiation from, and melting points of, palladium and platinum. The final values obtained are 1546° for the melting point of palladium and 1753° for that of platinum. The whole paper is an important contribution to the difficult subject of pyrometry, leading to the establishment of a definite high-temperature scale.

II. Geology and Natural History.

1. *Devonic Fishes of the New York Formations;* by Charles R. Eastman. New York State Museum, Mem. 10, 1907, pp. 235, pls. 15.—This clearly written and interesting treatise on the Devonian fishes (Agnatha and Pisces) of New York is of far wider scope than is indicated by the title. The work treats, in one form or another, of all American Devonian fishes, while the classification and evolution takes into account all that is known of these Precarboniferous animals. Of species described there are fifty-eight and of these thirty-six are found in New York. The volume should be owned by all paleontologists, and is one of the best of the New York State Survey publications.

After a short introduction there is presented a list of the American Ordovician, Silurian and Devonian fishes geologically arranged with the localities of their known occurrence. A perusal of this list, taking into consideration also the nature of the deposits and their invertebrate contents, brings out strongly the conclusion that nearly all of these fishes are of a normal marine habitat and that at but two localities is the evidence decidedly in favor of estuarine waters (Campbellton, New Brunswick and Scaumenac, Quebec). Therefore a fresh-water fish fauna is as yet unknown in these older Paleozoic strata. The tables further indicate that an abundant fish fauna, remarkable for its fishes, the Arthrodires, appears with the warm water coral fauna represented by that of the Onondaga formation; this the reviewer holds is an invasion from the Gulf region through the Indiana Basin, thence spreading eastward into New York while one (*Machæracanthus sulcatus*) continues as far as Gaspé, Quebec. A further analysis of the American species shows that of this warm water fauna at least three genera (*Ptyctodus*, *Acantholepis*, and *Dinichthys*) spread westward into the Dakota sea while the western province furnished but one migrant (*Heteracanthus*) into the Mississippian area.

Under Geological Conclusions, in regard to the paths of migration as worked out by Schuchert and Clarke, the author remarks that "the known distribution of the fishes is in all respects consonant with, and one is tempted to add, confirmatory of the principles that have been formulated from a study of the invertebrates." The American Middle Devonian fish assemblage of the Appalachian basin is found to occur somewhat earlier in Bohemia, migrating westward across the Atlantic (probably not northwestward as stated by the author) and into the Mississippian sea by way of the Indiana basin. "The most conspicuous elements of the fauna are Arthrodires and Ptyctodonts, groups which began immediately upon their introduction to attain a most remarkable development. Throughout the Hamilton, and later Devonic, conditions must have been eminently favorable in the Appalachian sea for the furthur specialization of armor-clad Dipnoans of the type represented by Dinichthys and its congeners. Like their earliest predecessors, they became of greatest importance locally in Ohio."

Of the Agnatha, or fish-like vertebrates, the author does not at all follow the suggestion of Professor Patten that these animals were developed out of some Arthropod stock. He holds the class to be an independent one, differing from the true fishes in not having "the slightest trace of ordinary jaws, of a segmented axial skeleton in the trunk, or of arches for the support of paired limbs. Indeed, appendages themselves are confined to a single order, the Antiarcha, where oarlike swimming organs appear to have developed from an integumentary fold on either side of the body, unsupported by rays, and in a manner fundamentally different from the fins of the typical fishes." That they are not transitional between vertebrates and invertebrates (either Ascidia, Crustacea or Arachnida) the author holds is disproved as follows: (1) the dermal plates are composed of true bone; (2) the head shield and body armor of Asterolepids have a well developed sensory canal system; (3) in Pterichthys, at least, there is a tail covered with scales, a dorsal fin, and a genuinely piscine heterocercal caudal fin."

The oldest fish remains so far discovered (Ordovician of Colorado) and made known by Walcott, the author is not called upon to treat but admits one of the three species, *Astraspis desiderata*, to the Agnatha.

The Dipneusti or lung-fishes are treated in considerable detail. There are a large number of them in the American Devonian because the author, following Smith Woodward, refers to this sub-class the Arthrodira. The test for relationship the author finds in the jaw of Arthrodires, for it conforms "strictly to the Dipnoan type, a fact of cardinal importance for their classification." C. S.

2. *The Paleontology of the Niagaran Limestone in the Chicago Area. The Trilobita;* by STUART WELLER. Nat. Hist. Survey, Chicago Acad. Sci., Bull. iv, pt. ii, 1907, pp. 163–281, pls. xvi–xxv.—Professor Weller gives here a complete account of the Silurian trilobites of the Chicago area which extends from Milwaukee, Wisconsin on the north, south to Joliet, Illinois. There are 41 species and of these 19 are new. There is also one new genus, *Illaenoides.* The detailed stratigraphy is not yet determined but four horizons are recognized in the dolomites, seemingly ranging from the Clinton well up into the Guelph. On pages 181–210 a complete bibliography is given of all North American species of trilobites, of which there are 105. The illustrations are good, being photographic reproductions of crayon work on stipple paper. C. S.

3. *Revision der Ostbaltischen Silurischen Trilobiten;* Abh. VI, von FR. SCHMIDT. Mém. Acad. Imp. Sci. St. Pétersbourg, xx, No. 8, 1907, pp. 104, pls. 3.—This extensive and valuable work, treating of the Ordovician and Silurian trilobites of the eastern Baltic region, begun thirty years ago by the author, is now completed. In this part a general review of the work is given, supplementing the old species with such information as has been gleaned from new material and such changes as are due to the interaction of the work of others during the interim. In 1858 Estland, Livland and Ösel had furnished Schmidt fifty species. Since 1876 he has made known from these and the St. Petersburg regions 256 species or varieties, and of these he has named about 105 forms. From the Lower Cambrian there is but a single species, *Olenellus mickwitzi.* The next trilobite zones are to be correlated with the American Stones River and Chazy formations of the Middle Ordovician and from these and the Upper Ordovician horizons there are not less then 229 forms. Not a single one of these passes into the Silurian, a fact of far greater significance in the Baltic region than in America because of the many prophetic species of the marine invertebrates in the higher Ordovician beds of Estland. Of Silurian species there are 26 (the Swedish island, Gotland, alone having 76) and 6 of these are cosmopolitan forms, ranging as far south as Ireland and England. Of the southern European faunas there is but one in common with Bohemia, *Deiphon forbesi.*

Of the 229 western Russian Ordovician species, at least 64 are also found in Sweden or Norway. The close proximity of these regions leads one to look for a greater number of forms in common than is here indicated. As there was then, seemingly, no land barrier between these regions, and as the fossils show that all belong to one marine province, the discrepancy must be

explained in difference of geological horizons. In Sweden (Oeland) the Upper Cambrian passes gradually into the Ordovician while in Estland a sandstone and black-shale zone of no great thickness represents the last of the Cambrian and reposes conformably upon the Lower Cambrian. Upon the former then follow glauconitic sands and glauconite-bearing dolomites holding a fauna that can be compared in America only with the highest members of the Lower Ordovician. The sequence in Estland then seems to continue without any marked break to the end of the Ordovician, but in southern Sweden these higher horizons are certainly not faunally present in Oeland. They are, however, sparingly represented to the north in the Leptaena Kalk of Dalarne. These regions have therefore dissimilar sediments of various transgressions of a sea from the south and west overlapping on the Baltic shield of Suess. With England and Ireland there is far less in common, there being but 11 species, and nearly all of these are from the uppermost Ordovician or Lyckholm (F) formation. With the Lower Ordovician of England there seems to be nothing in common, but this must be ascribed to the very backward condition of British Ordovician paleontology.
C. S.

4. *The Stratigraphy of the Western American Trias;* by J. P. SMITH. Festschrift zum siebzigsten Geburtstage von Adolph v. Koenen, 1907, pp. 377-434.—In this important paper Professor Smith gives a general summary of the western American marine Triassic formations, their faunas, and the probable waterways of invertebrate migrations. These inter-migrations are complex and in the main are based on abundant ammonite evidence. Having shown that migrations take place from the Mediterranean across the Atlantic and Mexico to California and, in the opposite direction from India around the northern shores of the Pacific, the author then takes up the later migrations of Mesozoic and Cenozoic time. The hindrance to continuous northern Pacific migrations during geological time he thinks is due to the deep channel east of Kamchatka, through which now courses the cold water current from the Bering Sea. This barrier has been effective at different times and, at others, has been considerably shallowed through elevation. "A rise of 200 meters would close Bering Strait, and about one-half of Bering Sea, giving a shoreline coinciding approximately with a great circle. It would then leave the Aleutian chain as a long narrow peninsula reaching out from Alaska towards Siberia, separated from Kamchatka by a narrow but deep channel; while the mainland of Alaska and Siberia would be united by a broad land-bridge. This change in the height of the land would cut off all influx of cold water from the Arctic Sea."
C. S.

5. *Remarks on and Descriptions of new Fossil Unionidæ from the Laramie Clays of Montana;* by R. P. WHITFIELD. Amer. Mus. Nat. Hist., Bull. xxiii, 1907, pp. 623-628; pls. 38-42. —Herein are described eight new species of *Unio*, six other

forms from near the same locality having been defined by the author in an earlier volume. In regard to these the writer remarks: "Considering all the similarities between these Laramie fossils and their representatives in the Mississippi and Ohio watersheds, I venture to state that these farther western waters of the Laramie times were the original home of much of the *Unio* fauna of these more eastern recent localities." C. S.

6. *Palaeontologia Universalis*, fasc. iii, ser. ii, August, 1907, sheets 112-125.—This fasciculus treats of fourteen species, being the work of Bézier, Boussac, Chelot, Cossmann, Lemoine and Sacco.

7. *Die Fossilen Insekten;* von ANTON HANDLIRSCH.—The sixth Lieferung of this monograph, published by W. Engelmann, Leipzig, has come to hand. It has pages 801-960 and plates 46-51 and treats of the Tertiary insects. The remainder of the work will appear during the coming winter. C. S.

8. *Illinois State Geological Survey.* Bulletin No. 4. Year Book for 1906. H. FOSTER BAIN, Director. Pp. 260, with 4 plates and 4 figures. Urbana (University of Illinois), 1907.—Earlier bulletins have already been noticed in the Journal (xxii, 543, xxiii, 227). The present one, No. 4, contains the administrative report of the Director for 1906, with also an account of the progress made in the topographic survey being carried on with the coöperation of the U. S. Geological Survey and the State Geological Commission. The State has hitherto had no accurate and official topographic map, so that the results of the present work are most important. Of the special subjects also discussed may be mentioned several chapters on the study of coal and also an account of two remarkable drill cores, both from Hamilton county, one 920 feet deep (at Delafield) and the other (near McLeansboro) extending to a depth of 1294 feet. The records kept and here summarized are very complete and yield valuable geological sections.

9. *Connecticut Geological and Natural History Survey, Bulletin No. 8. Bibliography of the Geology of Connecticut;* by HERBERT E. GREGORY. Pp. 123. Hartford, 1907 (The Case, Lockwood & Brainard Company).—The eighth bulletin of the Connecticut Geological Survey is devoted to the bibliography of the geology of the State. This has been prepared by Prof. Gregory after a critical study of the literature extending over a number of years. It presents a practically complete list of titles of papers published up to January, 1906, with brief statements giving the main results brought out in each. Upwards of three hundred entries are included in the bibliography, and a list of nearly one hundred references to maps is also added. The work cannot fail to be of great value to all concerned with Connecticut geology.

10. *Tables of Minerals including the Uses of Minerals and Statistics of the Domestic Production;* by SAMUEL L. PENFIELD. Second edition. Pp. vi, 88. New York, 1907 (John Wiley & Sons).—The first edition of these very useful tables was prepared by Professor Penfield in 1903 and is noticed on page 330 of vol. xv. The second edition, now issued by Dr. W. E. Ford, has been brought down to date, especially with respect to statistics of mineral production; Part III, dealing with minerals useful in the arts, has also been re-written and enlarged.

11. *New California Minerals.*—Benitoite and Carlosite are new species recently discovered near the head waters of the San Benito river in San Benito County, California, and described by G. D. LOUDERBACK. *Benitoite* occurs in small hexagonal crystals of pyramidal habit, referred to the trigonal division. The hardness is 6·25–6·5 and the specific gravity 3·64–3·65. The color varies, sometimes in the same crystal, from colorless to deep sapphire-blue; the latter variety has been cut as a gem and is of particularly brilliant luster—rivalling the sapphire—because of the high refractive index ($\omega = 1·77$, $\epsilon = 1·80$ for sodium light). In composition it is a titano-silicate of barium, $BaTiSi_3O_9$. An analysis by W. C. Blasdale gave:

SiO_2 43·68 TiO_2 20·09 BaO 36·33 = 100·10

Carlosite is associated with benitoite as a black, or brownish black, prismatic mineral, with perfect prismatic cleavage yielding an angle of 80° 10′. Its hardness is 5–6 and as it is biaxial and shows oblique extinction, it is inferred to be monoclinic. The composition is as yet undetermined, but it fuses easily (1·5) to a black enamel bead yielding a soda flame. These minerals occur disseminated in narrow veins in a basic igneous rock. A more complete examination is in progress.—*Bull. Geol. Univ. California*, vol. v, 149, 1907.

12. *Elements of Biology: A Practical Text-Book Correlating Botany, Zoology, and Human Physiology;* by GEORGE WILLIAM HUNTER. Pp. 445; New York, Cincinnati, Chicago, 1907 (American Book Company).—The aim of the book is to present in simple language such of the more important principles and facts of botany, zoology, and human physiology as can be readily comprehended by the pupil in the first year in the high school. Features which are of more popular interest and practical importance are emphasized and all unnecessary description is omitted. Numerous suggestions as to laboratory and field work encourage the pupil to carry on personal investigations outside the classroom. At the conclusion of each chapter are lists of reference books for the pupil and for the teacher. The illustrations are numerous and well chosen. This book should prove of unusual value, not only for the pupil beginning the study of biology, but also for the teacher without wide experience, who is called upon to give elementary courses in biology or nature study. W. R. C.

13. *Elements of Physiology;* by THEODORE HOUGH and WILLIAM T. SEDGWICK. Pp. 321; Boston, New York, 1907 (Ginn & Company).—This book consists of a reprint of Part I

of The Human Mechanism (see this Journal, vol. xxii, p. 549) and contains that portion of the larger work which treats of Physiology. A single chapter on drugs, alcohol and tobacco from Part II has been added to meet the requirements of certain State laws. W. R. C.

14. *The Young of the Crayfishes Astacus and Cambarus;* by E. A. Andrews. Smithsonian Contributions to Knowledge, vol. xxxv, pp. 1–79, pl. 1–10. Washington, 1907.—"The memoir describes and illustrates the young of two kinds of crayfishes, one from Oregon and one from Maryland, which represent the two most diverse forms found in North America. . . . It determines the form and habits of the first, second, and third larval stages, ... describes the hitherto unknown nature of successive mechanical attachments of the offspring to the parent, and opens up the problem of the nature and causes of the incipient family life in the crayfish." New data are supplied which lead toward the solution of the problems of the geographical distribution and the origin of the species of crayfish, the evidence furnished pointing toward the wider departure from the ancestral state and the more highly evolved condition on the part of Cambarus than of Astacus. B. W. K.

15. *Evolution and Animal Life. An elementary discussion of facts, processes, laws, and theories relating to the Life and Evolution of Animals;* by David Starr Jordan and Vernon Lyman Kellogg. 8vo, 489 pp., 298 cuts, 2 colored plates. New York: D. Appleton & Co. 1907.—This is a very complete and comprehensive discussion of the various factors and theories of evolution, as indicated by the title. It includes, besides the subjects ordinarily discussed in elementary works on evolution, useful chapters on Paleontology and Geographical Distribution, Adaptations, Parasitism and Degeneration, Commensalism, Instinct and Reason, etc. Altogether it is the most useful and up to date treatise on evolution that we have seen. A. E. V.

16. *Report on the Crustacea (Brachyura and Anomura) collected by the North Pacific Exploring Expedition, 1853–1856;* by William Stimpson (edited by Miss M. J. Rathbun). Smithsonian Miscellaneous Collections, part of vol. xlix, 1907, 8vo, 240 pp., 26 plates.—This is the full report on the Crustacea of the two groups named, prepared by Dr. Stimpson and sent in to the Navy Department just before the great Chicago fire in 1871. Dr. Stimpson, himself, seems to have forgotten that he had delivered this report, for in his statement of the losses by the destruction of the Chicago Academy, he enumerated this as well as his other unfinished reports, and all his drawings. This report was, however, discovered in 1872, shortly after his death, accompanied by a full series of carefully executed drawings, largely made with a silver point on hard cardboard, as Dr. Stimpson told the writer during an interview in Chicago about six months before the fire. At the same time he showed large numbers of drawings of Crustacea of the remaining groups, as well as of mollusca, tunicates, etc., done in the same painstaking man-

ner, in addition to a large collection of colored drawings made from life by himself, while on the expedition. All that was saved was this forgotten report. Shortly after its discovery it was submitted by Prof. S. F. Baird, Secretary of the Smithsonian Institution, to specialists for their opinions as to its value; among others, to Prof. S. I. Smith, of Yale, then the leading carcinologist in this country, and to the writer. Prof. Smith and others, including the writer, reported that it was a very important and valuable paper, that should be published at once. It gave full descriptions of large numbers of new genera and species of which Dr. Stimpson had published only very brief Latin diagnoses, without figures, and of which the types had all been lost in the Chicago fire. The writer and others repeatedly at later times urged its publication, but without avail. The only reason given was the lack of funds to reproduce the figures. It had to wait till the cheap modern methods of reproduction were invented before any department of the U. S. Government or the Smithsonian Institution could afford to print it! Yet it was an official report of an important government expedition, made by the naturalist of the expedition, and the very great expense of making the drawings had already been paid for, as well as the great cost of making the report. It is an illustration of the lack of appreciation of the value of high class, painstaking scientific illustrations, and also of the difficulty of getting posthumous works published, no matter how valuable. Of course, the processes of engraving have been so reduced in cost for more than ten years that the original excuse has not been valid for a long time. It is, then, a matter for congratulation, that under the present efficient officers of the Smithsonian, and with the able editing of Miss Rathbun, this valuable report has at length been brought out. It includes 358 species and the numerous forms described by Stimpson as new are nearly all illustrated. The editor has given in footnotes the modern names when they have been changed. A. E. V.

17. *Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific, in charge of Alexander Agassiz, by the U. S. Fish Com. Steamer Albatross, from Oct., 1904 to March, 1905.* Lieut. Com. L. M. GARRETT, U. S. N. commanding. X. The Brachyura, by Mary J. Rathbun. 4to, 54 pp., 9 plates. Memoirs Mus. Comp. Zoology, vol. xxxv, No. 2, Aug., 1907.—This is an important contribution to our knowledge of the Crustacean fauna of the Central and South Pacific. The species are in large part from the deep sea, but many shore and shallow water forms are also included. The total number of species included is 136, of which 18 species and one genus are new to science. The numerous excellent illustrations are in large part reproductions of photographs. A. E. V.

OBITUARY.

M. MAURICE LOEWY, the eminent French astronomer, Director of the Paris Observatory, died suddenly on Oct. 15 at the age of seventy-five years.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XLI.—*The Internal Temperature Gradient of Metals;* by SCHUYLER B. SERVISS.

IN the Physical Review for October, 1906, Dr. C. B. Thwing reported experiments in which he found that cylindrical specimens of common materials showed at points 3^{cm} from their surfaces an excess of temperature above their surroundings, ranging from 0°·000015 in the case of marble to 0°·000308 for aluminum oxide. This he ascribed to their radio-activity. Now the work of Strutt, Eve, McLennan and Burton, Cooke, Wood, and Campbell, shows that common materials have the power of ionizing air to a slight extent. But Strutt and Rutherford are of the opinion that the feeble radio-activity of common materials is a superficial rather than a volume effect, so further experiments seemed advisable. Thus far the results have been entirely negative.

In the meantime H. Greinacher has reopened the subject by publishing in the Annalen der Physik for October, 1907, an interesting computation of the magnitude of the effect to be expected, showing that Dr. Thwing's results are much too large. It has, therefore, seemed worth while to publish these experimental results immediately, without waiting for the completion of certain other experiments of rather a different sort, which were to have been made.

Since the value of any work of this sort is entirely dependent upon the accuracy of the manipulation, the reader must pardon even a tedious fullness of detail in the description of apparatus which follows:

The Apparatus.

Dr. Thwing's general method was followed; viz., the substance to be tested is used in the form of two equal cylinders, set in an air bath, one on top of the other, with a thermopile consisting of a large number of junctions wound radially around a ring of mica, between them to measure the mean gradient along the radii. Certain modifications in the details were, however, made; these will be pointed out as the apparatus is described. There may be some further departures from Dr. Thwing's construction—his paper is unfortunately brief, especially in the description of his apparatus.

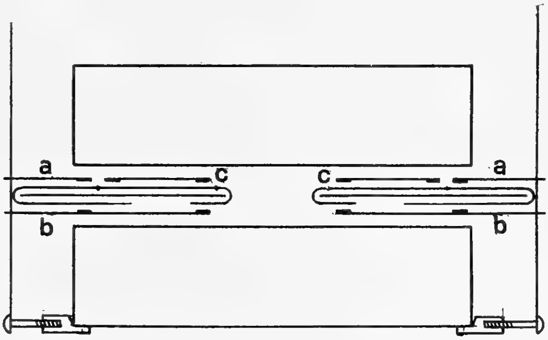
The Specimens.—For these experiments cylinders of lead and of iron were cast, about 12^{cm} in diameter and 4·5 or $5{\cdot}0^{\mathrm{cm}}$ thick, and turned down to $10 \times 2{\cdot}5^{\mathrm{cm}}$. As the castings appeared less porous on the bottom and consequently that end of the cylinders seemed likely to be more uniform, the lower end of each casting was turned down until a satisfactory surface was obtained and then the top cut off until the cylinder was of the desired thickness. It was necessary to oil the cutting tool to obtain smooth surfaces, so after the cylinders were taken from the chuck they were washed with naphtha to remove the oil, and placed in a cabinet until tested. The top side of each (as cast) was marked; when the specimens were not in use, the unmarked base was exposed to the air, and when tested, placed next to the thermal couples. The weights of the cylinders after turning indicated that they were solid. The specimens were of ordinary commercial purity. The lead was cast in the laboratory by melting clean weights which were no longer needed. The iron came from a local foundry and was fine and homogeneous.

The thermopile consisted of 100 copper-constantan thermal couples, made from wires $0{\cdot}020^{\mathrm{cm}}$ in diameter (No. 32 on the Brown and Sharpe gauge). All the wire of each kind was cut from the same strand. Pieces of the constantan 1·5 meters long were annealed by clamping the ends to wide U-shaped, rigid, wooden frame and heating to incandescence in free air by a current of 3·5 amperes from a direct current dynamo. The current was of uniform strength and was maintained for about three seconds in each case. The ends of wire were held at the same level, so that while hot, it hung in approximately a catenary. When the wire was clamped on the frame it was drawn just taut, and after cooling returned to its original tension, so it was not permanently extended to any appreciable degree.

Two lengths were selected at random and laid aside for calibration. The remainder was cut into pieces exactly 3^{cm}

long and the copper into lengths of $7\cdot6^{cm}$. Pairs of these were butted and brazed with an alcohol flame. Silver solder was used with borax as a flux. Care was taken to use as small a quantity of silver as practicable, but if too small a bead is used, it flows entirely to one or the other of the wires. All junctions which suffered an accident in making, were bent, or happened to have an undesirably large excess of silver, or which did not successfully flow the first time, were rejected. After the experience of making 100 good junctions, I was able to join these couples end to end in a similar manner, winding them on the mica ring as completed, so that all the junctions of the thermopile were as uniform as they well could be. The outer diameter of the mica ring was $12\cdot8^{cm}$ and the diameter of the hole was $2\cdot4^{cm}$. Dr. Thwing placed the outer row of junctions of his thermopile outside the cylinders and the inner row between them. I so placed the constantan that my outer row of junctions would come $0\cdot6^{cm}$ inside the convex surface of the cylinders, and the inner row was, of course, 3^{cm} nearer the center. This change was made in order to expose all the junctions in the same manner. This is a fundamental difference between my work and his, and it will be discussed at length in connection with the results.

1



Experiments in this laboratory have shown "that moderately sharp bending (with a radius of $0\cdot5^{cm}$) is not very injurious in the ordinary thermo-electric use of german-silver wire"* but, of course, the bend about the ring of mica is necessarily much sharper than this. Under these circumstances, it seemed best, since the softer and more homogeneous copper would suffer less than the harder alloy, to leave the constantan straight; the junctions were, therefore, all on the same

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* Proc. Amer. Acad., xli, p. 559, 1906.

side of the thermopile, and the copper was bent twice to pass around the ring. The edges of the mica were marked at regular intervals and very slightly notched to hold the wires in position. The first and the last members of the thermopile were, of course, copper, and were soldered directly to longer pieces of the same wire. These were slipped through small rubber tubing, coiled twice around the inside of the thermostat at the level of the thermopile, and then through 85^{cm} of copper tubing passing through the ice, and then soldered to the galvanometer leads. Thus fully a meter and a half of each lead wire was at zero, adequately protecting the end junctions of the thermopile from heating by conduction through them. In Dr. Thwing's apparatus, these wires came in through a short tube between the thermostat and the ice vat. Now it is probable that any constant error arising from this source would tend to warm the outer junction rather than the inner one, which is just the reverse of what Dr. Thwing found. Therefore, if in spite of the possible masking of the effect by conduction along his short lead wires, Dr. Thwing is able to find an excess of temperature at the inner row, then that excess ought to be as great, if not greater, when, as here, this source of error is certainly eliminated.

After the thermal couples were all in place on the mica frame, they were painted with a thin coat of asphaltum varnish and baked in an electric oven for several hours at 120° C. The insulation was found to be defective in a few places, but after a second treatment stood a severe test. This varnish proved a very satisfactory insulator when used for two years on the main bars of the Thomson effect researches of Professor E. H. Hall, in which the writer had a part.* It was accordingly adopted in preference to the beeswax and rosin used by Dr. Thwing, which may have contained acid, since there is no evidence to show that it was especially prepared. Furthermore, the use of asphaltum and thinner wires enabled me to make a thermopile only a third as thick as Dr. Thwing's, which is of course an advantage. And finally there was a mechanical advantage. Although the couples with large joints had been rejected, still the junctions were unavoidably slightly larger than the wires themselves, and the weight of the upper cylinder rested upon these two hundred joints. This insulation was a thin, smooth, hard coating which was not rubbed off or squeezed aside by this pressure.

There remains some possibility of disturbing effects due to the circulation of air in the channels between the wires. To prevent this, three rings of very thin mica (*a*, *b*, *c* in fig. 1)

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* Proc. Amer. Acad., xli, 23–55, 1905, and xlii, 595–626, 1907.

were cut and rings of asphaltum varnish spread around them as shown. The weight of the upper cylinder pressed this between the wires, leaving the junctions in narrow annular air spaces in contact with the upper cylinder. Possibly it may seem preferable to have placed the rings of additional asphaltum directly on the thermopile, without the additional mica. But as it was advisable to keep the thermopile flexible, this last asphaltum was dried without baking, hence these thin rings were needed to prevent the cylinders from sticking to the thermopile. If the whole frame had been baked hard, the wires would have been much more liable to accident in changing the specimens, the channels between the wires would not have been so thoroughly closed, and the thermopile would have been more likely to warp, opening a wide gap or producing a strain under the weight of the upper cylinder. Incidentally the inner diameter of the ring in the top of the thermostat had been made slightly too small to admit the thermopile without bending it a little, and by leaving the mica frame flexible it was not necessary to cut this ring. As the distance between the cylinders was not materially increased by the presence of the additional mica, it did no harm, but increased the insulation, distributed the weight of the upper cylinder over a wider area, and also protected the copper wire projecting beyond the cylinders from possible air currents, which might cause trouble. The thickness of the thermopile was $0{\cdot}74^{mm}$ and its resistance at 0° was 48·6 ohms.

Calibration of the Couples.—50^{cm} was cut from the middle of each specimen selected for the calibration tests. These were used to make couples as nearly like those on the thermopile as possible, and tested between 0° and 8°. They gave 42·2 microvolts per degree, which agrees very well with the ordinarily accepted value of 43 microvolts. A more careful calibration was not necessary, as the very small differences of temperature which are the subject of this investigation cannot be measured within this degree of percentage accuracy. As it is difficult to maintain small constant differences of temperature for calibration purposes, it is necessary to assume that the thermo-electric height of constantan against copper is a right line in the neighborhood of zero. A mean difference of $0^{\circ}{\cdot}000001$ between the inner and the outer row of junctions of the thermopile will, then, generate $4{\cdot}3\text{x}10^{-9}$ volts.

The thermostat was of thin sheet copper, $17{\cdot}5^{cm}$ in diameter and 25^{cm} in extreme height. A composition casting was fitted and soldered in the top. The cover was a second casting held to this by twelve machine screws with a gasket between. A light brass ring was suspended by double silk threads, attached, through swivels, to screws (for leveling) in the under side of the ring at the top. The suspended ring had a socket which held the lower cylinder without slipping. The threads were set vertically on a circle slightly larger than the circumference of the thermopile. The junctions were thus easily put in position symmetrically and could not be displaced by any jar during the experiment. The weight of the upper cylinder was relied upon to hold it in place. On opening the thermostat nothing was ever found disarranged or wet.

The thermostat was clamped to a beveled ring, which was firmly supported by three lengths of maple dowelling rod. The ice vat was 42^{cm} in diameter and 72^{cm} tall at the center. A one-inch pipe was inserted in the bottom to insure complete drainage. The whole was set in a barrel and packed loosely with sawdust.

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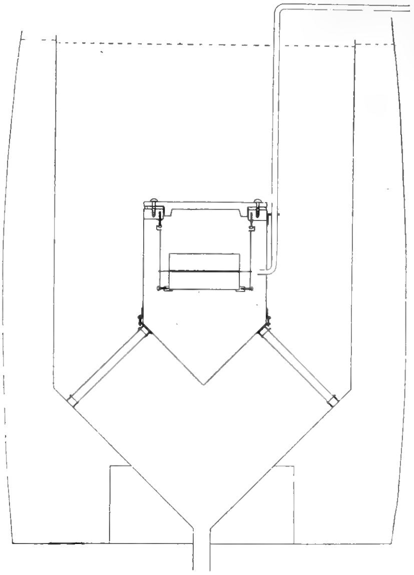

For convenience in draughting the three suspending threads and the three legs are shown as two.

The Ice Bath.—As an ice bath is often used to produce a constant temperature, I here give a detailed account of the various schemes tried, hoping that my experience may be of service to other experimenters. I may state here that this was the most troublesome part of the whole investigation.

Dr. Thwing mentions a noticeable rise of temperature ($0^\circ{\cdot}00001$ to $0^\circ{\cdot}00002$) caused by the melting of the ice from the bottom of the thermostat during the twelve-hour intervals between which he packed the ice down. In other words, steady conditions were not realized. I attempted to obviate this difficulty by making the bottom of both vessels conical at an angle of 45°, hoping that the weight of the ice would cause it to settle and replace that which melted, and so establish a steady condition. But I found almost immediately that owing to the comparatively narrow annular space between the two cans and the regelation of the ice, this device alone was insufficient. Still it is an improvement over a flat-bottomed thermostat, for the ice is kept in contact with the whole of the conical bottom all the time, which materially aids in maintaining constant conditions.

Throughout the work, ice was added at regular intervals, usually every four or five hours, sufficient to keep it near a fixed level. At the same time, the drain water was weighed. During the use of the first arrangement, these weights were irregular, indicating a honeycombing of the ice and regelation. When the ice was crowded down, considerable changes were noticed in the temperature, similar to those observed by Dr. Thwing. About 12 kgms. of ice were used in 24 hours, the amount depending somewhat on the room temperature.

Next a spudger was built out of an iron casting and six $\frac{1}{4}$-inch iron rods projecting vertically downward in a circle midway between the thermostat and the vat. A fan motor and reducing gear raised and lowered this, with some freedom of rotation, every seventeen seconds. A very good quality of natural ice was used throughout this work. During these tests it was ground into pieces weighing 10 grams or less. For a time this seemed to be successful. But the pressure of the prongs raised the melting point sufficiently to disturb the gradient and regelation followed. The ice from the upper third of the vat was removed, and the remainder was found frozen into nearly a solid mass, in which the melting point was variable under the changing pressure of the spudger. The external junctions showed sudden and considerable changes in temperature within a few minutes. Consequently this scheme was abandoned.

The third attempt was successful. Larger lumps of ice were used, averaging 35 or 40 grams in weight. These were cut from the 100-lb. pieces with a sharp chisel, and the corners rounded by washing in running tap water, which prevented relegation, and the consequent freezing into a single, solid mass. But the melting point still varied a little, as indicated by the fluctuations in the gradient. It is a well known fact that the temperature of a mixture of ice and water rises considerably above zero, depending on the amount of water that has accumulated. By stirring the ice and collecting the drip at short intervals, it was found that water was held between the lumps of ice by capillary action. As the stirring was continued, this water was released, the drip became uniform, and the temperature gradient steady. Only slight stirring between the observations was necessary to keep the conditions sensibly constant. A mechanical device, consisting of two endless chains driven in opposite directions vertically through the ice, has been installed to accomplish the stirring uniformly.

Connections.—All of the wiring outside of the thermostat and the copper tube was from the same bobbin of No. 18 copper annunciator wire, with double cotton insulation. The connections throughout were hard soldered, in the same manner as the thermal junctions, except at the galvanometer coils and at the points where the shift was made from direct circuit through the galvanometer to a potentiometer. At these places, copper binding screws were used to clamp the ends of the wires in contact. The connections in the galvanometer were undisturbed; those at the observing table were cleaned daily or oftener with infusorial earth, in addition to the care which was always taken to avoid contact of the bared ends with contaminating objects, especially the fingers. Warming one or another of these binding screws produced no perceptible deflection in the galvanometer. The constant temperature room of the laboratory was unfortunately occupied by another research, but every precaution was taken to protect the apparatus from changes of temperature. The doors and the windows were kept closed, the galvanometer and the observing table were further protected from air currents by screens, the copper lead wires were wound thickly with strips of cotton batting, and carried from one instrument to another over a wooden frame. The resistance of the lead wires was 0·48 ohms at 20°.

Commutators.—When the specimens were first placed in position in the thermostat, the current from the thermopile was sent directly through the galvanometer, shunted by a standard coil, or with a resistance in series. The lead wires were branched so that the current through the galvanometer could be reversed either by a four-point mercury commutator or by a double throw copper switch. Both were tried and the mercury commutator was found to be less disturbed by local thermal effects; at least they were more uniform and so more perfectly allowed for. The copper switch was, therefore, removed from the circuit, so as to have no branch wires projecting, and the mercury commutator used exclusively.

The mercury commutator was made from a new block of mahogany, the mercury was freshly distilled, and the lead wires amalgamated by cleaning thoroughly with emery cloth and rubbing with the mercury; no acid was used. This commutator was placed in a small wooden box, and well protected by two thicknesses of heavy asbestos paper and loose asbestos fiber. A small wooden dowelling rod passed up through the cover to reverse the key. The thermal disturbances in the commutator and galvanometer could be found by disconnecting the thermopile and short-circuiting the lead wires beyond the commutator. The effects due to the galvanometer could be measured by lifting the reversing key and closing the galvanometer terminals at their mercury cups by a copper strap, operated through the side of the protecting box. These deflections were always small, never exceeding a few millimeters, and rarely amounting to 1^{mm}, although the entire resistance of the circuit was about 11 ohms.

The galvanometer was a three-cased "Panzer" of the duBois and Rubens design.* This was an extremely satisfactory instrument because of its high and nearly constant sensitiveness, its freedom from external magnetic disturbances, and the steadiness of the zero. The resistances of the coils were 5·5 and 5·3 ohms at 20° C., the heavier suspension (300 mgm.) was used, hung by a very fine quartz fiber. The sensitiveness was tested twice a day or oftener with a potentiometer, using a cadmium cell for a standard of electromotive force and several standard coils. This circuit was entirely independent of the rest of the apparatus and was disconnected from the galvanometer when not in use. The telescope, made by Alvan Clark of Cambridgeport, gave a large, clear image and tenths of millimeters could easily be read. A current of $4{\cdot}1\times10^{-11}$ amperes gave 1^{mm} deflection from zero at a scale distance of 4·2 meters. When the thermopile was connected directly through the galvanometer, 60 ohms were in circuit and a difference of $0^{\circ}{\cdot}000001$ between the inner and the outer row of junctions would give a deflection of $1{\cdot}7^{mm}$ from zero. so that a mean gradient of $0^{\circ}{\cdot}0000001$ per cm. could certainly have been detected.

The Potentiometer.—The electromotive force of the thermopile was usually measured by a potentiometer, kindly placed at my disposal by Professor B. O. Peirce. The slide wire, which could be easily changed, rested upon a glass scale. The keys were provided with springs, insuring uniform pressure on the wire. The contacts and the cable were copper, and like all the other connections were covered with cotton. A standard cadmium cell was used, and the resistance (R) in the main circuit was adjusted so that the fall of potential was 1 volt over 10,000 ohms in r. A D'Arsonval galvanometer (D), sensitive to a change of 1 ohm in the box R, was used for this adjustment. Unless the glass scale of the potentiometer was kept very clean, troublesome leakages and short circuits occurred. Washing the glass with alcohol and with ether was found to be effective.

* Zeitschr. für Instr., xx, pp. 65–78, 1900.

When the cylinders were first placed in the thermostat, the outside cooled down rapidly and the gradient was large. It was more convenient to follow this down by sending the current directly through the galvanometer. But after some hours the difference of temperature was small, and it was then measured on the potentiometer.

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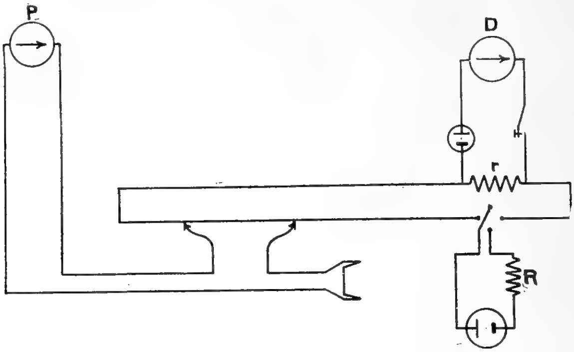

Three copper slide wires were used, as follows:

Size.	Diam.	Ohms/meter.	Cm./0°·000001.
18	1·024^{mm}.	0·01979	0·22
12	2·053	0·004922	0·86
3	5·827	0·0006106	7·1

Summary.—A brief enumeration of the changes made in Dr. Thwing's apparatus may now facilitate comparison. These changes were made, not so much because they were necessary as because they seemed to add to the certainty of the results.

(1) The junctions were all placed inside the cylinders, in order to expose them in the same manner.

(2) In the final observations, the circuit was all of copper to avoid disturbing thermo-electric forces.

(3) An armored astatic galvanometer of unusual qualities was available, instead of a D'Arsonval, which usually has internal electromotive forces.

(4) A potentiometer was used to measure the e.m.f. of the thermal couples instead of sending the current produced by them through the galvanometer.

(5) Constant conditions were maintained by slowly stirring the ice to drain it dry and using conical bottoms on the thermostat and ice vat to prevent the ice from melting away from the thermostat. To this same end the external parts were protected from large or sudden changes of temperature.

(6) The specimens were suspended in the air bath so as to expose them at all surfaces equally, instead of piling them on a block of stearine and a paper box.

(7) Finer wires and thinner insulation were used in the thermopile, bringing the cylinders closer together.

(8) The lead wires from the thermopile to the outside connections were much longer, insuring against conduction of heat to the end junctions.

Observations and Results.

I shall now give a brief history of the experiments. As Dr. Thwing found the largest effect in lead, it was selected; iron was taken for a second metal, chiefly because of the ease with which it can be worked. Four cylinders of each metal 12×5^{cm} and two 12×9^{cm}, were cast early in January; all of each metal were of the same pouring. Two of the smaller size were also cast from a different sample of lead. One pair of the smaller cylinders of each metal was turned at once and laid aside while the rest of the apparatus was being constructed; owing to delays and trouble with the ice bath, the final observations were not made until July.

When I outlined this investigation, I provided for certain variations and check experiments. I planned to use cylinders from the same pouring with fresh surfaces and with aged surfaces, hence the extra small cylinders and the considerable allowance for turning; also as a check experiment, to use cylinders twice as thick; but for this, I should have made my thermostat 5 to 8^{cm} shorter. As my results have been entirely negative, these other forms of the experiment have not been made. The work on the radio-activity of metals shows that it may be much lessened by scraping the surfaces, and if a specimen long exposed to the air does not give a positive result, a fresh one could not be expected to do so. The variation with thicker cylinders was also given up for the same reason.

Throughout the work, all the ice and drip-water was weighed to detect honeycombing of the ice. The ice was kept at nearly the same level by the addition of a sufficient quantity every four or five hours to fill the vat to a certain mark. The thermopile was tested before and after each pair of specimens. There was a very slight e.m.f. detected, due probably to uncontrolled external conditions. This was less than the slight continuous movement of the zero.

The first run (April 5–13) was made on lead. In this set of observations the current from the junctions was sent directly through the galvanometer, which was only about 1/20 as sensitive as in the other runs. The ice was kept covered with a blanket, and crowded down from time to time. A steady condition was not reached, owing to the manner of managing the ice-bath. The gradient was variable, even reversing at times, after the ice had melted out, at times rising to values fully as large as those observed by Dr. Thwing; but even this imperfect series gave no indication of a steady gradient, i. e. there was no positive effect toward which it returned after being disturbed.

The second run (May 8–20). The spudger had meanwhile been installed, the sensitiveness of the galvanometer increased to its final value ($4{\cdot}1 \times 10^{-11}$ $^{\mathrm{amp}}/_{\mathrm{mm}}$ from zero at a scale distance of $4{\cdot}2^{\mathrm{m}}$). Owing to trouble with the spudger and a final breakdown, this run gave no additional evidence on the problem.

The third run (June 29–August 1). The use of the spudger was at first continued, but after a few days was replaced by stirring the ice at frequent intervals. In this run the work was continued day and night, much of the observing being done at night when the room temperature was less variable and the building was free from mechanical jars. The intermissions were brief, and during them the apparatus was left under the care of some other person, who stirred the ice occasionally to prevent too great an accumulation of water and who added more ice if necessary. Two samples of lead and one of iron were very carefully tested and sufficiently steady conditions were maintained for three or four hours at a time to show unmistakably that no mean gradient as great as 0°·0000001 existed.

It would be interesting to compare the cooling curves with those computed, but as the labor of maintaining steady conditions was so great I did not attempt to make observations until I knew the cylinders had cooled practically to zero throughout. The specimens were placed in the thermostat at about 20°, and it seemed to require fully 24 hours to bring the junctions of the thermopile to sensibly the same temperature. This is considerably longer than is required for the cylinders to cool to the same gradient, the difference indicating a lag between the junctions and the cylinders, due to the insulation of the asphaltum, but this is no evidence that they did not ultimately assume the temperature of the adjacent metal. The pressure at the bottom of the thermostat, due to the weight of 25^{cm} of ice, is about 1/50 of an atmosphere, which will cause a lowering of the melting temperature of 0°·00015. Possibly, when the vat is jarred by the stirring, convection currents may be set up, but they will not affect the temperature of the copper wire projecting beyond the cylinders, for the additional mica covers them (see fig. 1), and may be relied upon to protect them from so small an effect as that due to the passing of the small quantity of air transferred by convection.

In the early part of this paper (p. 453), I called attention to the fundamental change I made by placing all my junctions between the cylinders in order to expose both rows equally. I wish now to explain why this change was made.

Let us compute the gradient in a sphere of radius c, in which b calories are generated per gram per second. Take ρ = density, k = conductivity, h = surface conductivity. Then when a steady state has been set up,

$$\frac{4}{3}\pi r^3 \rho b = -4\pi r^2 k \frac{dt}{dr}$$

$$r = -\frac{3k}{\rho b}\frac{dt}{dr}$$

Integrating, $$\frac{r^2}{2} = -\frac{3k}{\rho b}t + \mathrm{C}$$

To determine the constant of integration,

when $r = c$, $$\frac{4}{3}\pi r^3 \rho b = 4\pi c^2 hkt_c$$

$$t_c = \frac{c\rho b}{3hk}$$

$$\mathrm{C} = \frac{c^2}{2} + \frac{c}{h}$$

and the temperature at any point is given by the equation

$$\frac{r^2}{2} = -\frac{3k}{\rho b}t + \frac{c^2}{2} + \frac{c}{h}$$

from which it appears that the gradient is a parabola.

Strutt* in a determination of the ionizing power of common materials, states "radium is 100,000 times more active than uranium, and uranium 3000 times more active than the most active material I have experimented with. So that one part of uranium in 300,000,000 would suffice to account for the observed effects." His results show as wide a range for different specimens of the same metal as for different metals. So although he did not try iron, we may reasonably suppose that it would give an effect similar to that set for the maximum; the order of magnitude is all that can be shown by such a computation as this. Curie and Laborde† found that radium

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* Phil. Mag. (5), v, pp. 680-685, 1903.

† Comptes Rendus, cxxxvi, p. 673, 1904.

radiated heat at the constant rate of about 100 gram calories per hour per gram. Applying this, Strutt's most active material would radiate 9×10^{-11} gram calories per second per gram. Substituting this and the other constants for iron, we have, with $c = 5^{\text{cm}}$,

$$15\times10^{8}t = 8025-r^{2},$$

from which we get,

r	$15t$	t
0^{cm}	$8\cdot025\times10^{-5}$	$5\cdot35\times10^{-6}$
1·0	8·024	
1·4	8·023	
2·1	8·021	
4·4	8·006	
5·0	8·000	5·33

The junctions of my thermopile came at the third and the fifth of these points, and it will be seen that the difference between these could certainly have been detected with my apparatus. Dr. Thwing gives the temperature of iron at $r = 2\cdot1$ as $3\cdot2\times10^{-5}$, i. e. his iron was about six times as radio-active as Strutt's most active substance, if we grant that the outer junctions of the thermopile in the air bath were at zero, and that the entire leak in Strutt's electrometer was due to the radio-activity of the specimens tested and not partially due to other causes, as the emanations from the earth.

It is interesting to compare, in this connection, the gradients in the same sphere of iron, heated to 20° throughout and allowed to cool in the air bath at 0°;* we get:

r	5 min.	15 min.	1 hour	2 hours	3 hours	6 hours
0	19·°221	17·687	12·450	0·1010	0·00717	$2\cdot57\text{x}10^{-6}$
1·4		17·683				
2·1		17·679				
4·4		17·645				
5·0	19·161	17·632	12·410	0·1007	0·00715	$2\cdot56\text{x}10^{-6}$
Diff.	0·060	0·055	0·040	0·0003	0·00002(2)	$0\cdot08\text{x}10^{-6}$
%	0·31	0·31	0·32	0·32	0·31	0·31

Similar computations have not been made for lead, because, so far as I can find, experiments have failed to measure the radio-activity of lead.

These tables show the decided discontinuity at the surface; in fact, in both cases, only about 0·3 of 1 per cent of the total difference of temperature between the center and the air bath occurs in the sphere itself; and moreover, this fraction remains very nearly constant throughout the range computed. The poorer the surface conductivity, other things remaining equal,

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* W. E. Byerly: Fourier's Series, etc., pp. 116-122. Boston, 1893.

the greater will be the fraction of the total difference occurring at the surface. The computations were made for spheres rather than for a cylinder, because of the greater simplicity of the formulas. The gradients in the plane through the center and parallel to the bases of a cylinder 10^{cm} in diameter and 5^{cm} tall will be similar to those in the spheres but the part of the drop which is in the metal will be smaller, because of the greater surface in proportion to the volume and the fact that the center is nearer the surface along the axis than before; hence the relative discontinuity at the surface will be even greater for the cylinder.

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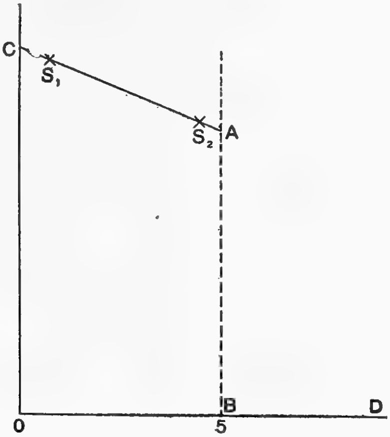

Suppose, then, that the cylinders are cooling in air, either with or without a generation of internal heat; the gradient is CA–BD. My inner junction at S_1 will come to the temperature of the adjacent metal, unless there is some small gradient in the thin coating of asphaltum, and this is certainly slight, as the quantity of heat transferred to maintain equality is small. So long as the sphere is cooling, i. e. so long as the gradient CA exists, heat will flow into this junction and down the constantan wire, as well as through the cylinders themselves. Again, the outer junction comes very nearly to the temperature of the adjacent metal; there may be a gradient through the insulation here as at the inner junction, and this gradient may be from wire to cylinder or from cylinder to wire, depending on the relative ease of conduction and radiation from the cylinders and from the thermopile to the surrounding air. So the difference of temperature between the junctions is (except for the possible case of opposite gradients in the insulation, which are probably very small compared with that between the junctions) equal to that in the adjacent metal. This method measures the gradient in the metal itself, while Dr. Thwing's does not, although he states his results in that way. But it is to be noted that any method working on gradients in the metal is insensitive, because the large discontinuity at the surface makes the gradient in the metal itself small.

Suppose, on the other hand, that the outer junction be placed in the air bath, as in Dr. Thwing's arrangement. It would seem, at first sight, that this would be a much more sensitive method for detecting internal generation of heat, because while the inner junction is at the temperature of the adjacent metal as before, the outer junction is supposedly at the temperature of the air bath. This reasoning I believe is dubious. Heat is still flowing down the wire, and must now be radiated into the air from the junction itself through its coating of asphaltum, and while we may well believe that the inner junction is at, or very near, the temperature of the metal at that point, and that the temperature of the wire as it passes along the radius of the cylinder is not far from that of the adjacent metal; still the outer junction, cooling as it does, is above the temperature of the air bath, due to the greater discontinuity when cooling takes place with the poorer surface conductivity through the insulation. This well known fact must be borne in mind when, as here, a thermojunction is exposed in air, and proper precautions must be taken to insure that the true temperature of the surroundings is attained.

In conclusion, I desire to express my sincere thanks to Professor E. H. Hall, who first suggested the work to me and who made valuable suggestions at the beginning, and to Professor B. O. Peirce for his kind interest and encouragement and the generous loan of apparatus.

Jefferson Physical Laboratory,
Harvard University,
Nov. 11, 1907.

Art. XLII.—*Aggraded Terraces of the Rio Grande*; by Charles R. Keyes.

The Rio Grande is probably the most remarkably terraced drainage-way in the world. Bordering the stream is an extensive succession of high-level mesas that constitute the most striking feature of the great valley's surface relief.

These escarpmented plains, or mesas, inclining strongly towards the river, are abruptly cut off as they near the banks of the stream. The different series of terraces are at levels 20 to 250 or 300 feet above the flood-plain. The areal shape of the plains is roughly that of a parallelogram, very long in proportion to the width, the longer axis disposed at right angles to the stream. Viewed from the side, the relationships of several mesas is as represented in diagram below (fig. 1):

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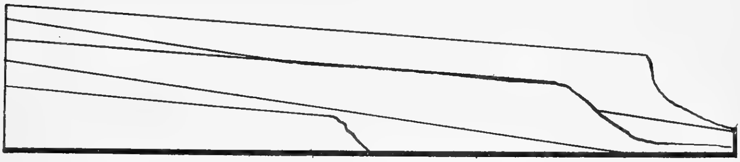


Relationship of Rio Grande mesas.

In their wide extent, in their marked inclination towards the river, in their isolated character, and in their smooth and even surface, these high-lying plains present notable accentuations of physiographic expression that are rarely recognizable outside of the semi-arid regions. These elevated plains of the broad river valley have long attracted the attention of travelers. Many have been the explanations of their origin. No solution of their genesis has yet appeared that is at all satisfactory, or that takes into account the unusual climatic conditions of the region, and the novel geologic agencies at work.

The Rio Grande is one of the great rivers of the American continent. It is as long as the Mississippi. Unlike the case of the latter stream, it has, for a long river, a very high gradient. For the first thousand miles, from its headwaters, the average fall is over five feet to the mile. In times of flood, when the snows are melting in the mountains, the waters are almost of torrential nature. At other times, as in the months of July and August, the stream is often very nearly dry, although there is always a strong underflow beneath the sandy bottom.

After leaving the headwaters region, a distance of perhaps

300 miles, the Rio Grande receives no lateral augmentation from perennial tributaries in a distance of nearly one thousand miles, or nearly to the mouth of the Rio Pecos in Texas. Through most of this part of its course the river-bed is 1,000 to 2,500 feet below the level of the bolson plains lying on either side of the great valley.

Physiographically the Rio Grande has had a complex origin. That portion of its course which lies in New Mexico is largely antecedent in character. Other parts may be consequent. Climatic conditions with which most of us are not very familiar are chiefly responsible for many of the bold and unusual relief effects that characterize the region through which the Rio Grande flows. The valley mesas, or table-plains, are among the most instructive of all of these topographic features.

Being a stream of such high gradient, with an average fall, as already stated, for its 300 miles in New Mexico of over five feet to the mile, its corrading powers are little short of marvelous and its carrying capacity amazing. During the dry season of the year the waters of this stream are greatly overburdened with sediments and the channels rapidly silt up. In late years, since most of the water has been taken out for irrigation purposes, the silting-up process has become a very serious matter. Many localities show clearly that within the last dozen years the deposition has filled up the valley to heights of 20 to 30 feet.

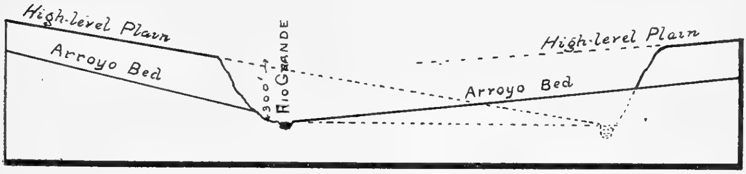
As already mentioned, no lateral drainage of a perennial nature is received by the Rio Grande within the borders of New Mexico. All increase of the grand stream from the sides takes place only during brief periods of very heavy rainfall. The side waters are then torrential. At other seasons of the year these tributaries are true arroyos, or dry creeks, as their Spanish title signifies. These arroyos have very steep gradients, often two to four and even five per cent.

In the mountain ranges on either side of the valley of the great stream the arroyos occupy deep canyons. In this part of their courses the channels are being rapidly cut deeper and deeper into the indurated bed-rocks. After emerging from the mountains these lateral drainage-ways are as pronouncedly constructive in character as they were destructive before.

Into the broad Rio Grande valley the side arroyos pour vast quantities of coarse mountain waste. The alluvial fans which are formed become confluent. On either side of the river broad plains several miles wide are built up; and these are inclined strongly towards the channel of the master stream. Were the river free from meandering, these plains on each side would doubtless become continuous and even.

In the course of its wide meandering the stream cuts rapidly into its banks on the convex side of its broad swings. In a distance of two or three miles lateral change of channel a cliff 100 to 200 feet in height may be formed. Arroyos entering the river from the bowed side quickly shorten their paths, assume new and higher gradients, and scoop out canyons in the old fans. Thus, between the adjacent arroyo-courses there is left a high-level terrace, or mesa, bordering the main waterway. On the opposite side of the bow the arroyos lengthen their courses, lower their gradients, and build out new extensions of their fan-plains to the water's edge. This phenomenon is best shown in diagram, by an actual section across the Rio Grande at Socorro (fig. 2).

2



High-level plains of the Rio Grande, at Socorro.

The processes described are repeated again and again, along the entire course of the river. As a final result there are found sloping terraces at many different levels. The effects are apparently as unique as they are striking. Closer inquiry clearly shows that the same relief effects exist along the streams in more humid regions: only in the last named cases the characteristic phenomena are all but totally obscured because here destructive processes are far more active than the constructive. In the semi-arid districts the gradation conditions are reversed.

The typical characters of the high-level plains along the Rio Grande are well displayed at many points. At El Paso, at Rincon, at Socorro, at Albuquerque and at San Filipe they are finely shown. Near the last named place another interesting factor comes into play. At different times during the latest geologic epoch great basalt-flows have moved down the plains towards the river. These have preserved the surfaces of the old mesas at different levels. In some instances the river has quite recently cut through the lava-cap, as represented below (fig. 3).

The best description of these high-level terraces is given by Herrick.* Although they were thought by this writer to be striking enough to deserve the distinguishing title of clino-plains, he did not even hint at their real origin.

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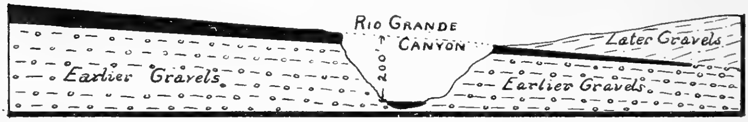
* American Geologist, vol. xxxiii, p. 376, 1904.

A more recent description of what appears to be a very similar phenomenon, but upon a miniature scale and in the humid region of Vermont, is that of Fisher.* This account is important in this connection in showing that the general features are also recognizable beyond the arid districts.

The original surface of the line of bolson plains, through which the Rio Grande now treads its way, appears to be from 700 to 1000 feet above the present bed of the stream. At the present time there are remaining only few traces of these old bolson surfaces. Most of these remnants have been preserved only on account of being covered by extensive lava sheets. The Albuquerque volcanoes and basalt sheets, six miles west of the city, on the divide between the Rio Grande and the Rio Puerco, seem to rest on the old bolson surface. The basalt fields near Santa Fe have similar relations. The elevated plain, southwest of Socorro, also appears to belong to the same class. Farther south at Paraje, at old Fort Selden and at El Paso, the same remnantal levels are noted. All of these mesas are to be carefully distinguished from the so-called clinoplains of the Rio Grande valley proper, that are seldom found rising more than 200 to 300 feet above the water-level in that stream.

3



Basalt flows cut by the Rio Grande at San Filipé.

There is still another class of plains which might be easily taken for terraces bordering the Rio Grande, that should be clearly separated from all the others. These may be in a sense regarded as lake-benches. They are due to the damming of the river for a brief period. Evidences are abundant indicating that the Rio Grande has been in very recent times and at various points dammed by the crossing of volcanic flows. At old Fort Selden, at San Acacia above Socorro, at Algodones above Albuquerque, at the White-Rock canyon west of Santa Fe and at the Black canyon south of San Antonio, basalt-flows have covered the course of the river and produced a temporary choking up of its waters. These barriers thrown across the river were from 200 to 500 feet in height.

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*Proc. Boston Soc. Nat. Hist., vol. xxxiii, pp. 942, 1906.

Under the conditions now existing it would be expected that such dams would leave conspicuous traces of the existence of the lakes. Such, however, does not appear to have been the case. At least, the lakes were so ephemeral in character that they left no evidences of distinct beach-levels, or elevated lines of delta-fans. It may be that the fans were confluent in such cases, and that the entire areas of the high plains, as those existing above the White Rock canyon, at Rincon, and above the mountain barrier at El Paso, represent these temporary lake deposits.

Notwithstanding the turbid character of the river waters and the prodigious quantities of coarse materials carried by the swiftly flowing stream, any lake that may have been formed must have quickly disappeared through the cutting of the dam or holding barrier. Even with some extraneous accumulations of sediments the local gradient was soon lowered, and the great influx of coarse sands and gravels from the lateral arroyos must have rapidly destroyed all traces of the lake beds and moulded them into new aggradation surfaces. In any case it would be exceedingly difficult to differentiate these plains of old lake-basins from ancient arroyo fillings. Moreover, the plains aggraded by the arroyos extend, at the distal and more elevated side, very much higher than would be possible for lake beds to do. If any deposits of the last mentioned class were formed, they would be quickly destroyed, or so disguised as to be almost unrecognizable.

When the barriers finally disappeared, enabling the river to recover its original lower level and to renew its old meanderings, the gradients of the lower courses of the arroyos were greatly increased, and the high aggradation-plains were cut by canyons more or less parallel to one another. This may be the explanation of certain local series of close-set, parallel canyons found at such places as in the Pajarito Park district west of Santa Fe.

Many erroneous notions are entertained regarding the history of the Rio Grande. Travelers unaccustomed to the novel effects of the workings of the geologic agencies in the arid and semi-arid regions are prone to explain everything in terms of their native humid heaths. As a result much that is fanciful has been indulged in. With the exception of W. J. McGee even the trained geologists, who have traveled through the region, seem to have entirely overlooked the two most vigorous geologic processes of the arid regions—the eolian and the planorosive, the latter more widely known among the dwellers of those regions as sheet-flood erosion. Both are practically unknown to people living in those parts of the world where there are abundant rains. They give rise to phenomena the explanation of which present great difficulties by the other and more familiar agencies.

There appears to be much misconception regarding the composition of the deposits which go to make up the aggraded plains of the Rio Grande and other large rivers of the Southwest. The substructure is almost invariably spoken of as gravel. This seems hardly correct. To be sure, the entire surface of the plains might easily be mistaken for exposures of gravel-beds. Closer inspection clearly shows that by far the greater part of such deposits is made up of clay, called by the the Mexicans adobe. In this adobe there are commonly a few small pebbles. For the most part the most gravelly surface when turned by the plow gives a loamy soil, such as is possessed by the prairies of the Mississippi valley, except the color. There are some gravel-beds, but on careful examination they are found to be very limited and to represent gravel-trains of former arroyo-courses. They are sharply defined gravel streams traversing the old fans.

Over most of the arid regions the winds blow away the fine soil at the surface until there is left a layer of closely set pebbles which act as a protection to the further action of this kind. The fact that the plains deposits are largely adobe instead of coarser materials, as one would naturally expect from surface appearances and from long experience in humid regions, is at first very surprising. That the deposits in question are composed chiefly of fine clays is due mainly to the effects of planorosion, or flood-sheet erosion as it is termed by McGee. The deposits of this vigorous geologic process are principally clays rather than sands and gravels. This is probably an explanation for most of the extensive so-called Tertiary and Quaternary "lake-deposits" of many portions of the West. Planorosion is peculiar to arid regions. It is neither fluviatile, nor lacustrine, nor maritime in nature, but sheet-flood erosion in its strictest sense, modified by eolian influences during dry times.

ART. XLIII.—*Waterglass;* Part VI; by JOHN M. ORDWAY.

[Continued from vol. xl, p. 190, 1865.]

THE urgent duties of a busy life have interrupted this investigation for many years, but latterly changed circumstances have allowed the work to be resumed, and now something may be added to what has already been set forth.

It has been shown that alcohol throws down the silicates of potassium and sodium from their solutions, retaining at the same time a portion of their base. Acetone and methylic alcohol are found to answer equally well as precipitants. Sometimes neutral saline solutions may be advantageously used for the same purpose. And most of such deposits, as well as precipitated silicates of the other metals and hydrated silicic acid itself, can be nearly freed from the mother liquor by folding the drained curd in closely woven cotton cloth and subjecting to strong pressure applied gradually. The cloth can be peeled off from the cake with very little loss.

Of course the water in the cake is partly water of hydration and partly absorbed mother liquor; and how much there is of each cannot always be determined. But when a chloride, incapable of forming a basic salt, has been used in the precipitation, the amount of retained mother liquor may be ascertained by comparing the percentage of chlorine in the pressed curd with that in the remaining liquid.

Experiments 3*a*, *b* given below will serve to show what differences there may be between the gross analyses and the net composition obtained by deducting the small quantities of solids due to retained mother liquor. But the differences are slight, and for our present purpose perfect exactness has been deemed unnecessary. Therefore, except when otherwise specified, the gross analysis is given; and for the sake of convenience and brevity, the results are expressed approximately in empirical, dualistic formulas, the water of combination being left out of account.

Silicates of Lithium.—These are sometimes spoken of as being insoluble in water. But this really applies only to the anhydrous compounds such as are formed by fusing the carbonate with silica. In fact when we mix weak solutions of sodium waterglass and lithium chloride there is no precipitation. Hence either no exchange of bases takes place or the lithium waterglass remains dissolved. But when strong solutions are put together an abundant deposit is formed, the nature of which is shown by the following experiments:

1. 13 grams of a 31 p. c. solution of lithium chloride added to 100 cubic centimeters of a solution containing 10 g. of $Na_2O{\cdot}3SiO_2$

gave no precipitate, but alcohol threw down a curd which when hard pressed weighed 21 g. and contained 65 p. c. of $5(Li_2O{\cdot}3SiO_2) + 6(Na_2O{\cdot}3SiO_2)$. This dissolved readily in a little more than twice its weight of water.

2. 40 g. of the 31 p. c. lithium chloride solution with 100^{cc} of the same sodium trisilicate gave 17 g. of cake showing 55 p. c. of $3(Li_2O{\cdot}3SiO_2) + Na_2O{\cdot}3SiO_2$, and soluble in 1·6 times its weight of water.

3, *a*. 86 g. of a 20 p. c. lithium chloride solution were put with 154 g. of a 20 p. c. solution of $Na_2O{\cdot}4SiO_2$. The cake weighed 48 g. It contained gross 56 p. c. of $7(Li_2O{\cdot}4SiO_2) + 6(Na_2O{\cdot}4SiO_2)$. Net 54·4 p. c. of $7(Li_2O{\cdot}5SiO_2) + 6(Na_2O{\cdot}4SiO_2)$.

3, *b*. The cake of *a* was dissolved in twice its weight of water. 133 g. of this liquid with 75 g. of the lithium chloride solution gave 46 g. of cake containing gross 51·7 p. c. of $7(Li_2O{\cdot}4SiO_2) + 3(Na_2O{\cdot}3SiO_2)$; net 50·7 p. c. of $9(Li_2O{\cdot}4SiO_2) + 5(Na_2O{\cdot}5SiO_2)$.

3, *c*. The cake of *b* treated with 102 g. of water left a very little sediment; 120 g. of the filtered solution with 60 g. of a 25 p. c. lithium chloride solution gave 49 g. of cake not entirely soluble in 150 g. of water. The dissolved portion contained net 42 p. c. of $2(Li_2O{\cdot}4SiO_2) + (Na_2O{\cdot}4SiO_2)$.

4. 110 g. of a 12 p. c. solution of $Na_2O{\cdot}3SiO_2$ with 40 g. of a 31 p. c. lithium chloride solution yielded a curd containing 54 p. c. of $3(Li_2O{\cdot}3SiO_2) + Na_2O{\cdot}3SiO_2$. This dissolved readily in twice its weight of water.

5. 50 g. of a 20 p. c. solution of $K_2O{\cdot}2SiO_2$ with 30 g. of an 18 p. c. solution of LiCl gave 7 g. of cake containing 40 p. c. of $Li_2O{\cdot}2SiO_2 + K_2O{\cdot}2SiO_2$.

6. 30 g. of a 20 p. c. solution of $K_2O{\cdot}3SiO_2$ with 30 g. of an 18 p. c. solution of LiCl gave 10 g. of cake mostly soluble in 4 parts of water. The clear solution contained 7 p. c. of $3(Li_2O{\cdot}3SiO_2) + 2(K_2O{\cdot}2SiO_2)$.

So we may make an endless variety of mixed or double silicates of lithium and sodium or lithium and potassium. Starting with a given potassium or sodium waterglass, the relative proportion of lithium may be gradually increased by dissolving the successive cakes and reprecipitating with lithium chloride. And until we get beyond a tetrasilicate the deposit is completely soluble in a small amount of water. Were the precipitations continued, it would be necessary to add lithium hydroxide to the later solutions to keep them from being too silicious. But an attempt to eliminate the sodium entirely would probably develop into an infinite series of trials.

A saturated solution of the lithium hydroxide contains but a small percentage of the alkali and to concentrate a siliceous liquor which has been much diluted with such a solution we cannot resort to evaporation by heat. For it has been found that when any sodium lithium waterglass is heated a precipitate is formed which, if the heating is not long continued, is mostly or wholly redissolved on cooling. This precipitation must be due to the lithium constituent, since sodium waterglass alone is not so affected. Could the deposit then be a simple lithium silicate?

In making quantitative trials with respect to this matter it is, of course, necessary to keep up the heat till the curd is removed from the solvent action of the mother liquor. Therefore the dish holding the liquid, the stirring stick, the press cloth and frame, the draining dish and the press boards were heated together in an oven kept at the desired temperature. While still in the hot space the curd was transferred to the cloth and drained and the folded cloth was placed between the boards. These were then quickly withdrawn from the oven and subjected to strong pressure.

7. 37 g. of a solution containing 19 p. c. of $2(Li_2O{\cdot}3SiO_2)+Na_2O{\cdot}2SiO_2$ were heated to 80° C. The cake was transparent and weighed a little over one gram and had 49 p. c. of $Li_2O{\cdot}3SiO_2+Na_2O{\cdot}3SiO_2$. It dissolved readily in cold water.

8. 85 g. of the same solution heated to 90° C. yielded 6·5 g. of transparent cake containing 58 p. c. of $5(Li_2O{\cdot}3SiO_2)+2(Na_2O{\cdot}3SiO_2)$. This dissolved completely in three times its weight of water. 24 p. c. of the solid matter had been thrown down.

So this lithium constituent imparts its thermic character to its associate and the two refuse to part company.

It seemed barely possible that mixed monosilicates with the lithium element largely predominant might be made to yield a pure lithium silicate by fractional crystallization.

9*a*. 56 g. of a 13 p. c. solution of $Na_2O{\cdot}4SiO_2$ with 60 g. of a 7 p. c. solution of LiHO produced a coagulum which soon redissolved. A dish holding the clear solution was put under a bell glass with two dishes of calcium chloride in lumps. In four weeks, the temperature ranging sometimes as high as 40° C., the weight was reduced to 21 g. In this residue were some bits of an apparently crystalline crust amounting to nearly two grams. These were perfectly soluble and consisted of $7(Li_2O{\cdot}SiO_2{\cdot}4H_2O)+Na_2O{\cdot}SiO_2{\cdot}4H_2O$. The rest was a somewhat pasty mass of opaque amorphous matter.

From what has been detailed so far it may fairly be inferred that the clean dissociation of double silicates cannot be brought about by any mode of treatment.

After the discovery of the peculiar effect of heat on lithium-bearing silicates, the way was clear to attempt the formation of a simple hydrated lithium silicate by direct synthesis. The union must be effected without the use of heat.

In preparing silicic acid hydrate by mixing weak solutions of sodium waterglass and ammonium chloride, it was found advantageous to add some methyl alcohol to aid in the disintegration of the coagulum. The precipitate was hard pressed, crushed and washed with water and alcohol. After a second washing the pressed cake was dried in the air. The hydrate seems to have no fixed and definite composition, but after becoming apparently dry it may continue to part with water, like an efflorescing salt. Thus when some which appeared at first to be a sexhydrate was kept in dry air three weeks it was reduced to $2SiO_2+H_2O$.

Lithium sulphate being decomposed by barium hydroxide the very dilute solution was boiled down in a nickel dish till it let fall some of the oxide. This saturated solution contained about seven per cent of $LiH{\cdot}O$. When it was digested, at the ordinary temperature of the air, with enough of the silica to form a monosilicate, very nearly all of the silica was taken up and the filtered solution showed 8·5 p. c. of Li_2SiO_3 besides a slight excess of LiHO.

9b. 128 g. of this clear liquid, in a glass dish which would allow the slightest change to be seen, were confined over calcium chloride, the temperature at no time exceeding 22° C. In five days a faint deposit began to appear and the loss amounted to 32 g. The point of saturation being thus reached, it appears that lithium monosilicate is perfectly soluble in water and the solution may contain as much as eleven per cent of Li_2SiO_3.

10. 30^{cc} of dilute chlorhydric acid (3·65 g. of HCl in 100^{cc}) mixed with 50 g. of a 5 p. c. solution of Li_2SiO_3 caused no apparent change. The addition of 40^{cc} of alcohol produced a soluble cake weighing 4·7 g. and containing 35 p. c. of $Li_2O{\cdot}2SiO_2$.

11. 304 g. of a solution containing 6 p. c. of Li_2SiO_3 and 0·3 p. c. of Li_2O treated with 149 g. of dilute nitric acid (5·4 p. c. N_2O_5) gave with 370^{cc} of methyl alcohol 36 g. of cake mostly soluble in less than three parts of water. It showed 36·5 p. c. of $10Li_2O{\cdot}23SiO_2$. The residue consisted chiefly of 0·5 g. of SiO_2.

Some of the cake solution being evaporated began to show a deposit when it contained 24 p. c. of the silicate. The evaporation being continued till the percentage amounted to 30 it became a very stiff, opaque, amorphous mass. This dissolved completely in its own weight of water. This latter solution with half its bulk of alcohol gave a deposit holding 39 p. c. of $10Li_2O{\cdot}27SiO_2$ and soluble in twice its weight of water.

12. 105 g. of a solution containing 7 p. c. of Li_2SiO_3 and 0·2 p. c. of Li_2O with 43 g. of dilute nitric acid (10 p. c. N_2O_5) and 50 g. of 18 p. c. LiCl yielded 9 g. of cake not entirely soluble. The soluble part amounted to 21 p. c. of $10Li_2O{\cdot}19SiO_2$.

The mother liquor with 100^{cc} of methyl alcohol gave 7·9 g.

of cake almost entirely soluble and containing 38 p. c. of $10Li_2O\cdot 23SiO_2$.

13. 50 g. of a 7 p. c. Li_2SiO_3 solution heated almost to the boiling point gave an abundant precipitate of which about five-sixths redissolved on standing two days.

14. 47 g. of a liquor holding 21 p. c. of $10Li_2O\cdot 23SiO_2$ heated to 90° C., made a hard mass that could not be got out of the beaker. On cooling it liquefied again and the next day showed very little sediment.

Rubidium Silicates.

From the chemical similarity of the light metals we might suppose that rubidium would afford a series of silicates like those of potassium. But positive proof is better than analogical conjecture. And verification was possible because happily the lepidolite that furnished material for the lithium experiments contained rubidium also. Some rubidium hydroxide was made by decomposing the sulphate with baryta, and some by the better method of burning the bitartrate and boiling the resulting carbonate with lime. A clear solution was evaporated in a nickel crucible till it contained 21 p. c. of Rb_2O. Nearly enough silicic acid hydrate being added to make a monosilicate, the boiling down was continued till the Rb_2SiO_3 amounted to 82 p. c. The thick liquid on standing showed no disposition to crystallize. Diluted and heated with more silica it took up sufficient to form a bisilicate. Precipitation with alcohol gave more silicious compounds.

15. 100 g. of a solution containing 16·5 p. c. of $3Rb_2O\cdot 10SiO$ with 35^{cc} of alcohol gave a cake weighing 16 g. and containing 71 p. c. of $Rb_2O\cdot 4SiO_2$. This dissolved in twice its weight of water.

The mother liquor with 40^{cc} of alcohol let fall a curd weighing 2·5 g. which showed 71 p. c. of $2Rb_2O\cdot 7SiO_2$.

16. 160 g. of 21 p. c. $4Rb_2O\cdot 7SiO_2$ with 150^{cc} of alcohol gave a clear liquid precipitate weighing 43 g. It contained 45 p. c. of $10Rb_2O\cdot 23SiO_2$.

17. 92 g. of liquor containing 15 p. c. of $10Rb_2O\cdot 29SiO_2$ with 22^{cc} of alcohol produced 22 g. of cake not entirely soluble. The soluble part amounted to 58 p. c. of $10Rb_2O\cdot 46SiO_2$. The residue consisted chiefly of 1·5 g. of SiO_2.

18. 45 g. of 15 p. c. $4Rb_2O\cdot 9SiO_2$ with 30 g. of 11 p. c. LiCl let fall 4 g. of cake, not completely soluble. The soluble portion amounted to 29 p. c. of $17(Rb_2O\cdot 2SiO_2)+14Li_2O\cdot SiO_2$.

Action of Ammonia on Waterglass.

When caustic soda is poured into a strong waterglass solution it produces a momentary cloud; lithium hydroxide gives a temporary precipitate; but ammonia has a more lasting effect.

The ammonia water used in the following trials was of sp. gr. 0·900.

19. 40^{cc} of ammonia water mixed with 50 g. of a 29 p. c. solution of $3Na_2O{\cdot}11SiO_2$ gave a curd weighing 16·8 g. and showing 43 p. c. of $5Na_2O{\cdot}17SiO_2$.

20. 50 g. of a 21 p. c. solution of $5Na_2O{\cdot}19SiO_2$ with 40^{cc} of ammonia water threw down a cake containing 40 p. c. of $Na_2O{\cdot}4SiO_2$.

21. 20 g. of a 31 p. c. solution of $10K_2O{\cdot}33SiO_2$ gave 6·2 g. of cake containing 54 p. c. of $10K_2O{\cdot}38SiO_2$.

22. 40 g. of $K_2O{\cdot}3SiO_2$ with 50^{cc} of ammonia water afforded a 3 g. cake containing 55 p. c. of $K_2O{\cdot}4SiO_2$.

23. 50 g. of a 9 p. c. solution of Li_2SiO_3 with 30^{cc} of ammonia water made a 4·3 g. cake with 44 p. c. of $3Li_2O{\cdot}4SiO_2$.

24. 50 g. of a 33 p. c. solution of $10Rb_2O{\cdot}37SiO_2$ with 30^{cc} of ammonia water produced a cake weighing 10 g. and containing 23 p. c. of $10Rb_2O{\cdot}44SiO_2$.

25. 15 g. of a 45 p. c. $Rb_2O{\cdot}9SiO_2$ and 15^{cc} of ammonia water gave 9·7 g. of thin liquid precipitate. Evaporated to 7·2 g. it became very thick and almost solid. It then contained 70 p. c. of $5Rb_2O{\cdot}12SiO_2$.

In summing up results it appears that while the solubility of the silicates of sodium, potassium and rubidium is unlimited the lithium silicates have each its definite point of saturation, and the monosilicate is less soluble than the more silicious ones.

Simple lithium silicate solutions give precipitates when heated which are mostly redissolved on cooling.

Hence to concentrate weak solutions we must resort to spontaneous evaporation in dry air or in a vacuum.

So, too, we cannot expect to obtain the hydrates by boiling the anhydrous silicates in water.

Combinations of lithium silicates with those of the other alkaline metals when precipitated by heat or by other means are not dissociated, though the composition is changed somewhat.

The composition of soluble rubidium silicates, like that of potassium waterglass, may vary infinitely between the proportions of one equivalent of silicate, one equivalent of rubidium oxide and nine of silicic acid to two of base.

With lithium silicates the range is not so great.

Ammonia may give precipitates with strong solutions of all the more silicious of all silicates.

Sometimes when lithium-bearing precipitates are dissolved there is a residue which makes much show but really weighs very little.

Art. XLIV.—*The Action of Dry Ammonia upon Ethyl Oxalate;* by I. K. Phelps, L. H. Weed, and C. R. Housum.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—clxvii.]

Liebig* states that dry ammonia acts upon ethyl oxalate only with difficulty to form ethyl oxamate and a little oxamide; and further that the greater part of the ethyl oxalate remains undecomposed. Within our knowledge this is the only statement in the literature concerning the action of dry ammonia upon anhydrous ethyl oxalate. This paper records the results of experiments made to show the action both in the cold and at a higher temperature of dry ammonia upon dry ethyl oxalate.

For this work ethyl oxalate was purified by repeated fractional distillations until a product was obtained that boiled within the limits of two-tenths of a degree. For each experiment portions of this sample were freshly distilled into a dry flask. Dry ammonia was obtained by boiling concentrated ammonium hydroxide in a flask connected with a return condenser and leading the ammonia gas obtained in this way through a lime tower.

To show what effect ammonia might have on ethyl oxalate in absence of water, a qualitative test was made by passing ammonia, prepared as stated above, through a glass tube, into pure ethyl oxalate chilled in a bath of ice and salt. A white precipitate appeared after some minutes in the liquid still chilled in the mixture, but wherever the interior of the tube had been wet with the ethyl oxalate a white precipitate appeared almost immediately. This precipitate proved to be a mixture of ethyl oxamate and oxamide. The crude material obtained was freed from ethyl oxalate and the large mass of oxamide by crystallization from alcohol, and from the remaining traces of oxamide by distillation under diminished pressure. The ethyl oxamate separated by distillation in this way was recognized as pure by its melting point—114·5°. It boiled at 145° C. under 15^{mm} pressure. It was found that the ethyl oxamate may be quantitatively distilled *in vacuo* as is shown by the following experiment. A portion of the ester weighing 7·6496 grm. was introduced into a Claissen flask of 100^{cm^3} capacity connected through a rubber stopper for a vacuum distillation with a 100^{cm^3} flask used as a receiver. The side tube of the Claissen flask was short—$5·5^{cm}$—and was connected with another tube of 6^{mm} bore of sufficient length to reach well into the bulb of the receiver, the rubber stopper closing the receiver serving also as the connector between the sideneck of the Claissen flask and its extension.

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*Ann. Chem., ix, 129.

Table I.

	Ethyl oxalate	Unchanged Ethyl oxalate	Oxamic ester	Oxamide	Ethyl oxalate accounted for	Reaction time	Loss of Ethyl oxalate
No.	grm.	grm.	grm.	grm.	grm.	min.	grm.
(1)	22·319	0·545	12·714	3·461	22·144	20	0·175
(2)	13·667	3·243	5·798	1·872	13·580	27	0·087
(3)	9·627	0·240	4·375	2·300	9·510	25	0·117
(4)	10·944	0·828	4·408	2·713	10·825	23	0·119

After the flasks had been evacuated to a pressure of 15^{mm}, the mass of the ester was distilled by plunging the flask into a bath of acid potassium sulphate heated to 200°. By flaming the Claissen flask and increasing slightly the current of air through the flasks, the remaining traces of ester are driven either into the flask used as a receiver or into the extension tube leading into it. The increase in weight of this flask with its rubber stopper and the extension tube was taken as the weight of the ethyl oxamate distilled. This amounted to 7·6361 grm., showing a loss of 0·0135 grm. in distillation under these conditions. It was found further that by the use of this apparatus a mixture of ethyl oxalate and ethyl oxamate could be separated and each determined. The ethyl oxalate was first distilled off by heating the Claissen flask after evacuating the flasks to a pressure of 15^{mm} in a deep bath of acid potassium sulphate, the flask being plunged into the bath as deeply as possible and the receiver being kept cool by a stream of cold water striking it constantly during distillation. This operation was continued until the Claissen flask when heated for half an hour under these conditions showed a loss in weight as small as 0·010 grm. between successive weighings. A mixture composed of 10·7749 grm. of ethyl oxalate and 3·3184 grm. of ethyl oxamate gave by heating with the arrangement of apparatus as described above, with the bath at 115°, a distillate of 10·7151 grm., showing a loss consequently of only 0·0598 grm., of ethyl oxalate; and by heating further with the bath at 200°, a distillate of 3·3015 grm., showing here a loss of only 0·0169 grm. of ethyl oxamate. Since oxamide undergoes no change when heated to 200° under diminished pressure, it is possible to separate and estimate mixtures of ethyl oxalate, ethyl oxamate, and oxamide. Table I records the results of experiments obtained by treating the recorded weights of the pure ethyl oxalate with the dry ammonia gas prepared as already given. The ethyl oxalate was weighed out in the Claissen flask of the apparatus described above after the apparatus had been dried by leading through it dry air for half an hour. In place of a capillary tube usually used in a vacuum distillation, a tube not constricted in bore was used, since in the operation to follow ammonia gas was led in through this tube. The weighed ethyl oxalate was thoroughly chilled in a mixture of ice and salt by immersion of the Claissen flask connected with its receiver ready for the vacuum distillation to follow, and was kept as cool as possible with this mixture during the period of treatment with ammonia. The flask was shaken violently at frequent intervals to facilitate the cooling of the mixture, but more particularly to break up the solid mass of precipitate and allow as complete contact as possible between the ammonia gas and the liquid ethyl oxalate. After the ammonia had been passed in for the time stated, the flask was removed from the freezing mixture and the system evacuated by the water pump. The receiver being kept cool by a stream of cold water, the Claissen flask was heated first with a water bath, brought slowly to the boiling point, and finally at 115° with a bath of acid potassium sulphate to drive off completely the ethyl oxalate, which was collected as already described and weighed; similarly the ethyl oxamate was distilled and weighed. The weight of the residue left in the Claissen flask was taken as the weight of the oxamide produced. The first period of heating at 115° to drive off the ethyl oxalate was uniformly made of a half hour's duration. It was presumed that during this heating all alcohol together with any excess of ammonia would be driven out. Incidentally there must have been a slight loss of ethyl oxalate carried off in vapor form to the pump. In subsequent heatings to complete the separation of ethyl oxalate, the loss in weight of the Claissen flask was taken to represent the weight of ethyl oxalate separated, rather than the weight of ethyl oxalate condensed in the receiver. The weight was, however, taken as a check. The loss of ethyl oxalate in vapor form was naturally largest when perceptible amounts of ethyl oxalate were distilling during the longest periods of time. In the experiments of Table I the largest amount of this loss observed was 0·043 grm. At the higher temperatures at which the oxamate distilled the rubber stoppers lost somewhat in weight, but no correction was made for the error thus introduced.

In experiment (1) of Table I the ratio between the ethyl oxamate and the oxamide formed is 3·09 : 1; in (2), 3·67 : 1 although in (2) there is a much larger amount of unchanged ethyl oxalate. We observed nothing which could be definitely assigned as the cause of this fact. There was a falling off in the amount of oxamate found in relation to the amount of oxamide in experiments (3) and (4) when compared with that in experiments (1) and (2). The solid mass was better broken up by shaking in the case of (3) and (4), thus indicating that under these conditions the production of the end product, oxamide, is only a question of contact between the active materials. To further test this conclusion the experiments of Table II were tried.

TABLE II.

	Ethyl oxalate	Absolute alcohol	Ligroin	Reaction time	Oxamide		
					Theory	Found	Error
No.	grm.	cm³.	cm³.	min.	grm.	grm.	grm.
(1)	8·231	20	—	20	4·965	4·968	0·003 +
(2)	6·554	20	—	20	3·953	3·956	0·003 +
(3)	6·033	—	10	20	3·639	3·638	0·001 —

Dry ethyl oxalate was weighed out in the dried apparatus and treated with the dry ammonia in the cold, in presence of absolute alcohol in experiments (1) and (2), and in presence of a purified low-boiling ligroin in experiment (3). The time of action of the ammonia was twenty minutes in each case before the distillation which was made in (1) and (3) as previously described, while in (2) all volatile material was removed without raising the temperature. No evidence of unchanged ethyl oxalate or of any ethyl oxamate appeared in any of these experiments, although the flask was heated at 115° for the removal of ethyl oxalate before weighing, and at 200° for the removal of ethyl oxamate. The residue left in the flask was taken, as in the experiments given in Table I, as the weight of the oxamide produced.

Hence it appears that dry ammonia in excess acts upon anhydrous ethyl oxalate in the cold to form a mixture of ethyl oxamate and oxamide as far as the ethyl oxalate is acted upon; and, if with the same proportion of reagents contact between the dry ammonia and ethyl oxalate is facilitated by a suitable medium such as ethyl alcohol or ligroin, the final product produced in the same time appears to be oxamide exclusively.

ART. XLV.—*Note on Volcanic Activity*; by C. BARUS.

1. LAST year[*] I published a brief discussion on the origin of volcanic heat containing, as I think, certain features of sufficient interest to deserve a more definite statement. The remarks were based on the experiments which I described some time ago,[†] showing that water glasses may be made in the laboratory which melt (aqueous fusion) even below 200° C. In their general physical properties like density, hardness, refraction, etc., these glasses need not differ remarkably from ordinary igneous glasses, in spite of the content of water in the first case. The solution takes place under a contraction of the system (liquid water and glass) of from 20 to 30 per cent; and it occurs more rapidly as the temperature of the system is higher, the observations extending from between 180° and 300° C.

That water may be kept liquid near the shores of an ocean, even if it should, by some accident, penetrate as far as an isotherm of several hundred degrees C., will at once be granted. Similarly other properties of this volcanic mechanism fit the actual occurrences fairly well, as was pointed out in the articles cited. Thus the contraction of the system is favorable to the evolution of heat; a region of activity comparable in depth with the depth of the ocean may be inferred; etc.

2. My purpose in the present note, however, is to dwell more specifically on the phenomenon of diffusion. I have argued that since water is more rapidly soluble in glass at 300° than at 200°, diffusion of liquid water would take place from the lower to the higher temperatures, and that the larger vapor pressures associated with the higher temperatures would have no appreciable bearing on the phenomenon. However we may approach the order of values of osmotic pressure, they are usually to be estimated in thousands of atmospheres.

In the case of dilute solutions (for which there is an adequate theory) the increase of a diffusivity D, with temperature, θ, is sufficiently well substantiated. If we take Nernst's expression,

$$D = R\theta \frac{2U_1U_2}{N_1+N_2},$$

sion, D increases both with the absolute temperature θ and with a mobility, U_1 and U_2 of the ions. True the case of solution of

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[*] Science, xxiv, p. 400, 1906.

[†] This Journal, xlvi, p. 110, 1891: vii, p. 1, 1899: ix, p. 161, 1900; Phil. Mag., xlvii, pp. 104, 461, 1899.

glass in water will not be amenable to these simplified conditions at once, but there can be no doubt that the general bearing of the effect of temperature on *D* is definitely foreshadowed by Nernst's equation, even if the case above is rather one of the solution of water in glass. If it were known that this liquid is more soluble in hot glass than in colder glass, under the requisite temperatures, similar conclusions as to the diffusion of cold to hot might be drawn; but all that has been proved by experiments is the occurrence of a larger rate of solution for the hot glass.

Apart from theoretical considerations, however, the question as to the distribution of a solvent in a solution, the parts of which are kept at different temperatures, is one of considerable interest. It is well worthy of extended experimental investigation, particularly in those cases in which a high degree of concentration obtains. On this subject I hope to offer some contributions myself, at another opportunity.

3. To return to the subject of vulcanism; as I take it, the diffusion of water takes place from colder to hotter strata under the relatively small pressure required to keep it liquid. Thus it is conceivable in a favorable case, that the lower strata will in the course of time be more fluid than the upper strata both from heat and from solution, so that heat may pass from lower to higher levels by convection. In such regions, in other words, convection would bring an excessively high temperature abnormally near the surface; or there would be an abnormal local rise of the isotherms. Hence, recalling that the solution of water in glass is accompanied by a remarkable contraction of the system of glass and water, and is therefore in itself favorable to the localized production of heat, while the identical phenomenon (by reason of the diffusion of water from cold to hot) is at the same time tending to raise the deeper and hotter isothermal levels nearer to the earth's surface, one may reasonably conclude that two phenomena both conducive to volcanic activity are acting in concert. Furthermore they are liable to be evoked along the shore line of the ocean, and particularly in those places where this line is unstable and undergoing displacement. For it is here that water will most probably have access accidentally to unusual depths.

Brown University, Providence, R. I.

ART. XLVI.—*Artificial Hematite Crystals;* by CHARLES E. MUNROE.

IN Deacon's process for the isolation of chlorine hydrogen chloride is decomposed by passing it, in the state of a gas, over a "contact" substance which practically acts as a conveyor of oxygen from the air to the hydrogen chloride, so that the reaction appears to result only in the oxidation of the HCl as follows: $(HCl)_4 + O_2 = (H_2O)_2 + (Cl_2)_2$. The most satisfactory "contact" substance for use in this art is cupric chloride, for when heated to 400° C., it dissociates into cuprous chloride and chlorine $(CuCl_2)_2 = Cu_2Cl_2 + Cl_2$. On exposing the cuprous chloride to oxygen, cupric oxide is formed and the remainder of the chlorine is liberated in accordance with the following equation: $Cu_2Cl_2 + O_2 = (CuO)_2 + Cl_2$. If now the cupric oxide be exposed to hydrogen chloride gas it reacts with it, forming cupric chloride and water as follows $(CuO)_2 + (HCl)_4 = (CuCl_2)_2 + (H_2O)_2$, so that the "contact" substance is regenerated and the cycle of changes begins anew. Theoretically it is unnecessary to employ an external source of heat in the process after it is once begun, because while 32 calories are absorbed in the dissociation of the cupric chloride 60·4 calories are evolved in the two subsequent reactions, showing a gain of 28·4 calories for the cycle, but in practice it is found advantageous to heat the air and hydrogen chloride up to 400° or 500° C. before they are brought to the contact substance.

Although there are differences in the details of the different apparatus in which this manufacture is carried on commercially, yet they in general consist of a salt-cake pan or retort, in which the hydrogen chloride is liberated; a set of cooling pipes and drying tower, in which the moisture is condensed; superheaters, in which the gases are heated in iron pipes, set in masonry, to the desired temperature; the "decomposer" or "digester," containing the contact substance absorbed in porous material, where the above reactions take place; and the condensing apparatus and coke towers for drying and purifying the chlorine. As the catalytic substance becomes inactive after a time, the process is interrupted every two or three months and air is passed through the heated pipes to the contact mass to regenerate it.

A Belgian apparatus of this general description had been employed in the generation of chlorine at the Ammonia Company's works in Philadelphia for about seven years when the iron heater pipes about the digestor became burned through. This was evidently due to the action of the heated air and sulphur dioxide on the outside, for the inside of the pipes was not pitted. When the pipes were removed they were found incrusted on their interior surfaces with finely developed and brilliant crystals of hematite, which had evidently been formed by the action of the hydrochloric acid on the iron, producing iron chloride, and the subsequent conversion of this compound to the oxide by the air passed through the pipes. These crystals were attached to the surfaces of the pipes by their edges and many of them were grouped in rosettes like the famous iron roses of the Alps. A noticeable fact in connection with their occurrence was that the size of the crystals varied with the size of the pipe in which they were produced. A six-inch pipe, for instance, furnished crystals whose longest diameter was about one centimeter, while a twenty-inch pipe yielded crystals whose longest diameter was slightly over three centimeters.

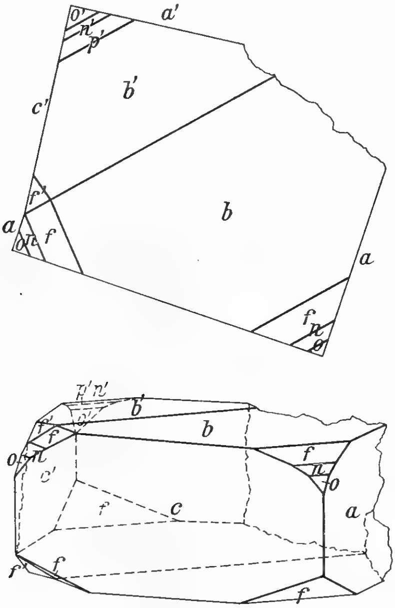
The George Washington University, Washington, D. C.

ART. XLVII.—*Anhydrite Twin from Aussee;* by F. BASCOM and V. GOLDSCHMIDT.

THE subject of this paper is a twin crystal, obtained from F. Krantz in Bonn by Mr. R. Schroeder.

Description of Crystal.—The crystal is colorless and transparent. Its dimensions are $15^{mm} : 13^{mm} : 5^{mm}$. A twinning plane divides the crystal into two nearly equal parts. Figure 1 shows both a top-view of the crystal, projected upon the plane $b = 0\infty$ (010) of Goldschmidt's Winkeltabelle (WT),* and also the crystal in perspective; figure 2 is a gnomonic projection of the same with a similar orientation.

1



Combination.—The forms present on the crystal are the following:

a	*b*	*c*	(*r*)	*o*	*n*	*f*	*p*	
0	0∞	∞0	10	1	12	13	15	(WT)
∞0	0	0∞	∞	1	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{5}$	(projection on *b*)

Of these forms *r* appears only as the twinning plane and

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* WT means here and in the following,—V. Goldschmidt, Krystallographische Winkeltabelle, 1897.

constitutes the plane of contact for the two individuals. $p = 15\,(151)$ is a new form for anhydrite. It appears on the smaller individual with a well defined face and occupies the place of the plane f, which, though present on the larger individual, is missing on the smaller.

The face gives a fair signal and the form was determined by the following measurements:

Measured: $\phi\rho = 41°\ 57' : 16°\ 23'$
Calculated: " $= 41°\ 45' : 16°\ 42'$

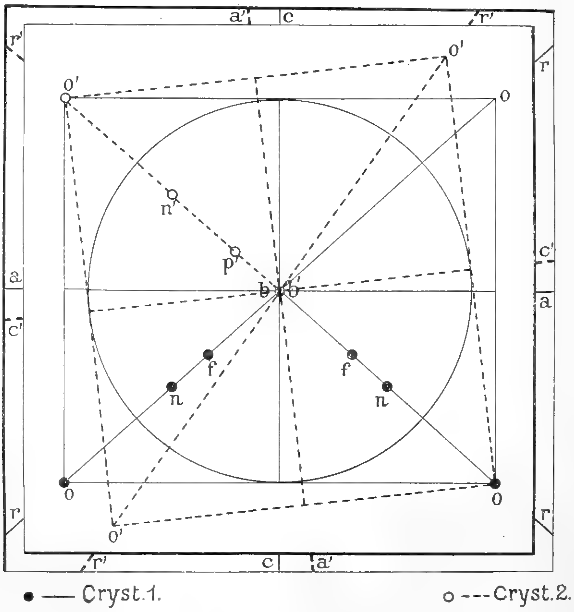
Not only is the agreement between the measured and calculated angles assuring, but the form fits perfectly into the series, as is shown by the following discussion:

	r	o	n	f	p*	b
$pq =$	10	1	12	13	15	0∞
$q =$	0	1	2	3	5	∞
$\frac{1}{2}(q\text{-}1) =$	—	0	$\frac{1}{2}$	1	2	∞

The series ob is a normal one and the form p is accordingly established.

General Discussion.—Anhydrite twins, with twinning plane parallel to $r\,(10)$, were first described by Hessenberg.† These crystals came from Berchtesgaden and are an inch in diameter.

2



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* Senkenb. Abh. 1872, vol. viii, p. 12, pl. 1, fig. 14.

They are bounded only by the three pinacoids and show twinning striations parallel to the twinning plane. Later Preiswork[*] described some more highly developed crystals twinned according to the same law.

The crystal in question is still richer in forms: The parallel orientation of the faces $b\,(0\,\infty)$ and $r\,(10)$, which is characteristic and genetic, is the decisive factor for the twinning law of anhydrite. They are the chief planes of coincidence, and moreover all planes of the zone *br* coincide. We therefore call this a zone of absolute coincidence. This zone is next in importance to the dome-zones *ac* and *ab*, which are the most richly developed zones in anhydrite. It includes the forms *b.p.f.n.o.r.* The gnomonic projection (figure 2) makes quite apparent these relations.

It should be observed that the *b* faces of both individuals fall into a single plane, as is also the case with several of the twins figured by Preiswork,[†] and further that the *r* face is a plane of contact (grenzfläche) for both individuals. The transformation of the elements and symbols of the Winkeltabelle (WT) to those of the projection on $b = 0\,\infty$. (B) is made according to the formulæ.

$$pq(\mathrm{WT}) = \frac{1}{q}\ \frac{p}{q}\ (\mathrm{B})$$

$$p_0q_0(\mathrm{WT}) = \frac{1}{q_0}\cdot\frac{p_0}{q_0}\cdot(\mathrm{B})$$

The elements and table of angles on p. 490 belong to the projection on *b* and may sometimes prove convenient for use.

The following forms, which are distinguished thus (?) in the table, are uncertain:

		a	τ	μ	ρ	σ	
Orientation	=	$0\frac{2}{3}$	$0\frac{4}{5}$	$0\frac{5}{3}$	02	03	= Hessenberg
Orientation (B)	=	$\frac{3}{2}0$	$\frac{5}{4}0$	$\frac{3}{5}0$	$\frac{1}{2}0$	$\frac{1}{3}0$	

The forms a and ρ are given by W. H. Miller[‡] but designated by him as uncertain. The forms τ, μ, and σ are figured by A. Schrauf[§] without further description. They also cannot be considered assured forms. All these forms should be omitted from the list until they have received additional confirmation.

Heidelberg, July, 1907.

[‡] Jahrbuch Min., 1905, vol. i, p. 39, pl. 3, fig. 5-8.
[†] Jahrbuch Min., 1905, vol. i, pl. 3, figs. 5, 7, 8.
[‡] Phil. Mag. 1874, vol. xlvii, p. 124.
[†] Atlas 1871, pl. 15, fig. 4, 5.

Anhydrite Elements (B) Projection on $b = 0\infty$ (WT).

$a=1{\cdot}1204$	$\lg a=004938$	$\lg a_0=000034$	$\lg p_0=999966$	$a_0=1{\cdot}0008$	$p_0=0{\cdot}9992$
$c=1{\cdot}1195$	$\lg c=004904$	$\lg b_0=995096$	$\lg q_0=004904$	$b_0=0{\cdot}8932$	$q_0=1{\cdot}1195$

TABLE OF ANGLES (B).

No.	Letter	Symb.	Miller	φ'' $(90-\xi_0)$	ρ'' $(90-\eta_0)$	ξ_0'' $(90-\eta_0)$	η_0'' (ϕ)	ξ'' $(90-\rho)$	η (ξ)	X'' (Prisms) $(x:y)$	y''	d'' $(\mathrm{tg}\rho)$
1	*a*	$\infty 0$	100	90° 00	90° 00	90° 00	90° 00	90° 00	0° 00	∞	0	∞
2	*b*	0	001	—	0 00	0 00	0 00	0 00	“	0	“	“
3	*c*	0∞	010	0 00	90 00	90 00	90 00	“	90 00	“	∞	∞
4	*d*	20	201	90 00	63 25	63 25	0 00	63 25	0 00	1·9984	0	1·9984
5	? *a*	$\frac{3}{2}0$	302	“	56 17·	56 17	“	56 17	“	1·4988	“	1·4988
6	? *τ*	$\frac{5}{4}0$	504	“	51 19	51 19	“	51 19	“	1·2490	“	1·2490
7	*s*	10	101	“	44 58·	44 58·	“	44 58·	“	0·9992	“	0·9992
8	? *μ*	$\frac{3}{5}0$	305	“	30 56·	30 56·	“	30 56·	“	0·5995	“	0·5995
9	? *ρ*	$\frac{1}{2}0$	102	“	26 33	26 33	“	26 33	“	0·4996	“	0·4996
10	? *σ*	$\frac{1}{3}0$	103	“	18 26	18 26	“	18 26	“	0·3331	“	0·3331
11	*ω*	5∞	510	77 22	90 00	90 00	90 00	77 22	12 38	4·4625	∞	∞
12	*t*	4∞	410	74 21	“	“	“	74 21	15 39	3·5700	“	“
13	*v*	3∞	310	69 31	“	“	“	69 31	20 29	2·6775	“	“
14	*e*	$\frac{5}{2}\infty$	520	65 51·	“	“	“	65 51·	24 08·	2·2312	“	“
15	*u*	2∞	210	60 44·	“	“	“	60 44·	29 15·	1·7850	“	“
16	*β*	$\frac{9}{5}\infty$	950	58 06	“	“	“	58 06	31 54	1·6065	“	“
17	*g*	$\frac{5}{3}\infty$	530	56 05·	“	“	“	56 05·	33 54·	1·4875	“	“
18	*q*	$\frac{3}{2}\infty$	320	53 14·	“	“	“	53 14·	36 45·	1·3387	“	“
19	*x*	$\frac{4}{3}\infty$	430	49 57·	“	“	“	49 57·	40 02·	1·1900	“	“
20	*l*	$\frac{5}{4}\infty$	540	48 07·	“	“	“	48 07·	41 52·	1·1156	“	“
21	*r*	∞	110	41 45·	“	“	“	41 45	48 15	0·8925	“	“
22	*k*	$\infty\frac{4}{3}$	340	33 48	“	“	“	33 48	56 12	0·6694	“	“
23	*γ*	$\infty\frac{5}{3}$	350	28 10	“	“	“	28 10	61 50	0·5355	“	“
24	*i*	$\infty 2$	120	24 03	“	“	“	24 03	65 57	0·4462	“	“
25	*h*	$\infty\frac{5}{2}$	250	19 39	“	“	“	19 39	70 21	0·3570	“	“
26	*o*	1	111	41 45	56 19	44 58·	48 13·	33 39	38 22·	0·9992	1·1195	1·5002
27	*n*	$\frac{1}{2}$	112	“	36 53	26 33	29 14·	23 33	26 36	0·4996	0·5597·	0·7501
28	*f*	$\frac{1}{3}$	113	“	26 34	18 26	20 28	17 20	19 30	0 3331	0·3732	0·5000
29	*p*	$\frac{1}{5}$	115	“	16 42	11 18	12 37	11 02	12 23	0·1998	0·2239	0·3000

ART. XLVIII.—*Occurrence of Olivine in the Serpentine of Chester and Middlefield, Mass.;* by CHARLES PALACHE.

SOME years since, while examining the private mineral collection of Mr. E. L. Cowles of Chester, the writer's attention was drawn to certain specimens which were identified as olivine, a mineral which had long been sought for in the region but without success. Mr. Cowles was so kind as to supply specimens for study and, on a later excursion to Chester, conducted the writer and several students to the locality where he had found the olivine, giving us opportunity to collect abundant material and to see the nature of the occurrence. At the same time specimens of the serpentine, which occurs in a large mass at the locality, were obtained and olivine was found in the rock in subsequent study of thin sections.

As considerable interest attaches to these occurrences of olivine, publication of the observed facts seems desirable.

Both occurrences of olivine are in a lense-shaped mass of serpentine, about a mile and a half long and nearly a half mile wide, that extends from the town of Middlefield into the town of Chester. According to Professor Emerson* this serpentine contains chromite locally, and also supplied the specimens of serpentine pseudomorphs after olivine known as "hampshirite," to which reference will again be made in these pages. But notwithstanding these suggestions of the derivation of the serpentine from a peridotite, Emerson was unable to definitely determine olivine in any of his slides, which were made from the western half of the bed, and came to the conclusion that the serpentine was in large part at least derived from the associated amphibolite and not from olivine. Professor Emerson found much olivine in the continuation of this bed to the south and much coarse enstatite rock.

In thin sections of a massive dark green serpentine collected near the eastern boundary of this serpentine area where the Chester-Middlefield road crosses it, olivine was found in abundance, in complete anhedra and as centers of a network of platy serpentine developed in characteristic fashion by the alteration of the olivine. Much of the serpentine in the slides bore marks of the same derivation; other smaller areas had a different character, suggesting rather the alteration of a pyroxene, but no fresh pyroxene was seen. Grains of magnetite are sparsely present. In every detail the specimen is a typical peridotite and seems conclusive evidence to the writer of the igneous origin of this serpentine mass.

*U. S. G. S., Monograph xxix, p. 81, and pp. 99–101.

The specimens of olivine discovered by Mr. Cowles occurred in the railroad cut where it passes through this same Middlefield serpentine mass, probably on the Chester side of the town line. He noticed the mineral, which he took for apatite, in a narrow vein on the side of the cut, exposed during the widening of the road bed; collecting specimens at the time, he also noted the spot beyond the cut where the rock was being dumped by the workmen, and it was from blocks thus located, several hundred yards from the place of occurrence, that we were able to collect material. The olivine forms a narrow vein, two inches or less in width, cutting massive serpentine like that described above. The olivine is dark to light green in color, vitreous in appearance and hard; parts of the vein are completely filled by granular olivine; other parts of the vein show the olivine in rude, rounded crystals, up to an inch in length, embedded in a matrix consisting of greenish white serpentine with the structure of picrolite, densely felted white chrysotile and occasionally broad plates of clear cleavable brucite. Large anhedra of magnetite up to an inch across occur rarely in the vein and, like the olivine crystals, these are wrapped around by the matrix in intimate fashion. Although some of the olivine crystals have undergone partial serpentinization and show glistening scales of brucite, it is easy to find those which appear perfectly fresh and show under the microscope the characteristic appearance and optical characters of the mineral.

Such material, carefully selected as free from visible impurities as possible, was analyzed in the laboratory of the U. S. Geological Survey by Mr. Schaller and the analysis is published here by permission of the Director and through the kindness of Professor Emerson, for whose studies it was made.

SiO_2	39·43%
FeO	7·83
MgO	49·26
MnO	·12
CaO	none
F	none
H_2O-	1·20
H_2O+	1·49
CO_2	·77
	100·10

Note by Mr. Schaller. "Some impurity from the grinding machine was accidentally introduced into the sample. The value for ferrous iron represents total iron."

The analysis shows that the material was less fresh than it appeared. But if CO_2 be regarded as present in form of magnesite and H_2O as equally divided between brucite and serpentine, both known to be present in the sample, we have

Magnesite	1·47%
Brucite	4·34
Serpentine	10·35
	16·16

Deducting this 16·16 per cent alteration products from the analysis and recalculating to 100 per cent, we obtain the following figures, which give a ratio almost exactly that of olivine.

		Mol. ratio		Ratio	Theory for olivine with Mg : Fe = 9 : 1
SiO_2	41·58%	·688		1	41·00%
FeO	9·33	·130	1·355	1·97	9·8
MgO	48·94	1·223			49·2
MnO	·14	·002			
	100·00				100·00

In view of the discussion on a later page (p. 495) the absence of fluorine is important.

The vein containing the olivine is sharply defined in the enclosing serpentine and is evidently a younger formation. We have here apparently another case of the regeneration of olivine in a rock mass which has undergone a general serpentinization—a process previously recorded by Weinschenk* in serpentine in the Tyrol and observed by the writer† in the peridotite of Mine Hill, Cumberland, R. I.

The curious appearance of these specimens of olivine embedded in serpentine recalled the description of the above mentioned hampshirite pseudomorphs as given by Emerson‡; it seems to the writer, and his conclusion is wholly confirmed by Professor Emerson after seeing the specimens, that the close accordance in general locality of Mr. Cowles' specimens and the original hampshirite and the general similarity of the minerals, save that in the single specimen of hampshirite studied by Professor Emerson the olivine was wholly altered to serpentine and brucite was not developed with it, point to the conclusion that we have here a rediscovery of the long-lost locality of the pseudomorphs and final proof of their derivation from olivine.

On the latter point it is necessary to refer to a recent paper by Mr. A. D. Roe and Mr. A. L Parsons,§ in which the history and nature of these pseudomorphs is discussed.

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* Beiträge zur Petrographie der östlichen Centralalpen speciel des Grossvenedigersstockes. Abh. Kgl. bayer. Akad. Wiss. II cl. 1894, xviii, 651.

† An occurrence soon to be described by Dr. C. H. Warren in a paper on this interesting locality.

‡ Emerson, B. K., Mineralogical Lexicon, Bull. 126, U. S. G. S., pp. 92, 146.

§ A Mineral Resembling Meerschaum from the Serpentine Range of Hampden County, Mass., with Descriptions of Interesting Included Crystals, Bull. Minnesota Acad. Sci. IV, No. 2, 1906, pp. 268, 276.

First discovered by Dr. E. Emmons and described by Dewey* as crystals of steatite, they came later to be regarded as steatite pseudomorphs after quartz. Emerson first assigned olivine as the original mineral, basing the determination on measurements of the crystals, and comparison with serpentine pseudomorphs after olivine from Snarum, of similar size and color.

In this paper Mr. Roe describes the locality and the finding by himself of all extant specimens of hampshirite so far as known, and this locality agrees exactly with the one from which our material comes. He gives analyses of the pseudomorphs and of the meerschaum-like serpentine matrix made by E. E. Nicholson: both correspond fairly well with ordinary analyses of serpentine although somewhat low in water. To the matrix serpentine is given the name hampdenite, hampshirite being retained for the serpentine of the pseudomorphs; both names seem to the writer superfluous since no varietal distinction from serpentine is established, and the name picrolite embraces varieties of serpentine with the characters of the so-called hampdenite. Large magnetite crystals showing dodecahedral and octahedral planes were associated with the serpentine pseudomorphs.

Mr. Parsons decribes the crystals, giving contact measurements and sketches of a number of them, and pointing out the close resemblance to humite which they present in form and angles. He regards as strongly confirmatory of the derivation of the crystals from humite the facts: (1) that minerals of the humite group are abundant in other Massachusetts localities† and at Tilly Foster Mine, N. Y., in the last case in somewhat similar paragenesis: (2) that crystallized olivine in good-sized crystals has never been found in the region: (3) that the size of these pseudomorphs is altogether exceptional for olivine.

In view of the discovery of olivine crystals close at hand as described above, quite comparable in size with the pseudomorphs, although not so perfect in form, the confirmatory facts given by Parsons of course lose all weight. The agreement in crystal measurements is, it is true, less satisfactory for olivine than for humite, as the following table, taken from Parsons' paper with the addition of the figures for olivine, shows:

Humite			Pseudomorphs (measured)	Olivine		
210 to $2\bar{1}0$	49°	40′ $\frac{1}{2}$	49°–50°	110 to $1\bar{1}0$	49°	57′
001 to 014	45	32 $\frac{1}{2}$	46 $\frac{1}{2}$–47	001 to 021	49	33
001 to 011	76	13	74	001 to 041	66	55
001 to 103	55	44	55	001 to 101	51	33
001 to 216	58	16	58	001 to 111	54	15

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* See Dana, System, 1892, p. 675.

† Mr Emerson informs us that the localities cited are many miles distant from Chester, and of different geological age and association.

The difficulty of securing accurate contact measurements on material of this sort with more or less curved faces is, however, so great that too much weight should not be attached to the discrepancies shown on the olivine side of the table. And it is further to be noted that, of the angles given by Parsons as "measured," only the first between the dominant prism planes could actually have been measured on these crystals since the basal pinacoid is absent, and this first angle agrees equally well with humite and olivine; the other angles must have been derived from the actual measurements, presumably by halving angles measured over the summit of the crystal between small faces; such measurements are liable to much greater error than those on larger faces at obtuse angles. On the whole then, the crystallographic evidence alone seems too weak to establish the derivation of the hampshirite pseudomorphs from humite.

The possibility that the mineral described above as olivine might be humite was carefully considered, especially when the fact was noted that the optical characters of the two minerals are so similar that in granular form they are practically indistinguishable under the microscope. The result of the analysis and the proved absence of fluorine seem to settle this point conclusively.

Harvard University, June, 1907.

SCIENTIFIC INTELLIGENCE

I. Chemistry and Physics.

1. *Speculations in Regard to Atomic Weight Numbers.*—Starting with the old assumption that the atomic weights are obvious whole numbers and the old deduction that the elements are multiples of the element hydrogen, H. Collins has made some observations which appear to be of more interest than is usual in the case of such speculations. He observes that the "artiads" below 63 are generally odd numbers, while the "perissads" are usually even. The antiquated terms just used refer to odd and even valency, respectively. He states that nitrogen is the single exception, but it seems to the reviewer that beryllium and scandium are absolute exceptions, and that helium and argon, having no known valency, are not strictly "perissads." It appears further that this application is of little importance with Ti, V, Cr, Mn, Fe, Co, and Ni, which show both odd and even valencies. However, there are enough cases conforming with this rule to make the observation an interesting one. Another observation is that these atomic weights, below 63, based on oxygen as 16, are either whole numbers or greater than whole numbers, with the exceptions of argon, iron and nickel. The author makes the deduction that the increase in the atomic weights above whole numbers is due to the condensation of a "protyle" within each atom, but he does not explain why the oxygen atom may not also possess a "protyle." He observes further that in nine instances a difference of 4 in the list of "obvious whole numbers" (below 63) corresponds to a difference of two valencies; for instance,

Li	Monad	7	4	Na	Monad	23	4
B	Triad	11		Al	Triad	27	
Mg	Dyad	24	4	Al	Triad	27	4
Si	Tetrad	28		P	Pentad	31	

He observes also that several changes of a single valency involve changes in weight of 1 and 3; for example,

B	Triad	11	1	Na	Monad	23	1
C	Tetrad	12		Mg	Dyad	24	
Mg	Dyad	24	3	Si	Tetrad	28	3
Al	Triad	27		P	Pentad	31	

He makes the deduction that the acidity or non-metallic nature of an element is always due to a pair or pairs of electro-positive forces, each pair emanating from a portion of the element, of which the mass is 4, taking the mass of an atom of hydrogen as unity. He believes that the constitution and structure of each element can be deduced in a rational and uniform manner by taking into consideration all of his observations and deductions (only a part of which have been touched upon here), and the portion of each element which is metallic is thereby made evident. It is not clear that the author has any good reason for using metallic elements as a basis, for it might be argued that the opposite change—non-metallic to metallic—was brought about by increases in mass. It is not probable that many chemists will accept these views as possessing any significance.—*Chem. News*, xcvi, 176. H. L. W.

2. *The Vapor-tension of Sulphur at Low Temperatures.*—By passing gases over sulphur in such a manner that saturation took place, condensing the sulphur in a cold tube and weighing it, Dr. H. GRUENER of Adelheid College, Cleveland, O., has succeeded in determining its vapor tension at temperatures between about 50 and 120° C. At the two temperatures just mentioned the pressure of the vapor was found to be ·00008 and ·0339^{mm} respectively. At 100° C, it was found to be ·007^{mm}, and the same result was obtained by boiling water in which finely divided sulphur was suspended, passing the vapor through a column of solid sulphur, condensing the water, and determining the sulphur in it. It is of interest to know that as much as ·013 g. of sulphur may be carried off with the steam of 100 g. of water. Another interesting point brought out in this investigation is the fact that sulphur is scarcely oxidized at all by air below 100°, but that a trace of SO_2 is formed at that temperature. The author states that the odor perceived when sulphur is heated to 100° is due to volatilized sulphur and not to SO_2.—*Zeitschr. anorgan. Chem.*, lxvi, 145. H. L. W.

3. *Helium in Natural Gas.*—The announcement of the discovery of considerable quantities of helium in the natural gas from a well in Kansas was made some time ago by D. F. McFarland. CODY and MCFARLAND have now examined for helium some 47 samples of natural gas, most of them from the Kansas region, but including samples from Ohio, Indiana, West Virginia, California and Louisiana. It appears that the gas originally examined contains more helium, 1·84 per cent, than any other of the numerous samples, although there are two or three other gases that contain nearly as much. However, it is noteworthy that in only one case was no helium found, and that in most of the gases its quantity was over ·10 per cent. The authors observe that the helium content of a gas tends to increase with an increase in nitrogen, although no direct relation between the two was observed. The gases richest in helium contained over 82 per cent of nitrogen. A further observation was made that in the Kansas region the amount of helium present in the gases varied according to the geological strata.—*Jour. Amer. Chem. Soc.*, xxix, 1523. H. L. W.

4. *Electro-Analysis;* by Edgar F. Smith. 12 mo, pp. 336. Philadelphia; 1907 (D. Blakiston's Son & Co.)—This is the fourth edition, revised and enlarged, with 42 illustrations, of a well known, valuable text-book. The changes in the new edition are far more important than is usual in new revisions, for here is included an account of recent developments in the subject from the author's laboratory, which are of the greatest importance and interest to analytical chemists. Electrolytic analysis heretofore has dealt chiefly with the determination of a few of the heavy metals, but the range of its applications has been gradually enlarged by the discovery of new applications. An instance of this kind is the determination of the halogens by collecting them upon a silver-plated anode. Dr. Smith's new work has greatly improved and extended this application of electrolysis, and he has shown that rapid and accurate determinations of not only the halogens, but of such anions as the carbonate, ferrocyanide, ferricyanide, phosphate and sulphide radicals, can be made readily. These remarkable results have been made possible by an ingenious device whereby the alkali metals, as well as barium and strontium, are passed through a layer of mercury into an outer compartment of the electrolytic cell. This same device has enabled the author to make various separations of metals in an exceedingly simple and accurate manner; for example, an alkali metal, or barium or strontium, from calcium, magnesium, etc. These new methods devised by Professor Smith will certainly find extensive practical applications, and they mark an important epoch in electro-analysis. H. L. W.

5. *Fizeau's Research on the Change of the Azimuth of Polarization due to Movement of the Earth.*—The endeavors to discover an effect on optical phenomena due to movements of the earth have led to negative results. Fizeau, however, believed that he had noticed such an effect. He passed a polarized light ray through a series of inclined glass plates and noticed a change in the polarizing angle, as the ray passed in the direction of the earth's movement or in the opposite. Fizeau found a difference in the polarizing angle of 0·024°. Bruce repeated Fizeau's experiments with a different order of apparatus and found an angle change of only 0·003°, which is within the limits of error, and Bruce concludes that Fizeau's result must have been due to some other cause than that of the movement of the earth. B. Strasser's has taken up the subject and shows that Fizeau's use of a reflecting mirror to change the direction of the ray of light was faulty. It is important that the source of light should not be changed, but should move with the apparatus. Strasser gives a diagram of his apparatus which shows how this result is accomplished, and his tabulated results show that the Fizeau effect does not exist, and that no experiment shows any effect upon optical phenomena due to movement of the earth.—*Ann. der Physik*, No. 11, 1907, pp. 137–144. J. T.

6. *Secondary Cathode Rays Emitted by Substances Exposed to γ-Rays.*—R. D. KLEEMAN concludes that the γ-rays from radium consist principally of two groups of rays, the constituent rays of each group differing not much from one another in their properties. The rays of one of the groups are more efficient in producing secondary cathode radiation from aluminium, sulphur, iron, nickel, zinc, and tin, than from lead, and are all more or less easily absorbed by each of these substances excepting lead. the absorption by lead being much less. The rays of the other group are more efficient in producing secondary cathode radiation from lead than from the other substances, and are more easily absorbed by lead, mercury, and bismuth, than by any of the other substances. There is also a third, apparently weak group of rays which is most efficient in producing secondary radiation from carbon. This group of rays is less easily absorbed by the above mentioned substances than either of the other groups.—*Phil. Mag.*, Nov. 1907, pp. 618–644. J. T.

7. *Secondary Röntgen Radiators from Gases and Vapors.*—Careful investigation of this subject was made by BARKLA (Phil. Mag. v, 1903, vii, 1904), who concluded that:

(1) All gases, when subjected to X-rays, are a source of secondary radiation.

(2) The absorbability of the secondary radiation is, within the limits of experimental error, the same as that of the primary producing it.

(3) For a given primary radiation, the intensity of the secondary radiation is proportional to the density of the gas from which it proceeds.

(4) The ratio of the intensities of the primary and secondary beam is independent of the hardness and intensity of the primary rays.

Barkla's experiments were performed on few gases and not of a varied type. Mr. J. A. CROWTHER has repeated the experiments with a large number of gases—of varied atomic weights—and confirms Barkla's results.—*Phil. Mag.*, Nov. 1907, pp. 653–675. J. T.

8. *Abrupt Limit of Distance in the Power of the Positive Rays to Produce Phosphorescence.*—It has been found by the various observers that the α-rays from polonium and radium lose their power abruptly of producing phosphorescence and of affecting the photographic plate. Dr. JACOB KUNZ, reflecting that the positive rays are similar in nature to the α-rays of the radioactive elements, was led to believe that the positive rays would also show an abrupt falling off in a manner similar to the α-rays. The tube used for the production of the canal or positive rays was enclosed in a larger tube, exhausted to the same degree: and the inner tube by means of spiral springs connected to the electrodes could be moved to varying distances from a willemite-

screen. It was found that there was, as expected, an abrupt limit of distance in the power of the positive rays to produce phosphorescence.—*Phil. Mag.*, Nov. 1907, pp. 614-617. J. T.

9. *The Vacuum Bolometer.*—It has often been observed that a bolometer strip placed in a vacuum is more sensitive than in air. E. WARBURG, G. LEITHÄUSER and ED. JOHANSEN have investigated this phenomenon and give a tabulated résumé of their results. The conditions of sensitiveness vary with the strength of currents employed and the breadth of the bolometer strips; in general the sensitiveness in a vacuum is from three to four times that in air.—*Ann. der Physik*, No. 11, 1907, pp. 25–42. J. T.

10. *Ratio of the Electrical Units.*—The paper by E. B. ROSA and N. E. DORSEY on a new determination of the ratio of the electromagnetic to the electrostatic unit of electricity, alluded to in the last number (p. 442), is completed in the current issue of the Bulletin of the Bureau of Standards (pp. 541–604). The final value obtained reduced to vacuo (assuming the dielectric constant of air at 20°C and 760^{mm} as 1·00055) is

$$v_0 = 2{\cdot}9971 \times 10^{10}$$

Accepting the velocity of light as $2{\cdot}9986 \times 10^{10}$, this value of v_0 shows a difference of 5 parts in 10,000 with a possible uncertainty of 2 parts in 10,000. The explanation of the resulting difference (1 in 3000) is as yet uncertain. A supplementary paper by the same authors (pp. 605–622) gives a critical comparison of the various methods of determining the above ratio.

II. GEOLOGY AND MINERALOGY.

1. *The Geology of North Central Wisconsin;* by SAMUEL WEIDMAN. Wisconsin Geol. and Nat. Hist. Surv., Bull. xvi. Madison, 1907, 8vo, pp. 697, maps in cover.—The area whose geology is described in this memoir contains about 7200 square miles, about one-eighth of the state, and is situated as described in the title. The city of Wausau (15,000 pop.) near the center is the largest place in the district. It is without especially characteristic topographic features and is chiefly an agricultural country.

The geological problems of the district are mainly those relating to the pre-Cambrian rocks, which consist to a relatively small extent of metamorphosed sedimentaries and very largely of igneous intrusives, and those relating to the latest deposits, which are Pleistocene, or glacial. One-half of the volume is, therefore, devoted to the working out of the petrographical problems presented, the other to glacial geology and physiography. In the time-interval between these two, the Paleozoic alone is represented by the Potsdam sandstone. Of the igneous rocks, the most interesting are those found in a series of intrusions in the neighborhood of Wausau, which consist of syenites and nephelite-syenites. One of the latter is noteworthy in that its pyroxene is a hedenbergite and it contains fayalite. As is so often the case, these rocks in their pegmatitic developments contain many interesting minerals. These have been carefully investigated and many of them have been analyzed, as well as the rocks and rock-minerals. The whole makes a very thorough and excellent piece of petrographic investigation. It is an interesting fact that the intrusion of the alkalic rocks has no accompanying retinue of differentiated dikes and satellite masses which are so common a feature in such occurrences elsewhere.

Following the petrography, the matter of chief interest is the result of the study of the glacial geology. The various characters of the ice invasion and of the deposits it left are described in detail for all parts of the area. The writer finds evidence of four distinct glacial formations, each believed to have been formed by a separate ice invasion. One part of the region is driftless and nonglaciated, and the author, in explanation of this, adopts the view of Chamberlain for the larger areas to the southwest, that is the diversion of the ice currents by the highlands of northern Wisconsin and Michigan.

The work concludes with a description of the topographic features of the region and a discussion of its physiographic development. The volume is well printed and embellished by many fine half-tones, and as a whole, both in the results obtained and in the manner in which they are presented, it is an excellent work, of general as well as of local interest, reflecting credit on the author and on the State survey. L. V. P.

2. *Research in China (in 3 vols, and atlas): Vol. I, Part II; Petrography and Zoology;* by Eliot Blackwelder. 4°, pp. 357–528, plates 12. Washington, 1907 (published by the Carnegie Institution).—Some years since, as is well known, the Carnegie Institution despatched to China an expedition under the leadership of Mr. Bailey Willis of the United States Geological Survey. One of its chief purposes was the study there of the earliest stratified rocks, in the hopes of throwing light on important questions concerning Cambrian and pre-Cambrian geology and paleontology. While the success of the expedition in this particular direction was perhaps not greater than that which has attended the study of these strata in other places, a considerable amount of material, valuable in several branches of science, and of interesting information concerning the regions traversed, was obtained and, under the auspices of the Carnegie Institution, these have been studied and collated and the results are now being published.

The present volume by Mr. Blackwelder, who was Mr. Willis's chief assistant, describes the petrography of the rock specimens collected along the route of travel. They represent a large variety of types, igneous, sedimentary and metamorphic, which have been studied under the microscope and classified. Among the igneous rocks, granites, diorites, gabbros and several porphyries, with effusives of rhyolite, andesite and basalt, are the ruling types, and it is interesting to note that no rocks of pronounced alkalic nature were encountered. The work is of a purely descriptive character, and as no summation or generalizations of the observed facts are given, it is inferred that these are reserved for that part of the work dealing with the general geology of the region visited.

Of the zoological material gathered by Mr. Blackwelder, the description of the reptiles and birds is given by himself with the assistance of Drs. Stejneger and C. W. Richmond. Of the Reptilia only a few specimens were obtained, consisting of several lizards and one snake, of already described species. The Birds are represented, however, by a larger collection of 64 specimens containing 49 species. Most of these are naturally of small kinds, larks, finches, sparrows, wrens, thrushes, etc. While none of the specimens proved to be of an absolutely new species, an interesting new variety of the Chi-li winter wren was obtained—*Olbiorchilus fumigatus ideus* Richmond. This part of the text is embellished by several fine colored plates of the birds collected.

The volume concludes with a syllabary for the transcription of Chinese sounds in the dialect of Peking, modified for literary purposes by Dr. FRIEDRICH HIRTH of Columbia University.

L. V. P.

3. *Miscellanea Palæontologica;* von Prof. Dr. ANTON FRITSCH. 1. *Palæozoica.* Pp. 23, plts. 12. Published by the author, Prag, Bohemia, 1907.—In this quarto paper the author describes and illustrates seventeen invertebrate Paleozoic animal remains. Among them are discussions of several American species, as follows: *Proscorpia osborni*, *Palæocampa anthrax* (gives also a restoration of this Polechæt worm; states that it is not a Myriapod), *Propolynoë laccoei* (a new genus and species of annelid from Mazon Creek, Indiana), *Hesionites bioculata* (Chætopod from Mazon Creek), *Latzelia primordialis* (the oldest Chilopod and related to the recent genus *Scutigera*).

There is also described a new *Camerocrinus quarzitarum*, extending the range of these extraordinary crinoid floats to the Ordovician (etage Dd2). The balance of the work is devoted to a description of the Permian Coprolites of Bohemia (26 species!).

C. S.

4. *Evidences of a Coblenzian invasion in the Devonic of Eastern America;* by JOHN M. CLARKE. Festschrift zum siebzigsten Geburtstage von Adolf v. Koenen, pp. 359–368, Stuttgart, 1907.—In this short paper the author gives his views in regard to the relation of the Helderbergian and Oriskanian and the probable waterways of migration of the faunas about Gaspé, Quebec, Dalhousie, New Brunswick, and localities in Maine. It is in the latter region that marked Coblenzian affinities are shown in the faunas.

C. S.

5. *The Geology of Islay;* by S. B. Wilkinson; with notes by J. J. H. Teall and B. N. Peach. Memoirs of the Geol. Surv., Glasgow, 1907; 8°, pp. 82, pls. 8.—This Memoir describes the Geology of Islay and Oronsay with portions of Colonsay and Jura, islands on the west coast of Scotland. In the introduction a brief reference is made to the physical features of the islands. A short sketch is given of the progress of geological research in Islay. The special feature of the Memoir is the detailed account of the metamorphic rocks which enter into the structure of Islay, the correlation of the gneisses of the Rhinns of Islay (the western hills) with the Lewisian gneisses of the counties of Sutherland and Ross in Scotland and the description of the sediments overlying the gneisses of the Rhinns which resemble subdivisions of the Torridon Sandstone in the Northwest Highlands. A detailed account is given of the rock groups in the southeast of Islay which have been linked with Eastern Highland types. The glacial and recent deposits are also described.

6. *Geology and Water Resources of the Bighorn Basin, Wyoming;* by Cassius A. Fisher. Professional Paper No. 53 U. S. Geol. Survey.—As stated in the introduction, this paper is designed mainly to furnish information regarding geologic structure and the prospects for underground water. A general account of the surface waters is given, including a statement of their present and proposed uses for irrigation, and the economic products of a geologic nature are also described. The region considered comprises the Bighorn basin, a part of the Clark Fork basin, and the slopes of the adjoining mountain ridges, the entire area comprising 8,500 square miles. The basin is floored by Eocene strata overlying Laramie strata of great thickness. The surface is now dissected by streams which flow in deep but broad sloping valleys, bordered by terraces rising to adjoining highlands. Bad-land structure is rather common in these Eocene strata.

J. B.

7. *The Geology of the Guaynopita District, Chihuahua. A contribution to the knowledge of the structure of the Western Sierra Madre of Mexico;* by Edmund Otis Hovey, Ph.D.—This paper occupies pages 78 to 95 of the volume written by the students of Professor Rosenbusch in celebration of his seventieth birthday. The first pages sketch the general structural features of Mexico, pointing out that the limits of the plateau have been determined by profound faulting, and calling attention to that feature of the surface consisting in the "Bolsons" or basin deserts. Following this introduction the details of the Guaynopita district, lying in the heart of the Western Sierra Madre, are given. The fundamental rocks are gneiss and schist overlain by limestone, the whole now folded. These are capped by a series of eruptives and are cut by granite which Hovey regards as probably of intermediate age in the eruptive series. J. B.

8. *Tertiary Mammal Horizons of North America;* by Henry F. Osborn. Bull. Amer. Mus. Nat. Hist., xxiii, 1907, pp. 237–253.—This is one of the most valuable geological summaries of our present knowledge of North American mammal horizons. The thickness of these Tertiary strata is over 18,000 feet. The major facts may be tabulated as follows:

Seventh mammal phase. Increasing cold, moisture, and forests. Another but gradual Eurasian intermigration. Much extinction of previous native stocks.	Lower Pleistocene or Preglacial. Sheridan or Equus beds.	Provisional correlations with other countries.
Sixth mammal phase. Intermigrations with South America.	Upper Pliocene development as yet not recognized in America.	Sicilien.
	Middle Pliocene. Blanco or Glyptotherium beds. Up to 3,000 feet.	Astien.
Fifth mammal phase. Intermigration with Eurasia. Increase of summers droughts.	Lower Pliocene. Republican or Peraceras beds 100 feet.	Messinien-Plaisancien.
	Upper Miocene. Loup Fork or Protohippus beds. Up to 120 feet.	Tortonien.
	Lower Miocene. Ticholeptus beds. Up to 1,000 feet.	Langhien-Helvétien.
Fourth mammal phase. First Great Plains forms. Second, or Lower Oligocene intermigration with western Europe.	Transitional to Miocene. Arikaree or Promerycochœrus beds. Upper John Day 400 feet.	Langhien-Aquitanien.
	Upper Oligocene. John Day or Diceratherium beds. Mountain fauna. Up to 1,000 feet.	Aquitanien.
	Middle Oligocene. Upper Brule or Leptauchenia beds. Lower John Day. Up to 300 feet.	About Stampien.
	Middle Oligocene. Lower Brule or Oreodon beds.	
	Lower Oligocene. Titanotherium beds. 200 feet. This and the Lower Brule horizons have decided European affinities in the Perissodactyla.	?Ludien in part. Sannoisien.

Third mammal phase. Continued physical conditions without new intermigrations. Eocene deposits probably mainly of volcanic origin.	Transition to Oligocene and Upper Eocene. Uinta or Uintatherium beds. Up to 1,750 feet. Tertiary genera 87 per cent; Cretaceous genera 13 per cent.	Absolute dissimilarity between America and Europe.
	Middle Eocene. Washakie or Eobasileus beds, 500 feet.	Bartonien.
	Middle Eocene. Bridger or Orohippus beds. Up to 1,800 feet. Modernized mammal genera 81 per cent; Cretaceous genera 19 per cent.	Bartonien. Upper Lutétien in part.
	Lower Eocene. Wind River or Lambdotherium beds. Up to 1,400 feet. Modernized mammal genera 63 per cent; Cretaceous genera 37 per cent.	Lower Lutétien in part. Yprésien.
Second mammal phase. First decided migration of modernized forms between America and Europe.	Lower Eocene. Wasatch or Coryphodon beds. Up to 2,500 feet. Modernized mammal genera 42 per cent; Cretaceous genera 58 per cent.	Yprésien. Sparnacien.
First mammal phase. Archæic or Mesozoic forms.	Basal Eocene. Torrejon or Pantolambda beds, 300 feet. European connections seen in the similar stages of development in America and France. Modernized mammal genera 4 per cent; Mesozoic genera 96 per cent.	Thanétien or Cernaysien.
	Basal Eocene. Puerco or Polymastodon beds, 500 feet. Mesozoic mammal genera 100 per cent.	Affinity with Nostostylops beds of Patagonia. Cretaceous or Basal Eocene. Intermigration late Cretaceous.

C. S.

9. *Gold Nuggets from New Guinea.*—Professor A. Liversidge of Sydney describes two small gold nuggets from New Guinea, which, after being polished and etched with aqua regia, showed near the edges a clearly marked *concentric* structure. This is regarded as probably indicating successive deposition in the walls of the cavity analogous to that observed in agates.—*Roy. Soc. N. S. W.*, xl, 161.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Annual Report of the Board of Regents of the Smithsonian Institution, showing the Operations, Expenditures, and Conditions of the Institution for the year ending June 30, 1906.* Pp. li, 546, with 41 plates. Washington, 1907.—The annual volume now issued contains the report of the Acting Secretary, Mr. Richard Rathbun, which (as separately published) was noticed in an earlier number of this Journal (vol. xxiii, p. 242). The general appendix (pp. 91–546) contains as usual a series of illustrated papers, selected for republication here as giving concise accounts of recent scientific discovery in different fields. The subjects included range from radio-activity and wireless telegraphy to ethnography and geography. The volume closes with a biographical notice of the late Professor Langley by Cyrus Adler.

This report by the Acting Secretary shows that the Institution was maintained at its full efficiency during the time following the death of the former Secretary. The recent accession of Dr. Charles D. Walcott, who was elected Secretary in January last, gives promise of new activity and expansion for the varied interests involved.

Some of the prominent publications recently issued under the auspices of the Smithsonian Institution are given in the following list:

Twenty-fifth Annual Report of the Bureau of American Ethnology for 1903–04. Pp. xxix, 296, with 129 plates and 70 figures.—This volume, besides the report of the Chief of the Bureau, Mr. W. H. Holmes, contains two memoirs by Jesse Walter Fewkes; one of these is devoted to the Aborigines of Porto Rico and Neighboring Islands, the other to Certain Antiquities of Eastern Mexico.

Smithsonian Contributions to Knowledge: Part of Volume xxxv. The Young of the Crayfishes Astacus and Cambarus; by E. A. ANDREWS. Pp. 79, with 10 plates and 93 figures. See p. 449.

BULLETINS.—No. 50. The Birds of North and Middle America. Part IV; by ROBERT RIDGWAY. Pp. vi, 973, with 34 plates.

No. 53. Part II. Catalogue of the Type and Figured Specimens of Fossils, Minerals, Rocks and Ores in the Department of Geology, United States National Museum. Prepared under the Direction of GEORGE P. MERRILL. Part II. Fossil Vertebrates; Fossil Plants; Minerals, Rocks, and Ores. Pp. v, 370.

No. 57. The Families and Genera of Bats; by GERRIT S. MILLER, Jr. Pp. v, 282, with 14 plates.

No. 58. Herpetology of Japan and Adjacent Territory; by LEONHARD STEJNEGER. Pp. xx, 577, with 35 plates and 409 figures.

Contributions from the United States National Herbarium, Vol. x, Pt. 5. Report on the Diatoms of the Albatross Voyages in the Pacific Ocean, 1888–1894 ; by ALBERT MANN. [Assisted in the bibliography and citations by P. L. RICKER.] Pp. v, 221–419, with plates xliv–liv.

Smithsonian Miscellaneous Collections ; Quarterly Issue, Vol. iv, Pts. 1, 2. Among the papers here published may be mentioned one by Merrill and Tassin (pp. 203–214) describing the remarkable shale balls found among the Canyon Diablo meteorites ; also (from vol. iii) a catalogue of earthquakes on the Pacific coast, 1897–1906, by A. G. McAdie.

2. *National Academy of Sciences.*—The autumn meeting of the National Academy was held in New York City on Nov. 19–20, President Remsen presiding. About forty members were in attendance. The following is a list of papers presented :

M. I. PUPIN : A new application of dynamics to electrical circuits.

LEIGHTON B. MORSE : The selective reflection characteristic of carbonates ; wave length of displacement a function of the atomic weight of the base. Oxygen the active atom in the characteristic reflection of carbonates, nitrates, sulphates and silicates.

A. P. WILLS : A modification of the Bjerkness hydrodynamics analogy.

A. G. WEBSTER : On Rayleigh's disc as an absolute measure of sound.

GEO. E. STEBBINS : On the minimum audible sound.

J. F. KEMP : Buried river channels of the Hudson Valley.

W. M. DAVIS : Glacial erosion in Wales.

CHAS. D. WALCOTT : Summary of studies of Cambrian brachiopods.

CHAS. S. MINOT : On certain changes of nuclei in relation to age.

J. MCK. CATTELL : Researches from the Psychological Laboratory of Columbia University.

H. F. OSBORN : Additions to the Collections of Extinct Vertebrates in the American Museum of Natural History.

W. K. BROOKS : A biographical memoir of Alpheus Hyatt.

RESTON STEVENSON and J. LIVINGSTON MORGAN : Drop weight and the law of Tate ; the determination of the molecular weight in the liquid state by the aid of drop weights.

E. C. PICKERING : The relation of the spectra, magnitudes, and colors of stars.

SIMON NEWCOMB : Tables of Minor Planets discovered by James C. Watson, prepared by A. O. Leuschner under the direction of the Watson Trustees of the National Academy of Sciences.

It was announced that General Cyrus B. Comstock had given to the National Academy of Sciences $10,000 as a fund, the income to be used for the advancement of knowledge in magnetism, engineering and radiant energy.

3. *American Association for the Advancement of Science.*—The fifty-eighth meeting of the American Association will be held at Chicago, in the buildings of Chicago University, from December 30, 1907, to January 4, 1908, with Professor E. L. Nichols as the president. The meetings of the usual affiliated societies will also take place at the same time. A preliminary announcement relating to this, the sixth of the Convocation week meetings, has recently been issued by the Permanent Secretary, Mr. L. O. Howard of the Smithsonian Institution, Washington.

4. *Annual Report of the Board of Scientific Advice for India for the year 1905–1906.* Pp. 171. Calcutta, 1907 (Government Central Press).—The Board of Scientific Advice for India was established in 1902 as a central authority for the coördination of official scientific inquiry, with the design of making research work as effective as possible and also of aiding the Government of India in connection with the investigation of questions of economic and applied science. The subjects included are economic and agricultural chemistry, astronomy and meteorology, geology, geodesy and geography, botany and zoology. The volume now issued contains concise reports by different authors in these different departments and presents many interesting facts. In geodesy, Lieut.-Col. Burrard gives the results of determination of the altitude of some of the peaks of the Himalayas as influenced by atmospheric refraction; the height of Mt. Everest, for example, as observed from the plains of India, is some 29,002·3 feet, while from the Darjeeling Hills it is 29,141. The same author in connection with the Seistan (Afghanistan) geography, discusses desiccation in Central Asia, expressing the opinion that the theory of a permanent climatic change within the human period calls for meteorological proof before it can be accepted. The constant tendency of the sand to increase while the amount of water is constant is shown to have an important bearing on the problem.

5. *Mendelism;* by R. C. Punnett. Second edition, pp. vii + 85. Cambridge, 1907 (MacMillan & Bowes).—The appearance of a new edition of this well-written essay on Mendel's principles of heredity within two years after the first printing of the work indicates the cordial reception which the little book has received. The stories of Mendel's discoveries and their applications in the breeding of plants and animals is presented in popular language by one who has had wide experience in testing the applicability of the so-called law. Even in the short time that has elapsed since the printing of the first edition, discoveries have been made which have necessitated considerable revision of the original text, and it is obvious that the end is not yet.

W. R. C.

6. *Les Prix Nobel in 1904.* Stockholm, 1907 (P. A. Norstedt & Söner).—This annual volume describes the distribution of the Nobel prizes in 1904. It contains sketches and portraits of the recipients of the prizes—in science, Lord Rayleigh, Sir William Ramsay and Dr. I. P. Pawlow,—and also reproductions of the Nobel medals and diplomas. The Nobel lectures, delivered at Stockholm by the three gentlemen named, are also reproduced.

7. *Memorials of Linnæus.* British Museum of Natural History, Special Guide No. 3. Pp. 16. London, 1907.—This pamphlet contains a list of the collection of portraits, manuscripts, specimens, and books brought together at the British Museum to commemorate the bicentenary of the birth of Linnæus.

8. *Astronomical Observatory of Harvard College*, Edward C. Pickering, Director.—Recent publications from the Harvard College Observatory are included in the following list (continued from vol. xxiii, 323):

Annals.—Volume XLVII, Part I. A photographic Study of Variable Stars, forming a part of The Henry Draper Memorial; prepared by Williamina V. Fleming under the direction of Edward C. Pickering. Pp. 113, with 5 tables. Volume LVII, Part I. Observations of Seventy-five Variable Stars of Long Period during the years 1902-1905; prepared for publication by Leon Campbell under the direction of Edward C. Pickering. Pp. iv, 210, with 2 plates and 13 tables. Vol. LX, No. IV. 1777 Variables in the Magellanic Clouds; by Henrietta S. Leavitt. Pp. 87-108, with 2 plates and 6 tables. No. V. Ten Variable Stars of the Algol Type; by Henrietta S. Leavitt. Pp. 109-146, with 3 plates and 15 figures.

Volume LXII, Part I. Determination of Constants for the Reduction of Zones Observed with the Meridian Circle during the years 1888 1898; by Arthur Searle. Pp. 145, with 9 tables.

Circulars—No. 125. Stellar Magnitudes; by Edward C. Pickering. Pp. 3, with one table.

No. 126. Two Variables discovered by M. Baillaud; by Edward C. Pickering. Pp. 3, with two tables.

No. 127. New Variable Stars in Harvard Map, Nos. 3 and 6; by Edward C. Pickering. Pp. 4, with three tables.

No. 128. Missing Durchmusterung Stars; by Edward C. Pickering. Pp. 4, with one table.

No. 129. 15 New Variable Stars in Harvard Maps Nos. 31 and 62; by Edward C. Pickering. Pp. 4, with two tables.

No. 130. 71 New Variable Stars in Harvard Maps, Nos. 9, 12, 21, 48, and 51; by Edward C. Pickering. Pp. 4, with two tables.

9. *New York State Museum, Albany, N. Y.* John M. Clarke, Director.—The following publications have recently been issued:

Third Report of the Director of the Science Division, 1906, including the 60th Report of the State Museum, the 26th Report of the State Geologist, and the Report of the State Paleontologist for 1906. Pp. 182.

Bulletin 111, Geology 13. Drumlins of Central Western New York; by H. L. Fairchild. Pp. 391–443.

Bulletin 112, Economic Geology 16. The Mining and Quarry Industry of New York State: Report of Operations and Production during 1906; by D. H. Newland. Pp. 80.

10. *Dew-ponds;* by Edward A. Martin, F.G.S. Reprinted from "Knowledge and Scientific News," Maryland, June 1907.—These ponds are shallow artificial hollows, without inlet or outlet, made on the English downs. The writer discusses their construction and the theories accounting for their filling. He regards it as certain that mists contribute largely to these ponds, and points out that if dews contribute also it may be necessary to revise somewhat the theory that dew is really formed from moisture which rises out of the soil rather than from moisture condensed from the air. J. B.

INDEX TO VOLUME XXIV.*

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* This Index contains the general heads, Botany, Chemistry (incl. chem. physics), Geology, Minerals, Obituary, Rocks, Zoology, and under each the titles of Articles referring thereto are mentioned.

Dr. Cyrus Adler,
Librarian U. S. Nat. Museum.

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1907

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IMPORTANT NOTICE.

If you wish to secure choice rare or ordinary minerals and cut gems, now is the time to buy them, as we have inaugurated our yearly summer reductions of 10 per cent. on rare, showy minerals and cut gems, and 20 per cent. on ordinary minerals. This reduction is for the months of July and August only. Our stock is the largest and finest that has ever been. Especial attention is called to the immense size of some of our precious and semi-precious cut gems, running as high as 30 carats, all of which will make a brilliant addition to your collections:—Siberian Amethysts, deep purple color, at night reddish color, like Arizona Garnets, from 1 to 30 carats; Topaz, Bahia, Brazil, from 1 to 40 carats, deep golden color; Red, pink, green and blue Tourmalines, from Minas Geraes, Brazil, from 1 to 10 carats; Red Tourmalines, from Ural Mts., from 1 to 8 carats; Opals, Whitecliff, New South Wales, Australia, from 1 to 8 carats, milky with deep fire. Fine Opal Shells, perfect; are considered very rare when perfect.

RARE NORWAY MINERALS

Leucophane crystals, in the matrix, finest in the world; Polycrase xls in matrix; Thorite xls; Gadolinite xls; Broggerite xls; Hellandite, new mineral, xls in matrix; Monazite xls in matrix, and loose xls; Rutile xls; Malakon xls in the matrix; Apatite xls; Xenotime xls; Euxenite xls in matrix; Katapleit xls in matrix.

NEW CRYSTALLIZED NATIVE COPPER

which was advertised and illustrated in the American Journal of Science and Mineral Collector. We secured the whole output of one pocket. Five of the finest specimens still remain, price from $10 to $70. (Write for further particulars and illustrated circular.)

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We have an extra fine lot of these Scientific Rubies, from ½ to 4 carats, at $5 per carat.

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Anatase, Binnenthal, and St. Gothard, Switz., $4–$10. Dioptase, Siberia, $7.50–$20. Phosgenite, Eng., $2–$10. The *new mineral* Zeophyllite, Radzein, Bohemia, $3–$7.50. Bismuthinite, $4–$6. Eulytite, Saxony, $5–$6. Alexandrite, Ural Mts., xls from $3–$5, matrix specimens from $20–$25. Zeinerite, Joachimsthal, Bohemia, $3. Terlinguaite, Terlingua, Texas, $3. Graftonite, Grafton, N. H., from $2–$3.

CALIFORNIA MINERALS

Pink Beryls, Pala, in matrix, and loose xls, $8–$35. Blue and white Topaz, Romana Co., $8–$10. Colemanite, San Bernardino Co., $2–$5. Californite, Pala, polished slabs, $1–$5. Kunzite, from 50c. to $50. Cinnabar, from Sonoma Co., and New Almaden, fine xls in matrix. $2–$5. Tourmalines, Mesa Grande, and Pala, in matrix and xls, different colors, 50c.–$100.

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Stibnite, from 25c to $7.50. Barite, different colors, $1–$5. Realger, $4–$5. Orpiment, $1.50–$3. Cinnabar, $2–$5. Bournonite, $1–$3. Sphalerite and Quartz, 50c–$4. Blue Chalcedony Pseudomorph, 50c–$2.

Crystallized Gold, Silver, Calaverite, and Copper

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RECENT ARRIVALS

Scheelite, massive xls, and yellowish Powellite, Oak Springs, Nevada, $2.50 to $5; Tetradymite and Green Bismutite, Nevada, $1 to $3; Rose Chalcedony, Aurora, Nevada, $1 to $5; Zinkenite, Mosey, Nevada, $1.50 to $3; Copalite on Coal, Castle Gate, Utah, 50c. to $1; Calaverite, Cripple Creek, Colorado, 50c. to $5; Onegite, El Paso Co., Colorado, $1 to $3; Cobaltite, Cobalt, Canada, $3 to $7.50; loose crystals, 10c. to 25c.; Niccolite, Cobalt, Ontario, Canada, 75c. to $4; Native Silver and Niccolite, Cobalt, Ontario, Canada, $2 to $10; Erythrite, in native silver, Cobalt, Ontario, $1 to $5; Rhodonite, Franklin Furnace, N. J., $2.50 to $10; Petrified Wood, Chalcedony Park, Wyoming, $2.50 to $5; Opal, Barcoo River, Queensland, Australia, 50c. to $5; Tourmaline, Mesa Grande, California, different colors, in matrix, and loose xls, from $2 to $50; Hubnerite, 75c. to $5; Bismuth and Cassiterite, Bohemia, $2 to $5; Native Antimony, Prince William, New Brunswick, $1 to $2; Tellurium, Boulder, Colorado, $1 to $5; Native Platinum, Columbia, S. America and Oregon, from $2 to $5.

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IMPORTANT NEWS.

We have secured one of the finest collections ever gotten together by a Brooklynite, and we think all will know its owner without mentioning his name. It is rich in the much-sought-after old finds and rare minerals which were plentiful 25 or 30 years ago, but which cannot be secured at any price to-day, except out of very old collections. It is valued at over $10,000. Some of these specimens are so rare and fine that the owner has been importuned many times to part with them by universities, museums and the better class of collectors, but in every case he has refused their offers, not wishing to break the collection. It will now be offered on and after September 1st, in lots to suit purchasers, at a very reasonable figure. First come first served will be the rule. Don't delay and then blame us, as we know there will be a rush to secure the finest of these specimens. If you cannot call on us send us your wishes and they will be filled to best advantage. This collection has been correctly labelled according to the Dana System by its owner, so that all purchasers are assured of the accuracy of these specimens. Further particulars on application.

"OUR NEW CIRCULAR."

We have just issued a new 8-page Circular, covering almost all our stock at present date, except the Brooklyn Collection, the East Indian and Russian Gem Collections, and two other European collections that are on their way. Special Circular will be issued of these as soon as they arrive and are arranged.

RECENT ARRIVALS

Tetradymite and Green Bismutite, Nevada, $1 to $3; Rose Chalcedony, Aurora, Nevada, $1 to $5; Zinkenite, Mosey, Nevada, $1.50 to $3; Copalite on Coal, Castle Gate, Utah, 50c. to $1; Calaverite, Cripple Creek, Colorado, 50c. to $5; Onegite, El Paso Co., Colorado, $1 to $3; Cobaltite, Cobalt, Canada, $3 to $7.50; loose crystals, 10c. to 25c.; Niccolite, Cobalt, Canada, 75c. to $4; Native Silver and Niccolite, Cobalt, Canada, $2 to $10; Erythrite, in native silver, Cobalt, Canada, $1 to $5; Rhodonite, Franklin Furnace, N. J., $2.50 to $10; Petrified Wood, Chalcedony Park, Wyoming, $2.50 to $5; Opal, Barcoo River, Queensland, Australia, 50c. to $5; Tourmaline, Mesa Grande, California, different colors in matrix and loose xls, from $2 to $50; Hubnerite, 75c. to $5; Native Antimony, Prince William, New Brunswick, $1 to $2; Tellurium, Boulder, Colorado, $1 to $5; Native Platinum, Columbia, S. America and Oregon, from $2 to $5.

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ENGLISH MINERALS

Violet Fluorite, Durham; Gray Fluorite; Fluorite and Galena; Yellow Fluorite, a great variety of different colors; Emerald green Fluorites, very rare; Quartz, studded with fine Fluorites; Barytes, different varieties and colors, double termination; Cockscomb Baryte, Frizington; Fleam Calcite; Calcites, different varieties and colors; Calcite, twin forms with Dolomite, Park House; Specular Iron with pearl calcite; Hexagonal Calcite, showing moss structure; Pyrites, Frizington; Iridescents, Woodend; Hausmannite, Cumberland—this is quite a new local mineral.

SCIENTIFIC RUBIES

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NEW ARRIVALS.

Azurite Balls, Bisbee, Arizona, 25c. to $5. Azurite, Copper Queen, Arizona, 50c. to $10. Psilomelane, Inwood and Montreal, Mich., 25c. to $3.50. Herderite, Poland, Me., 50c. to $20. Malachites, Russia and Arizona, 50c. to $5. Aragonite, Chessy, sixlings, doubly terminated, 25c. to $1. Stalactites, Arizona, 25c. to $15. Diaspore, crystallized, Chester, Mass., $2.50 to $5. Wulfenite, Organ Mts., Arizona, $1 to $7.50. Chalcotrichite, Morenci, 75c. to $5. Calamine, Montana and New Jersey, 50c. to $5. Chalcanthite, Arizona, 50c. to $4. Topaz, Utah, matrix, $1 to $1.50. Native Antimony, Prince William, N. B., $1 to $2. Native Copper, Lake Superior, Mich., 50c. to $5. Native Silver and Copper, 50c. to $12. Native Gold, crystallized, Hungary, $15, and Nova Scotia, in quartz, $8 to $15. Tourmaline, Mesa Grande and Pala, Calif., Hamburg, N. J., Haddam, Conn., Paris, Me., 25c. to $1.50. Chrysocolla, Arizona and Chili, 50c. to $8. Azurite and Malachite, Arizona, 50c. to $5. Freibergite, Cobalt, 50c. to $1. Cobaltite, $1 to $5; loose crystals, 10c. to 25c. Smaltite and Silver, 75c. to $10. Native Silver on Cobalt, $2 to $10. Erythrite on Native Silver, $1 to $5. Agates, Brazil, Michigan, Germany, etc., 25c. to $5. Petrified Wood, Arizona, $1.50 to $5. Opal, Australia, 50c. to $25. Phenacite, Chatham, N. H., 50c. to $2. Topaz, Chatham, N. H., $1 to $3. Amethyst, 50c. to $5. Amazonstone, 35c. to $5.

ENGLISH MINERALS.

Calcites, nailhead, flame, red, white, pink, many forms and colors, 25c. to $3.50. Fluorites, green, purple, brown, yellow, 35c. to $7.50. Hausmanite, new find, 35c. to $2.50. Chalcosiderite, $1 to $5. Hematite, specular with Pearl Spar, 35c. to $2.50. Dolomite with Calcite Twins, 35c. to $1.50. Pyrite, iridescent, 50c. to $1.50; rare form, 75c. to $1.50. Barite, 25c. to $5.

NORWAY MINERALS.

Gadolinite, $8. Hellandite, $5. Monazite crystals, $1 to $5. Rutile, $3. Malakon, $1. Xenotime, $8. Thorite, $2.50. Apatite, 25c. to 75c.

OTHER LOCALITIES.

Zinkenite, Nevada, $1.50 to $3.50. Calaverite, $1.50 to $3. Mixite, 50c. to $1.50. Linarite, 50c. to $1.50. Bixbyite, $5 to $7. Brochantite, 50c. to $1.50. Zeunerite, Utah, 75c. to $2. Hessite, Hungary, $10 to $25. Anatase, Binnenthal, $4 to $10. Crocoite, Brazil and Dundas, Tasmania, $3 to $15. Columbite, N. C., $1 to $5. Graftonite, N. H., $1 to $4. Microlite in Albite, and loose crystals, Amelia, Va., $4 to $7. Phosgenite, England, $2 to $15. Samarskite, N. C., 50c. to $5. Euclase, Urals and Brazil, $5 to $40. Argentite, $5 to $12. Zeophyllite, Radzein, $1 to $5. Enargite, $2.50 to $5. Bournonite, $2 to $5. Tetrahedrite, $1.50 to $10. Cinnabar, $3 to $10. Pink Beryl, Pala, Calif., $10 to $35.

We still have three of those rare native coppers from Bisbee, Arizona, described in this Journal of March. Write for further particulars.

GEM MATRIX SPECIMENS.

Diamond in the matrix, Old Mine, Kimberley, South Africa, $25 to $40. Ruby in limestone, Burmah, $25 to $35. Alexandrite in matrix, fine crystals, $20 to $25. Hiddenite in matrix, $10 to $25. Ruby Spinel in limestone, Burmah, $5 to $10. Ruby Spinel Crystals from Ceylon, 35c. to $2.50. Emerald in matrix, Bogota, $10 to $50; Ural Mts., $10 to $50; Habacktelthal, Austria, $2 to $10; Alexander Co., N. C., $2 to $10. Rubellite in matrix, Alabashka, $5 to $15. Lot of Topaz, Ural Mts., crystals and matrix specimens, $7.50 to $20; lot of crystals, Minas Geraes, Brazil, 75c. to $5; crystals from Mexico, 25c. to $5; matrix specimens, 50c. to $10; from Siberia, $5 to $10. Beryls, a variety from different localities, 25c. to $10. Kunzite, $1 to $25.

A. H. PETEREIT,
81-83 Fulton St., New York City.

Dr. Cyrus Adler,
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WHAT WE HAVE DONE, AND WHAT WE INTEND TO DO.

OUR PAST ACHIEVEMENTS.

Another Fall and Winter Campaign in the Mineral Business is before us. A little review of our work in the past and prospects for the future is not, therefore, at this time out of place. We are going to "blow our horn," but will simply state facts.

Two years ago we were almost unknown in the Mineral World; to-day we are the leading emporium of minerals in America, and the leading firm in the distribution of foreign minerals. We have in the past two years bought out and sold wholly or in part thirty-five collections, ranging in value from $500 to $5,000. We have had exhibitions at the Miners' Exposition, the American Museum of Natural History, and the Brooklyn Institute of Arts and Sciences. We have sold a number of notable and rare minerals, among them a remarkable Tourmaline Crystal from California, remarkable Kunzite Crystals, extraordinary Cut Gems, some extremely rare and new German minerals, etc., etc.

OUR FUTURE PROSPECTS.

The prospects for this Fall were never so promising in the number of remarkable collections, large or small, we have secured for our patrons. First and most notable is the consignment of Russian and East Indian Gem Minerals, which will soon be here. This consignment is so large and so remarkable that no dealer in gems in this country can equal it. Some of the individual specimens are so fine that it will be almost impossible to satisfy all our patrons without auctioning them off. But of this more in the future number.

Next in importance is the "Brooklyn" Collection, so called because the owner does not wish his name known. This is full of what are called unattainable specimens, that is, specimens from exhausted localities, in so fine examples that other localities producing the same minerals have never equalled them in crystallization or beauty. In other words, just those specimens you have "hankered after" but could not get, even though you carried "a wad of the long green." This collection is now on sale.

Then next in importance comes the English consignment, comprising a large shipment from the well-known English localities. It is not necessary to speak of the great beauty of these specimens, as you are all familiar with them, except to say they are fresh specimens, never before offered for sale, and contain several new shades on color in the Fluorite, Calcites, etc.

There are still three other European consignments on the way that we will describe later.

Of small lots of minerals there is an innumerable number either here, on the way, or under negotiation. So that we are not exaggerating when we say that never has there been so many and so fine and rare specimens offered at one time; and while we would be justified in feeling proud of our success, we take greatest pride in our file of letters from well pleased and satisfied patrons, both private and public.

Send for our three new circulars describing our stock, our gems, and the Brooklyn Collection.

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NEW ARRIVALS.

These minerals come direct from the mine, not from any dealer, and is the finest consignment ever received from Europe. There are large and small specimens, some excellent for Museums, and all at very reasonable prices. Those from Hungary are the most important. On account of the large number of specimens and in order to introduce them to you, we will have Bargain Sales every day this month, so do not fail to come and see them. If not convenient for you to call, we would be pleased to send the goods on approval. A few of them we name below:

Rhodochrosite, Kapnik, 50¢ to $5; with Quartz and Calcite, Kapnik 50¢ to $5; with pink quartz, 50¢ to $5; Barite, different colors, Felsöbanya, with stibnite, realgar, etc., 75¢ to $5; Stibnite, Felsöbanya, star groups, fine large groups, with stout crystals on smoky quartz, 75¢ to $10; Plumosite, Felsöbanya 75¢ to $4; Calcite, pink, from Borpasak. Kapnik, and Feketebanya, 75¢ to $2; Pyrite, Felsöbanya, and Kapnik, with bournonite and braunspar, 25¢ to $3; Fluorite, Kapnik, lilac color, 50¢ to $3; Bournonite, Kapnik and Felsöbanya, with tetrahedrite, pyrite, sphalerite, etc., 50¢ to $5; Cinnabar, Kapnik, $1 to $4; Chalcopyrite, Felsöbanya, and Kapnik, with wurtzite, sphalerite, braunspar, etc., 75¢ to $3; Pearlspar, Kapnik, 75¢ to $2.50; Libethenite, Libethen, $2.50 to $5; Sphalerite, Kapnik, and Felsöbanya different colors, with chalcopyrite, galena, tetrahedrite, etc., 50¢ to $4; Galenite, Felsöbanya, and Kapnik, with tetrahedrite, calcite and braunspar, 50¢ to $4; Galena, twin, Rodna, $1 to $1.50; Tetrahedrite, Kapnik with bournonite, sphalerite and chalcopyrite, $1 to $5; Marcasite, Felsöbanya, 50¢ to $2; Braunspar, different tints, Felsöbanya, $1 to $2.50; Quartz, different colors, Felsöbanya, with citrine, braunspar, and chalcopyrite, 50¢ to $2.50; Sphereosiderites with stibnite, Felsöbanya, $5 to $7.50, Amethyst, Nagybanya, with Marcasite, 50¢ to $3; Helvite, Kapnik, $1 to $2.50; Realgar, Felsöbanya, beautiful crystals, $1 to $5; Chalcedony, Trestia, different colors, 50¢ to $7.50; Semseyite, very rare, with Galenite, Felsöbanya, $5 to $12; Gypsum, crystals beautiful, Diembrava, 75¢ to $2.50; Grossularite, Vasco, $1 to $4; Cerussite, Rodna, 75¢ to $2.50; Greenockite, Dognacska, $3 to $5; Sylvanite, Nagyag, $5 to $7.50; Hessite, Botes, $20 to $35; Gold, beautifully crystallized and in leaves, some in matrix, $2 to $15; Topaz, Schneckenstein, Saxony, in matrix and loose crystals, 20¢ to $3.

We have a very fine lot of all the known gems on hand, which will be suitable for a Christmas Gift; write for our gem circular.

There are a number of other important consignments on the way, one of which is now in the Custom House, and will be on exhibition and for sale at the same time as above. Some of these are so extremely rare that they will repay a long trip to see. Further particulars cheerfully furnished.

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