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NATRAMBLYGONITE.

Having secured a small lot of this new mineral as described in this Journal, No. 181, January 1911, by W. T. Schaller, I am now in a position to furnish desirable specimens of same, at very reasonable prices.

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A. H. PETEREIT,

81—83 Fulton Street, New York City.

Phone Beekman 1856.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*An Open-Air Telescope*; by DAVID TODD.

> "Out upon the border-land I see the glimmer of new lights that wait for their interpretation, and the great telescopes of the future must be their interpreters." — *Alvan Graham Clark* (1893).*

But enthusiast for the great telescope as Clark always was, the advance of astronomy during the fifteen years since his death has far outstripped even his sanguine expectation. Already we have a number of newly-discovered variable stars of the antalgol type, bright at intervals but most of the time very faint, and the minimum light of some of which goes far beyond the visual reach of present telescopes. Ritchey's marvelous photographs of nebulæ and star-clusters have

FIG. 1.

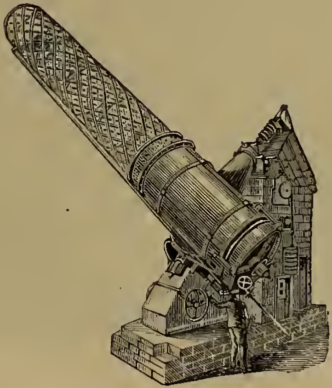

FIG. 1. 4-foot Melbourne Reflector. (Designed and built by Thomas Grubb.)†

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* Clark, Astron. and Astrophys., xii, 678, 1893.
† Grubb, T., Phil. Trans. Roy. Soc., clix, 127, 1869.

brought to light unexpected features of these primal cloud-like forms, without minute optical knowledge of which we can scarcely hope ever to know their full significance in the cosmogony. These are but two of the "new lights" that await the present-day astronomer's interpretation.

All telescopes are made up of three parts: Objectglass, eye-piece, and some form of rigid mechanical connection between the two. Usually this last is a round tube, either cylindrical or conical; but there is no optical reason why it may not take any shape that the exigencies of mechanics or engineering may demand.

FIG. 2.

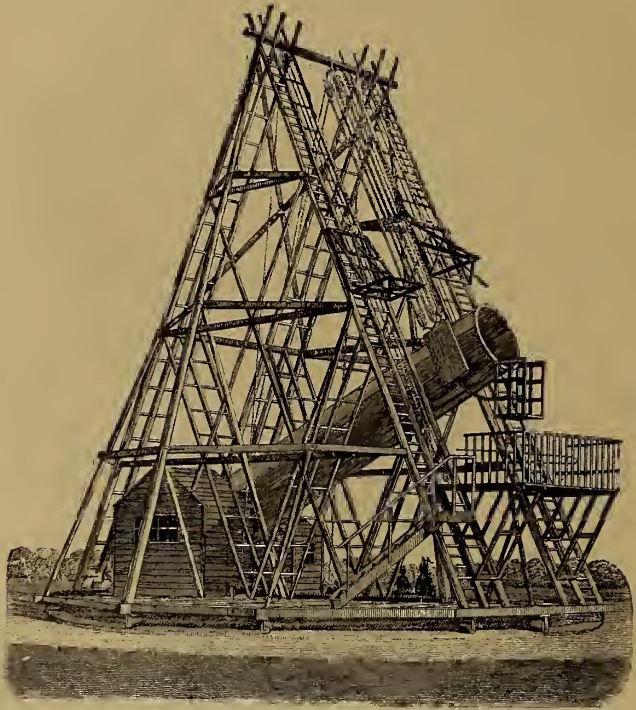

FIG. 2. Sir William Herschel's 40-ft. Telescope. (Inscribed to his Royal Patron, King George the Third, 1795.)*

Many open-tube telescopes have been built. Huygens (1629-95) even built one with no tube at all, an aërial telescope, as he called it; the objective in a counterbalanced cell with universal joint, mounted on top of a tall pole. He drew the

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* Herschel, W., Phil. Trans. for 1795, p. 347.

axis of the objective into approximate line with the axis of the ocular by means of a small cord or wire reaching down to the observer on the ground. No objective of modern optical excellence could ever be satisfactorily used in this way. The 4-foot Melbourne reflector designed and built by Thomas Grubb (1800-78) has an open tube of spirally interlacing straps of steel. (Fig. 1.)

FIG. 3.

FIG. 3. Lord Rosse's Great six-foot Reflecting Telescope. (Birr Castle, Parsonstown, Ireland.)*

The superior performance of a great telescope in the open air has long been known to astronomers. The huge instruments of Sir William Herschel (1738-1822) (fig. 2), of Lord Rosse (1800-67) (fig. 3), and of Lassell (1799-1880),† were all open-air instruments. All these were reflectors of course; but the

---

* Rosse, Phil. Trans., cli, 681, 1861.

† Lassell, Mem. Roy. Astron. Soc., xxxvi, 1867.

same is true of refractors, as I found in 1907 when exigency required the mounting of the 18-inch Amherst refractor in the open-air tennis court of Oficina Alianza, in the foothills of the Andes above Iquique, Chile. With a serene atmosphere, cloudless, rainless and windless, it was not surprising that the Expedition brought back to Professor Lowell many thousand photographs of Mars which far surpassed all contemporary pictures. The universal excellence of definition at Alianza was largely due to open-air working of the telescope; and no astronomer who has once had such an experience would ever insist on operating a telescope from the interior of a dome, except as protection from the weather necessitated it.

Fig. 4.

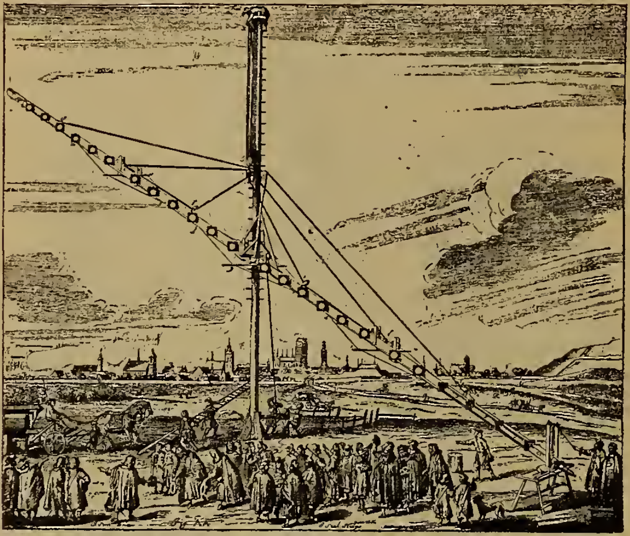

Fig. 4. Typical Great Telescope of the 17th Century. (Built and used by Hevelius at Dantzig.)

The design for a type of open-air telescope which it is the object of this paper to present is the outcome of many years of practical work with both reflectors and refractors.

The optical advantages of great focal length were known to the earliest telescope makers, especially Huygens, Cassini (1625-1712), Hevelius (1611-87), and Bianchini (1662–1729), whose instruments had single-lens objectives, the harmful aberrations of which were, they found, very greatly reduced by figuring the lens nearly flat, so as to throw the focus remote from the objectglass. But these early makers of long telescopes were deprived of realizing the full optical advantage of this construction by the backward condition of: first, the art of making optical glass; second, the art of figuring and polishing a lens; third, the undeveloped stage of metal working; and fourth, the lack of suitable engineering design. (Fig. 4.)

To any practical astronomer, the almost insuperable difficulties in the use of such a telescope would immediately occur. Auzout (1630–91) perhaps built and used a similar one 600 feet in length, but I cannot see how he could ever have done either, with the lack of resources of his day.

The Hall-Dollond (1703–71)-(1706-61) invention of the achromatic objective did not cancel the desirability of great focal length, and subsequent investigators have not wholly eliminated it. With the longer radii of curvature of the surfaces, both crown and flint lenses can be reduced to a minimum in thickness with corresponding reduction of the loss of light by absorption. The chief gain of great focal length, as Hastings has shown,* is that both spherical and chromatic aberrations are more effectively reduced.

While the parts that make up the complete telescope are but three, the elements that interfere with, and even preclude, its perfect construction and working are essentially but three also. Foremost of all is the ever mobile atmosphere which, though it be transparent, is always quivering and tremulous, never quiescent; second, the imperfections of work of glassmaker and optician; and third, insufficient and imperfect design or malconstruction of mechanical parts of the telescope or mounting, which often interfere seriously with its working, or stand in the way of advance to greater optical power.

A century ago the 40-foot reflector of Sir William Herschel was in use at Slough, and six-inch object glasses were considered the largest possible. A half-century later Lord Rosse had finished his 6-foot reflector at Parsonstown, and the Clarks were beginning an 18½-inch objective,—a truly great advance.

The years since then have brought unparalleled progress in glass construction,† in optical methods, and even more in the mechanic arts. Telescope builders have advantaged greatly from all this practical progress, culminating in the 40-inch Yerkes telescope (1897), a noble instrument which has given excellent account of itself in the skillful hands of Barnard and Burnham, Frost, Hale, and Ritchey.‡ (Fig. 5.) But it is a close approach to the ultimate size attainable in the refracting telescope, so long as we confine ourselves to this type of mounting.

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*Hastings, The Sid. Messenger, x, 335, 1891.

†Vogel, Astrophys. Jour., v, 75, 1897.

‡Hale, Astrophys. Jour., vi, 37, 1897.

FIG. 5.

FIG. 5. 40-inch Telescope of the Yerkes Observatory. (Glass by Mantois, objective by Alvan Clark & Sons, of Cambridgeport, mounting by Warner & Swasey, of Cleveland. The tube is about 65 feet long; and, although the moving parts of this great telescope weigh over 15 tons, the whole is easily managed by one man, through control of several electric motors. The counter-weighted dome-floor rises and falls 23 feet, on the plan originated by Sir Howard Grubb. The photograph shows it near its lowest position. The dome is 90 feet in diameter, and weighs 140 tons.)

The 40-inch glass, too, is in itself so weighty, in consequence of great thickness of both the lenses requisite to accommodate a relatively short tube, that actual flexure of the glass begins to appear as an obstacle to perfect optical performance at varying altitudes. And it is probable that larger objectives of this relatively short focal length would have to be figured for best performance only within a limited range in zenith distance. Needless to say, too, the protecting dome and the cumbrous rising-floor, when added to the cost of the instrument itself, practically prohibit much farther increase of size.*

Solution of the problem of the long telescope, then, resolves itself into two general divisions: (1) to build the tube so that its flexure shall be negligible. The elder Herschel and Lord Rosse both succeeded in this; but their tubes, although the largest ever built, were relatively short. (2) to mount the weighty tube so that it can be pointed with ease to any part of the sky. The mechanical genius of Herschel selected the only feasible type of mounting for a structure of such great weight; and with certain modifications embodying the engineering and mechanical practice of the present day, his design must remain forever the basis of that type of mounting, which, all told, is the best, for future great telescopes. Lord Rosse, however, adopted, not this form of universal mounting, but a modified type in which his "Leviathan" was restricted in use to small hour-angles between two north and south walls.

I have begun my projected telescope not at the end but in the middle, just as a bridge engineer builds a cantilever. (Fig. 6.)

The basis of its tube is a cubical section or compartment of steel plates, reinforced as in box-girder construction, so as to be absolutely rigid and unyielding. For a telescope 200 feet or 300 feet long, I would build this central cube about 20 feet square. On two opposite sides it is perforated to allow the cone of rays to pass through; and on two other sides of the cube, at right angles to the cone of rays, are attached the circular bed-plates of the bearing-pins. In other words, tube and axis are the same in construction as the ordinary type of transit instrument, with shortened axis and a minimum distance between the pivots. Needless to say, this is the form which, in the evolution of transit and meridian circle, has been found to give minimum flexure.

As we are *per force* restricted to standard commercial forms of structural steel, the two halves of the tube must be built up, not as cones (the ideal form) but as square pyramids. As we have rotation about only one axis to deal with, the flexure of the great tube is easy to handle.

Mr. Spencer Miller, the eminent cable engineer, suggests the construction of a 10-foot model of this tube, from standard brass angles. Subjecting this model to known stresses and measuring up the observed flexures would afford the data necessary in deciding what forms and weights of structural steel would be best adapted to the construction of the full-sized

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* All the previous illustrations are taken from my *Stars and Telescopes*, by courtesy of the publishers, Messrs. Little, Brown & Company, Boston.

FIG. 6.

FIG. 6. Proposed Open-Air Refracting Telescope. Todd (1911).

tube. The weight of objective and cell at one end, and of observing-carriage, the observers and accessory apparatus at the other, can be accurately estimated.

It will be apparent that the alt-azimuth type of mounting follows as a necessary consequence of this evolution; and the altitude motion gives no trouble whatever in either design or practical construction: it is only when we reach the azimuth motion that mechanical and engineering difficulties arise, though they are not wholly insuperable ones.

As we go downward from the telescope to the ground, our troubles increase; and they become a maximum when we reach the plane of junction between earth and mounting. Let us now consider the method of dealing with this problem.

Apparently a simple one, it admits of several solutions at first sight practical, but which would actually prove infeasible on trial. The most obvious plan is the one adopted in Sir William Herschel's mounting. Modern ball-bearings provide a vast improvement on the Herschelian construction; but the weakest member of the whole scheme is the horizontal, circular track, which must be at least 50 feet in diameter. To true up this track to a perfect, jointless horizontal plane, and maintain it so, is a practical mechanical impossibility: at least I have not found any mechanical engineer who would undertake either to do it or to suggest a certain way of accomplishing it. Easy enough it is to think such an ideal steel track into existence, but to build one that will stay so is quite another affair. Mounting and adjusting the rollers in a circular race offer no great difficulties; in fact, Mr. Henry Hess of the Hess-Bright Manufacturing Company of Philadelphia, and his corps of able engineers, have worked out the bearing details of at least two feasible designs. In these the rollers are attached to the horizontal base-member supporting the two upright pyramidal towers on which rest the Y's of the horizontal altitude axis.

The simplest and least expensive of the three Hess-Bright designs for rotating motion of the azimuth-base would utilize 50 commercial car-wheels with ball-bearing mounts, and travelling on a 90-pound rail track about 76 feet in diameter. But the best design and the easiest working one is an adaptation of the "Grubb live-ring" with coned rollers of large diameter, their axles turning in ball-bearings and the live-ring travelling with half the speed of the plate itself.

Another plan which presents some advantages would involve the inversion of this design, the rotatory track attached to the underside of the base plate being trued off on its lower side. The supporting wheels would then be themselves stationary, and adjustment vertically as well as horizontally and radially would be facilitated.

But all these designs would offer serious difficulties in actual construction and operation. (1) To make a circular track so near a perfect plane that the load would be evenly distributed among the rollers. In experience with the 35-foot dome of Amherst College Observatory, supported on 14 rollers with an average weight of a ton on each, I have found equable distribution of the load by no means easy, and oftentimes one or two rollers travel part way round as "idlers." With the number of rollers increased to 50, as in the proposed telescope, I think the obstacles to equable load would be very greatly enhanced. (2) To preclude overturning of the entire structure by wind-thrust, a track on the upper side of the base plate would be necessary; and trued up in a plane absolutely parallel to that on its underside. (3) The wind-thrust on the central pintle might prove so great as to deform it, and thus enforce expensive and time-consuming repairs. (4) It is absolutely necessary that the whole structure, weighing perhaps 50 tons, shall turn with perfect smoothness and unvarying resistance, so that the clock-motion in azimuth may drive it with a positive motion, and with that uniformity of speed-variation requisite to maintain the telescope's collimation-line always coincident with the star's vertical circle.

Temperature-adjustment of the base-plate offers no serious difficulty, as the entire plate is readily enclosed within a weather-proof house, in the same manner as the dome at Amherst is sealed against the smoke, dust, fog and temperature-fluctuations of the outer air; that is, by means of a thick hair-felt diaphragm which slips round on a stationary ring faced with planished copper. Also by mounting the vertical towers symmetrically on the base-plate, the stresses in it become very favorable for preventing its deformation.

All the above mentioned Hess-Bright designs contemplate the sustentation of the entire load upon the rollers. As this load need not exceed a ton on each, there is no reason whatever to fear that the whole structure might not turn round with ease, and with some approach to entire smoothness. I am, however, doubtful about its being the best method, even if the principle of flotation were added.

The cardinal objection to this whole plan, which Herschel was the first to employ, lies in the circular horizontal track. In practical use, it would always be accumulating dust, and any defect of precise radial adjustment of the axes of the rollers would give rise to variable friction. This is wholly unallowable, unless the clock-motion is a motor with excessive reserve power.

Let us see if we cannot get along without the horizontal track entirely. What we want is an absolutely smooth, positive and yet exceedingly easy motion of a huge vertical shaft. In order to meet those requisites, and treating it as a shaft simply, we should extend its length downward, and confine its motion as a journal between two horizontal friction rings, slipping between roller bearings on vertical axes. These rings, with perhaps 100 roller bearings for each, 50 outside and 50 in, should have horizontal wheels or rollers of large diameter, ground to perfect cylinders. These rings are intended to operate only when the telescope is in use in the wind. When the air is still, a smoother azimuth motion would be possible if the friction rings are clamped motionless to the concrete well in which the vertical drum revolves.

Then I would float the entire structure in either oil or water, leaving only a few hundred pounds of load on a central button or pintle. In this way a clock of minimum power would suffice to drive a maximum load with perfect smoothness. The expanded vertical axis, then, would be a little like the inner tank of a gasometer when at its lowest point. It should be not less than 50 feet in length, or vertical height; and this drum-shaped form would afford an easy interior construction insuring absolute rigidity of the vertical towers, which might go down through it, as far as thought best. No wind could ever topple the structure over, and the open-air telescope would be safely usable on all but the windiest occasions. By lowering the pintle underneath, and pumping out enough of the flotation to allow the drum to settle down to stationary beds, the drum could be rigidly clamped near the top and bottom, so as to withstand securely all stormy weathers when not in use. In case of a severe gale, the telescope would be pointed quartering to the wind, observing carriage and tail-piece unshipped, and tube directed to the nadir. Here the objective would be double-housed against the storm, and the cell clamped firmly. This would secure both bearings and open-air pyramids against harmful stress due to excessive wind-thrust, as the gale would strike the structure edgewise.

I have not intended in this paper to deal with the solution of any but the most general problems of this proposed telescope. All details have, however, been critically worked out, so that an approximate estimate of cost is available. A 5-foot objective would cost about $125,000, and the entire instrument would represent about double that amount. For instance, the weather-protection of objective and eyepieces, of altitude bearings and of altitude clamp, quick motion and slow motion; also electric motors for operating the same in both coördinates, and for the requisite variable clock-motion in both altitude and azimuth, as well as for driving the rotary tail-piece on a ball-race. With this arrangement, and an adaptation of Prof. Ritchey's double-slide plateholder with independent rotary motion, micrometric work and even precision photography might be quite practicable. All the clamps and motions and clocks may be controlled by electric motors operated from triplicate switchboards in (1) the observing box, (2) the altitude house (not shown on the upright piers), and (3) from the azimuth room concealed beneath the basal drum.

In lieu of observing-chair or rising-floor, observer and assistant ride in a light carriage on the eye-end, swinging on a horizontal ball-bearing axis which passes through the focal plane. This may be wholly enclosed for weather protection, and it can readily be warmed electrically in winter. Should such an instrument ever be erected on a high mountain, as for instance, Fuji-yama in Japan, 12,400 feet elevation, where a saddle within the crater provides an ideal location such that wind would rarely shake the telescope, it would be wholly feasible, in fact very easy, to supply the observing-box with air artificially compressed to sea-level tension. Thereby we should avoid the disastrous effect of mountain sickness, which not only interferes greatly with one's comfort at elevations much in excess of 10,000 feet, but in consequence of the quickened pulse, tends to shorten the life-span of anyone who persists in tarrying long at great elevations, without frequent return to safe and lower altitudes.

Only the open-air alt-azimuth is discussed in the present paper. On the successful construction of such an instrument, an equatorial of similar type would be found easy to design and construct on a mountain side sloping poleward. The best design would be a lengthened polar axis, with adequate flotation drums near each end, and a forked overhanging head, very similar to the alt-azimuth design here given, only more strongly braced, and in which no added weight is requisite for declination counterpoise.

Observatory: Amherst College,
April 22, 1911.

Art. II.—*A New Type of Mercury Air-Pump;* by S. R. Williams.

Perhaps no single piece of apparatus is more generally used in a physics laboratory than an air-pump. Demonstrations involving its use are to be found in mechanics, in heat, and in all the other branches of physics, especially in that comparatively new and widening field of study, the discharge of electricity through gases. A still larger field of usefulness presents itself in the manufacture of incandescent electric lights.

Of the many and varied types of air-pumps each has its own advantages and disadvantages, but for efficiency we recognize two conditions as essential. These are, first, the power to exhaust rapidly and to a high degree, and, secondly, the ability to exhaust against atmospheric pressure. Other desirable features are, of course, compactness, simplicity, and cheapness of construction.

Among the various types of air-exhausting pumps the Geryk, or pulsometer pump (Fleuss Patent), comes the nearest to fulfilling the requirements asked for above. It exhausts rapidly and against atmospheric pressure, but the degree of exhaustion cannot go beyond the vapor pressure of the oil used, and for the average pulsometer which one finds in laboratories throughout the country the degree of exhaustion cannot go beyond the vapor pressure of the moisture which has been drawn into the pump and mixed with the oil. In other words, too much care and trouble must be taken with the pulsometer to keep it in good working condition. It ought never to be used in an experiment to show the triple point of water.

Among the mercurial pumps those who have used the Sprengel or Toepler, or any of their numerous modifications to any great extent, must have welcomed the advent of the Kaufmann, or the Gaede pump, which could be driven with a motor, and at the same time worked rapidly. The Kaufmann and Gaede pumps, however, will not exhaust against atmospheric pressure. This means hitching another pump in tandem with them, which is inconvenient. Frequently this preliminary pumping is done by means of a filter pump, but in many laboratories the water pressure is not sufficient to do this.

It is interesting to note that in the best types of air-pumps mentioned we have their prototypes in devices for lifting water. The piston pump corresponds to the pulsometer, and the old spiral of Archimedes was the forerunner of the Kaufmann and Gaede pumps. In this locality the chain and bucket pump is used very extensively in lifting water. In considering the principles involved, it occurred to me that possibly a mercurial pump might be constructed on the principle of the chain and bucket water-pump which would involve all of the conditions required for efficiency. The object of this paper is to describe such a piece of apparatus.

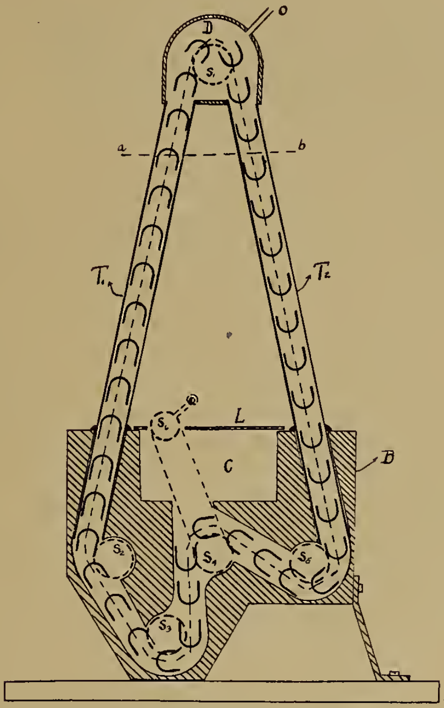
Fig. 1 is a vertical section of the pump devised. Over the sprocket wheels s_1, s_2, s_3, s_4 and s_5, an endless chain runs to which are attached any desired number of buckets. This chain and bucket system is housed in the cast-iron base, B, the two tubes, T_1 and T_2, and the small chamber, D; s_6 is a drive wheel actuated by a crank or motor. Mercury is poured into the chamber, C, until it is nearly full. This fills all the passages below where the sprockets, s_2, s_3, s_4, and s_5, are located. The machine is then ready for use. The vessel to be exhausted is attached to the tube, O. The crank is turned so that the buckets in the tube, T_2, rise. As they ascend they carry themselves full of mercury, which on passing over the sprocket s_1 is dumped out and runs down either T_1 or T_2. On descending through T_1, the buckets are inverted and now carry themselves full of air, which is imprisoned in the buckets when they reach the level of the mercury. This is carried on down around sprocket s_2, and when the buckets pass under s_3 they are turned with the top up, which permits the air to escape, and which rises up through the mercury in chamber C, and so passes to the outside atmosphere through the opening in the cover, L, where the drive chain passes from s_4 to s_6. The buckets then pass on around s_4 and s_5 to repeat the operation. As the exhaustion advances the mercury rises higher and higher in T_1 and T_2 until it stands at barometric height, for instance, at the level indicated by the dotted line $a-b$. In order to take care of what extra mercury rises in the barometric tubes T_1 and T_2, the chamber, C, is recessed out in the casting B.

Instead of the sprocket s_6 and crank, a pulley may be attached and the pump run by a motor. A neater but more expensive form of construction, perhaps, would be to replace the drive chain with a shaft and bevel gearing. In constructing this pump I have made the base B of cast iron and the tubes T_1 and T_2 of boiler tubing, while the chamber D is also a casting galvanized over on the outside to insure that it is air-tight. It will be noticed that only the chamber B and the tubes T_1 and T_2 need to be air-tight, as the bottom of the tubes are sealed off just as in the ordinary barometer tubes.

The speed of the pump in exhausting is limited only by the rate of diffusion of the gas through the tube O from the vessel being exhausted. The pump will exhaust to X-ray vacua.

There are no valves or stop-cocks or cone-shaped bearings to cause a leak just at a critical moment. It is extremely simple, both in construction and operation. Any one who has used a mercury pump knows how exasperating it is to have a connection break at some point and the mercury violently thrown through the pump by the inrush of air, and as a result a pool of mercury and a pile of broken glass in the middle of the floor. If anything breaks about this pump the mercury simply runs back through the tubes into the chamber C and no harm done.

Fig. 1.



It is also apparent that this pump exhausts directly against atmospheric pressure, which the average laboratory will find a decided advantage, as it does not require a second pump in tandem with it. If the cover, L, were air-tight and the buckets driven by a shaft passing through B in an air-tight bearing, it would be possible to shorten the tubes T_1 and T_2, but this would then necessitate another pump attached in tandem and exhausting from chamber C. The buckets may take on any design or shape. Not only the buckets but also the chamber

D and the tubes might very well be enameled inside, which would give the same surface as glass, but the strength of iron or steel.

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Physical Laboratory, Oberlin College,
Oberlin, Ohio, March, 1910.

ART. III.—*Contribution to the Geology of the Boston and Norfolk Basins, Massachusetts. I. The Structural Relations between the Quincy Granite and the Adjacent Sedimentary Formations*;* by G. F. LOUGHLIN.

Introduction.

The rocks, both igneous and sedimentary, of eastern Massachusetts and Rhode Island offer a host of most interesting but, as yet, unsolved problems in petrology, structural geology, and stratigraphy. One of these problems, of critical importance and at the same time unique, is the relation between the Quincy granite mass, just south of Boston, and the adjacent sedimentary formations of the Boston and Norfolk Basins, to the north and south respectively (fig. 1).

The Quincy granite mass, including the prominent Blue Hills range, forms a topographic as well as geologic barrier between otherwise continuous areas of conglomerate, sandstone, and shale.† The sediments of both basins were believed by Prof. Crosby to be the younger, and to contain pebbles of the Quincy granite. The Quincy granite was believed to be of the same age as all the granites of the district. More recent work by Mansfield‡ failed to prove the presence of Quincy granite pebbles in the conglomerate members of the sediments, though pebbles of other granites in the district are plentiful. No explanation of this general absence of Quincy granite pebbles in the conglomerates is offered, but the sediments are, nevertheless, assumed to be younger than the granite. Clapp§ still more recently has found evidence which shows that the alkaline granites in eastern Massachusetts, of which the Quincy granite is one, are distinctly younger than the other granites and related rocks of the district.

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* The field study of this problem was greatly simplified by the exhaustive work of Prof. W. O. Crosby (see Geol. of Boston Basin, Vol. I, Part III, 1900), who has located every outcrop, and discussed at great length the major structural features in the district here considered. The present paper is a modification of certain of his results, based chiefly on the evidence of petrographic study, but is quite in accord with his interpretation of the major structural features of the area.

† The solitary outcrop of gray quartzitic sandstone due west of Great Blue Hill contains partings of carbonaceous shale, and more closely resembles strata in the western Narragansett Basin, R. I., than rocks in the area here discussed. It is of no definite value as a connecting link between the Boston and Norfolk Basins, and may possibly be unconformably related to the rocks in them.

‡ Origin and Structure of the Roxbury Conglomerate; Bull. Comp. Zool. Harvard Univ., vol. xlix, Geol. Ser. vol. viii, No. 4, pp. 161, 168, 169, 1906.

§ Manuscript thesis in part fulfillment of requirements for degree of Ph.D., Mass. Inst. Tech., Geol. Dept., 1910.

The question thus arises: what are the exact age and structural relations between the Quincy granite and the adjacent sedimentary formations? An answer, based on petrographic and structural evidence, and on the finding of Quincy granite-porphyry pebbles in the Norfolk Basin only, is given in the following pages. The evidence appears to prove that the Quincy granite is older than both sedimentary formations, and in the main, to confirm Prof. Crosby's conclusions; but it raises other questions of structural and stratigraphic geology, which will be cited at the close of this paper.

Fig. 1.

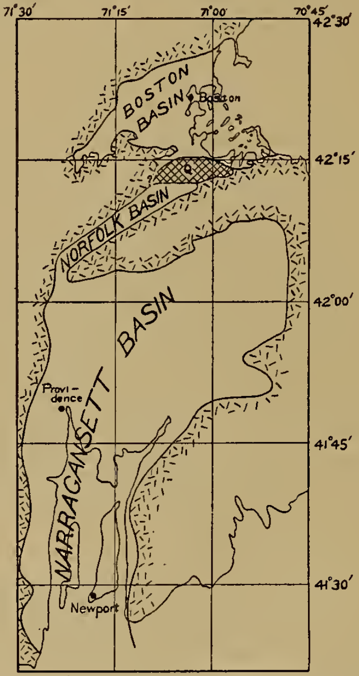

Fig. 1. Outline map showing positions and areas of the three sedimentary basins in S.E. New England (mostly after W. O. Crosby and J. B. Woodworth). "Q" represents the Quincy granite series.

Outline of Geology.

The area involved in the present discussion is shown on the map (fig. 2). The oldest rocks of the district are Cambrian slates, of considerable extent in the eastern part of the area but elsewhere represented only by scattered patches. They are clearly older than all the igneous rocks of the region and need no further mention in this paper.

Biotite-Granite Series.—The next formation in order of age is the biotite-granite series. It extends over a great part of eastern Massachusetts. On the map it is shown along the southern edge, separated from the Norfolk Basin by a profound fault. It also extends around the west and north margins of the Boston Basin with more or less continuity. It includes several phases; alaskite (very subordinate), normal granite, granodiorite, and diorite of varying basicity, which in some places are gradational into one another, and in others are marked by sharp contacts. Where sharp contacts exist, the more acid phases are intrusive into the more basic.

It is of prevailing subalkaline character. The more acid phases, those involved in the present problem, are gray to reddish in color, fine- to rather coarse-grained, and in places porphyritic with reddish feldspar. The chief minerals are gray to white plagioclase (oligoclase to andesine) microscopically altered to aggregates of sericite and epidote with more or less calcite, reddish microcline-microperthite, in which the potassic member is dominant and, as a rule, very free from products of deep-seated alteration; quartz in gray to white glassy grains; biotite in small evenly scattered flakes, largely altered to chlorite. Hornblende, where present, is considerably altered to chlorite and epidote. The most common order of crystallization is: (1) plagioclase accompanied or followed by the femic minerals; (2) microperthite and quartz. The rock is nearly everywhere full of irregular slickensided fractures filled with the secondary minerals, especially epidote. The epidote, as well as the granite walls, is slickensided.

Older Felsite.—Felsites, not including those in the Blue Hills, are found more or less abundantly over much of the same area as the biotite-granite series. They vary somewhat in texture and mineral composition. Where porphyritic, the chief feldspar is gray to white plagioclase, more or less altered to sericite and epidote. Quartz phenocrysts are also commonly present. The predominating femic mineral is green hornblende, more or less chloritized. The groundmass is even-microgranular.

Quincy Alkaline Granite Series.—The Quincy granite series covers a roughly elliptical area, with an east-west major axis, extending across Milton and Quincy, including the entire Blue Hill range, and the northern parts of Braintree and Weymouth. It is bounded on the north by an east-west fault contact with the Boston Basin sediments; on the south in Braintree by another east-west fault, and farther west by uncomformable contact with the Norfolk Basin sediments. Certain irregularities in these boundaries are due to faults of north-south trend, which offset the east-west faults.

The series includes rather coarse- to medium-grained granite, granite porphyry, and quartz porphyry, all of essentially similar composition. The color of the unoxidized rock is mostly a dark bluish, less commonly greenish, gray; that of the oxidized rock pink to red. The chief minerals are microperthite, in which the potassic member is microcline, usually without the characteristic gitter structure, and the sodic member is albite. The latter is equal to, or slightly dominant over, the microcline, and in many thin sections forms outer rims which have the same orientation as the albite streaks within the crystal. There is little plagioclase independently crystallized. The femic accessory minerals are riebeckitic amphibole and aegirite in megascopic dense crystals, and also in crystallites enclosed by feldspar and quartz. Aegirite commonly forms a border around riebeckite. The quartz forms glassy grains, more or less darkened by femic inclusions. The only products of deep-seated alteration are inky-blue crocidolite and magnetite derived from the femic minerals and developed in films along slickensided joint surfaces. Epidote and chlorite are entirely absent, even where the minerals of the rock have been mashed and recrystallized along slickensided fractures. The apparent order of crystallization is: (1) microperthite, (2) femic minerals and quartz. Chemical analyses show but traces of lime and magnesia.*

Thus the Quincy granite series differs markedly from the biotite-granite series in texture, mineral and chemical composition, and in the absence of alteration products, and is readily distinguished in fresh specimens and especially in thin-sections. There may, however, be some difficulty in distinguishing between highly weathered and bleached pebbles of the two rocks.

The porphyry phases of the Quincy granite are limited to the Blue Hills range, and mark the upper contact zone of the intrusive mass.† Their present limited extent is believed due to an upward tilting of the mass to the north, before or during the period of folding and compression faulting, followed by prolonged erosion, which has to-day left only the least elevated portion of the inclined upper contact zone. The superior weathering qualities of the porphyry phases in comparison to those of the normal granite account for the relief and position of the Blue Hills.

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* H. S. Washington, Prof. Paper, U. S. Geol. Survey, No. 14, 1903, p. 144. The analysis shows 0·3 per cent CaO, and a trace of MgO. According to T. Nelson Dale (Bull. U. S. Geol. Survey, No. 354, 1908, p. 94), one half of the CaO is present as $CaCO_3$.

† For detailed evidence see W. O. Crosby, op. cit. p. 364.

A minor phase of the series in West Quincy is a basic alkaline porphyry, containing microperthite as phenocrysts and augite as a constituent of the groundmass. The groundmass, where noted along faults or shear zones, is altered more or less to epidote. This is evidence that where the composition of the rock was favorable, i. e., where lime-alumina silicates were present, alteration to epidote took place during the period of compression. The absence, therefore, of such alteration products as epidote and chlorite in the Quincy granite seems due rather to the absence of lime and magnesia in the rock than, as might at first be supposed, to any wide difference in age.

Alkali Felsite.—The Quincy granite series is cut, on, and west of, Pine Hill in West Quincy, by an irregular mass of felsite, which may be confused megascopically with the felsites above mentioned; but the microscope proves it to be of distinctly alkalic character, and closely related to the Quincy granite in mineral composition. Intrusive bodies of the same type of felsite are found at a few other places in the Blue Hills, and an extrusive body lies between Pine Hill and the ponds to the south.

Evidence in the Boston Basin.

The Boston Basin sediments, assigned to the Carboniferous Age, include a thick mass of Roxbury conglomerate conformably overlain by the Cambridge slate. They are bounded on the north by a fault scarp, which extends west-southwest from Lynn to Waltham or farther, and separates them from the hills of granite, diorite, and felsite; on the south by another fault, of nearly east-west trend, which separates them from the Quincy granite. The sediments narrow westward, and end in a narrow band which curves southward through Needham and Dover. The whole series is thrown into a series of nearly east-west folds, the erosion of which has left alternating bands of conglomerate and slate.

The conglomerate with its intercalated sandy and slaty beds, consists chiefly of felsite, granite, and quartzite fragments, with a minor amount of basic igneous rocks and Cambrian slate. The felsite pebbles are, in most cases, readily identified megascopically as derived from the older felsite masses. A few, which resemble the younger alkaline felsite megascopically, have been proved in thin-section to belong to the older felsite. The granite pebbles also have been proved megascopically and microscopically to belong to the biotite-granite series, though an occasional pebble resembles closely the much weathered surfaces of Quincy granite. Slaty intercalated beds are, so far as seen, of prevailing reddish or purplish color.

These colors are also present in the matrix of the conglomerate where not obscured by the abundance of pebbles or by a strong development of green alteration minerals.

The Cambridge slate, which overlies the conglomerate conformably, is characterized by a bluish gray to nearly black color, and by a distinct, though not prominent, banding.

While evidence throughout the Basin is of general importance, that of most critical value lies in the outcrops nearest the Quincy granite along the south boundary. The structural relations, largely concealed by an extensive covering of glacial drift, have been interpreted as follows by Prof. Crosby*: A band of arkose, measuring from 450 to 500 feet across the strike and dipping steeply to the north, extends eastward along the boundary fault from north of great Blue Hill as far as East Milton. Its terminations west and east are concealed under drift, but evidence as a whole favors the conclusion that its eastward end is bevelled off by the fault. Overlying the arkose is a bed of purplish slate, 100 feet thick, and over that a conglomerate extending through Milton Centre and south of Forbes Hill in Quincy, where it is in contact with the boundary fault. The dip of the sediments varies from 40° N. to vertical or even slightly overturned to the north, and is attributed in part to the drag effected by the faulting. The conglomerate south of Forbes Hill is overlain by Cambridge slate, and has a thickness of 200 to over 400 feet. The thickness of the entire conglomerate series is far greater, and all but the upper part of the series has been concealed by the fault. The displacement along the fault has been estimated by Prof. Crosby to be at least 2000 feet, and is believed to have grown during the deposition of the conglomerate series. The writer's own evidence neither confirms nor denies these conclusions.

Prof. Crosby believed many granite pebbles in the conglomerate south of Forbes Hill to be of weathered Quincy granite, but megascopic and microscopic study by the present writer have failed to identify any of the granite pebbles as belonging to the Quincy type. The so-called arkose was believed both by Prof. Crosby and Dr. Mansfield to contain detritus of Quincy granite, but microscopic evidence fails to confirm this opinion. The rock contains no feldspar, but consists of purplish quartz grains cemented and somewhat enlarged by a recrystallized matrix of sericite and quartz. One or two sericitic aggregates found were more suggestive of altered felsite than of altered feldspar. The "arkose" then gives only negative evidence. It is worth noting, however, that in the biotite granite, even where much altered, the microperthite is very free from sericite; also that where the Quincy granite

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* Op. cit., pp. 417-485.

is exposed adjacent to the fault, its pink microperthite shows no marked alteration to sericite. It therefore seems probable that, had the "arkose" been derived from the Quincy granite, considerable microperthite would be found in thin-section.

This evidence also disproves the suggestion of Dr. Mansfield* that the arkose was the basal member of the series, resting unconformably upon the Quincy granite, and that the boundary fault lay some distance to the north. Further evidence against this suggestion was found by the present writer in the summer of 1909 at Blue Hill village, where a new road cut had exposed the Quincy granite in fault contact with the "arkose." The exposure was small, but showed the fault to be reversed. Its strike crossed that of the "arkose" at a very low angle, its dip was uneven but averaged about 80° south. The dip of the "arkose" was very steep to the north.

The above evidence is reasonable proof that the portion of the conglomerate series now exposed in the Boston Basin was not derived from the Quincy granite; but the absence, on the other hand, of any intrusions from the Quincy granite series into the conglomerate series fails to indicate that the latter is older than the former. Evidence thus far is wholly negative.

Evidence in the Norfolk Basin.

The Norfolk Basin comprises a series of sediments, extending in a belt one to over two and a half miles wide, from Great Pond in Braintree west-southwest to Wrentham, where it joins the Narragansett Basin. Its eastern boundary is concealed by drift, but is believed to be a north-south fault. Its southern boundary is a nearly east-west fault which separates it from the biotite-granite series. The northern boundary, within the area considered, is the south base of the Blue Hills. The sediments consist to some extent of very coarse conglomerate, grit and arkose, but mostly of reddish sandstone and slate. As a whole they strike nearly east-west, and dip 70° to 90° south; outcrops are few and far between, but their attitude as a whole is suggestive of a monoclinal, or closely folded synclinal structure bevelled by the south boundary fault, and modified by minor faults along certain shaly beds. One or two outcrops on the west side of Great Pond have a nearly southward strike and westward dip, indicating a westward pitching syncline. The minor faults are more or less clearly exposed in the railroad cuts about three miles southwest of Great Blue Hill.

The lowest member of the series is called by Prof. Crosby a "giant conglomerate." It is exposed intermittently along

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*Op. cit., p. 206.

the base of the Blue Hills from north of Great Pond westward to Houghton's Pond. Its dip is nearly, or quite, vertical. It is composed chiefly of bowlders, up to four feet in diameter, of a dark reddish granite-porphyry, with smaller rounded pebbles of felsite, slates, and sandstones. The matrix is inconspicuous, save in occasional sandy or shaly lenses, which have a red color.

Prof. Crosby* considered that the granite-porphyry bowlders had been derived from the adjacent hills of Quincy granite-porphyry; and accordingly, that the giant conglomerate was a basal conglomerate; but Dr. Mansfield† failed to identify any pebbles of the Quincy granite series in the giant conglomerate, finding only granite of the biotite type. He, therefore, favored the conclusion that the giant conglomerate was not basal and that the true basal member had been concealed through downfaulting along the present base of the Blue Hills.

The writer first visited the locality with Prof. Crosby in 1909, and later made a microscopic study of the granite-porphyry then collected. It proved undoubtedly to be of the Quincy type, and was free from sericite, epidote, and chlorite. Some of the bowlders in the conglomerate contained portions of small quartz veins which did not pass in the matrix. The same type of quartz vein was found in the adjacent granite-porphyry ledges. The felsite pebbles were not studied in thin-section, and may be partly or wholly derived from the older felsite, but their study was not necessary, so long as the character of the granite-porphyry was proved. Evidence thus proves the presence of Quincy granite detritus in the exposed sediments of the Norfolk Basin, and its absence in the exposed sediments of the Boston Basin.

The giant conglomerate, where measured, has an exposed thickness of 450 to 500 feet. It grades abruptly upward into a greenish gray sericitic grit, or fine conglomerate, in which only one or two small pebbles of Quincy granite-porphyry have been found. Thin lenses of red shale or fine sandstone are also intercalated in the grit. The best exposure of this gradational relation is on the north side of the eastward-flowing stream, south of Bear Hill and but a few steps west of the fork in the north-south road (Randolph Ave.). The grit on the south side of the stream passes upward into red sandstone and slate, which, to the southwest along the railroad, gives way to gray sandstone and slate.‡

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* Op. cit., pp. 471–478. † Op. cit., pp. 221–226.

‡ The outcrops of gray sandstone and shale are isolated and their stratigraphic position uncertain. They may overlie the red sandstone, or may be the equivalent of the grit or fine conglomerate and form the south limb of a syncline. In figs. 3 and 4, the gray sandstone is shown tentatively above the red sandstone.

Field study of the giant conglomerate proves that bowlders and pebbles of Quincy granite-porphyry are confined to those outcrops close to the south base of the Blue Hills range. Several outcrops of coarse conglomerate were studied along, and near, the curving road (Pecunit St.) which borders the Neponset River swamp, a mile and a half southwest of Great Blue Hill, and here, too, pebbles of the Quincy granite series were found to be limited to the northernmost exposures, giving way southward to an increasing number of the epidotic granite, felsite, quartzite, and slate pebbles. The giant character of the conglomerate, however, prevailed even where pebbles of the Quincy series were inconspicuous or absent.. Thin pebbly beds in the red and gray sandstones and shales were found in several places, and in these too the absence of Quincy granite material and abundance of pebbles derived from the biotite granite series is the rule without exception.

INTERPRETATION OF STRUCTURE.

Significance of the Giant Conglomerate.—There can, therefore, be little doubt that the strictly local giant conglomerate is the basal member of the Norfolk Basin sediments along the Blue Hills.

The presence in the conglomerate of bowlders and pebbles of only the granite-porphyry phase implies that only the upper part of the Quincy granite mass could have been exposed at the time. Again, the gradation upward from the giant conglomerate into the grit, sandstone, and shale, of different composition is evidence that the Quincy granite mass was protected from erosion during the deposition of all but the basal member of the Norfolk Basin sediments. Whether it was submerged below sea-level, or buried beneath continental deposits, is a question beyond the scope of the present paper. The considerable thickness, 450-500 feet, of so extremely coarse a conglomerate, and the absence in it of sharply angular bowlders suggest a deposit similar in origin to an alluvial cone, or an accumulation at the base of a wave-beaten cliff as the original form of the giant conglomerate. Either of these forms, as well as the submergence of the Quincy granite mass during sedimentation, would accord with Prof. Crosby's conclusion that the sediments were depositedin a graben.* The bulk of the Norfolk Basin sediments were derived from a land composed of the biotite-granite series, the older felsite, and the Cambrian sediments.

Whether or not identical conditions then existed along the north boundary of the Quincy granite mass is an unanswerable

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* W. O. Crosby, op. cit., pp. 500–502.

question. If they did, pebbles from the granite mass must there too have formed only a local basal member of the Boston Basin sediments, before the Quincy granite was protected from erosion. The absence of such a basal member from the surface to-day may be attributed to the formation of the boundary fault, which left only the upper part of the conglomerate exposed on the downthrow side.

Significance of faults.—Two principal systems of faults are generally recognized through the formations involved in the present discussion—one of nearly east-west, the other of north-south trend. Four faults of the east-west system are of

FIG. 2.

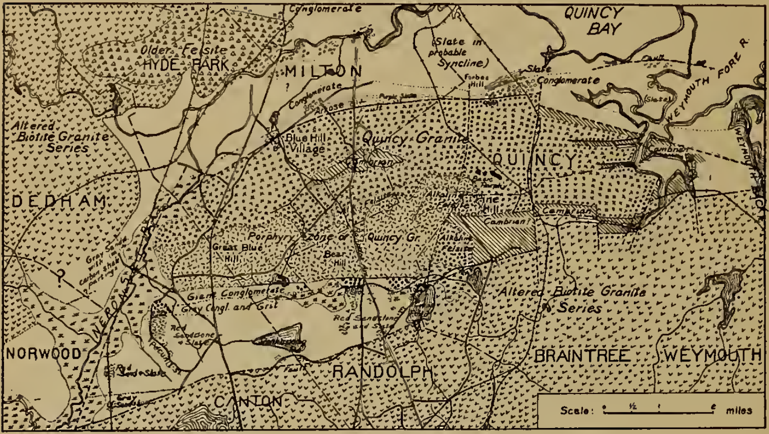

FIG. 2. Map showing the Quincy granite mass, with the adjacent parts of the Boston and Norfolk Basins, and the surrounding area of biotite granite and feldsite. Only actual exposures are mapped within the two sedimentary basins. Boundaries not definitely mentioned in the text are based on Prof. Crosby's descriptions. (Op. cit.) Streams, roads, etc., are copied from parts of the Boston, Boston Bay, Dedham, and Abington topographic sheets of the U. S. Geol. Survey.

especial importance in the present instance. Two are represented on the map (fig. 2), a third passes through Newton Centre and Brookline in the middle of the Boston Basin, and the fourth forms the north boundary of the Boston Basin. These are interpreted as compression faults for the following reasons:—The southernmost fault is almost entirely concealed by drift; but, where exposed in the railroad cuts at Weymouth Landing, the wall rocks, especially the Cambrian slates, are highly slickensided and show the general effects of intense compression and shearing. The fault plane is nearly or quite vertical, but, as a whole, dips steeply to the south with granite as the hanging wall.* In the Norfolk Basin, as already mentioned, the strata lie nearly or quite vertical. Furthermore, slaty cleavage, minor faults, and the more or less conspicuous development of secondary mica, all bear witness to intense compression. In a compressed area consisting of granite and fine sediments, the great contrast in resistance to stress would promote a thrust fault between the two.

The fault between the Quincy granite and the Boston Basin sediments has already been described as of a reversed character. Shearing effects are excellently shown in the "arkose" by minor vein-filled joints, and by the cleavage in slate partings, both diagonal to the dip of the beds and to the trend of the fault. These facts, together with the semi-metamorphic character of the "arkose," favor the interpretation of the fault as one of compression.

The Newton Centre fault needs no discussion. Exposures of it show the slate overridden by conglomerate in an overturned syncline.

The northern boundary fault of the Boston Basin is completely concealed and evidence regarding it cannot be satisfactory; but a small area of conglomerate and sandstone in Medford shows the effects of severe compression, and the large Medford diabase dike crosses the fault without sending branches along it. There must, therefore, have been intense compression along the fault, and the fault must have remained tightly sealed after its formation. There exists, also, as along the southernmost of the faults, the contact between rigid granite and the more flexible sediments. As these faults all lie nearly parallel to the axes of the folds, it seems proper to attribute both faults and folds to a single period of compression. Movement along these faults may have been accompanied by some rotation of the fault blocks, as will be shown beyond. It is also possible that, both before and after the compression period, normal faulting may have taken place along some of these planes, but not to such an extent as to obscure the effects of the compression faulting.

Geologic History.—A restoration of original conditions which accord with the present structure is represented in fig. 3. The Quincy granite mass, with only its top exposed to erosion through a cover of Cambrian slates, then formed a relatively low prominence within a lowland or shallow sea, floored wholly or in part with Cambrian slate of moderate dip. The surrounding highlands were made up of the biotite-granite series, older felsites, and remnants of Cambrian strata. Deposition of detritus from the highlands, and in the lowland,

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* W. O. Crosby, op. cit., p. 392, et seq.

or shallow sea, was accompanied by gradual subsidence of the region, and resulted in a great thickness of conglomerate and sandstones. During the first stages of deposition, the local giant conglomerate of the Norfolk Basin (and perhaps also of the Boston Basin) was laid down, but the Quincy granite mass was soon covered and protected from the erosion. The great thickness of conglomerate in the Boston Basin, according to this hypothesis, is largely represented in the Norfolk Basin by grit and reddish sandstone and slate, and implies that the principal source of the sediments lay to the north and west. The color of the red sandstones is due to a diminishing in size and quantity of gray rock and mineral fragments, and to a corresponding increase in the red clay which forms the matrix of the conglomerate in both basins. Continued subsidence and gradual change of climatic conditions caused the gradation from conglomerate through sandstone and slate, and finally into the blue-black Cambridge slate. How far southward the latter extended is questionable, but its thickness, possibly 2000 ft. or more,* in the Boston Basin is sufficient to warrant the supposition that it formerly extended over the sediments of the Norfolk Basin also.

FIG. 3.

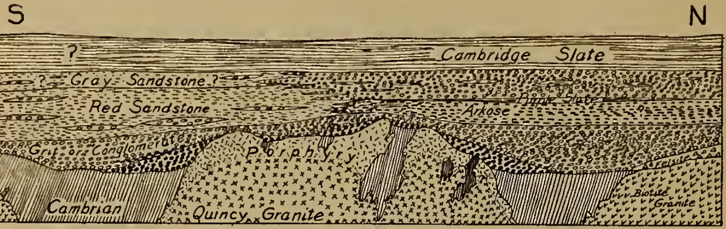

FIG. 3. Hypothetical section showing the supposed relations between the sediments of the Boston and Norfolk Basins before folding and faulting. The red sandstone of the Norfolk Basin must, according to this view, have been in general equivalent to the upper part of the conglomerate—"arkose" series of the Boston Basin, the size of fragments diminishing and the amount of red clay matrix increasing southward. The position of the gray sandstone of the Norfolk Basin, as stated in the text, is open to question. Prof. Crosby's graben theory is generally applicable to the lower half of the section, but, according to the writer's conclusions, the two basins must have been continuous after the deposition of the basal strata.

Following this period of deposition came one of north-south tangential compression. The mass of newly formed sediments offered the least resistance to deformation and, yielding between the blocks of rigid biotite granite, were resolved into a series of

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* L. LaForge, quoted by J. R. Mansfield, op. cit., p. 196.

folds. The southernmost fold in question, a close syncline (simple or, perhaps, compound) gave way under excessive strain to a compression fault (fig. 4). Similarly the syncline forming on the north side of the rigid Quincy granite mass gave way to a compression fault, the rigid granite riding up against the conglomerate and "arkose." The vertical dip of the giant conglomerate close to the Quincy granite mass indicates that the

Fig. 4.

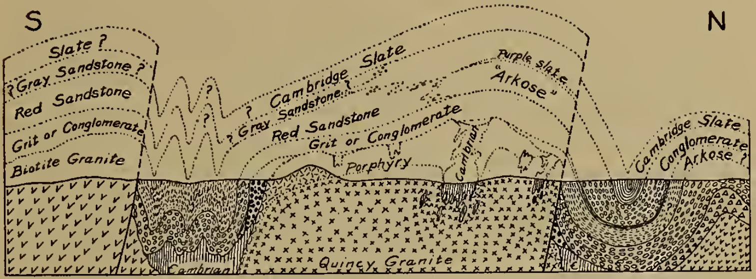

Fig. 4. N–S section through Bear Hill (see fig. 2) showing relation between the sediments of the Boston and Norfolk Basins. The compound synclinal structure of the Norfolk Basin, though very possible, is hypothetical, and serves to indicate the amount of compression expressed in outcrop. An equally good interpretation, based upon the attitudes of outcrops, would be a simple close synclinal fold with the south limb removed by faulting. The "arkose" of the Boston Basin is exposed only along the boundary fault. Its total extent is not known. Vertical scale about twice the horizontal.

fault block (or blocks) containing the present exposed mass of Quincy granite must have suffered some rotation during faulting. This rotation, as already stated, accounts for the position of the still uneroded portion of the porphyry contact zone. According to Prof. Crosby's interpretation, the Quincy granite mass was a tilted fault block prior to the period of folding and compression faulting. Such earlier tilting may have been increased by the later rotation.

On the other side of the compressed area, the granite was thrust from the north against the sediments to form the northernmost of the four faults. The Newton Centre fault resulted in the breaking of an overturned syncline, relatively massive conglomerate overriding relatively plastic slate from the north. Other minor compression faults were formed, and some of them have been mentioned; but they are inconspicuous beside the four just considered.

These movements were accompanied by the development of secondary minerals, depending upon the composition of the rock. Quartz and sericite are the most common minerals in the sediments, though epidote, chlorite, and calcite are conspicuous in places. The rigid biotite-granite batholith yielded to compression, not through folding, but through complex fracturing, and in these fractures, as well as throughout the rock, the secondary minerals, quartz, sericite, epidote, chlorite, and calcite, were formed through alteration of lime- and magnesia-alumina silicates. The slickensided character of the fracture fillings shows that these minerals had, in part at least, been deposited before the movements ceased.

The Quincy granite, containing hardly more than a trace of either lime or magnesia, was chemically more stable under the conditions of compression. Even the highly fractured exposure at the fault contact in Blue Hill village shows no conspicuous secondary minerals, other than quartz in veinlets, which may well have been derived from the contacting arkose. Crocidolite and magnetite (as alteration products) appear limited to films along slickensided joints.

The greater freedom of the Quincy granite from minor complex fractures would seem dependent on this same condition. Its greater immunity from alteration gave it greater resistance to the compressive movement, and it yielded by relatively few persistent fractures, which are represented in its quarries to-day by highly slickensided joints of nearly east-west strike and either northward or southward dip. The greater tendency of the biotite granite to alter weakened its resisting powers, and it yielded, not only along major joints and faults, but especially along the numberless minor fractures, in which the secondary minerals had the opportunity to form.

Subsequent events in the geologic history of the district, while of general interest, are of no great immediate importance. The only events which deserve mention here are: (1) development of the system of faults, with nearly north-south trend, which offset the compression faults; (2) long continued erosion which resulted in the dissected Cretaceous and Tertiary* peneplains and removed the sediments from the upthrow sides of the compression faults; and (3) glaciation, which has greatly obscured field evidence.

Further Questions of Correlation.—The writer showed in a former paper† that sediments generally recognized as Carboniferous along the western edge of the Narragansett Basin were older than the Sterling granite batholith—a reddish gneissoid biotite granite without marked hydro-thermal alteration, and with a minor phase of muscovite granite. It is shown in the present paper that the sediments of the Boston and Norfolk Basins, also generally recognized as Carbonifer-

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* See W. O. Crosby, op. cit., p. 538.

† This Journal, vol. xxix, pp. 452–456, May, 1910.

ous, are younger than all the granites which lie adjacent to them, including a reddish biotite granite. Fossil plants,* found at certain points in both the Narragansett and the adjoining contiguous Norfolk Basin, are the principal evidence of the Carboniferous age. The questions now arise :—(1) are there in the region two batholiths of reddish biotite granite, one non-gneissoid, but epidotized, and older than all the sediments, and the other gneissoid, but not greatly epidotized, and younger than all the sediments? (2) Do both granites belong to the same batholith, in portions of which the gneissoid structure was developed by compressive forces acting during, or closely after, intrusion, and in other (or in part the same) portions of which epidotization was developed by much later compressive forces acting long after the granite had become rigid and had cooled far below its crystallization temperature. If the latter case can be proved, there must be a pronounced unconformity separating these sediments of the Narragansett Basin older than the granite from those in the Narragansett and Norfolk Basins which are younger than the granite.†

The above questions, suggested by the facts presented in this paper, outline further interesting problems to be investigated in the region of eastern Massachusetts and Rhode Island; but their solutions may depend upon the study and solution of many minor problems throughout the whole region. Some of these more special problems are now under consideration.

Summary.

The igneous rocks in the area studied include an altered biotite granite series, an older felsite series, the Quincy alkaline granite series, and alkaline felsite; the sediments, much folded, are the conglomerates, sandstones and slates of the Boston and Norfolk Basins. The principal boundaries between sedimentary and igneous rocks are faults of nearly east-west trend, with one exception—along the south edge of the Quincy granite mass, where the basal and strictly local "giant conglomerate" is composed chiefly of bowlders of Quincy granite-porphyry. At no other place have pebbles of the Quincy granite series been found in the sediments of either basin. The evidence leads to the conclusion that the Quincy granite mass formed a low prominence which suffered erosion for a time, but was soon

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*Crosby and Barton, this Journal, vol. xx, ser. 3, 1880, pp. 416–420; Shaler, Woodworth, and Foerste, U. S. Geol. Surv., Mon. xxxiii, 1899.

† J. B. Woodworth (Mon. xxxiii, U. S. Geol. Surv., 1899, p. 186) suggested that an unconformity might exist in the upper portion of the Narragansett sediments, and that the younger of the sediments might then be correlated as Permian.

buried beneath a great thickness of sediments. A period of north-south compression ensued, throwing the sediments into east-west folds. The southernmost fold in the area, a syncline, gave way under severe compression to a fault, granite riding up against sandstone and slate. Similarly another fault developed on the north side of the Quincy granite, the granite riding up against conglomerate and arkose, and concealing the basal member of the sediments, where Quincy granite pebbles would be expected.

The contrast in alteration is noted between the epidotized biotite granite and the relatively unaltered Quincy granite, and evidence is offered to show that the former, containing lime- and magnesia-alumina silicates was especially subject to alteration, while the latter, containing no lime or magnesia, was relatively stable under conditions of compression. The difference seems due to composition, and not, as might at first be supposed, to great contrast in age.

The above conclusions give rise to further questions regarding the correlation of granites and of sedimentary formations in Rhode Island and eastern Massachusetts.

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Art. IV.—*The Problem of Xeromorphy in the Vegetation of the Carboniferous Period*; by Alfred Dachnowski.

The comparatively abundant information which we possess concerning the present vegetation in aspect, form, structure and function as related to differences in physical, chemical and biological factors, is in striking contrast to the absence of a correlation of similar data as regards environmental conditions during geological periods. From the point of view of ecology, the vegetation conditions of the past are of considerable value, however the method of endeavor to understand the factors which the fossil plants record. Those who have confined their ecological study to the environmental investigations of the present must sooner or later test and supplement their investigations by reference to the past, correlate structural characteristics with physiological conditions of growth and apply the knowledge of relations gained from living plants. Whether or not the data can be accepted as sound links in the chain of evidence rests largely in the value of the experimental work at hand and in the degree with which they interpret many apparent anomalies.

The limiting climatic and physiographic features which characterize bogs, and the structural features and functions of the vegetation peculiar to them, have seemed to the writer of sufficient interest to invite attention to an inquiry on the probable cause of the xerophily of many of the Carboniferous plants which lived in swampy areas. The present paper is intended, therefore, as a continuation of the ecological studies, which appeared from time to time on the vegetation of an Ohio bog and peat deposits. The problems involved in the following discussion are by no means to be solved within the limits of this paper; merely an adjustment of perspective is made, leading from a consideration of the fossiliferous plant remains of the Coal Measures.

The characteristic xerophily of the Carboniferous vegetation has been interpreted by geologists as indicative of a warmer, moister atmosphere, more heavily charged with carbon dioxide than at present.* To the writer the facts are hardly consistent with the external conditions assumed. The supposition that xeromorphy involves factors of climate is not necessarily wrong, but calls for a fuller consideration and comparison along with additional factors, the character and magnitude of which is capable of producing like results. A more satisfactory interpretation of the phenomenon of xerophily would be found

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*Chamberlin, T. C., and Salisbury, R. D., Geology, ii, 603, New York, 1906.

in the fact that the present vegetation of undrained swamps and of bogs has many of these xerophytic features, none of which are correlated with atmospheric influences. The chief cause for both the xerophily of the coal flora and the great accumulation of vegetable matter is not to be looked for merely in climatic implications. High temperature and humid air do not promote, in a high degree, decomposition. The formation of peat has been reported even for regions about the equator.* The great thickness of the Carboniferous deposits suggests, however, that the preservation of the debris was favored by a temperate climate and by agents in the soil such as are involved in the accumulation of peat to-day. Similarly the force of the inference from the xerophytic aspect of the Carboniferous vegetation,—namely, the peculiarities of leaf size and leaf structure for maintaining a balance between supply and loss of water,—gives additional support to the view that the plants encountered adversities of soil-water content rather than of climate. A satisfactory explanation of the phenomenon, not controverted by any known facts, has been found in the experimental investigations of the writer on the reduction action and toxic character of bog water and bog soil,† the results of which are briefly as follows. Poorly drained and undrained water basins and lowlands, whether in areas characterized by limestone formations, by sandstone, or glacial drift, become physiologically arid habitats with the accumulation of vegetable debris. Although water is so abundant in bogs and swamps, yet it is largely unavailable to the plants on account of various decomposition products due to the activity of low organisms in the debris-substratum, especially such saprophytes as bacteria and fungi. Peat soils contain bacteria and other fungi in greater number than supposed hitherto, inducing diastatic, inverting, proteolytic, cytohydrolytic and reducing action in the upper layer of the substratum. They vary in kind and number with the nature of the substratum, and show marked interdependence as well as antagonistic action. It has been found that, as a general rule, there is an accumulation of injurious substances which must be removed if no deleterious action is to follow, and if complete decomposition of the debris is not to be retarded. The complex and rather ill-defined, "humus acids," more specifically humic, ulmic, crenic and apocrenic acids, are not the important constituents to which peat owes its antiseptic properties and which interfere with the action of bacterial organisms. In Ohio peat deposits, at least, the presence of injurious substances in the

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* Potonié, H.. Die Entstehung der Steinkohle, 152. Berlin, 1910.

† Dachnowski, A. The Vegetation of Cranberry Island and its relations to the substratum, temperature, and evaporation. Bot. Gaz., li, 1911.

substratum is not in direct relation to acidity in the soil. Tests on the reducing powers of peat soils show that the wind-driven aëration has little effect on the peat substratum beneath the two-foot level. A shallow, superficial zone of oxidation exists in peat soils, and the debris below this is sometimes so charged with injurious decomposition products and gases, and so far unaërated as to be inhospitable to all organisms but anaërobic bacteria.

In the growing season the temperature of peat soil, in the more xerophytic of the succeeding bog associations, is not below that of other soils. Rapid and passing changes of air temperatures and the occasional extremes do not affect the substratum temperatures. Only average effects prevail and the great periodic seasonal changes of the dominant climate. The temperatures of the deeper peat strata indicate that there is scarcely anything of a seasonal descent. The continued growth and persistence of the closely related plant association and the slow succession of vegetation types in a habitat of that character is no longer incomprehensible if we remember that the vegetation grows on top of the accumulating debris and that the water table is always at a high level. The disturbance of the balance produced in the soil is thus not unfavorable to the dominance of the associations. There occur natural successions which are determined, however, not by a deficiency of mineral nutrients, such as lime, potash, phosphoric acid, or great distance from the mineral substratum, but by an excessive or defective action in the substratum. The lack of mineral constituents does not even render it difficult for mesophytic shrubs and trees to invade and grow as the deposit is built up and oxidation processes become prominent in the surface layer of the substratum. Acidity, toxicity, and reduction action represent merely stages in the decomposition of organic matter. Each plant association augments the efficiency of the soil as a habitat. It cannot be too strongly emphasized that the soil processes exhibit an efficient natural process for the maintenance of productivity relations, and that the prime condition determining bog forest successions is not an increase in the mineral constituents in the peat soils. To what extent bog plants require the organic compounds arising in peat soils is still undetermined. The assimilation of such substances is undoubtedly made less difficult on account of the number of saprophytic fungi and the endotrophic mycorhiza usually present.

The characteristic foliage of heath and shrub bog plants is distinctly an effect to a habitat with a moderate or scanty physiological soil-water content. Extreme xeromorphy is reached in the upper layer of open shrub associations; here the CO_2 percentage of the vertical gradient is least and approximates that of the free air; the combined effect of the intensity of light and the greater saturation deficiency of the air is provided for by an increased thickness of the mesophyll layer in the foliage to minimize disturbances in the carbon dioxide supply. This and the narrow leaves with restricted stomata confined to deep furrows and, in some cases, protected by hairs, wax, or heavy cuticle, are devices common to plants in bogs where the plants must protect themselves against unfavorable atmospheric influences. The aërial parts of plants are constantly losing water by transpiration, a process similar to evaporation but controlled by the plants within certain limits. To reëstablish equilibrium this water loss is replaced by the supply of water from the substratum by root absorption. The taller plants are thus subjected to a difficulty in maintaining the balance between absorption and transpiration, in the same manner as are plants living in deserts or in sandy regions. Though the amount of transpiration exhibited by plants is partly influenced by the physical conditions of the atmosphere such as temperature, humidity and wind, yet these factors are much more uniform than are the amounts of available water supply. The limitations of this paper do not permit going into greater detail in respect to the nature and the degree of toxicity in bogs, or in respect to the kinds of plants or the parts of plants which are most affected.

The nearest analogue of the accumulation and the conditions of growth for the vegetation of the Coal Measures are the bogs and marshes of to-day. Were there no other trustworthy records of the occurrence of bacteria and fungi in Paleozoic times,* it would still be a natural supposition that these organisms were abundantly represented, and produced physical and chemical changes in the substratum. The transformation products, of whatever nature, checked the activity of the roots of plants and depressed their transpiration. The striking similarity of the aërial shoots of the Carboniferous plants to those of modern times in bogs and undrained swamps restrain one, therefore, from assuming that the atmosphere differed greatly in temperature and humidity, or was different in the chemical constituents from what it is now. There may have been moderate variations in the carbon dioxide content of the air, but this would require experimental proof upon bog plants and the group of plants similar to those which lived in Carboniferous times, the scouring rushes, the lycopods, ferns, cycads and gymnosperms, to assign its limits. The statements in current literature as to the strengths of that

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* Renault, B., Recherches sur les bacteriacees fossiles. Ann. Sci. Nat. Bot. (8), ii, 275–349, 1896.

gas which green plants can endure are conflicting* and call for further work in the field and in the laboratory.

The consideration of these facts leads to another point, the inevitable conclusion that the form characters and the fundamental resistance to drought and desiccation distinctive of xerophytic plants, whether in bogs or deserts, must have made their appearance within early geologic time. They are not of recent development.† The climate of northern America has undergone oscillations between periods of maximum aridity and maximum precipitation and humidity, with extreme variations in temperature during and following the several glacial periods; the amplitude occupying periods of perhaps many thousands of years. Variations in climate so wide apart indicate an almost complete change in the character of the flora during the geologic periods. The xerophytic features which characterize bogs and deserts are not to be taken, therefore, as having come about by a direct and continuously increasing edaphic or climatic aridity. Aside from the question as to the methods and the activating conditions in evolutionary development, it seems certain that the origin of xerophytic forms is not one of recent development in the vegetable kingdom, but must have been concomitant with the diastrophic and gradation processes of the great geologic periods. The great floral evolutions of geologic history were principally one of growth-form, physiognomy, and functional behavior, and not of floral structure alone. Water has always been the most important of all the life relations in the environment of plants. In the early types of gametophytic vegetation it remained necessarily of greatest importance for the movements of gametes in effecting fertilization and for dissemination. The luxurious development of these forms in the ancient areas of low-lying land became checked in the stress of aridity encountered with the accumulation of their debris. With the origin and the development of the sporophytic types of vegetation, which were from the first less dependent upon free water, the prolongation of vegetation activity enabled the plants to occupy the areas with greater habit reactions. The effects of desiccation in the physiologically arid habitats resulted in greater differentiation of organs, in protective and resistance features‡ and in a greater range of dispersal. The vegetation had now developed to forms capable of occupying dry land, and able to maintain themselves as bog or desert vegetation in localities

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* Czapek, F., Die Ernährungsphysiologie der Pflanzen seit 1896. Progressus Rei Botanicæ, i, 468, 1907.

† McDougal, D. T., Influence of aridity upon the evolutionary development of plants. The Plant World, xii, 217–230, 1909.

‡ Dachnowski, A., Physiologically arid habitats and drought resistance in plants. Bot. Gaz., xlix, 435–340, 1910.

restricting functional activity. The general movement finally resulted in a land flora of which the mesophytes are the highest expression. The lowland basins and regions of coal formation were undoubtedly the regions of the evolution of the flora as a whole* and of the several natural plant formations which include many diverse species in a unity of characteristic physiognomy and growth form. The extensive change in floral types which is particularly evident through the subordination of the ferns to grasses and heath plants, and the elimination and replacement of the primitive gymnosperms by the later gymnosperms and angiosperms is largely one of range and variability of protoplasmic forces. In some types the characteristics often bear no apparent relation to the environment and are retained under the most varied conditions; yet many others are profoundly and rapidly modified by changes in climate, physiography, and soil processes. Probably the arctic regions were then the most favorable for the growth and development of xeromorphic forms. Migration from northern centers of dispersal, the periods of climatic aridity and the changes immediately before and after ice-invasions, undoubtedly accentuated the ecological evolution of this type of vegetation.

The great development of form in response to the environmental stress was attended by a rapid and luxuriant expansion in range, in successions of vegetation formations, and in sequence of associations. Several forms of the cycads, Bennettites and conifers now inhabit desert areas. Not less interesting is the fact that many species of heather-plants of Europe such as Calluna, Empetrum, several species of pines (*Pinus sylvestris*, *P. montana*), juniper (*Juniperus communis*) birches (*Betula pubescens*, *B. nana*), Labrador tea (*Ledum palustre*), bladderwort (*Utricularia cornuta*) and others, can grow both on extremely dry, warm soil and on extremely cold or wet soils. The observation has repeatedly been made by the writer that in the northern parts of Michigan several species of bog plants leave the peat soils entirely and are only found upon dry and poor soils. This is notably the case with tamarack (*Larix laricina*) the chokeberries (*Aronia nigra*, *A. arbutifolia*), the blueberries (*Vaccinium corymbosum*, *V. canadense*), the black huckleberry (*Gaylussaccia bacata*), the shrubby cinquefoil (*Potentilla fruticosa*), sweet gale (*Myrica gale*), the steeple bush (*Spiræa tomentosa*) and several other xerophytes of the peat bogs of Ohio. The cranberries (*Vaccinium* sp.), creeping snowberry (*Chiogenes hispidula*), and wild rosemary (*Andromeda polifolia*) occur in moist ravines and rich woods, while leather leaf (*Chamædaphne calyculata*), the buck bean

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* Bower, F. O., The origin of a land flora. London, 1908.

(*Menyanthes trifoliata*) and Labrador tea (*Ledum grœnlandicum*) are found along slow streams. The majority of these plants occur in Europe and Asia, in habitats of similar conditions. They are bog plants only in the southern part of their range. This departure is in no sense an adaptation to climatic influences but is an equilibrium relation or balance between the absorbing organs, the conducting shoots and the transpiration surface against drought conditions common to either habitat. The structures and distribution habits are induced by physiological aridity or poverty of available water; morphological limitations in the absorption or in the conduction of water do not play a rôle. The physiological water relation alone must be taken into account for the form and habits of bog and swamp xerophytes, even if the plants inhabit regions of pronounced rainfall and milder temperatures. The appearance of such differentiation cannot be taken as one of rapid and notable evolutionary development or as one of the most important in the history of plants; nor would it be safe to assume that bog and desert floras owe their origin to gradual adaptations resulting from the action of climatic changes. The possibilities of survival are very great for forms thrown into the complex conditions of a locality where the functional and structural capacities are suitable for the limiting physico-chemical factors encountered in the habitat. The plants are functionally fitted to occupy the place in a zone with its system of factors. The qualities of growth which enable competition in the crowding out of other forms are not of primary importance in the struggle and selection where physiological capacities and structural modifications have the survival value for activity during drier seasons. Invaders would not exclude the forms by which a bog or desert is characterized, except where the influence of external conditions has produced irreversible changes in a hereditary line. The structural alterations in roots and shoots of bog plants cannot be looked upon as of comparatively recent origin. The phenomenon of xeromorphy has exhibited itself too generally in a variety of plants and of conditions in space and time. The transition to xeromorphy has been made not once but several times along different lines of descent. It arose in the highest plants independently from that of the ferns and cycads, and the xeromorphy exhibited here and there among families in a genus probably arose independently along a minor line of development; as such it is the general response in plants to minimize or balance disturbed physiological water relations.

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ART. V.—*A Discussion of the Formulas of Pearceite and Polybasite*; by FRANK R. VAN HORN.

THE calculation of the formula of the pearceite from the Veta Rica mine, Sierra Mojada, Coahuila, Mexico, which was given in a preceding paper,* showed conclusively that the analysis conformed more closely to the formula $(Ag,Cu)_{16}As_2S_{11}$ than to that of the molecule $(Ag,Cu)_{18}As_2S_{12}$. The latter was assumed to be isomorphous with polybasite, $(Ag,Cu)_{18}Sb_2S_{12}$, the formula of which was proposed by Heinrich Rose in 1829,† and has been accepted by most mineralogists ever since. The writer, while looking up the literature on the subject, found a few words relative to the matter in Hintze's Mineralogy.‡ The statement was made that, in 1875, Rammelsberg in his Mineralchemie gave two formulas for polybasite, namely: $(Ag,Cu)_{18}Sb_2S_{12}$ and $(Ag,Cu)_{16}Sb_2S_{11}$; further, in the last edition of the same book in 1895, the latter formula was given alone, evidently discarding the Rose formula. Hintze also pointed out that Bodländer in 1895 showed that in polybasite there was a variation in the proportion of $R_2S:R_2S_3$ which ranged between 7·22 and 10·1. Bodländer therefore concluded that polybasite was a mixture of $7R_2S.Sb_2S_3$ and $9R_2S.As_2S_3$. With the formula of the new occurrence of pearceite from Sierra Mojada, as well as the statements of Hintze in mind, the writer became interested in recalculating all previous analyses of both pearceite and polybasite in order to ascertain what the actual combining ratios were.

Pearceite.

Upon investigation, it was found that there have been but five analyses published prior to that of the preceding paper. These five, with that of the Sierra Mojada pearceite, will be given in chronological order beginning with the oldest, as follows:

1. Schemnitz, Hungary, H. Rose, Pogg. Ann., xxviii, 158, 1833.
2. Arqueros, Chile, crystals, Domeyko, Min., 1879, 393.
3. Molly Gibson mine, Aspen, Colorado, crystallized, Penfield and Pearce (analysis by Penfield), this Journal, xliv, 17, 1892. In this analysis 12·81 per cent of impurities were deducted, and the analysis was recalculated by Penfield in the present form.
4. Same locality as 3, but massive with 28·18 per cent deducted for impurities. Penfield and Pearce as above (analysis by Pearce).

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* A New Occurrence of Pearceite; by Frank R. Van Horn and C. W. Cook, this Journal, xxxi, 518, 1911.

† H. Rose, Pogg. Ann., xv, 575, 1829.

‡ C. Hintze, Handbuch der Mineralogie 1904, i, 1171.

5. Drumlummon mine, Marysville, Montana, crystals, Penfield (analysis by Knight), this Journal, ii, 18, 1896.

6. Same analysis as 5 with the ·42 per cent of insoluble matter distributed proportionately.

7. Veta Rica mine, Sierra Mojada, Mexico, crystals, Van Horn and Cook (analysis by Dubois), this Journal, xxxi, 523, 1911.

	1	2	3	4	5	6	7
S	16·83	17·07	18·13	17·73	17·71	17·78	17·46
As	6·23	7·29	7·01	6·29	7·39	7·43	7·56
Sb	0·25	0·43	0·30	0·18	----	----	----
Ag	72·43	63·54	56·90	59·73	55·17	55·40	59·22
Cu	3·04	10·70	14·85	12·91	18·11	18·19	15·65
Fe	0·33	0·60	----	----	1·05	1·05	----
Zn	0·59	----	2·81	3·16	----	----	----
Insol.	----	----	----	----	0·42	----	----
	99·70	99·63	100·00	100·00	99·85	99·85	99·89
Sp. g.		6·33	5·94 (recal.)	5·92 6·10 (recal.)	6·125 6·166		6·067

A comparison of the analyses shows that the two most recent ones, 6 and 7, are most similar in chemical composition, both being the pure arsenical molecule. However there was no iron in 7. The analysis resembling 6 and 7 most closely is 2. It is also significant that these three analyses were made from pure crystallized mineral, while 3 and 4 were made from material so impure that 12·81 and 28·18 per cent had to be deducted for impurities, and the result recalculated before it could be expressed in the form given above. Furthermore it was stated that there was 0·46 and 2·57 per cent of $FeCO_3$ in 3 and 4 respectively, and although some siderite may have been visible, it seems plausible that some iron should be credited to the mineral, since that element is fairly constant in most pearceite as well as polybasite. It is not certain what kind of material Rose used in 1, although Hintze[*] mentions under polybasite "trigonal gestreifte Krystalle (Rose's Analyse vergl. S. 1169) in Quarz-Drusen, sowie blättrige bis schalige Massen, mit Pyrargyrit, Silberglanz, Eisenkies, brauner und gelber Blende." It is to be noted that the specific gravity was not determined, and that none of the undoubtedly crystallized material given in 2, 6, and 7 contains zinc. The first five analyses given above were recalculated in order to find their combining ratios. In doing this the International Atomic Weights for 1911 were employed with the following values: S, 32·07; As, 74·96;

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[*] Op. cit. page 1173.

Sb, 120·20; Ag, 107·88; Cu, 63·57; Fe, 55·85; Zn, 65·37. The following combining ratios were obtained:—

Analysis.	S	(As,Sb)	(Ag_2Cu_2Fe,Zn)
1. Schemnitz, 1833	12·330	2	8·690
2. Arqueros, 1879	10·570	2	7·728
3. Aspen, crystallized, 1892	11·786	2	8·830
4. Aspen, massive, 1892	12·766	2	9·852
5–6. Marysville, 1896	11·188	2	8·446
7. Sierra Mojada, 1911	10·800	2	7·886

An inspection of these ratios shows that the proportions obtained in 2, 6, and 7 conform more nearly to the formula $(Ag_2Cu_2)_8As_2S_{11}$ than to $(Ag_2Cu_2)_9As_2S_{12}$; 4 does not conform to either, which is probably due to the fact that 28·18 per cent of impurities had to be deducted before the analysis was available for calculation at all. In addition to this, 2·57 per cent of $FeCO_3$ was deducted, some of which probably belonged to the pearceite. Analysis 3 lies between the two formulas, and slightly nearer the larger values, but since the same methods employed in 4 were used, and 12·81 per cent of impurities had to be deducted, the writer is inclined not to attach great importance to the ratios obtained in this analysis. It certainly could not be used as convincing proof of the correctness of the larger formula. The remaining analysis, 1, was made in 1833 and conforms more nearly to the larger formula, but the sulphur is considerably more than required, while the silver is much less than is demanded by the larger formula, thus showing a wide variation in results. Considering all facts in connection with the analyses of pearceite, and especially the purity of material used, the writer feels justified in suggesting the formula $8(Ag,Cu)_2S.As_2S_3$ or $(Ag,Cu)_{16}As_2S_{11}$ instead of $(Ag,Cu)_{18}As_2S_{12}$, which was first proposed.

Polybasite.

Since pearceite is regarded as being isomorphous with polybasite, and shows the same relation to it which is observed between proustite and pyrargyrite, or between tennantite and tetrahedrite, the writer became interested in polybasite analyses. All authors with the exception of Rammelsberg (cited under pearceite) accept the formula $9(Ag,Cu)_2S.Sb_2S_3$ or $(Ag,Cu)_9SbS$ which was proposed by H. Rose in 1829. However Hintze* in the table of polybasite analyses gives the theoretical composition of the formula proposed by Rammelsberg, $Ag_{16}Sb_2S_{11}$, in addition to that of Rose. The writer has been able to find but ten analyses of this mineral which are arranged chronologically, beginning with the oldest, as follows:

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* Op. cit. page 1174.

1. Guarisamez, Durango, Mexico, H. Rose, Pogg. Ann., xv, 575 1829.
2. Freiberg, Saxony, H. Rose, Pogg. Ann., xxviii, 158, 1833.
3. Cornwall, Joy, cited by Rammelsberg, Mineralchem., 5 Suppl., 1853, 194.
4. San Pedro Nolasco, Tres Puntes, Chile, Taylor, Proc. N. Sc. Phil., Nov. 1859.
5. Přibram, Bohemia, Tonner, Lotos, 1859, 85, and Neues Jahrb., 1860, 716.
6. Tres Puntes, Chile, Domeyko, Min., 1879, 391.
7. Al Finhallada, Tres Puntes, Chile, Domeyko, Min., 1879, 391.
8. Terrible Lode, Clear Creek Co., Colorado, Genth, Amer. Phil. Soc. xxiii, 39, 1886.
9. Santa Lucia mine, Guanajuato, Mexico, Prior, Min. Soc., Lond., ix, 14, 1890.
10. Quespisiza (Chile?), Peru, Bodländer, Neues Jahrb., i, 99, 1895.

	1	2	3	4	5	6	7	8	9	10
S	17·04	16·35	15·87	16·14	15·55	16·10	15·30	(16·70)	15·43	16·37
Sb	5·09	8·39	5·46	11·55	11·53	4·20	9·50	10·18	10·64	5·15
As	3·74	1·17	3·41	----	----	4·10	----	0·78	0·50	3·88
Ag	64·29	69·99	72·01	64·18	68·55	64·30	62·10	62·70	68·39	67.95
Cu	9·93	4·11	3·36	8·13	3·36	9·00	6·00	9·57	5·13	6·07
Fe	0·06	0·22	0·34	----	0·34	0·70	1·10	0·07	----	----
Pb	----	----	----	----	----	----	----	----	----	0·76
Insol.	----	----	----	----	----	1·60	6·00	----	----	----
	100·15	100·30	100·45	100·00	99·13	100·00	100·00	100·00	100·09	100·18
Sp. G.	6·214	----	----	----	6·0302	----	----	6·009	6·33	----

In analyses 6 and 7, the insoluble matter was deducted and the analyses recalculated. The same method was followed with the lead in 10. The same atomic weights were used as in the calculation of the pearceite, and the following combining ratios were found:—

Analysis	S	(Sb,As)	(Ag_2Cu_2Fe)
1. Gaurisamez, Rose, 1829	11·524	2	8·176
2. Freiberg, 1833	11·938	2	8·470
3. Cornwall, 1853	10·898	2	8·062
4. San Pedro Nolasco, 1859	10·482	2	7·526
5. Přibam, 1860	10·110	2	7·202
6. Tres Puntes, 1879	11·224	2	8·498
7. Al Finballada, 1879	12·070	2	8·970
8. Terrible Lode, 1886	10·960	2	7·726
9. Santa Lucia, 1890	10·096	2	7·398
10. Quespisiza, 1895	10·800	2	7·676

An inspection of the ten ratios shows that seven of them (3, 4, 5, 6, 8, 9, 10) conform more closely to $(Ag,Cu)_{16}Sb_2S_{11}$ than to $(Ag,Cu)_{18}Sb_2S_{12}$. Furthermore in 1, which was the analysis upon which Rose based his formula, the silver is clearly nearer the smaller value (8·17), while the sulphur is almost as near the smaller quantity as it is the larger (11·524). There is only one analysis which conforms strictly to Rose's formula, namely 7. The remaining analysis, 2, conforms to the larger formula closely with respect to sulphur (11·938), but the silver is again nearer the smaller quantity (8·470). Therefore the evidence of all previous analyses of polybasite is overwhelmingly in favor of the formula $(Ag,Cu)_{16}(Sb,As)_2S_{11}$ which was first suggested by Rammelsberg in 1875. In addition to the testimony of the combining ratios given above, we also have the undoubted isomorphism of polybasite with pearceite in which the combining ratios conclusively point to the formula $(Ag,Cu)_{16}(As,Sb)_2S_{11}$. The writer therefore feels that all available evidence logically warrants the acceptance of the smaller formula for both pearceite and polybasite.

Geological-Mineralogical Laboratory,
Case School of Applied Science,
Cleveland, Ohio, February, 1911.

Art. VI.—*Cerussite Twins from the Begoña Mine, Cerro de San Pedro, San Luis Potosi, Mexico;* by Walter F. Hunt and Frank R. Van Horn.

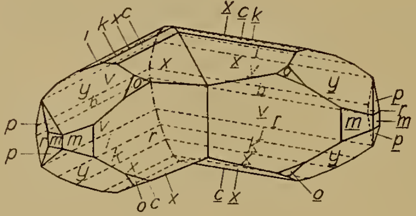
Introduction.

In March, 1910, Señor Felipe Borrego, foreman of the Guadalupe Mine, Cerro de San Pedro, Mexico, sent several specimens of minerals to Case School of Applied Science for identification. Among the specimens were 8 arrow-shaped twins which the junior author recognized as cerussite of rather uncommon development and type, on which account they were taken to the University of Michigan, where their crystallographic properties were studied by the senior author.

Geology.

The twins were found at the Begoña Mine in the Cerro de San Pedro district. Details concerning their occurrence were furnished by Señor Borrego, as well as by Mr. R. B. Cochran, Director of the Cia. Minera El Barreno y Anexas, San Luis Potosi. The San Pedro mining district is situated about 20 kilometers east of the city of San Luis Potosi, and the mines have been worked more or less since 1575. It has been stated that 413 million dollars were taken out of this region between 1656 and 1778. The village of Cerro de San Pedro is located at the foot of the hills at an altitude of 2180 meters above sea level. The district contains but little water and timber, and the mines are situated on low hills which are from 200 to 400 meters from base to summit. The mineralized district is practically confined to an area which extends about 2000 meters in a north and south direction, and 800 meters east and west. This area covers parts of three hills known as San Pedro, El Populo and La Raposa, which consist of limestone into which has intruded a mass of andesite locally known as "porfido." The strike of the "upper contact" of andesite and limestone is usually north and south, with a dip of 55° to the west, while the "lower contact" strikes in the same direction but dips westward about 70° degrees. There is but one mine, the Cocinera, on the lower contact. All the others, of which the Begoña is one, are situated on the upper contact. The main ore occurrences are between the limestone and andesite, although many large and rich deposits have been found in the limestone hanging wall up to a distance of 300 meters from the contact. The plane of the upper contact is very irregular, making troughs and rolls along both strike and dip. In these troughs or offsets the ores are often richer. In several instances, the mineralization has extended in narrow seams completely through the limestone to the surface, and on El Populo hill, the ore is mined on these seams in open cuts. The ores at present worked are rather low-grade gold and silver ones with some lead. They are mostly oxidized, although some sulphides are found. Gold occurs native, as also does silver. Other minerals which have been noticed are cerargyrite, argentite, cerussite, pyromorphite, and galena. Some zinc minerals are said to occur but copper compounds are very rare. Pyromorphite is very abundant, and sometimes occurs in large botryoidal clusters over 6 inches in diameter. The cerussite twins were found along with granular cerussite, gypsum, and limonite in one of the troughs or offsets of the Begoña Mine. They were taken from a cavity in the limestone about 1 meter from the andesite contact.

Fig. 1.



Crystallography.

The twinning plane observed, although not new, is the rather uncommon brachyprism *r*{130}. The crystallography is of interest inasmuch as a new locality for this type of twinning has been discovered, and also as the crystals examined revealed several forms, either not recorded on twins referred to this law or mentioned only as of doubtful occurrence. Cerussite twins referred to this law have been described by Kokscharow,* by Williams from the Mountain View Mine, near Union Bridge, Carroll County, Maryland,† and similar twins, sometimes abnormally developed by extension of the prism faces *r*, were recorded by Pirsson from the Red Cloud Mine, Yuma County, Arizona.‡ The contact twins from the Mexican locality ranged from one half to one centimeter in length and represented but one type of development, namely forms resembling arrow-heads, this development resulting in part from the

* Materialien z. Min. Russl., vi, 135, 1870.

† Johns Hopkins Univ. Cir., No. 87, April, 1891.

‡ This Journal, xlii, 405, 1891.

unusual growth of the brachyprisms *r* on either side of the twinning plane. As all of the crystals showed the same general type of distortion and distribution of forms, the accompanying drawing represents not the ideal form but the crystals as they actually appeared looking into the re-entrant angle. On five of the eight crystals the pyramids *o* and *p* and the prism *m* were either wanting or scarcely perceptible, while the brachydome zone was so striated and rounded that differentiation of those forms would be highly speculative. However, three crystals revealed without question all the forms represented in the drawing, as verified by the very close agreement of the observed with the calculated angles in the following table:

	Observed	Calculated
$m : m = (110) : (1\bar{1}0) =$	62° 44′	62° 45′ 50″
$r : r = (130) : (1\bar{3}0) =$	57 17	57 19
$r : b = (130) : (010) =$	28 38 30	28 39 30
$c : p = (001) : (111) =$	54 12 30	54 14
$c : o = (001) : (1\bar{1}2) =$	34 47	34 46
$c : y = (001) : (102) =$	30 39	30 39
$c : x = (001) : (012) =$	19 51	19 52 30
$c : k = (001) : (011) =$	35 53	35 52
$c : i = (001) : (021) =$	55 20	55 20
$c : v = (001) : (031) =$	65 16	65 15
$r : r = (1\bar{3}0) : (130) =$	65 22 30	65 20

In the above computations the axial ratio as determined by Kokscharow* was taken as a basis.

In this brief note no attempt has been made to treat the crystallography of cerussite exhaustively. References to somewhat similar and even more complicated twins have been brought together by P. F. Hubrecht in his paper "Uber Cerussitvierlinge von Sardinien," Zeitschr. f. Kryst., 1905, xl, 147–188.

Ann Arbor and Cleveland.

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* Loc. cit.—see also Dana, System of Min., 6th edition, p. 286.

ART. VII.—*Eglestonite from San Mateo County, California*;

by AUSTIN F. ROGERS.

EGLESTONITE is an isometric mercurous oxychloride named by Prof. A. J. Moses[*] in honor of Thos. Egleston, founder of the School of Mines of Columbia University. It has heretofore been found only at the original locality, Terlingua, Texas, where it occurs with kleinite, terlinguaite, montroydite, and mosesite, all recently described mercury minerals.

The writer wishes to put on record and describe this interesting mineral from a California locality. Some specimens from a quicksilver prospect in San Mateo County, about five miles west of Palo Alto, brought to my attention by Mr. W. R. Nobs, a mining student at Stanford University, contained cinnabar, mercury, calomel, and an unknown yellow mineral, which was soon identified as one of the Terlingua oxychlorides of mercury. Careful examination proved the mineral to be eglestonite. No other mercury minerals except those mentioned were found.

FIG. 1.

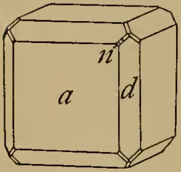

FIG. 2.

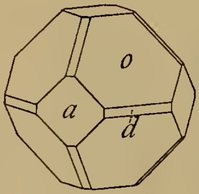

FIG. 3.

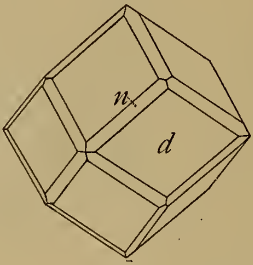

FIG. 4.

Occurrence.—The eglestonite occurs in a pale-brown siliceous material in serpentine. The serpentine is an irregular intrusive mass about four miles long and about three-fourths of a mile wide in Franciscan sandstone. This siliceous material is common in all the quicksilver mines and prospects of the Coast Ranges and was formed, no doubt, during the serpentinization of the original peridotite. Minerals collected around this prospect include dolomite, magnesite, opal, and quartz, in addition to the mercury minerals. The eglestonite occurs in minute crystals and crusts in seams and cavities directly associated with metallic mercury and calomel.

Crystal form.—The crystals of eglestonite are very small, the largest being only about $\frac{1}{2}^{mm}$ in diameter. Measurements

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[*] This Journal, vol. xvi, pp. 253-263, 1903.

prove them to be isometric, with the following forms: *a*{100}, *d*{110}, *o*{101}, and *n*{211}. These include four out of the seven common forms for eglestonite given by Schaller.* Four distinct habits were recognized, as represented, in figures 1 to 4.

The most common type of crystals is that with dominant cube, modified by the dodecahedron and very small faces of the trapezohedron {211} (fig. 1). Fig. 2 represents another type, dominant octahedron with prominent cube faces and narrow dodecahedron. Dodecahedral habit with narrow trapezohedral {211} faces is represented by fig. 3. Acicular crystals proved to be distorted dodecahedrons with striations parallel to the intersection edges are represented by fig. 4. Acicular crystals of this type were described by Schaller, but the cubic and cubo-octahedral habits are not known for the Terlingua eglestonite. The identification of the forms is based upon the following average measurements of four crystals:

		Meas.	Calc.			Meas.	Calc.
$110 \wedge 101$	(1)	59° 50′	60° 0′	$001 \wedge 211$	(1)	65° 32′	65° 54′
$211 \wedge 110$	(7)	30 1	30 0	$211 \wedge 21\bar{1}$	(1)	48 11	48 $11\frac{1}{2}$
$112 \wedge 101$	(2)	30 12	30 0	$100 \wedge 110$	(5)	45 13	45 0
$100 \wedge 010$	(1)	90 5	90 0				

The images were all sharp though often faint. Angles of 30° for two different zones, as given above, is proof of the isometric system.

Physical properties.—The luster is adamantine, the crystals though minute being very brilliant. The color varies from yellow or orange-yellow to brownish-yellow, being lighter than the Terlingua specimens. It becomes dark on exposure to light. Some crystals in a tube lying on a table for several weeks became black but retained their adamantine luster. The streak is yellow, with a greenish tinge. The mineral has no cleavage and is very brittle. Fragments examined under the microscope are irregular, perfectly isotropic, and have a high index of refraction (greater than sulphur in methylene iodide, 1·795, as tried by the Becke test).

Pyrognostic tests.—In the closed tube with soda or lime it gives a mercury sublimate; in the closed tube alone turns orange-colored, then black, and finally dark red (HgO), giving a white sublimate with mercury beyond. It volatilizes completely and gives no water in the closed tube.

Wet tests.—The eglestonite is decomposed by hot hydrochloric acid, becoming gray superficially. It is also decomposed by cold nitric acid, turning white. Hydrochloric acid added to the nitric acid solution gives a white precipitate, which

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* Bull. 405 U. S. G. S., p. 148, 1909.

is soluble on heating. The mineral is blackened by ammonia, and slightly darkened by hydrogen sulphide solution. Qualitative tests show the presence of mercury and chlorine and the absence of the sulphate radical.

Quantitative analysis.—In order to make the identification of the mineral eglestonite more certain, a quantitative analysis was made by the writer. The powdered mineral mixed with ignited lime free from water and chlorine was heated in a hard glass tube. The tube with the mercury sublimate was weighed, and then weighed again after driving off the mercury. The loss is mercury. The residue was dissolved in nitric acid and the chlorine determined by precipitating AgCl. The results obtained with 25 mg. of carefully picked, almost pure, mineral are as follows:

	Analysis	Atomic ratio	Calculated for Hg_4Cl_2O
Hg	88·00	2·10	90·21
Cl	7·43	1·00	7·99

The theoretical percentages for Hg_4Cl_2O, the formula established by Hillebrand,* are given in the last column. These quantitative results also agree with the calculated percentages for kleinite and terlinguaite, but considering the small amount of material and the slight impurities the agreement with eglestonite is as good as can be expected.

Identity with eglestonite.—The qualitative and quantitative tests prove that the mineral is an oxychloride of mercury, with a formula at least near that of eglestonite. The isometric character of the crystals limits the mineral to eglestonite or mosesite.† The habit of the crystals, the absence of twinning, the normal isotropic character, the darkening on exposure to light, and the absence of the sulphate radical, all taken together make it certain that the mineral is eglestonite.

Stanford University, Cal.,
April, 1911.

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* Journal of the Am. Chem. Soc., vol. xxix, p. 1193, 1907.

† Canfield, Hillebrand, and Schiller, this Journal, vol. xxx, pp. 202–8, 1910.

Art. VIII.—*On the Hydrolysis of Metallic Alkyl Sulphates;* by W. A. Drushel and G. A. Linhart.

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

I. *Ethyl Barium Sulphate.*[*]

In a recent article in Monatshefte für Chemie[†] results were published which lead to the unexpected conclusion that the velocity of the decomposition of ethyl barium sulphate in water solution is retarded by the presence of dilute hydrochloric acid. In preliminary experiments we were unable to obtain results in accord with this conclusion, but, on the contrary, found that ethyl barium sulphate is converted into barium sulphate more rapidly in any concentration of hydrochloric acid than in water alone, the velocity corresponding approximately to the concentration of acid used. These preliminary results suggested the desirability of making a further study of the velocity of the reaction in water alone and in varying concentrations of hydrochloric acid.

From our hydrolysis experiments with water in the absence of hydrochloric acid it was found that the rate of precipitation of barium sulphate, under conditions similar to those mentioned in the article cited, is only a little more than one milligram per 24 hours during a period of more than 30 days,[‡] so that, at this rate, it would require about 650 days for the precipitation of 721 mgrm., instead of 4,300 minutes (about 3 days) as found by Kremann. On the assumption that ethyl barium sulphate is decomposed more rapidly in water alone than in half normal hydrochloric acid but less rapidly than in normal acid, Kremann[§] obtained for the velocity of the reaction an expression too complex to solve for the velocity constant. It is the purpose of this paper to show that the reaction does not yield unexpected results, and that it may be expressed in a velocity equation from which satisfactory constants may be calculated.

Preparation and analysis of the salt.—Fuming sulphuric acid was introduced drop by drop into absolute ethyl alcohol cooled in an ice bath. When the requisite amount of sulphuric acid had been added the ice bath was replaced by a water bath which was kept at the boiling temperature for two hours. The acid mixture was now diluted with water to about five times its volume, neutralized with pure barium carbonate, transferred to a tall cylinder, and allowed to stand until the barium sul-

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[*] Work has been begun on the methyl and propyl barium sulphates.

[†] R. Kremann, Monatsh. für Chem. (III), xxxi, 165.

[‡] See Table I, p. 57.

[§] Kremann, loc. cit.

phate had settled. The clear liquid was decanted and concentrated on the steam bath in a large crystallizing dish to incipient crystallization.* The solution was then rapidly filtered, by means of suction, through a hot water funnel to prevent crystallization on the filter. The clear filtrate was quickly transferred to a crystallizing dish, which was placed upon snow or shaved ice. During the process of cooling the liquid was kept agitated by rapid stirring, and when well cooled the finely crystalline mass was transferred to a Büchner funnel and freed from mother liquor by suction. Finally the salt was well dried on a porous plate and between filter papers and put into glass stoppered bottles.

The salt thus prepared corresponds to the formula: $Ba(C_2H_5SO_4)_2.2H_2O$.

Salt analyzed	$BaSO_4$ found	$BaSO_4$ calculated from formula
$0{\cdot}9080^{grm}$	$0{\cdot}4998^{grm}$	$0{\cdot}5004^{grm}$
	$55{\cdot}05\%$	$55{\cdot}11\%$

Method of hydrolysis.—In order to duplicate, if possible, the results of Kremann we worked under conditions described by him, using, however, a temperature of 60° instead of 55° or 66° C. The hydrolyses were made in sealed test tubes of about 30^{cm^3} capacity. Twenty cubic centimeters of water, or aqueous hydrochloric acid, and $1{\cdot}351^{grm}$ of $Ba(C_2H_5SO_4)_2.2H_2O$ (corresponding to $1{\cdot}236^{grm}$ of $Ba(C_2H_5SO_4)_2$, the amount used by Kremann) were introduced into each tube. As soon as ten tubes were thus charged with the salt and water, or acid of a given concentration, they were sealed, cooled, and shaken until the salt was entirely dissolved. They were then submerged in the thermostat and held in position by coil springs. At certain intervals a tube was withdrawn and the hydrolysis checked by cooling in ice-water. The contents of the tube were filtered through an ignited and weighed perforated platinum crucible fitted with an asbestos mat. After thoroughly washing the precipitate with hot distilled water, the crucible was ignited, cooled in a desiccator and weighed.

The precipitate obtained as previously described was not quite pure barium sulphate, for on heating the crucible to incipient redness the material began to char, first around the edges, then gradually toward the center until the whole mass assumed a grayish appearance. This was not due to insufficient washing of the precipitate, for the final wash water gave no indication

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* Contrary to Kremann's results, we found that this method of preparation is very satisfactory, and that the loss of salt due to hydrolysis during evaporation is very small.

of ethyl barium sulphate, ethyl sulphuric acid, or hydrochloric acid. A combustion of the dried material showed about 0·17 per cent of carbon to be present. When the ignited precipitate was boiled with water for some time the filtrate showed traces of barium and chlorine in soluble form, possibly as barium chloride. Frequently some of the precipitated barium sulphate in the hydrolysis tubes was observed to be slightly crystalline, a form favorable under the conditions of hydrolysis for the inclusion of small amounts of impurities. However, the amounts of impurities found in the precipitate after ignition were not deemed sufficient to make it necessary to apply a correction to the weights of the ignited barium sulphate, and these uncorrected weights were accordingly used in the calculation of the velocity constants.

Theory.—We have found experimentally that both ethyl barium sulphate and ethyl sulphuric acid are fairly stable substances in water solution at room temperature; even at 60° C. the rate of hydrolysis is very slow. Both the salt and the acid were kept in water solution at room temperature for weeks with scarcely any hydrolysis. The hydrolysis of these esters in water may be expressed by the following reactions: From the action of water alone upon the ethyl barium sulphate and ethyl sulphuric acid,

$$Ba(C_2H_5SO_4)_2 + 2H_2O \rightleftarrows Ba(OH)_2 + 2HC_2H_5SO_4, \qquad (1)$$

where the amounts of $Ba(OH)_2$ and $HC_2H_5SO_4$ are very small,

and $$HC_2H_5SO_4 + H_2O \rightleftarrows H_2SO_4 + C_2H_5OH, \qquad (2)$$

where the equilibrium is approached extremely slowly.* When the two reactions proceed simultaneously barium sulphate is instantly formed,

$$Ba(OH)_2 + H_2SO_4 \longrightarrow BaSO_4 + 2H_2O. \qquad (3)$$

If the second reaction proceeds more rapidly than the first, then a fourth reaction occurs, and we found experimentally that this also is instantaneous.

$$Ba(C_2H_5SO_4)_2 + H_2SO_4 \longrightarrow BaSO_4 + 2HC_2H_5SO_4. \qquad (4)$$

The concentration of sulphuric acid in the reaction mixture at any moment must therefore be extremely small, and the increase in the acidity of the mixture must be wholly due to the accumulation of ethyl sulphuric acid. The whole process of converting ethyl barium sulphate into barium sulphate, ethyl sulphuric acid and ethyl alcohol in water solution may be expressed by the simple reaction:

* As shown in Table I, series 8.

$$Ba(C_2H_5SO_4)_2 + H_2O \longrightarrow BaSO_4 + HC_2H_5SO_4 + C_2H_5OH. \quad (5)$$

If the hydrolysis is made in the presence of hydrochloric acid there is present from the beginning an equilibrium mixture in which both ethyl barium sulphate and ethyl sulphuric acid undergo hydrolysis, or possibly chiefly ethyl sulphuric acid in the presence of high concentrations of hydrochloric acid. As we expected, we found experimentally that when strong hydrochloric acid is poured into a solution of ethyl barium sulphate at room temperature a precipitate immediately forms which is chiefly barium chloride. We may express the decomposition of ethyl barium sulphate in aqueous hydrochloric acid solution by the following equations:

$$Ba(C_2H_5SO_4)_2 + 2HCl \rightleftharpoons BaCl_2 + 2HC_2H_5SO_4, \quad (6)$$

and $$2HC_2H_5SO_4 + 2H_2O \rightleftharpoons 2H_2SO_4 + 2C_2H_5OH; \quad (7)$$

also $$BaCl_2 + H_2SO_4 \longrightarrow BaSO_4 + 2HCl, \quad (8)$$

and $$Ba(C_2H_5SO_4)_2 + H_2SO_4 \longrightarrow BaSO_4 + 2HC_2H_5SO_4. \quad (9)$$

Summing up and removing common terms from both members of the resulting equation, we have, as before, the simple expression:

$$\begin{aligned} 2Ba(C_2H_5SO_4)_2 + 2H_2O &\longrightarrow 2BaSO_4 + \\ &\quad 2HC_2H_5SO_4 + 2C_2H_5OH,^* \quad (10) \end{aligned}$$

or $$\begin{aligned} Ba(C_2H_5SO_4)_2 + H_2O &\longrightarrow BaSO_4 + \\ &\quad HC_2H_5SO_4 + C_2H_5OH. \end{aligned}$$

In either case (in the presence or absence of hydrochloric acid) there is an increase in the acidity of the reaction mixture over its initial acidity of $\frac{1}{2}x$ gram equivalents of acid for x gram equivalents of barium sulphate formed in any time t. By titrating the acid solution filtered off from the precipitated barium sulphate in a number of instances, it was found that this relation invariably exists. Consequently in the velocity equation the concentration of ester (i. e., $Ba(C_2H_5SO_4)_2$ and $HC_2H_5SO_4$) undergoing hydrolysis is decreased in time t by x and increased by $\frac{1}{2}x$, hence its concentration may be written $A-x+\frac{1}{2}x$, where A is the initial concentration of ester in gram equivalents per liter. The formation of ethyl sulphuric acid accelerates the reaction also by increasing the acidity of the mixture, hence for any time t the acid concentration may be written $B+\frac{1}{2}x$, where B is the concentration of hydrochloric acid used, in gram equivalents per liter.

If the velocity of the reaction is proportional to the total concentration of ester undergoing hydrolysis and the total con-

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* This equation was also derived by Kremann, loc. cit.

centration of acid accelerating the reaction, we have for the velocity equation:

$$\frac{dx}{dt}=\mathrm{K}(\mathrm{A}-x+\tfrac{1}{2}x)\ (\mathrm{B}+\tfrac{1}{2}x), \tag{11}$$

provided that ethyl barium sulphate and ethyl sulphuric acid are esters of similar stability, and that hydrochloric acid and ethyl sulphuric acid have about the same catalytic effect. Both of these conditions were satisfied experimentally, by the slow and similar rates of hydrolysis of ethyl barium sulphate and ethyl sulphuric acid observed in dilute hydrochloric acid, and by the very similar catalytic action of hydrochloric acid and ethyl sulphuric acid in the hydrolysis of ethyl acetate.* This equation may also be derived from the principle of "the coexistence of reactions," as follows:

$dx_1/dt=\mathrm{K}_1(\mathrm{A}-x)\mathrm{B}$, for the catalysis of $Ba(C_2H_5SO_4)_2$ by HCl, (12)
$dx_2/dt=\mathrm{K}_1(\tfrac{1}{2}x)\mathrm{B}$, " " " " $HC_2H_5SO_4$ by HCl, (13)
$dx_3/dt=\mathrm{K}_2(\mathrm{A}-x)\tfrac{1}{2}x$, " " " $Ba(C_2H_5SO_4)_2$ by $HC_2H_5SO_4$, (14)
$dx_4/dt=\mathrm{K}_2(\tfrac{1}{2}x)\tfrac{1}{2}x$, " " " $HC_2H_5SO_4$ by itself, (15)

then $$\frac{dx}{dt}=\frac{dx_1+dx_2+dx_3+dx_4,}{dt}$$

and $$\frac{dx}{dt}=\mathrm{K}_1[(\mathrm{A}-x)\mathrm{B}+(\tfrac{1}{2}x)\mathrm{B}]+\mathrm{K}_2[(\mathrm{A}-x)\tfrac{1}{2}x+(\tfrac{1}{2}x)\tfrac{1}{2}x]. \tag{17}$$

Since ethyl barium sulphate and ethyl sulphuric acid are esters of nearly like stability, and hydrochloric acid and ethyl sulphuric acid are of about the same strength, we may set $\mathrm{K}_1=\mathrm{K}_2=\mathrm{K}$, then equation 17 becomes

$$\frac{dx}{dt}=\mathrm{K}(\mathrm{A}-x+\tfrac{1}{2}x)\ (\mathrm{B}+\tfrac{1}{2}x), \tag{18}$$

which, on integration, gives the simple expression,

$$\mathrm{K}=\frac{2\times2{\cdot}3}{t(\mathrm{A}+\mathrm{B})}\log\frac{\mathrm{A}(\mathrm{B}+\frac{1}{2}x)}{\mathrm{B}(\mathrm{A}-\frac{1}{2}x)}. \tag{19}$$

It is interesting to consider the reaction, on the theory that the velocity is proportional to the total concentration of ester ions and of hydrogen ions. If d_1 is the degree of dissociation of the ethyl barium sulphate in the presence of the ethyl sulphuric acid and the hydrochloric acid in the reaction mixture, d_2 the dissociation of the hydrochloric acid in the presence of the ethyl barium sulphate and the ethyl sulphuric acid, and d_3 the degree of dissociation of the ethyl sulphuric acid in the presence

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* This ester was hydrolyzed at 60° C. by N/10 HCl and by N/10 HC_2HSO_4, obtaining the velocity constants 0·00946 and 0·00955 respectively.

of the other two constituents of the reaction mixture, we have from equation 18,

$$\frac{dx}{dt}=\mathrm{K}[d_1(\mathrm{A}-x)+d_3\tfrac{1}{2}x]\ [d_2\mathrm{B}+d_3\tfrac{1}{2}x]. \tag{20}$$

Considering d_1, d_2, and d_3 constant for short time intervals, equation 20, on integration, becomes

$$\mathrm{K}=\frac{2\times 2{\cdot}3}{(d_1d_3\mathrm{A}+2d_1d_2\mathrm{B}-d_2d_3\mathrm{B})t}\log\frac{d_2\mathrm{B}\,[d_1(\mathrm{A}-x)+d_3\frac{1}{2}x]}{d_1\mathrm{A}(d_2\mathrm{B}+d_3\frac{1}{2}x)}. \tag{21}$$

Obviously the accurate determination of the values of d_1, d_2 and d_3 under the necessary conditions is a matter of considerable difficulty, but, since ethyl sulphuric acid and hydrochloric acid differ very little in their degrees of dissociation, and since the ionization of strong acids is affected but little by the presence of salts of strong acids, $(\mathrm{B}+\frac{1}{2}x)d_2$ may be taken as the approximate concentration of hydrogen ions, where d_2 is the degree of dissociation of hydrochloric acid. For the approximate concentration of ester ions in dilute aqueous hydrochloric acid $(\mathrm{A}-x+\frac{1}{2}x)d_1$ may be used, where d_1 is the degree of dissociation of ethyl barium sulphate in total ester concentration, $(\mathrm{A}-x+\frac{1}{2}x)$, since the decrease in concentration of ester ions due to the formation of barium sulphate and to the depression of ionization resulting from the increasing concentration of ethyl sulphuric acid is in a large measure offset by the increase in ester ions resulting from the continually increasing concentration of the more highly dissociated ethyl sulphuric acid. We may therefore write as an approximately correct expression for the velocity of the reaction on the ionic theory the simpler equation,

$$\frac{dx}{dt}=\mathrm{K}[(\mathrm{A}-x+\tfrac{1}{2}x)d_1]\ [(\mathrm{B}+\tfrac{1}{2}x)d_2] \tag{22}$$

which on integration gives

$$\mathrm{K}=\frac{2\times 2{\cdot}3}{d_1d_2t(\mathrm{A}+\mathrm{B})}\log\frac{\mathrm{A}(\mathrm{B}+\frac{1}{2}x)}{\mathrm{B}(\mathrm{A}-\frac{1}{2}x)}. \tag{23}$$

When the hydrolysis occurs in a strong hydrochloric acid solution, as 1·8N and 4N, the reaction probably consists chiefly of the hydrolysis of ethyl sulphuric acid to sulphuric acid, which at once combines with the barium chloride formed by the action of hydrochloric acid upon the ethyl barium sulphate, so that in this case no great error is made by setting the degree of dissociation of the ester equal to that of the hydrochloric acid, i.e., $d_1=d_2$. Then equation 22 becomes

$$\frac{dx}{dt} = \mathrm{K}(\mathrm{A}-\tfrac{1}{2}x)\,(\mathrm{B}+\tfrac{1}{2}x)(d_2)^2, \tag{24}$$

and this on integration gives

$$\mathrm{K} = \frac{2 \times 2{\cdot}3}{(d_2)^2\,t\,(\mathrm{A}+\mathrm{B})}\,\log\frac{\mathrm{A}(\mathrm{B}+\tfrac{1}{2}x)}{\mathrm{B}(\mathrm{A}-\tfrac{1}{2}x)}. \tag{25}$$

Experimental results.—The catalytic effect of hydrochloric acid on the decomposition of ethyl barium sulphate is shown in the following graph. The weights of barium sulphate calculated to gram equivalents per liter are expressed as ordinates, and the time in hours as abscissas.

Fig. 1.

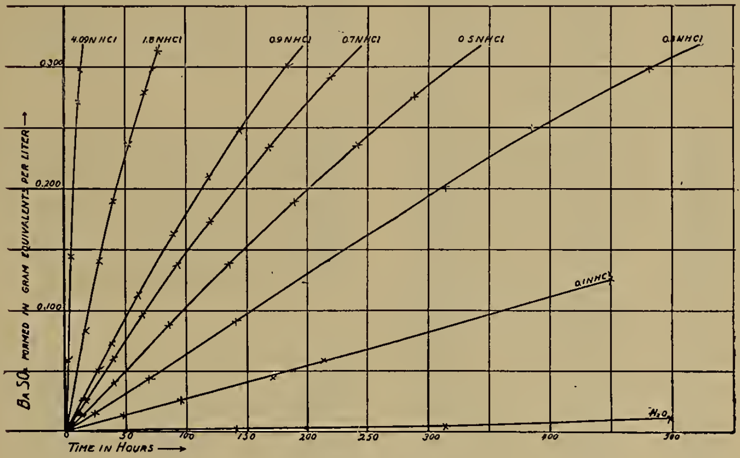

TABLE I.

t In hours	BaSO₄ In grams	 In grm. equiv.	K₁*	K₂†	K₃‡
	1	0·1 N HCl = B			
48·0	0·0287	0·0127	0·00806	0·0164	0·00941
95·0	0·0600	0·0257	0·00817	0·0166	0·00956
171·0	0·1042	0·0446	0·00765	0·0155	0·00898
213·0	0·1360	0·0583	0·00788	0·0160	0·00927
450·0	0·2910	0·1247	0·00737	0·0149	0·00874
∞	0·7440	0·3188=A			
	2	0·3 N HCl = B			
24·0	0·0370	0·0159	0·00687	0·0146	0·00875
69·0	0·1030	0·0441	0·00669	0·0142	0·00854
141·0	0·2120	0·0908	0·00674	0·0142	0·00863
218·0	0·3236	0·1388	0·00672	0·0141	0·00864
313·0	0·4690	0·2010	0·00688	0·0142	0·00888
384·0	0·5846	0·2502	0·00712	0·0146	0·00922
481·0	0·7178	0·2977	0·00692	0·0141	0·00898
∞	0·7440	0·3188=A			

* Calculated from equation 19. † Calculated from equation 23.
‡ Calculated from equation 25.

TABLE I (continued).

	3	0·5 N HCl = B			
14·0	0·0340	0·0146	0·00656	0·0143	0·00882
40·0	0·0967	0·0410	0·00652	0·0142	0·00879
85·5	0·2054	0·0880	0·00663	0·0144	0·00898
135·0	0·3230	0·1384	0·00677	0·0146	0·00921
189·0	0·4422	0·1895	0·00679	0·0145	0·00928
240·5	0·5510	0·2361	0·00684	0·0145	0·00938
288·0	0·6444	0·2761	0·00687	0·0145	0·00946
∞	0·7440	0·3188=A			
	4	0·7 N HCl = B			
17·0	0·0606	0·0260	0·00681	0·0154	0·00983
40·0	0·1392	0·0600	0·00688	0·0154	0·00996
64·0	0·2250	0·0964	0·00703	0·0158	0·0102
93·0	0·3224	0·1382	0·00712	0·0158	0·0104
120·0	0·4038	0·1730	0·00707	0·0156	0·0103
168·5	0·5478	0·2347	0·00712	0·0156	0·0104
219·0	0·6820	0·2922	0·00717	0·0155	0·0105
∞	0·7440	0·3188=A			
	5	0·9 N HCl = B			
14·0	0·0635	0·0272	0·00686	0·0160	0·0105
26·0	0·1178	0·0505	0·00693	0·0161	0·0106
38·0	0·1730	0·0730	0·00696	0·0161	0·0107
60·0	0·2638	0·1130	0·00699	0·0161	0·0108
89·0	0·3802	0·1629	0·00704	0·0161	0·0109
118·0	0·4892	0·2096	0·00707	0·0160	0·0110
144·0	0·5776	0·2475	0·00708	0·0159	0·0110
183 0	0·7019	0·3008	0·00710	0·0158	0·0111
∞	0·7440	0·3188=A			
	6	1·8 N HCl = B			
16·0	0·1934	0·0829	0·00956	0·0258	0·0200
28·0	0·3278	0·1405	0·00967	0·0259	0·0204
40·0	0·4422	0·1895	0·00953	0·0251	0·0201
52·0	0·5508	0·2360	0·00953	0·0251	0·0202
65·0	0·6510	0·2790	0·00942	0·0247	0·0200
72·0	0·6954	0·2980	0·00929	0·0242	0·0197
77·0	0·7320	0·3137	0·00931	0·0242	0·0198
∞	0·7440	0·3188=A			
	7	4·09 N HCl = B			
2·0	0·1378	0·0590	0·0236	0·0918	0·1022
5·0	0·3360	0·1440	0·0247	0·0945	0·1071
10·5	0·6318	0·2707	0·0253	0·0951	0·1097
12·5	0·6950	0·2978	0·0240	0·0892	0·1042
∞	0·7440	0·3188=A			
	8	Distilled water		$K=\frac{2\times 2{\cdot}3}{t}\log\frac{A}{A-\frac{x}{2}}$ *	
141·5	0·0057	0·0024		0·0000532	
313·0	0·0126	0·0054		0·0000544	
498·5	0·0230	0·0108		0·0000595	
862·5	0·0404	0·0173		0·0000634	
∞	0·7440	0·3188=A			

* Calculated as a monomolecular reaction. The gradual increase in the constant is due to the catalytic effect of the $HC_2H_5SO_4$ formed in the reaction.

TABLE II.

$A-\frac{x}{2}$	d_1	$B+\frac{x}{2}$	d_2
	1		
0·3188	0·5299	0·1000	0·9262
0·3125	0·5318	0·1063	0·9243
0·3059	0·5342	0·1129	0·9225
0·2965	0·5375	0·1223	0·9199
0·2897	0·5399	0·1291	0·9182
0·2564	0·5523	0·1624	0·9103
	2		
0·3188	0·5299	0·3000	0·8866
0·3109	0·5323	0·3079	0·8855
0·2967	0·5375	0·3221	0·8837
0·2734	0·5461	0·3454	0·8806
0·2494	0·5547	0·3694	0·8778
0·2183	0·5681	0·4005	0·8740
0·1937	0·5791	0·4251	0·8712
0·1700	0·5910	0·4488	0·8688
	3		
0·3188	0·5299	0·5000	0·8629
0·3115	0·5323	0·5073	0·8617
0·2983	0·5370	0·5205	0·8595
0·2748	0·5452	0·5440	0·8558
0·2496	0·5547	0·5692	0·8519
0·2240	0·5657	0·5948	0·8481
0·2008	0·5757	0·6180	0·8448
0·1808	0·5858	0·6380	0·8419
	4		
0·3188	0·5299	0·7000	0·8331
0·3060	0·5342	0·7123	0·8317
0·2890	0·5404	0·7298	0·8295
0·2710	0·5466	0·7482	0·8271
0·2500	0·5547	0·7691	0·8246
0·2330	0·5619	0·7865	0·8224
0·2020	0·5753	0·8173	0·8187
0·1730	0·5901	0·8461	0·8155
	5		
0·3188	0·5299	0·9000	0·8092
0·3052	0·5346	0·9136	0·8077
0·2936	0·5380	0·9252	0·8065
0·2823	0·5423	0·9365	0·8053
0·2623	0·5499	0·9565	0·8031
0·2373	0·5600	0·9815	0·8004
0·2140	0·5700	1·0050	0·7979
0·1950	0·5786	1·0240	0·7960
0·1684	0·5924	1·0500	0·7935
	6		
0·3188	0·5299	1·8000	0·6929
0·2773	0·5442	1·8415	0·6885
0·2485	0·5552	1·8703	0·6856
0·2240	0·5657	1·8948	0·6827
0·2008	0·5757	1·9180	0·6821
0·1793	0·5815	1·9395	0·6802
0·1698	0·5910	1·9490	0·6792
0·1619	0·5934	1·9569	0·6782
	7		
0·3188	0·5299	4·0900	0·4806
0·2893	0·5404	4·1195	0·4804
0·2468	0·5585	4·1620	0·4801
0·1829	0·5748	4·2259	0·4796
0·1699	0·5910	4·2389	0·4794

The equivalent conductivities of N/2 and N/16 aqueous solutions of ethyl barium sulphate were measured at 60° C., and the conductivities of intermediate concentrations were determined by Kohlrausch's method of graphic extrapolation. The equivalent conductivity of the salt at extreme dilution was found from the velocities of its ions at 25° C.* and the temperature coefficient calculated from conductivity measurements made at 25° C. and 60° C. The conductivities of different concentrations of hydrochloric acid at 60° C. were calculated from the values of Kohlrausch† at 18° C. and the temperature coefficients of Holborn.‡ From these conductivity values the values of d_1 and d_2 in Table II were found. For calculating the constants K_2 and K_3 the mean values d_1 and d_2 given in the corresponding series of Table II for the time intervals t_0 to t_n were used, since the total changes in d_1 and d_2 during the course of the reaction are small.

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* Bredig, Zeitschr. phys. Chem., xiii, 235.

† Landolt-Börnstein, Phys.-Chem. Tab., 746.

‡ Landolt-Börnstein, Phys.-Chem. Tab., 754.

Summary.—The experimental results lead to the following conclusions:

1. Ethyl barium sulphate and ethyl sulphuric acid decompose extremely slowly in water solution even at moderately high temperatures.

2. Fair velocity constants are obtained on the hypothesis that ethyl barium sulphate and ethyl sulphuric acid are esters of similar stability in the presence of aqueous hydrochloric acid, and that the reaction for their simultaneous decomposition is molecular.

3. The velocity constants are improved when dissociation factors for the ester undergoing decomposition and the catalyzing acid are introduced.

4. In dilute aqueous hydrochloric acid the total concentration of ethyl sulphate ions is apparently approximately equal to the product of the total ester concentration $(A-x+\frac{1}{2}x)$ and (d_1), the degree of dissociation of ethyl barium sulphate of like concentration in water solution.

5. In strong aqueous hydrochloric acid (1·8N and 4N) the formation of barium sulphate is probably chiefly due to the hydrolysis of the ethyl sulphuric acid, liberated from the ethyl barium sulphate by the hydrochloric acid, to sulphuric acid and its subsequent combination with the barium chloride set free from the ethyl barium sulphate, in which case d_1 may be set equal to d_2 in the velocity equation.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *New Volumetric Method for Manganese.*—METZGER and MARRS have devised a new volumetric method for the determination of manganese, which is particularly interesting as it is based upon a novel reaction, and as it appears to be unusually important on account of its simplicity and accuracy in its application to the analysis of iron and steel. It had been noticed previously, particularly by Hillebrand, that considerable amounts of hydrofluoric acid interfere with the usual titration of ferrous iron by permanganate on account of what appeared to be a partial reoxidation of the resulting manganous fluoride by the permanganate in such solutions. The present authors have found that with a sufficient amount of hydrofluoric acid and fluorides present, the reaction with manganous fluoride and permanganate proceeds to a definite end-point with the formation of manganic fluoride, MnF_3. This remarkable reaction is represented by the equation

$$KMnO_4 + 4MnF_2 + 8HF = KF + 5MnF_3 + 4H_2O.$$

Hence the iron value of the permanganate multiplied by the factor ·7868 gives its manganese value for the method under consideration. The manganic fluoride when present in considerable amounts imparts a brown color to the liquid, so that the method appears to be more suitable for small than for large quantities of manganese. The authors, thus far, have tested it only for rather small quantities, and have obtained exceedingly good results. Their method for steel and cast iron is as follows: Dissolve about 1 g. in 10^{cc} of 1 : 1 nitric acid. Cool slightly, add 1 g. of ammonium persulphate (to destroy carbon compounds), and let stand until effervescence ceases; boil briskly for a few seconds; remove cover and evaporate to dryness, but do not bake; take up in 20^{cc} of 1 : 2 sulphuric acid and 30^{cc} of water and boil until the solution is clear. Cool, transfer to a wax beaker, add 5 g. of ammonium fluoride, and 25^{cc} of hydrofluoric acid, dilute with water to $100–150^{cc}$, and titrate the colorless liquid with permanganate solution until a pink end-point is reached. In the case of cast iron containing much graphite it is advisable to filter off this substance before adding the ammonium fluoride and hydrofluoric acid. Since ferric iron does not interfere with this titration, and since no filtration is usually necessary, the method is remarkable for rapidity and simplicity.—*Jour. Indust. and Eng. Chem.*, iii, 301.

H. L. W.

2. *Sulphite Method for Separating and Identifying Strontium and Calcium.*—Since strontium sulphite is sparingly soluble (0·033 g. to the liter) while calcium sulphite is quite soluble (1·2 g. to the liter), and since strontium sulphite is considerably less solu-

ble than strontium sulphate (0·11 g. to the liter), J. I. D. HINDS proposes the use of freshly prepared sodium sulphite solution for the separation of the two metals in qualitative analysis. The test is best applied in strong acetic acid solution. It appears that much calcium sulphite is liable to be precipitated with the strontium sulphite, and that the method requires close adherence to prescribed conditions. Moreover, if the solution of sodium sulphite is kept long the sulphate in it is increased by oxidation and the reactions are not typical. It seems probable, therefore, that the method is much less satisfactory than the well-known treatment of the nitrates with amyl alcohol.—*Chem. News*, ciii, 157. H. L. W.

3. *Sketch of a Course of Chemical Philosophy*, by STANISLAO CANNIZZARO. 12mo, pp. 55. Edinburgh (The Alembic Club); Chicago (The University of Chicago Press), 1911.—This, the 18th of the Alembic Club reprints of celebrated chemical publications, is the translation of an article published in 1858 by the eminent Italian chemist, giving a summary of his course of lectures on chemical philosophy. Here for the first time, forty years after its publication, was the value of the hypothesis of Avogadro fully recognized. The publication led to fundamental changes of chemical formulas into the "New System"; HO became H_2O, KO became K_2O, CaCl became $CaCl_2$, etc., while at the same time it was necessary to double the atomic weights of the elements now considered bivalent and quadrivalent. It is a very clear and able discussion, with such a modern aspect that only those who are familiar with the chemical formulas of that time can fully appreciate the changes that were being advocated. Permission to publish this translation was received from the venerable chemist only a few days before his death on the 10th of May, 1910.

H. L. W.

4. *Qualitative Chemical Analysis*, by OLIN FREEMAN TOWER. 2d edition, revised. 8vo, pp. 74. Philadelphia, 1911 (P. Blakiston's Son & Co.).—The appearance of a new edition of this textbook indicates that it has been favorably received. The course of analysis followed appears to be well chosen, and differs in but few particulars from those usually found in books of its class. The directions for analysis are in tabular form, but are satisfactorily full in regard to detail, and are accompanied by copious explanatory notes. The striking peculiarity of the book is the almost complete lack of chemical equations, and the view of the author expressed in the preface that these "tend to kill initiative on the part of the student." Probably the great majority of teachers of analytical chemistry disagree with this opinion, believing that a thorough drill in chemical equations is desirable in connection with this study. An introduction of 14 pages is devoted almost entirely to the ionic hypothesis, and it is an excellent treatment of this subject; but the student can hardly be expected to understand this thoroughly before taking up qualitative analysis. It would seem better to base the ionic theory on the facts encoun-

tered in qualitative analysis rather than to explain the facts by the theory. The main fact is that acids, bases, and salts readily exchange their metals (including the hydrogen of acids) in solution, and a clear statement of this fact, devoid of theory, would serve as a good introduction to the study of analytical chemistry. At the present time, since the ionic theory is now presented in the text-books of elementary chemistry, there appears to be no more need of an introduction of the ionic theory than for one on the atomic theory in connection with qualitative analysis, for the student should already have an inkling of both these theories. These remarks on the use of the ionic theory in connection with qualitative analysis are not directed as much toward the book under consideration—for it is comparatively moderate in this respect—as toward the recent tendency to carry the use of the ionic theory to excess in such books. H. L. W.

5. *On Flames of Low Temperature supported by Ozone.*—In a paper read before the Physical Society of London on Nov. 25, 1910, it was shown that the yellow afterglow, often observed when an electric discharge has passed through a vacuum tube containing air, is due to the mutual reaction of nitric oxide and ozone, each formed in the discharge. The glow can be imitated by causing chemically prepared nitric oxide to mix with a stream of oxygen which has been through a vacuum tube at low pressure.

The investigation of this action of ozone has been extended by R. J. Strutt to other oxidizable gases and vapors. The essential parts of the apparatus used and the manner of experimenting may be briefly described as follows: After being admitted to the discharge tube at one end, oxygen passed through the tube and was partially converted into ozone by the action of an electric discharge which took place between electrodes placed in short, auxiliary tubes sealed to the main tube at right angles. The discharge tube was bent through 90° at a point a few centimeters from its exit end, and this portion of the tube was surrounded by a larger coaxial tube to which it was sealed near the bend. The outer or jacket tube was straight, it extended beyond the open end of the discharge tube, and it was terminated by a quartz window. The gas, whose ability to react with ozone was to be studied, entered the jacket tube at the end remote from the quartz window, passed along this tube and met the ozone and oxygen at the nozzle end of the inner or discharge tube. Then all the gases were sucked out of the apparatus by a mechanical pump which communicated with the jacket tube close to the quartz window. Thus the seat of any reactions which took place was in the region immediately surrounding the outlet of the discharge tube. Since this opening was directly opposite the quartz window it was a simple matter to focus on the slit of the spectrograph any light which accompanied the reactions. Obviously, the object in bending the prolongation of the discharge tube at right angles to the main axis of the region of discharge was to prevent light from the discharge from reaching the slit of the spectrograph directly. It was easy to make corrections for the small amount of light from the discharge which reached the window by sundry reflections from the inner walls of the glass tubes.

The vapors from volatile liquids were admitted to the jacket tube at the same place where gases were caused to enter from reservoirs. When it was desired to work with the vapor of a volatile solid, fragments were simply placed in the jacket tube, the window being temporarily removed to admit them. To observe the temperature of the various flames, a similar apparatus was employed, but with the jacket tube sufficiently prolonged to contain a mercury thermometer, which was placed so that its bulb was enveloped in the flame. A small, single-prism, quartz spectrograph was used, and good negatives of the spectra of the flames were usually obtained with an hour's exposure or less.

The following summary of results may be of interest : *Sulphureted hydrogen* mixed with ozone gave a sky-blue flame. The temperature recorded was 70° C. However, this value depends on the pressure. The spectrum was continuous from λ 2300 to λ 4800 with superposed bands from λ 2300 to about λ 2600. In this case, as in all the others, the glow ceased at the instant when the electric discharge was stopped. The combustion only occurs at these low temperatures and pressures in ozone; it is not maintained when oxygen is substituted. Identical results were obtained when a lump of solid *sulphur* was introduced into the jacket tube. On the other hand, the band spectrum is entirely different from that observed when sulphur burns in air at a pressure of about one atmosphere. *Carbon disulphide* gave a blue flame, apparently the same as sulphur or hydrogen sulphide. The spectrum was not examined. *Sulphur dioxide* gave no glow with ozone. Only when *selenium* was gently heated did it give a glow, and this was very inconspicuous. *Arsenic* was apparently not acted on by ozone. *Iodine* gave an orange glow, redder than that due to nitric oxide. It is oxidized to a yellowish white solid, probably iodine pentoxide. *Ammonia*, *carbon monoxide*, *hydrogen*, *nitrogen*, *nitrous oxide*, *methane*, *ethylene*, the vapors of *petrol*, *ether*, and *alcohol* gave no glow. *Acetylene*, in contradistinction to most hydrocarbons, gave a fairly conspicuous, bluish-green glow. The thermometer indicated 100° C., under the particular conditions of the experiment. The spectrum consisted of the Swan bands, together with the hydrocarbon band at λ 4315, and it is thus identical with the spectrum of the inner cone of a Bunsen flame. The color of the flame can be regulated by the acetylene supply. With a small supply it is green, the Swan bands predominating. With an increased supply the flame contracts, the ozone being now consumed before it has got far from the orifice where it issues into the acetylene. At the same time the color becomes bluer, and the hydrocarbon band brighter, relatively to the Swan bands, than in a Bunsen flame. Carbon monoxide seems to be the chief product of combustion. *Benzene* under some conditions gave a barely perceptible glow, too faint to be studied, though attended by a notable rise of temperature. On one occasion, when the glow was not observable, a white solid was deposited on the glass. This solid exploded spontaneously, with a loud report, breaking the apparatus, and leaving a deposit of carbon. The explosive compound was probably the "ozobenzene" of Houzeau and Renard. *Napthalene* and *camphor* failed to give a glow but were energetically acted on. The former substance was carbonized, and the latter converted into a dull, opaque white solid. *Cyanogen* gave a white glow with a purple tinge in the vicinity of the nozzle. The spectrum consisted of the characteristic cyanogen bands together with the hydrocarbon band at λ 4315. An unidentified band at λ 415 was also observed. Strutt suggests that this band "may eventually prove of interest in connection with the spectra of comets."—*Proceedings Phys. Soc. London*, xxiii, Feb. 1911. H. S. U.

6. *A Chemically Active Modification of Nitrogen, produced by the Electric Discharge.*—It is known that vacuum tubes frequently show luminosity of the contained gas after the discharge is over. In a previous paper Strutt showed that this effect, as it occurs in air, is of the nature of a phosphorescent combustion, and is due to the mutual reaction of nitric oxide and ozone, each formed in the discharge. In a second paper, reviewed above, it was shown that other phosphorescent combustions can be observed in ozone. Also, it was stated in the first paper that pure nitrogen gives no afterglow whatever when a simple induction coil discharge is used. This fact has been frequently verified by subsequent experiments of Strutt. On the other hand, E. P. Lewis has described an afterglow obtained in nitrogen when a Leyden-jar discharge with auxiliary spark-gap is employed. By using a jar discharge, in conjunction with apparatus of the type described in the preceding review, STRUTT has obtained the remarkable and important results given in his "Bakerian Lecture." The most interesting features of this paper will now be set forth.

As Lewis observed, the glow for nitrogen has a characteristic band spectrum not known in any other connection. In the visual region there are three bands, one in the green, another in the yellow, and a third in the red. The glow as a whole appears yellow. By using Dewar's continuous flow method, Strutt has "obtained the nitrogen afterglow intense enough to be conspicuous to an observer 30 feet off, when it was 18 inches below a 32-candle electric light." Contrary to Lewis, Strutt found that the effect could be obtained with nitrogen from natural and artificial sources, the purer the nitrogen the better the results. "In short, all the evidence obtained points to the conclusion that the glow is connected with nitrogen, and nothing but nitrogen."

The effect of temperature on the glow is important. If a long tube, through which a stream of glowing nitrogen passes, is moderately heated, the glow is locally extinguished. As the gas passes on to a cooler part of the tube its luminosity is recovered.

If, on the other hand, the gas is led through a tube immersed in liquid air, it glows out with increased brilliancy where it approaches the liquid air. The luminosity is completely and finally extinguished when, or before, the fully cooled portion of the tube is reached. The kind of atomic or molecular change which might be expected to behave in this way is an association, e. g. of dissociated nitrogen atoms into molecular nitrogen.

The glowing nitrogen has remarkable chemical properties. When it is pumped over a small pellet of phosphorus a violent reaction occurs, red phosphorus is formed, and the yellow glow is quenched. At the same time about one-half of one per cent of the gas is absorbed. This is a measure of the proportion of active nitrogen present in the whole stream and it is of the same order of magnitude as the percentage of oxygen converted in an ozonizer. When the discharge tube is closed at both ends and the afterglow is allowed to diffuse until it meets the phosphorus vapor the same reaction takes place. The absorption reduces the pressure of the gas so low as to stop the electrical discharge. The reaction is not affected by removing the ions from the gas by means of a suitable electrostatic field. The fact that nitrogen and phosphorus can combine under these conditions was not known before.

The glowing nitrogen also exhibits remarkable phenomena when led over iodine. Its normal yellow glow is replaced by a light blue flame at the place where it mingles with the iodine vapor. A slight rise of temperature is observed in this region. "The flame gives a magnificent spectrum of broad bands." "Details will follow in a later paper."

Antimony, carbon and selenium had no effect on the glow of the nitrogen. Hydrogen simply diluted the glow, while oxygen extinguished it. Arsenic and sulphur gave reactions which were not very striking.

Perhaps the most important discovery recorded in the paper is the fact that glowing nitrogen reacts quite vigorously with many metals and metallic compounds, and simultaneously gives rise to the characteristic spectra of the metals involved.

As Strutt remarks: "It opens up a new field of experiment to be able to produce metallic spectra in a vessel at so low an average temperature, and in the absence of an electric field."

The line spectra of cadmium, lead, magnesium, mercury, potassium, sodium, and zinc were obtained with the pure metals. Thallium was tried in the form of the chloride and gave a magnificent green light, in striking contrast to the yellow afterglow which it replaces. As with phosphorus, so also with metallic sodium and mercury, the absorption of nitrogen was demonstrated. It was also shown that none of the phenomena is due to the presence of ions in the glowing nitrogen, but only to the uncharged, "active" nitrogen. The ions were removed, of course, by means of a strong, electric cross-field introduced in the path of the flowing gas between the region of discharge and the place where the various reactions were observed.

Lack of space necessitates the omission of even a bare statement of many important observations recorded with respect to the action of glowing nitrogen on compound bodies. Nevertheless, attention must be called to two noteworthy cases.

Manganese dioxide and copper oxide are fatal to the glow. "The analogy to the known destruction of ozone by these substances cannot fail to attract attention."

Nitric oxide, when allowed to mix with the active nitrogen, shows a very strange behavior. A greenish flame, possessing a continuous spectrum, is produced and heat is developed at the point of confluence. To test whether any gas condensable at −180° C. was produced, the gases from the flame were led through a U-tube cooled in liquid air, and a dark blue substance was condensed out. This melted to an indigo-blue liquid, and finally revealed itself as nitrogen peroxide by evaporating off into an orange gas, soluble in caustic alkali. Repeating the experiment without exciting the electric discharge led to the formation of no nitrogen peroxide. Strutt says: "It is very surprising that a reaction between nitrogen and nitric oxide should lead to the formation of a substance, not *less*, but *more* oxidized than the latter."—*Proceedings Roy. Soc.*, lxxxv, May, 1911.

H. S. U.

7. *On Extremely Long Waves, emitted by the Quartz-Mercury Lamp.*—A brief account of a paper by Rubens and Wood, on this subject, was given in the May number of this Journal (pp. 456, 457). The investigation has been continued by RUBENS and VON BAEYER.

The apparatus used and the method of experimenting were the same as in the earlier work. Strong Leyden-jar sparks between electrodes of aluminum, bismuth, cadmium, iron, platinum, and zinc were first tried, but radiations of greater wave-length than those formerly obtained with a Welsbach mantle—108μ—were not found. "A comparatively very strong long-waved radiation was, however, obtained with the quartz-mercury lamp, especially at higher consumption of energy." With a current of 4 amperes on 100 volts, the arc being about 80^{mm} long, a deflection of more than 50^{mm} appeared in the micro-radiometer. A ray-filter of black cardboard, about $0·38^{mm}$ thick, proved most efficient for the isolation of the very long waves.

The authors proved that the longest waves are emitted by the mercury arc and not by the quartz walls of the lamp. The mean wave-length obtained was about 314μ, or nearly $0·3^{mm}$. Thus the infra-red spectrum sustains another enlargement of 1·5 octaves. A table of percentages of energy transmitted by seventeen useful substances is given, both for the Welsbach radiations, 108μ, and for the mercury arc, 314μ.—*Phil. Mag.* (6), xxi, 689. H. S. U.

8. *Prinzipien der Atomdynamik;* von Dr. J. STARK. I Teil. Die elekrischen Quanten. Pp. x, 124. Leipzig, 1910 (S. Hirzel).—According to the author's preface, the present pamphlet is to form the first part of a book which will consider especially the

relation of atomic theories to the physical theories based upon the properties of a continuous medium (the ether), such as the prevailing theories of electromagnetism and of light. That some reconciliation, or at least some adjustment, between the two points of view has become necessary is plainly apparent nowadays to all students of physics. It is perhaps the modern way of stating the question which used to be called the problem of the relation between ether and matter. In the part before us, the electric atoms (electrons and "archions") are considered ; and the two remaining parts which are to complete the book will deal with the atomic structure of radiation and of matter respectively. H. A. B.

9. *The Pressure of Light* ; by J. H. POYNTING. Pp. viii, 103. London, 1910 (Society for Promoting Christian Knowledge).—This little volume contains the substance of several lectures on the pressure of light which have been given by Professor Poynting before various popular audiences. It is marked by the lucidity and simplicity which are characteristic of the author, particularly in the illustrative experiments which are described. The whole of the text is untechnical and may be easily read by any one who is interested in this important development of physical science ; while for readers who desire to obtain some idea of the mathematical theory of the subject, an appendix is provided in which the necessary calculations are set forth. H. A. B.

10. *Physics* ; by C. R. MANN and G. R. TWISS. Revised edition. Pp. 424; 220 figures. Chicago, 1910 (Scott, Foresman and Co.).—This is a revision of a high school text-book which first appeared about five years ago. The new edition differs from the old both in subject matter and in method of presentation. In accordance with the growing sentiment against the laws of accelerated motion, the absolute units, etc., for high-school pupils, the authors have endeavored to limit their choice of material to that which would appeal to the pupils as significant and, by means of numerous problems in which the mathemathical difficulties are reduced to a minimum, to assure the mastery of the subject matter. The text is divided into two parts, of which the first is designed as a year's work to be of interest to everybody. The second part provides for an amplification of the course to meet the requirements of the College Entrance Board. Italics and heavy-faced type emphasize the more important conclusions.

D. A. K.

11. *The Principles of Electro-Deposition* ; by SAMUEL FIELD. Pp. xv, 383 ; 54 tables and 121 figures. New York, 1911 (Longmans, Green and Co.).—The aim of the author is to provide a laboratory guide which shall give a thorough understanding of the underlying principles of the subject, rather than to furnish a mass of details of workshop practice but briefly treated. The first seven chapters deal with cells, the properties of electric currents, principles of the dynamo and the arrangement of apparatus. Then follow four chapters on the preparation of materials and solutions, eight chapters on the deposition of various metals

and on metal coloring, six chapters on qualitative and quantitative analysis (limited to the study of the purity of the metals and solutions employed, and the methods of purifying them), a final chapter on the recovery of metals, and an appendix of twenty tables which should prove useful to a practical man of limited library facilities. D. A. K.

II. GEOLOGY AND MINERALOGY.

1. *United States Geological Survey;* GEORGE OTIS SMITH, Director.—Recent publications of the U. S. Geological Survey are noted in the following list (continued from vol. xxxi, p. 235):

TOPOGRAPHIC ATLAS.—Twenty-eight sheets.

FOLIO No. 175. Birmingham Folio, Alabama; by CHARLES BUTTS. Pp. 24; 1 chart, 4 maps, 1 page illustrations (I–XII).

No. 176. Sewickley Folio, Pennsylvania; by M. J. MUNN. Pp. 16; one chart, 4 colored maps.

BULLETINS.—No. 431. Coal and Lignite; by CHARLES BUTTS, M. R. CAMPBELL, E. G. WOODRUFF, C. T. LUPTON, J. S. DILLER, M. A. PISHEL, H. E. GREGORY, and A. C. VEATCH. Pp. 163; 12 plates, 4 figures. Contributions to Economic Geology, 1909. Part II.

No. 438. Geology and Mineral Resources of the St. Louis Quadrangle. Missouri–Illinois; by N. M. FENNEMAN. Pp. 73; 6 plates, one figure.

No. 439. The Fauna of the Moorefield Shale of Arkansas; by GEORGE H. GIRTY. Pp. 148; 15 plates.

No. 445. Geology of the Pegmatites and associated Rocks of Maine, including Feldspar, Quartz, Mica, and Gem Deposits; by EDSON S. BASTIN. Pp. 152; 19 plates, 8 figures.

No. 446. Geology of the Berners Bay Region, Alaska; by ADOLPH KNOPF. Pp. 58; 2 plates, 4 figures.

No. 447. Mineral Resources of Johnstown, Pennsylvania, and Vicinity; by W. C. PHALEN and LAWRENCE MARTIN. Surveyed in Coöperation with the Topographic and Geologic Survey Commission of Pennsylvania. Pp. 142; 7 plates, 22 figures.

Nos. 453, 459, 460, 461, 462. Results of Spirit Leveling done in coöperation with the States; R. B. MARSHALL, Chief Geographer. No. 453, Minnesota, pp. 39, 1 plate. No. 459, Missouri; pp. 48, 1 plate. No. 460, Iowa, pp. 32, 1 plate. No. 461, Michigan and Wisconsin, pp. 64, 1 plate. No. 462, Oregon, pp. 82, 1 plate.

No. 465. The State Geological Surveys of the United States; compiled under the direction of C. W. HAYES. Pp. 177.

No. 470–E, Contributions to Economic Geology, 1910. Rare Metals; by F. L. HESS. Pp. 12; 1 figure. 470–I, Mineral Paints; by B. L. MILLER. Pp. 15. 470–J, Sulphur and Pyrite; by R. W. RICHARDS and J. H. BRIDGES. Pp. 8; 1 figure.

Water Supply Papers.—No. 257. Well-Drilling Methods; by Isaiah Bowman. Pp. 139; 4 plates, 25 figures.

No. 258. Underground-Water Papers 1910; by M. L. Fuller, F. G. Clapp, G. C. Matson, Samuel Sanford, and H. C. Wolff. Pp. 123; 2 plates, 32 figures.

No. 270, Surface Water Supply of the United States, 1909. Part X. The Great Basin; prepared under the Direction of M. O. Leighton by E. C. La Rue and F. F. Henshaw. Pp. 192; 5 plates, 1 figure.

2. *Topographic and Geologic Survey of Pennsylvania. Richard R. Hice*, State Geologist. *Report No. 1. Geology of the Oil and Gas Fields in Sewickley Quadrangle;* by M. J. Munn. Surveyed in coöperation with the U. S. Geological Survey. Pp. 171; 10 plates. Harrisburg, 1910. *Report No. 3. Geology of the Oil and Gas Fields of the Clarion Quadrangle;* by M. J. Munn. Pp. 111; 9 plates, one figure.—These recently issued reports show the important work which is being carried forward by the Geological Survey of Pennsylvania in coöperation with the U. S. Survey. They have been prepared by the same author (who is also the author of the Sewickley Folio noted above), and give detailed and accurate information in regard to the gas and oil fields in the two quadrangles mentioned. The facts here presented will be of great value, not only locally but also to all oil and gas operators as well as to those concerned with the geological problems involved. The careful sections given in the series of deep wells exhibit the geologic relations. Perhaps the most interesting points discussed are those bearing upon the relation between the quantity of oil and gas and the geological structure shown in the anticlinal folds. The writer does not attempt to settle the difficult and frequently discussed questions involved, but the full and accurate statement of facts, particularly those of the better known Sewickley quadrangle, will do much to throw light upon the subject.

3. *North Carolina Geological and Economic Survey.* Joseph H. Pratt, State Geologist.—The following publications have recently appeared:

Biennial Report of the State Geologist, 1909–1910. Pp. 152.

Bulletin No. 22. The Cid Mining District of Davidson County, North Carolina; by Joseph E. Pogue, Jr. Pp. 144; 22 plates, 5 figures.

Economic Paper No. 21. Proceedings of the third Drainage Convention held at Wilmington, N. C., Nov. 22, 23, 1910; and North Carolina Drainage Law codified; compiled by Joseph H. Pratt. Pp. 61; 4 plates.

4. *The Ice Age in North America and its Bearings upon the Antiquity of Man;* by G. Frederick Wright. 8°, pp. 763; 166 figures. Oberlin, Ohio, 1911 (Bibliotheca Sacra Co.).—A fifth edition of this well-known work is proof both of the widespread interest in glacial phenomena and the geological period in which its results were so strikingly displayed, and also of Professor Wright's success in creating a work to satisfy it.

Chapters on the characters of glaciers, their distribution, with descriptions of occurrences in North America, lead up to the discussions of the glacial period, its varied results, and possible cause. Considerable new matter has been added in supplementary statements. The author gives the different hypotheses that have been advanced to account for the formation of the great ice-sheets, and discusses some of them at length. Croll's hypothesis is now so generally disregarded, or relegated to a minor position, that it hardly seems worth the extended treatment given to it. It is here that the work suffers in clearness of presentation to the general reader, caused by the retention of the older matter and the interspersal of new. An entire rewriting of this part would have greatly aided it. The author comes to no definite conclusion as to the cause of the glacial period, but considers it is a problem for the future.

Perhaps that part of the work which will continue to meet the most criticism is the final portion in which the age of man in this country is treated. As is well known, Professor Wright is an advocate of the human occupancy of North America during the glacial epoch. The arguments of the evolutionists he considers met by the great recency which he attributes to this period. It is not, however, the point of view but the treatment of evidence in which the writer must meet objection. Apparently all finds of underground human remains and implements, under any circumstances, have to him scientific value, and the criteria applied in other portions of the book, in considering alternative explanations, here seem to be largely wanting. The age of man in this country is still an open question, and it will not be settled to the satisfaction of scientists until a sufficient body of evidence has been produced by men whose training, both in geology and archæology, renders them thoroughly competent to undertake the necessary investigations, and to recognize the true value and relations, in place, not of a part, but of all the facts. L. V. P.

5. *Characteristics of Existing Glaciers;* by WILLIAM HERBERT HOBBS, Professor of Geology in the University of Michigan. Pp. xxiv, 301; 34 plates, 140 figures. New York, 1911. The Macmillan Co. Price, $3.25 net.—This work easily takes rank among the most important treatises on glaciation, and it is furthermore made attractive by good paper, clear topography, and handsome illustrations. The plates are half-tone reproductions of instructive photographs, and the line drawings are very effective in imparting graphic ideas beyond the reach of the camera. It is a study of existing glaciers with the emphasis placed upon the glacier as a whole and the relative function of each part, rather than, as in most previous works, a detailed treatise of such subjects as glacial motion or glacial erosion. The glacier is furthermore studied from the standpoint of its life history, from its inception in a gathering snowfield through the cycle of its growth and retreat to its ultimate extinction. From this rather new concept, however, definite ideas are derived on such debated topics as

glacial erosion or protection. The great distinctions in kind between mountain glaciers and continental glaciers are emphasized, a difference not only of size and form, but of mode of nourishment, motion and erosion. The over-emphasis which has, owing to its historical development, been put upon mountain glaciation is corrected in this book, two-thirds being given to Arctic and Antarctic glaciation.

The advance of glacial theory has been accompanied by long-drawn controversy, first in regard to the agency of ice or water, then as to land or marine ice, next of chronologic unity or complexity, and still of erosive competency or incompetency. This has been largely due to the relative lack of comprehensive studies of living glaciers as compared to the intensive study of past glaciation. This being the case, such a book as the present is of especial value, and, as Professor Hobbs remarks, "It is believed that more is gained from setting forth the evidence from one's own viewpoint than by entering into controversy." It is, therefore, a contribution in the spirit of Sir Charles Lyell—"the present is the key to the past." J. B.

6. *Les Variations Périodiques des Glaciers, XV^{me} rapport, 1909*; rédigé par Dr. Ed. Brückner, Professeur à la Université de Vienne, Président de la Commission et E. Murat, Inspecteur des Forêtes à Lausanne, Secrétaire de la Commission. Extrait des Annales de Glaciologie, vol. v, pp. 177–202, Jan. 1911.—In 1909, as in recent years, the world's glaciers, with the exception of those in Scandinavia, exhibited in general a further retreat. In the Swiss Alps, for example, 33 showed a definite retreat and only two a definite advance. The glacier d'Argentière of the Mont Blanc massif retreated 18·6^{m} between July 23, 1908, and July 28, 1909. On the latter date the front of the glacier was 1050^{m} from the point which it attained in 1819. In Norway the glaciers of the central high mountains exhibited a general decrease, but this is matched by an equally general increase in those of the Western Coast Range. In Alaska a map of Glacier Bay, based on surveys made in 1907, shows a very marked decrease of glaciers during the previous 15 to 20 years, recessions being noted of from 5 to 13·5 kilometers. J. B.

7. *Physik der Erde*; von Dr. M. P. Rudzki, O. Professor an der Universität Krakau. Pp. viii, 584; 5 plates, 60 text figures. Leipzig, 1911 (Chr. Herm. Tauchnitz).—This work consists of fourteen chapters, averaging 41 pages each, on such subjects as the figure of the earth, determinations of gravity and its anomalies, density and temperature of the earth's interior, seismology, deformation, waves, tides, ocean currents, rivers, ice and glaciers, the glacial period. The general mode of treatment is to give some pages of descriptive matter and tables of values followed by the mathematical theory. Conclusions from the latter are also given. The volume thus brings together a considerable amount of statistical data of various sorts, such as lend themselves to mathematical treatment, and the lines of that treatment are also

given. The book is essentially a compilation and, as seen from the space assigned to each subject, it is far from being exhaustive. The important results of Hayford, for instance, are summed up on two pages ; no mention is made of the volume published by the Carnegie Institution in 1909 on Fundamental Problems in Geology. Radium and its relation to the earth occupies but three pages. No mention is made of Chamberlin's hypotheses regarding the earth's interior and their relation to deformation. The photographic plates, while making the volume more attractive, are not essential to the text.

The book fulfils a certain purpose as an introduction to geophysics, but it should be noted that mathematical treatment has in the past inspired a false confidence in results which were often based on incomplete or uncertain premises. It seems, therefore, that such an introductory view should give a much larger space to multiple hypotheses and their geological and quantitative probability, indicating the lines of mathematical analysis which will further test such hypotheses or add to their fertility of results.

J. B.

8. *The Geological Survey of Sweden.*—The Swedish Geological Survey, which has always been active in its work and publications, has recently issued a series of important papers. These include three quarto volumes : The first series (Ca, No. 4) gives an account of the late Quaternary history of Gottland, by H. Munthe, with numerous striking illustrations. A second (Ca, No. 5) contains a series of papers by different authors, discussing the glaciers of Sweden in the year 1908, with twenty-six plates. The third (Ca, No. 7), by A. Gavelin and A. G. Högbom, describes the ice seas which occupied extended areas in the mountain region of Sweden at the end of the Ice Age. Several geological maps have also been issued, and further Year-Book No. 3 for 1909, containing eleven papers on various subjects by different authors. The first of these treats of the climate of Sweden in the late Quaternary period, by G. Andersson.

9. *The Fossils and Stratigraphy of the Middle Devonic of Wisconsin ;* by Herdman F. Cleland. Bulletin XXI, Wisconsin Geological and Natural History Survey, pages i–vi, 1–222, and 53 plates, 1911.—In this handsome volume Professor Cleland brings together all that is known in regard to the geology and fauna of the rather local impure dolomites known as the Milwaukee formation and correlated by the author with the upper part of the New York Hamilton. More than 200 species of invertebrates and fishes are discussed and illustrated, of which about 40 are described as new. The life assemblage clearly indicates a mixture of eastern and western faunas, and proves that " Southern Wisconsin was in the path of migration" between these two interior seas. " Some time before the close of the Hamilton communication was established between the Wisconsin and Iowan areas, in consequence of which we find at Milwaukee a mingling of Cedar Valley forms from the southwest and a modified post-

Corniferous fauna from the Ohioan region." This volume leads the way to a better understanding of the greater western fauna extending from Iowa to California, and from Arizona north into the Mackenzie country. C. S.

10. *Cambrian Geology and Paleontology, II—No. 2, Middle Cambrian Merostomata;* by CHARLES D. WALCOTT. Smithsonian Misc. Coll., 57, pages 17–32 and 6 plates. 1911.—This is the first paper of a series in which the Secretary of the Smithsonian Institution will give his preliminary studies of those wonderfully well-preserved Middle Cambrian fossils discovered by him near Mount Stephen, British Columbia. In the present part are described two new merostomes as *Sidneyia inexpectans* and *Amiella ornata.* It is the former only that is well preserved.

Walcott erects the new suborder Limulava for these eurypterid-like animals, but as they differ widely from the Eurypterida it will be better to raise it to an order. Sidneyia is a swimming merostome with well-developed antennæ, a lobster-like tail, and eleven body segments, two of which are annular and the other nine are said to bear leaf-like branchial appendages. The illustration shows no branchiæ on the two anterior segments, the third has them rudimentary, while on the other six each pair of branchiæ seems to be common to two body segments. If the illustration is correct, then Sidneyia has but six segments with branchiæ as in the Eurypterida, and the anterior non-branchiate segments may represent parts of the thorax that are united with the cephalon in the Eurypterida and Limulus. Furthermore, these two anterior thoracic segments bear limbs that in the Eurypterida are a part of the cephalo-thorax. Sidneyia when viewed from the ventral side is seen to have five pairs of appendages, but one does not see here that the cephalo-thorax is made up of three parts, the cephalon and two anterior segments, as is shown to be the case when viewed from the dorsal side. The eyes are on the edge of the cephalon, a very primitive condition in the light of trilobite ontogeny.

The discovery of these merostomes makes it the plainer that a greater amount of invertebrate evolution has taken place before the Cambrian than subsequently. C. S.

11. *Contributions to the Carboniferous Flora of North-Eastern Greenland;* by A. G. NATHORST. Danmark-Eksped. til Grönlands Nordöstkyst 1906–1908, Bd. III, No. 12, pages 339–346, 2 plates, 1911.—The small flora here described is the most northerly one known, being from north of 80° latitude on the east coast of Greenland. Over the granite there lies a great thickness of black shale, thought to be not less than 300 to 400 meters thick, and this has yielded in the upper part the plants here described. On this rests a red conglomerate (100^m), with well-rounded pebbles about the size of a hazelnut passing upward into variously colored sandstones (75^m), that in the upper 100 feet have an abundance of fossils, especially brachiopods. Higher is a dense limestone rich in corals, that is estimated to have a thickness of at least 700 meters.

The age of the plants is "Lower Carboniferous," and the same horizon is present in Spitzbergen. Eleven species are figured or described, but of these only five are specifically identified. These are *Calymmatotheca bifida*, *Sphenophyllum tenerrimum elongatum* (also in the Pottsville), *Asterocalamites scrobiculatus*, *Lepidodendron spetsbergense* (and three other species), *Lepidophyllum* cfr. *lanceolatum*, and *Stigmaria ficoides*. C. S.

12. *On a Trenton Echinoderm Fauna at Kirkfield, Ontario*; by FRANK SPRINGER. Mem. No. 15–P, Dept. Mines, Canada, Geol. Surv. Branch. Pp. 50 and 5 heliotype plates, 1911.—While excavating the Trent canal in the lower Trenton limestone much excellent echinoderm material was obtained from 25 to 80 feet above the Black River, all of which is here listed or described. Of crinoids there are 26 species (2 new), edrioasterids 4, cystids 3 and starfishes 5. The "most remarkable fossil echinoderm" *Hybocystis* is described in detail and illustrated in 12 fine figures on Plate II. An entire colony was found in which more than 100 specimens were crowded into a space of a few square feet. Four-fifths of these are *H. eldonensis* Parks. The genus is remarkable because it has but 3 erect blunt arms, the other 2 being recumbent as in some cystids and fastened to the calyx plates. Much labor has also been devoted to *Cupulocrinus*, which is not far removed from the radicle that gave rise to the order Flexibilia present at this locality in 2 species of *Protaxocrinus*. Interesting remarks are made on *Cleiocrinus regius*, which has the calycine pores and pore-rhombs of the cystids, and the species is referred to as a "case of premature secession from the cystids." *Astroporites ottawaensis* Lambe, originally regarded as a probable bryozoan, is here said to represent "the lower part, or floor, of an unusually highly organized root of a crinoid, consolidated by growth into a calcareous plate for attachment to flat surfaces." The illustrations are remarkably fine drawings by K. M. Chapman. C. S.

13. *Geology of the Thousand Islands Region*; by H. P. CUSHING, H. L. FAIRCHILD, R. RUEDEMANN and C. H. SMYTH, Jr. New York State Museum, Bull. 145, pp. 194, many illustrations and 6 maps, 1910.—A most excellent and detailed geologic, stratigraphic and petrographic report of an interesting area. The basement rocks are of the Grenville series, and are more or less overlapped from the east by the thin Potsdam sandstone and Theresa dolomite of Upper Cambrian age. On this follows a short erosion interval, and then a submergence from the south, the Beekmantown limestone, another erosion period followed by a little of the Stones River limestone (Pamelia), a third lost interval, and then a long marine invasion, the Mohawkian (Lowville, Watertown, and Trenton) limestone. The Pleistocene geology is by Professor Fairchild. C. S.

14. *Geology of the Poughkeepsie Quadrangle*; by C. E. GORDON. New York State Museum, Bull. 148, pp. 117, geological map and many illustrations, 1911.—The geology of the Pough-

keepsie region, greatly complicated through folding and thrust faulting, is described in this bulletin. For many years Professor Dwight of Vassar College collected the fossils, and among them the 25 to 30 species of nautilids in which Hyatt was so much interested, and of which almost nothing is yet known.

The basement upon which the sedimentaries are laid is the gneiss of Fishkill mountains, thought to belong in the Grenville series. Upon this lies unconformably the Lower Cambrian or Poughquag quartzite with Olenellus. There is then a long "lost interval," followed by the Barnegate limestone of Upper Cambrian age, and with a fauna in the basal beds like that found near Saratoga, New York. This series at Rochdale is from 1000 to 1200 feet thick, and also has the cephalopod fauna referred to. Another time break, and then follows a thin limestone with *Tetradium cellulosum* indicative of Lowville time, over which lies the Trenton limestone. The great mass of surface exposures is taken up by the "Hudson River slates" of the Atlantic province, which now override the above-mentioned formations of the Mississippian sea. C. S.

15. *Brief Notices of Some Recently Described Minerals.*—Neocolemanite is a calcium borate occurring near Lang, Los Angeles county, California, described by A. S. Eakle at the spring meeting of the Geological Society of America, at Berkeley, Cal. It is related to colemanite, but differs somewhat in its crystallographic and optical properties. A preliminary notice says that the deposit consists of alternate layers of crystallized borate and carbonaceous shales and has apparently been formed by the action of boracic acid on a lake or marsh deposit of calc-tufa or marl. The silicoborate of lime, howlite, occurs with the neocolemanite as snow-white, nodular compact masses ; it has been formed at the same time as the neocolemanite by precipitations from solutions containing soluble silica. The deposit is remarkable as a pure borate deposit unaccompanied by other calcium minerals or by sodium salts.

Molengraaffite is described by H. A. Brouwer from the lujaurite of the Piland mountains, northeast of Rustenburg in the Transvaal, South Africa. It occurs in yellowish brown prismatic forms, having a perfect cleavage like that of astrophyllite, to which it has some relation and the place of which it sometimes takes in the rock. There are also numerous pseudomorphs of catapleiite after eucolite. Chemically molengraaffite is more or less related to yttrotitanite, but it contains none of the rare earths, while soda is present in large amount. An analysis by Wijdhoek gave the following results:

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	H_2O
28·90	27·70	3·75	0·95	2·07	2·72	19·00	2·38	10·30	0·60	1·00=99·37

—*Centralblatt für Mineralogie*, etc., p. 129, 1911.

Gajite is a hydrated carbonate of calcium and magnesium described by Fr. Tucan from the Gorski-Kotar district in Upper

Croatia. It occurs in dense snow-white masses resembling magnesite; specific gravity 2·619. An analysis by the describer gave:

CO_2 32·41 CaO 37·13 MgO 23·75 H_2O 6·63 = 99·92

Although in composition near the mixtures that have been called pencatite and predazzite, no evidence of essential want of homogeneity of gajite could be found. It is named after the Croatian patriot, L. Gaj.—*Centralblatt für Min.*, etc., p. 312, 1911.

16. *Bismuth Ochers from California.*—W. T. SCHALLER shows in a recent paper (J. Am. Chem. Soc., xxxiii, 162) that the yellow bismuth ochers from San Diego County are either bismuth hydroxide, or bismuth vanadate, pucherite, or a mixture of the two; Bi_2O_3 was not found. The same author earlier found that molybdic ocher, instead of having the assumed composition MoO_3, was in fact a hydrous ferric molybdate.

17. *The Natural Classification of Igneous Rocks;* by WHITMAN CROSS. Quar. Jour. Geol. Soc., lxvi, 1910, pp. 470–506.—In this paper the author presents a thoughtful discussion of those features of igneous rocks which many petrographers consider essential in the formation of a so-called natural system of classification, in contrast to one where these features are omitted, others are used, and the result is termed by them arbitrary, or artificial.

He states that chemical composition, mineral constitution and texture are the properties of rocks generally considered available for their classification, and discusses each of these according to the different methods suggested by various authorities. In a full analysis of the attempts made by Becke and Harker to divide the igneous rocks geographically into two great chemical groups, the Atlantic and Pacific, he points out the many discrepancies that arise, and that, while the rocks of the Pacific zone of North America exhibit pronounced peculiarities, they are not those claimed for them by the advocates of such a grouping. He also points out that the generalizations made on this basis do not apply to the older rocks, which in many cases have been left out of account.

Discussing the factors of magmatic differentiation he takes up the dike rock group of Rosenbusch, and shows that the magmas cannot be divided exclusively into foyaitic-theralitic and granito-dioritic, gabbro-peridotitic series, because these are connected by intermediate magmatic series, such as the monzonitic. And if this is so, then the dike rocks cannot always have the exclusive associations claimed for them, and he cites numerous instances to prove that the associations are sometimes other than those claimed.

Taking up the suggestions of Becker, Vogt, and others that the principle of eutectics may furnish a means of classification, the author points out that if we followed Becker's ideas, in porphyries the groundmass alone would be used, and some rocks would not be susceptible of classification. Vogt's view is that magmas differentiate in the same way that they tend to crystallize, into those which are eutectic and those representing the component in excess. When crystallized they furnish anchi (nearly) eutectic rocks and anchimono-mineralic rocks. This is purely hypothesis, and for this reason and because the rocks which represent the entire magma are not considered, Cross dismisses magmatic classification by eutectics as fundamentally weak and practically inapplicable. In considering the factor of mineral composition as applied to classification, he concludes that the distinction between feldspathic and non-feldspathic rocks, which has been so sharply drawn in the past, is unnatural, and entirely arbitrary. The use of texture, in which correlations of specific kinds with geologic modes of occurrence are made, he considers to be based on long disproved generalizations made from limited observations.

He then takes up the quantitative system and replies to various criticisms which have been made upon it, showing in many instances that these have been based on misapprehensions. The reply is especially directed to refuting the strictures of Harker. In conclusion he questions whether any system of classification can be strictly natural, because all the important characters of igneous rocks are gradational. A logical classification must be based on the quantitative development of fundamental characters, and divisions must be based on artificial boundaries, since natural ones do not exist. This brings us logically to the Quantitative System.

The reader will find this an admirable statement and a critical discussion of present views regarding the subject of classification of igneous rocks. It should be carefully read and considered by all petrographers. L. V. P.

III. BOTANY.

1. *A Botanical Survey of the Galapagos Islands;* by ALBAN STEWART. Proceedings of the California Academy of Sciences, Fourth Series, Volume I, pp. 9–288, 19 plates, 1911.—On account of their isolated position the Galapagos Islands are of special interest to students of plant geography. The present important contribution to their flora is largely based on the personal collections and observations made by the author while botanist to the Expedition of the California Academy of Sciences, during the years 1905 and 1906. Since the expedition lasted for over a year, a thorough exploration of the islands was made possible. Mr. Stewart first gives a complete list of the vascular plants known from the islands, following the treatment pursued by Professor B. L. Robinson in his "Flora of the Galapagos Islands" of 1902. The list, which makes up the bulk of the paper, includes numerous species reported for the first time, ten of which are described as new. He then discusses, among other topics, the botanical regions of the islands, the general features of the flora, and the origin of the flora. A very useful bibliography of the botany of the Galapagos Islands, compiled by Miss M. A. Day, is given at the close of the paper. A. W. E.

2. *Blumen und Insecten: ihre Anpassungen aneinander und ihre gegenseitige Abhängigkeit;* by O. von Kirchner. Pp. vi, 436; with two plates and 159 text-figures. Leipzig and Berlin, 1911 (B. G. Teubner).—The remarkable adaptations which exist between entomophilous flowers and the insects which pollinate them have aroused interest ever since attention was first called to them by Sprengel over a century ago. Professor Kirchner's book gives a full and clear idea of our present knowledge in this field of biology. Although designed more especially for the public at large, the volume is full of observations based on personal study and contains much of value to the professional student. After discussing the structure of flowers and of the parts of insects which carry on pollination, the author describes in detail a large number of examples illustrating special adaptations. He classifies them, using the system of H. Müller, into eight groups. The first five are composed of flowers which receive a large variety of insect visitors; the last three of flowers which are visited largely or exclusively by insects belonging to definite natural groups, such as the Hymenoptera. He then discusses the distribution of these various groups in different parts of the earth, the causes of floral adaptations, and the theories regarding the origin of flowers. The numerous figures, most of which are original, are carefully drawn and sufficiently enlarged to illustrate clearly the descriptive text. A. W. E.

3. *A Research on the Pines of Australia;* by R. T. Baker and H. G. Smith. Pp. xiv, 458; with 300 figures (some of them in colors) and 3 maps. Sydney, 1910 (W. A. Gullick). Published by authority of the Government of the State of New South Wales, as No. 16, Technical Education Series.—Botanically speaking, there are no true "pines" native to Australia. The present elaborate work, however, is devoted to Australian Conifers, which are often spoken of as "pines" in the popular sense. Eleven genera are included, the most important, from an economic standpoint, being Callitris (eighteen species), Araucaria (two species), Agathis (two species), Dacrydium (one species), and Podocarpus (five species). The authors discuss the various species in great detail, not only from the standpoint of botany but also from the standpoints of forestry and chemistry. They also consider the practical applications which have been made of the lumber and other forest products. Many of the figures show details of microscopic structure; others show branches and cones, natural size; while still others illustrate the various types of coniferous forests found in Australia. All of the figures are reproduced from photographs. A. W. E.

4. *Plant-Life on Land, considered in some of its Biological Aspects;* by F. O. Bower. Pp. 172; 27 text-figures. Cambridge, 1911 (University Press).—A series of essays on terrestrial plants, emphasizing the peculiarities which enable such plants to maintain their existence on the land. A. W. E.

5. *A Monograph of the British Lichens. Catalogue of the Species in the Department of Botany, British Museum.* Part II, by ANNIE LORRAIN SMITH. Pp. 409, 59 plates. London, 1911.—Part I of the Monograph of the British Lichens, by Rev. James Crombie, was published a number of years ago, but the continuation of the work which he had undertaken was interrupted by his illness and death. Part II has now been brought to completion by Miss A. L. Smith. The descriptive text is accompanied by fifty-nine plates, showing the details of structure of the different species.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Report of the Superintendent of the Coast and Geodetic Survey*, O. H. TITTMANN, *showing the Progress of the Work from July 1, 1909, to June 30, 1910.* Pp. 454; 34 maps and 9 in pocket. Washington, 1911.—The annual volume of the Coast and Geodetic Survey opens with an account of the year's work by the Superintendent. The extended domain of the country, particularly in the far East, has increased very much the work to be done. It is noted, for example, that the triangulation for the year covered some 24,000 square miles in the Philippines, while the hydrographic work extended over 9,385 square miles; the topographic survey covered 1,708 square miles, and extended over 1,637 miles of coast line, or 10 per cent of the estimated mileage for the islands as a whole.

Among the Appendixes which accompany the report is one by R. L. Faris on the magnetic observations. Four magnetic observatories have been in continuous operation, namely: at Cheltenham, Md., Sitka, Honolulu, and on Vieques Island, P. R.; the fifth observatory at Baldwin, Kansas, was discontinued in October, 1909, and the instruments transferred to Tucson, Arizona. Appendix V contains the second part of the triangulation in California by C. R. Duvall and A. L. Baldwin. This occupies a considerable part of the volume, and is accompanied by a series of forty charts.

2. *Directions for Magnetic Measurements;* by DANIEL L. HAZARD. Pp. 131; 12 tables, 10 figures. U. S. Coast and Geodetic Survey. O. H. TITTMANN, Superintendent.—This Bulletin is prepared with the object of presenting in sufficient detail for the use of observers the methods employed by the Government in magnetic observations, and the use of the instruments involved. The Survey has been developed recently by the establishment of five permanent magnetic observatories, and also by the inauguration of magnetic observations on vessels at sea. The methods called for in these two classes of observations, therefore, require the special method of explanation here given.

The same author has also presented in a quarto publication of the Survey (pp. 94, 23 figures) the results of observations made at the Magnetic Observatory at Sitka, Alaska, in 1907 and 1908. Twenty-three figures reproduced from magnetograms show in a striking manner the principal magnetic storms of the period named.

3. *Report on the Progress and Condition of the U. S. National Museum for the year ending June 30, 1910;* by Richard Rathbun, Assistant Secretary of the Smithsonian Institution, in charge of the U. S. National Museum. Pp. 146. Washington, 1911.—This interesting volume gives a vivid picture of the rapid growth of the National Museum at Washington, the extent and wide range of its collections, and the many directions of its scientific activity. Dr. Rathbun has been connected with it so long that he is able to present the matter in a very full and interesting form. The completion of the new building, and the rapid transfer of the collections to it, makes this a period of great importance in the history of the Museum.

4. *Frost Data of the United States; and Length of the Crop-growing Season, as determined from the Average of the latest and earliest Dates of killing Frost;* by P. C. Day, Chief of Climatological Division. Prepared under the direction of Willis L. Moore, Chief of Weather Bureau. Pp. 5; 5 charts. U. S. Department of Agriculture. Weather Bureau, Bulletin V. Washington, 1911.—The Weather Bureau has instituted a new service for the country in presenting the five charts contained in this Bulletin. These have been prepared from data obtained at about one thousand stations, having records, except for some localities in the West, extending back from ten to thirty years. Furthermore, observations have been made in the open country, and hence are not subject to the modifying conditions involved in stations in the large cities. The importance of frost statistics for agriculture is obvious at a glance. The five charts show graphically for the entire country the average date of the last killing frost in spring and the first in autumn; the latest date in the spring and the earliest in the autumn; also the average length of the crop-growing season, reckoned between the average date of the last spring and early autumn killing frost.

5. *Carnegie Institution of Washington.*—Recent publications of the Carnegie Institution are noted in the following list (continued from vol. xxxi, p. 245.

No. 128. Guide to the Materials for American History in Roman and other Italian Archives; by Carl R. Fish. Pp. ix, 289.

No. 131. The Root Habits of Desert Plants; by William A. Cannon. Pp. 96; 23 plates.

No. 134. The Polynesian Wanderings; Tracks of the Migration deduced from an examination of the Proto-Samoan Content of Efaté and other Languages of Melanesia; by William Churchill. Pp. viii, 516; 2 plates.

No. 137. Inventory of unpublished Material for American Religious History in Protestant Church Archives and other Repositories; by William H. Allison. Pp. vii, 254.

No. 138. Investigation of the Rotation Period of the Sun by Spectroscopic Methods; by WALTER S. ADAMS assisted by JENNIE B. LASBY. Pp. iii, 132; 37 tables, 5 figures.

No. 142. The Maturation of the Egg of the Mouse; by J. A. LONG and E. L. MARK. Pp. iv, 72; 6 plates.

No. 143. Experiments with Drosophila Ampelophila concerning Evolution; by FRANK E. LUTZ. Pp. 40; 37 tables, 53 figures.

No. 144. On Germinal Transplantation in Vertebrates; by W. E. CASTLE and JOHN C. PHILLIPS. Pp. 26; 2 plates.

6. *National Academy of Sciences.*—During his recent visit to Washington at the time of the annual meeting of the National Academy of Sciences, Sir JOHN MURRAY presented a fund of six thousand dollars to the Academy for the purpose of founding an Alexander Agassiz gold medal, which shall be awarded to scientific men in any part of the world for original contributions to the science of Oceanography.

7. *Handbook of American Indian Languages;* by FRANZ BOAS. Part I. Bulletin 40 of the Bureau of American Ethnology, Smithsonian Institution. Pp. vii, 1069. Washington, 1911.—The work early begun by Major J. W. Powell in his Introduction to the Study of Indian Languages has led to the Handbook of which the first volume is now issued. The material for it has been accumulated during the period from 1897–1908. A general introduction is given by Dr. Boas, followed by ten chapters by himself and other authors on special languages.

8. *The Nature of Enzyme Action;* by W. M. BAYLISS, D.Sc., F.R.S. Second edition. Pp. 137. London and New York, 1911 (Longmans, Green & Co.).—In view of the large amount of work on enzymes published since the appearance of the first edition of this monograph (which was reviewed in 1909), the references in the bibliography of the new edition have greatly increased in number. Aside from occasional verbal changes, the only other essential additions consist in the introduction of chapter headings. As heretofore, the author's critique and judgment are commendable. L. B. M.

9. *Étude de L'Atmosphère Marine par Sondages Aériens Atlantique Moyen et Région Intertropicale;* par L. TEISSERENC DE BORT et LAWRENCE ROTCH. Pp. 241, 4to; 17 plates, 36 text-figures, Paris, 1909 (Gauthier-Villars).—This publication appears from the *Observatoire de Météorologie dynamique de Trappes*, working in collaboration with the Blue Hill Observatory in this country. It gives the results of a study of the ocean atmosphere by means of balloons and kites. The observations were made from the vessel *Otaria*, specially equipped for the purpose, in voyages extending from the Azores to Ascension Island in the South Atlantic. Twenty-four ascensions were made with captive balloons, and forty-six with self-registering kites. In addition, ascensions were made for a brief period from the *Romanic* between Boston and Gibraltar, and from the peaks of Fogo and Teneriffe. An interesting account of the *Otaria* and the observa-

tions made from it, with numerous illustrations, is given by H. Maurice. Some of the results have already been published in this country (see vol. xxiii, 398), but it may be worth while to quote here the résumé given by H. H. Clayton.

(1) The observations show, in the zone of the trade winds, a rapid diminution of temperature with adiabatic gradient from the sea-level to a height of some hundreds of meters.

(2) A layer, some hundreds of meters in thickness, where the temperature increases with the height; this commences with an altitude varying from 400 to 1500 meters.

(3) A lowering of the layer of inverse gradient from latitude 40° to latitude 20°, or even farther south, suggesting a descending movement of the air from 40° towards the equator above the inverse gradient.

(4) A maximum of temperature near the surface between latitudes 5° and 10° N. in summer, and a second maximum much farther north at a height of about one thousand meters.

(5) Finally, a progressive movement towards the north of the maximum of the upper atmosphere from about 15° N. in May to 30° N. of the area of the high pressures of the Atlantic during the same period.

10. *Science Progress in the Twentieth Century.* Vol. V, No. 19, January, 1911. Editors: H. E. ARMSTRONG, J. BRETLAND FARMER, W. G. FREEMAN. Pp. iv, 345–528. London, 1911 (John Murray).—This quarterly presents in each issue some eight or ten articles dealing with the prominent scientific problems of the times. The names of the editors and the members of the advisory committee are sufficient guarantee for the excellence of the work. A journal of this character is of much value in presenting subjects of the first importance in a form at once interesting and attractive to the general public.

11. *Science from an Easy Chair;* by Sir RAY LANKESTER. Pp. xiii, 423; 2 plates, 82 text figures. New York, 1911 (The Macmillan Company).—The papers, forty-three in number, which make up this volume have been collected from the *Daily Telegraph,* in which they appeared during the years 1908 and 1909. The subjects with which they deal are so varied in character, and of such general interest, that the delightful presentation of them here is a service to the public which cannot fail to be appreciated. We pass from the Darwinian theory to a discussion of dragons, imaginary and real, from tadpoles and frogs to comets and the men of the Neandertal. In other words, the subjects of the successive chapters are most varied, but all are of interest and numerous illustrations add to the value of the volume. The title-page is an admirable reproduction, from original water-color drawings, of the head of immature and mature specimens of the common eel, natural size. Other volumes of this series are planned.

12. *Die Konstitution der Protistenkerne und ihre Bedeutung für die Zellenlehre;* by Prof. Dr. MAX HARTMANN, Privatdozent in Zoology, University of Berlin. Pp. vi, 54; 13 text figures.

Jena, 1911 (Gustav Fischer).—Cytologists have hoped that the study of the nuclei of unicellular animals and plants would throw light on the complex morphology of the nuclear apparatus of higher forms, and on cell problems in general. In this they have not been disappointed, though continued research has shown that the structure of the cell of the lower organisms is far more specialized and complicated than was anticipated, and thus it offers an immense problem in itself. Professor Hartmann in this paper makes a critical analysis of some of the chief types of nuclear phenomena of the protista in an endeavor to derive some general principles from the mass of recently accumulated data. The result is suggestive, especially to one who has followed the recent advances in protisten cytology. L. L. W.

13. *Elements of Descriptive Geometry;* by ALBERT E. CHURCH and GEORGE M. BARTLETT. Pp. 286 with 143 figures. New York (American Book Company). — A modern treatment of descriptive geometry, with applications to spherical projections, shades and shadows, perspective, and isometric projections, for the use of technical schools and colleges. It is a thorough revision of Professor Church's book which has been long in use. The figures and text are included in the same volume, each figure being placed beside the corresponding text. In the treatment of curved surfaces, all problems relating to single curved surfaces are taken up first, then those of warped surfaces, and lastly those of surfaces of revolution. Thus the procedure is from the simple to the complex. An abundance of practical exercises is provided. W. B.

14. *Power;* by C. E. LUCKE. Pp. 316; 223 figures. New York, 1911 (The Columbia University Press).—This book is composed of eight popular lectures which emphasize the importance, in the organization of society, of the substitution of mechanical power for hand and animal labor. It is liberally illustrated by cuts of machinery and plants for the conversion of natural energy in any of its available forms into useful work, and in an interesting manner discusses the physical principles involved. D. A. K.

OBITUARY.

Professor NEVIL STORY-MASKELYNE, the veteran English mineralogist professor at Oxford from 1856 to 1895 and long in charge of the mineral collection of the British Museum, died on May 20 at the age of 87 years.

Dr. A. E. TÖRNEBOHM, the well-known Swedish geologist, died early in June at the age of 72 years.

Professor C. G. PRINGLE, curator of the Herbarium at the University of Vermont, died at Burlington on May 25 at the age of 73 years.

WILLIAM R. DUDLEY, Professor of Botany at Stanford University, died on June 4 at the age of 64 years.

Mrs. WILLIAMINA PATON FLEMING, curator of astronomical photographs at the Harvard College Observatory, and discoverer of many new stars and nebulæ, died on May 21 at the age of 54 years.

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SCIENTIFIC INTELLIGENCE.

Established by **BENJAMIN SILLIMAN** in 1818.

THE AMERICAN JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

FOURTH SERIES

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[FOURTH SERIES.]

ART. IX.—*An Experimental Investigation on the Reflection of Light at Certain Metal-Liquid Surfaces*; by LYNDE P. WHEELER, Assistant Professor of Physics, Sheffield Scientific School of Yale University.

Introduction.

WHEN light is incident on a transparent substance at an angle whose tangent has the numerical value of the index of refraction of the material, theory, as embodied in the Fresnel equations, demands that the reflected light should be plane polarized in the plane of incidence. Experience teaches, however, that but for a very few substances, solid or liquid, is this true. Most substances show at this angle an elliptic polarization of small ellipticity. This ellipticity (defined as the ratio of the amplitudes of the components of the vibration parallel and perpendicular to the plane of incidence) is found to be sometimes positive and sometimes negative. (Positive ellipticity corresponds to a counter-clockwise description of the ellipse when viewed from the side of the incident light.)

That this well-nigh universal though small discrepancy between theory and experiment cannot be entirely assigned to contamination of the reflecting surface seems to have been definitely settled by the experiments of Lord Rayleigh on very clean water surfaces.* He found that as the surface was made progressively cleaner, the negative ellipticity previously observed became numerically smaller, passed through a zero value, and for the cleanest surfaces obtainable, assumed a very small positive value. On the other hand, Drude, working with the fresh cleavage surfaces of transparent crystals where the chance of surface contamination is very remote, found that within the limits of error of observation the ellipticity van-

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* Phil. Mag. (5), xxxiii, p. 1, 1892.

ished.[*] It would thus seem to be established that the theory stands in need of correction in the case of reflection from liquids, while remaining entirely competent in the case of solids.

Now the boundary conditions from which the equations of Fresnel are deduced assume an abrupt, discontinuous change in physical properties as one passes through the surface separating the two media. As such physical discontinuity is, a priori, highly improbable, it is natural to seek the source of the observed discrepancies in a thin transition layer where the two media interpenetrate, and the physical properties change continuously though rapidly between the constant values they possess beyond the limits of the layer on either side. On this hypothesis it is natural to expect a thinner transition layer and hence a closer approximation to the conditions of a discontinuous change in the case of solids than of liquids. Thus admitting that such layers must exist in all cases, we must conclude from the experiments mentioned that it is only in the case of liquids that they attain a sufficient thickness to be appreciable.

But while the existence of the transition layer seems a fairly certain inference from the phenomena of reflection, it is equally certain that the greater part of the divergences of experiment from the predictions of theory are to be ascribed to films of surface contamination due to dirt or polisher. Such films may be exceedingly thin—of the same order of magnitude in fact as the transition layer. In any given case both the layer and the film may be present and the observed ellipticity be due to their combined action. The principal difference in the effect produced by these two causes would be due to the fact that in the case of the transition layer its index of refraction must vary between those of the two media; while in the case of the film of surface contamination its index should be approximately constant and its value might be greater or less than or intermediate between those of the two media.

Mathematically the effects to be expected from either the transition layer or the film can be thrown into identical form, the only difference in the two cases being that imposed on the interpretation of the results by the possible values of the index of refraction, as indicated above. The mathematical theory of such layers or films has been worked out in great detail by Drude,[†] who has shown that on the assumption that the thickness of the film is small compared with the wave length

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[*] Wied. Ann., xxxvi, p. 532, 1889.

[†] Wied. Ann., xxxvi, p. 865, 1889. A brief development of the theory of the transition layer is given in the *Theory of Optics*, by Drude, translated by Mann and Millikan, 1902, p. 287. Also in the *Physical Optics*, by Wood, 1905, p. 296; and in Winklemann, *Handbuch der Physik*, 2d Auf. 7, 1906, vol. vi, p. 1256.

of the light employed, its effect can be expressed as a correction term to the ordinary Fresnel equations. The form of this correction term shows that when the reflection takes place from the surface of a substance of greater index than that in which the light is incident, we should expect a positive ellipticity at the polarizing angle for any film which has an index lying between those of the two media, and a negative ellipticity for a film with a greater index than that of either medium. Thus a real transition layer can theoretically produce only a positive ellipticity; while a negative ellipticity must always be attributed to films of surface contamination with indices greater than that of the reflecting substance. Of course *all* of an observed positive ellipticity may not be due to a transition layer, for the matter contaminating the surface may have an index intermediate between those of the two media; but a negative ellipticity is theoretically a certain criterion of a film of contamination. Lord Rayleigh's experiments mentioned above are thus in striking accord with the theory.

The same general considerations hold in the case of the reflection from metals. Here, however, since metals naturally produce an elliptic (or a circular) polarization at all angles of incidence, the effect of the transition layer or film of contamination will be to change the ellipticity and the phase difference of the two components of the vibration from the values they would have if the film were not present. The theory, based on the same assumption as in the case of the reflection from transparent substances,* shows that, providing the index of refraction of the film or layer is greater than unity, the ellipticity should be slightly increased and the phase difference markedly decreased by the presence of such a film or layer. Expressed in terms of the principal incidence and azimuth instead of the phase difference and ellipticity, the theory predicts that the effect of the film should be to decrease the principal incidence markedly and to increase the principal azimuth but a very little. Unlike the result for the reflection from transparent substances the sign of the effect is independent of the magnitude of the index of refraction of the reflecting medium unless that should be less than unity.

We have here then no such criterion as before to enable us to distinguish between films of surface contamination and a real transition layer. A possible exception to this statement is the case of those metals which have an index of refraction less than unity. That some metals, notably gold, silver, and copper, do possess such small values of the index seems certain, since the same result is yielded by the reflection and the direct transmission methods. With these substances it might be

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* Wied. Ann., xxxvi, p. 865, 1889.

expected that the transition layer would have an index less than unity and that consequently according to the theory the phase difference would be increased and the ellipticity decreased over the values they would have if no such layer were present. However, from general considerations as to the degree to which it would be possible for the two media to interpenetrate and produce a transition layer, it would seem unlikely that we could obtain any evidence as to its existence; exactly as any such evidence fails in the case of reflection from transparent solids. And in confirmation of this expectation it is found that for all metals, increasing the cleanliness of the surface shows uniformly an increase of the phase difference and a decrease of the ellipticity; there is never any indication of any reversal of the sign of the effect. So that it is fair to assume that when perfect cleanliness has been attained, the correct values of the phase difference and the ellipticity are yielded by experiment, the effect of the transition layer being negligible.

Further light on the question of the transition layer is afforded by experiments on the reflection from metal mirrors immersed in transparent liquids. Here the uncorrected theory leads to an expression for the index of refraction of the liquid (n') in terms of the observed phase differences and ellipticities in air and in the liquid respectively.* An examination of the recorded observations of this nature shows, however, very considerable discrepancies between the values so calculated and those given by the direct refraction methods (n_0). In the following table are given the values of n' and n_0 as calculated from the experimental results. It includes all of the observations on record.†

	n'	n_0	Observer
Gold in water	1·30	1·33	Conroy
“ “ CS_2	1·54	1·64	“
Silver in water	1·25	1·34	Quincke
“ “ “	1·25	1·33	Conroy
“ “ “	1·43	1·34	Sissingh
“ “ turpentine	1·44	1·47	Quincke
“ “ CCl_4	1·35	1·46	Conroy
Copper in water	1·33	1·33	Drude
“ “ alcohol	1·32	1·37	“
“ “ cassia oil	1·60	1·61	“
“ “ CS_2	1·52	1·63	“
Mercury in water	1·24	1·33	Des Coudres
“ “ alcohol	1·28	1·36	“

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* See below, under heading, “Theory.”

† The values are taken from a paper by Drude, Wied. Ann., xxxix, p. 539, 1891. The calculations have been verified except in the case of the experiments of Sissingh and Des Coudres, to whose original papers I have not had access.

	n'	n_0	Observer
Mercury in HCl (dilute)	1·44	1·39	Des Coudres
“ “ “ (conc.)	1·30	1·39	“
“ “ $Na_2S_2O_3$ (conc.)	1·32	1·42	“
“ “ “ (sup. sat.)	1·28	1·43	“
“ “ petroleum	1·38	1·44	“
“ “ chloroform	1·37	1·44	“
“ “ olive oil	1·47	1·47	“
“ “ turpentine	1·25	1·47	“
“ “ “	1·32	1·47	“
“ “ CS_2	1·59	1·63	“
“ “ “	1·48	1·63	“

Now it is impossible to ascribe these discrepancies in every case to films of surface contamination; for they occur for those metals (notably copper and mercury) for which entirely satisfactory results in air have been obtained, and under circumstances apparently precluding the formation of any chemical film. Hence, as we have seen that it is highly probable that a perfectly clean metal possesses no appreciable transition layer when in contact with air, it is only possible to ascribe these discrepancies to a transition layer due to the liquid. Now an inspection of the above table shows that the index calculated from the reflection from the metal is, in all but four cases, less than that deduced by the direct refraction methods. On the theory as developed by Drude,* this result must be interpreted as due to a film or layer having an index less than that of the liquid. This suggests that the effect is due to a film of air or other gas caught between the liquid and the mirror, since the transition layer of a liquid-air surface would have an index less than that of the liquid. It is, moreover, natural to expect the presence of such films due either to entrainment in the act of immersion or to dissolved gas in the liquid, more probably the former.

On the other hand, if it is assumed that no such gaseous film is present, the observed discrepancies must be attributed to a transition layer due to the liquid. In view of the fact that the effects of the transition layer in the case of transparent solids in air are inappreciable, it would seem that the layer in question here cannot be a region of interpenetration of the metal and the liquid. Consequently we must conclude (if we reject the possibility of the gaseous film) that the observed discrepancies are due to a layer at the surface of the liquid which is independent of the medium with which it may be in contact and which has optical properties different from those in the interior. According to the theory, the index of such a layer will be less than that of the interior if n' is less than n_0;

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* Wied. Ann., xxxix, p. 539, 1891. See also, below, under heading, “Theory.”

while its index should be greater when n' is greater than n_0. Such effects might possibly be expected as a result of surface tension.

There are thus two possible explanations of the observed discrepancies. It would seem worth while, therefore, to attempt to eliminate the possibility of gaseous films between the mirror and the liquid. The desirability of doing this has been pointed out by Drude,* but so far as I can ascertain, it has not up to the present time been attempted. Drude has expressed the opinion that there would still remain evidence of a transition layer when such gaseous films have been removed.† But this opinion is supported by no evidence which cannot be interpreted, as we have seen, in another manner. Hence I have attempted, in the investigation reported in this paper, to see if any residual effect of a transition layer remains, when the possibility of the presence of a gaseous film between the mirror and the liquid is reduced to a minimum.

Theory.

The theory of metallic reflection in transparent liquids is not developed in any of the ordinary works of reference, though it is, of course, accessible in the original memoirs. So it may not be out of place to give a brief résumé of the theory here. We start with the equation

$$\frac{1 + \mathrm{tg}\,\psi e^{i\triangle}}{1 - \mathrm{tg}\,\psi e^{i\triangle}} = \frac{\sin\phi\sin\chi}{\cos\phi\cos\chi},\ddagger \qquad (1)$$

where ψ is the azimuth of the restored polarization (the angle whose tangent gives the ratio of the amplitudes of the two components of the reflected vibration when the incident vibration is polarized in a plane making an angle of 45° with the plane of incidence; $\mathrm{tg}\psi$ is what we have called the "ellipticity" in the introduction); e is the Naperian base; $i = \sqrt{-1}$, ϕ and χ are the angles of incidence and refraction respectively; while $\triangle$ is the phase difference between the two components of the reflected vibration.

In the case of the reflection in a vacuum (or air) we have the relation

$$\frac{\sin\phi}{\sin\chi} = \sqrt{K}, \qquad (2)$$

where K is the dielectric constant of the reflecting medium.

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* Wied. Ann., xxxix, p. 545, 1891. Also, Winklemann, Handbuch der Physik, 2te Aufl., 1906, vol. vi, p. 1308.

† Winklemann, loc. cit.

‡ The derivation of this equation may be found in any standard text on Optics; e. g., those of Drude, Schuster, Wood.

In the case of a metal this must be supposed complex and the real part of $\sqrt{K}$ is the index of refraction. If we substitute for χ in (1) from (2), replace the exponential by its equivalent trigonometrical expression, and rationalize the denominator of the left-hand side of (1), we obtain

$$\frac{\cos 2\psi(1+i\sin\Delta\operatorname{tg}2\psi)}{1-\cos\Delta\sin 2\psi}=\frac{\sin\phi\operatorname{tg}\phi}{\sqrt{K-\sin^2\phi}}$$

This may be simplified by making the following substitutions:

$$\begin{aligned}&\sin\Delta\operatorname{tg}2\psi=\operatorname{tg}Q\,;\ \cos\Delta\sin 2\psi=\cos P\,;\\&\cos 2\psi=\cos Q\sin P;\ S=\operatorname{tg}\frac{P}{2}\sin\phi\operatorname{tg}\phi;\end{aligned}\tag{3}$$

which yield

$$e^{iQ}=\frac{S}{\sqrt{K-\sin^2\phi}}.\tag{4}$$

In the case of the reflection in a transparent medium of index of refraction n_0, we have in place of (2) the relation

$$n_0\frac{\sin\phi}{\sin\chi}=\sqrt{K}.$$

Substituting from this in (1) and performing the same operations and making the same substitutions as before; we get

$$e^{iQ_0}=\frac{n_0S_0}{\sqrt{K-n_0^2\sin^2\phi}}.\tag{5}$$

Dividing (4) by (5) and substituting for the radical in the denominator its value from (4) we get

$$n_0\frac{S_0}{S}e^{i(Q-Q_0)}=\frac{e^{iQ}}{S}\sqrt{K-n_0^2\sin^2\phi}.$$

Using in this the value of K from (4),

$$K=\frac{S}{e^{i2Q}}+\sin^2\phi,$$

we obtain

$$n_0\frac{S_0}{S}e^{i(Q-Q_0)}=\sqrt{1-\frac{\sin^2\phi}{S^2}(n_0^2-1)e^{i2Q}}.$$

Expanding the radical and retaining no terms higher than the second in $\frac{\sin\phi}{S}$,* and substituting

$$\delta = -\tfrac{1}{2}\frac{\sin^2\phi}{S^2}(n_0^2-1)\cos 2Q \quad (6);$$

$$\epsilon = \tfrac{1}{2}\frac{\sin^2\phi}{S^2}(n_0^2-1)\sin 2Q; \quad (7)$$

we have, on equating the real and imaginary parts of each side, approximately,*

$$n_0 = \frac{S}{S_0}(1+\delta) \quad (8); \quad Q - Q_0 = -\epsilon. \quad (9)$$

Thus from the observed values of Δ and 2ψ we can calculate, by means of equations (3) and (6) the right-hand side of equation (8). Calling the value so calculated n', we have, $n_0 = n'$; or, the index of refraction of the liquid calculated by refraction methods should be the same as that deduced from the change of phase and the ellipticity produced by the metal.

If there are transition layers or films of surface contamination present, their effect may be expressed as a correction term to equation (5) as follows:

$$e^{iQ_0} = \frac{n_0 S_0}{\sqrt{K - n_0^2\sin^2\phi}}(1 - i\sqrt{K}A).\dagger \quad (10)$$

If we assume that there is but one transition layer, that between the liquid and the gas film, the value of A will be given by

$$A = \frac{2\pi}{\lambda}\int_0^L \left(\frac{n_0^2}{n_1^2} - 1\right) dl,\dagger \quad (11)$$

where λ is the wave length of the light employed, L the thickness, and n_1, the index of the layer. Of course a similar correction term to equation (4) can be written down, but under the assumption that a metal in air possesses no appreciable transition layer, that may be omitted.

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* These approximations are justified by the magnitudes of S and Q as found from experiment.

† Since the results of the experiments I have to report in this paper seem to show that A=0 (for the liquids used, at least), it seems scarcely worth while in this place to devote the very considerable amount of space which would be required, to the derivation of equations (10) and (11). The derivation is given in full in the papers of Drude in Wied. Ann. already cited.

Proceeding now as before, we obtain the equation

$$n_0 \frac{S_0}{S} e^{i(Q-Q_0)} = \sqrt{1-\frac{\sin^2\phi}{S^2}(n_0^2-1)\,e^{i2Q}\,(1+i\sqrt{K}\,A)}.$$

Substituting in the correction term the approximate value of $\sqrt{K}$ from (4) we have on expanding and making the substitutions (6) and (7),

$$n_0 = \frac{S_0}{S}(1+\delta+AS\sin Q) \quad (12); \quad Q-Q_0 = -\epsilon+AS\cos Q. \quad (13)$$

If we set as before, $n' = S/S_0\,(1+\delta)$, equation (12) can be written

$$n' = n_0(1-AS\sin Q), \qquad (14)$$

since both δ and AS sin Q are small quantities.

By means of this equation and equation (11) we can compare the results of experiment with theory. Thus from the latter we see that if n_1 is less than n_0, then A will be positive and consequently by equation (14) n' should be less than n_0. This then is the result we should expect in case there is a gaseous film between the mirror and the liquid; or, providing that is eliminated, it is the result to be expected in the event that a real transition layer (belonging to the liquid alone, as we have seen) exists. Similarly, if n_1 is greater than n_0, we see from equation (11) that A will be negative, and consequently from equation (14) that n' should be greater than n_0. Such a result would mean a film of greater index than that of the liquid and hence must be attributed either to films of surface contamination or to a real transition layer, no gaseous film being possible under these conditions. Finally, we see that if $A = 0$, $n' = n_0$, and this is the result to be expected if no films of any kind are present.

Thus if we can make sure that there is no gaseous film nor any film of surface contamination present, a value of n' less n_0 would indicate that at its surface a liquid has an index of refraction less than in the interior; while a value of n' greater than n_0 would be evidence showing that the index of the liquid at the surface is greater than in the interior.

Experimental Arrangements.

In repeating these experiments which have been performed so many times and by such competent observers, it was sought to improve upon their results in two directions: first, in securing a mirror which should be more free from surface contamination than those used before; and second, in reducing the possibility of a gaseous film between the mirror and the liquid to a minimum. On account of the difficulties in the way of certainly getting rid of films of surface contamination in solid mirrors, it was decided to attempt to attain the first object by using a mercury mirror. The advantages of such a mirror are, first, it admits of obtaining an extraordinarily clean surface much more easily than any other metal; second, exactly similar surfaces can be easily and quickly reproduced; and third, the degree of cleanliness attained can be estimated better than with mirrors of solid metal. The method of cleaning the surface by stretching the dirt to the edges (first suggested, in the case of water, by Lord Rayleigh)* was adopted in the form recommended by Röntgen.† This is described below.

It was feared at first that the attainment of the second object would present formidable if not insuperable difficulties. Drude has suggested the possibility of removing the film of gas by heating;‡ but this would involve obvious complications and difficulties. As mentioned in the introduction, it seems probable to expect that the gas film is introduced by entrainment in the act of immersion. Hence it was decided to produce the clean mercury surface *while* the mirror was immersed. The method of Röntgen for producing the clean surface lends itself very readily to this purpose, and it would seem, from the results obtained, that complete success in this important object has been attained. The form which the apparatus for producing the mirrors finally took is shown in the figure.

A glass tube of about 4^{cm} diameter was drawn down to form a funnel-shaped vessel (A), into the neck of which was sealed a small tube (B), having its end drawn out to a capillary point and projecting into the funnel. This tube, passing through a cork at the bottom of the cylindrical iron vessel (C) which surrounded the funnel, was supported so that the mouth of the funnel (ground to a plane) came slightly above the top of the cylinder. Another tube (D) through the cork (which was provided with a suitable stopcock, not shown in the figure) carried away the mercury which overflowed the funnel. The iron cylinder passed through the bottom of an open rectangular iron box (E) and projected to within about $1{\cdot}5^{cm}$ of its top. This box served to hold the liquids under which the reflection was observed.

This surface-cleaning apparatus was mounted on a stand furnished with levelling screws to enable one to adjust the mouth of the funnel accurately to a horizontal plane. The

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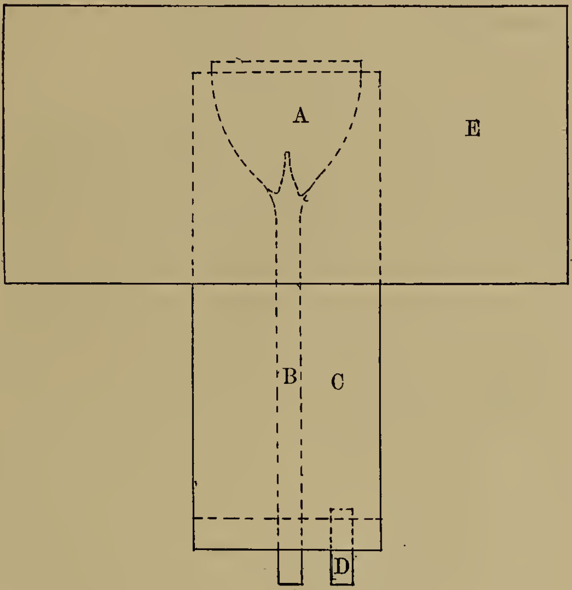
* Phil. Mag. (5), xxx, p. 392, 1890.

† Wied. Ann., xlvi, p. 152, 1892.

‡ Wied. Ann., xxxix, p. 545, 1891.

stand was also provided with a rack and pinion to give the vertical adjustment necessary to bring the reflecting surface to the center of the spectrometer table. A reservoir of mercury hung at a higher level than that of the funnel was connected with the tube (B) by a flexible tube provided with a suitable pinchcock. In order to secure a mirror sufficiently free from vibration, it was found necessary to mount the stand in a Julius suspension.

The operation of producing a clean surface was simply to allow the mercury to overflow the edge of the funnel rapidly for a few seconds. If care is taken to make the overflow uniform all around the edge (accomplished by adjusting the levelling screws), surfaces of extreme cleanliness can easily be obtained. The test of the cleanliness is the behavior of a drop of water placed on the surface. In making the test it is essential that the drop itself be clean. This is most easily done in practice by dipping a piece of platinum wire (cleaned by heating) beneath the surface of a beaker of distilled water, and removing the adhering drop quickly to the mercury surface. If the surface is really clean, the drop is immediately stretched out to the edge in a film of invisible thickness. The appearance of a mercury surface to the eye is no test at all of its cleanliness; it may seem to be a perfect mirror and yet the drop remain in an hemi-



spherical form when placed on it, unless it has been recently cleaned in the manner described. It is not necessary to start with especially clean mercury,—it cleans itself in a very short time. Nor is it necessary to test the cleanliness of the surface except after each fresh filling of the reservoir. A good surface gets contaminated in the air in a brief time, but retains its cleanliness long enough to permit the necessary observations to be taken comfortably; while a fresh surface can be obtained easily and quickly.

Thus it is reasonably certain that the reflecting surfaces used were free from surface contamination. Of course it is not so certain, a priori, that the film of gas was removed when the mirror was submerged. It is natural to expect, however, that the rapid overflowing of the mercury would tend to carry away any such film and leave a more perfect contact between the two media. And from the final result of these experiments it would seem that this expectation is fully justified. During the course of a set of observations under a liquid it was of course necessary to close the overflow tube (D), consequently the cylinder (C) was made large enough to hold all of the mercury which it was necessary to allow to overflow in the course of such a set. The liquid thus displaced from the box (E) was made to overflow at one corner and was caught in a suitable vessel.

In order to avoid any deviation of the beam of light by refraction at the free surface of the liquid, glass tubes terminated by plane-parallel glass ends were carried in suitable brass holders by both the collimator and telescope arms; when the mirror was in position the ends of these tubes were just submerged in the liquid in (E). The length of the box (E) was made as great as the space between the tube-holders would allow, in order to obtain as large an angle of incidence as possible. The space thus available was, however, too small to permit the use of angles of incidence greater than 60°, which, though lessening the precision attainable in this kind of experiment, still yielded ample accuracy for the ends in view.

The apparatus for measuring the phase difference and azimuth of restored polarization was of a familiar type and needs but brief description. The spectrometer* was one by the Société Genevôise, arranged so that the table could be swung to a vertical position to accommodate a horizontal mirror. The collimator arm carried the polarizing nicol behind the lens, the Babinet compensator was mounted before the objective of the telescope, while the analyzing nicol was carried at the other end of the telescope tube. The nicol and compensator came with the spectrometer and were of good quality. By means of

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* This was obtained by the aid of a grant from the Bache fund of the National Academy of Science.

a second lens which could be inserted behind the analyzer, and an extra draw tube, the eyepiece could be focused on the compensator fringes. Since these are not definite objects on which to focus, a small circular diaphragm was inserted behind the last lens of the ocular in order to avoid a small residual parallax which was otherwise necessarily present. These modifications of the apparatus as originally received from the Société Genevôise, and also the holders for the glass tubes and the surface-cleaning apparatus described above, were made in the instrument shop of the Sheffield Scientific School. The divided circle of the spectrometer table could be read to 20″, and those of the nicols to 6′ of arc. The source of light used was that obtained from the sodium flame of a small blast lamp fed with oxygen.

Measurements.

The preliminary adjustments of the apparatus, i. e., making the axes of collimator and telescope to intersect the axis of the spectrometer table orthogonally, and the adjustment of the axes of the nicols to parallelism with those of the collimator and telescope, were made in the usual manner. The positions of the polarizer giving light polarized in the plane of incidence were determined by reflection from water at the polarizing angle. The water surface was cleaned in the same manner as described above for the mercury. This plane was determined several times in the course of the investigation and with several minor modifications of method. Thus, sometimes the extinction position of the analyzer was determined with the reflection taking place at the polarizing angle, and then that of the polarizer by getting its "crossed" position with reference to the analyzer when the two were put in line; or, sometimes the extinction position of the polarizer for the reflection at the polarizing angle was determined directly, the beam of light being sent through the apparatus in the reverse direction: another modification was the use of glass of known index in place of water. None of these various determinations yielded a position of the polarizer differing from that of any other determination by an amount as large as the probable error of the readings. The result of all these determinations gives a value of 156·58° for the position of the polarizer. The probable error is less than 0·003°.

The calibration of the compensator was made with the polarizer in all four of the positions yielding light vibrating in a plane making an angle of 45° with the plane of incidence. For each position the reading for the center fringe and the first fringe on either side of the center was determined as the mean of fifteen settings. Thus each position of the polarizer yields two values of the displacement of the compensator corresponding to a change of phase of 360°. The results, in terms of turns of the compensator screw, follow:

Polarizer set to	21·58°	201·58°	111·58°	291·58°	
Compensator (left)	8·988	8·967	8·982	8·962	
" (right)	8·971	8·982	8·974	8·979	
" (av.)	8·980	8·975	8·978	8·970	8·9756 ± 0·0021

Compensator left or right means that the first fringe to the left or right of the central one was under the cross wires. On two occasions in the course of the investigation it became necessary to take the compensator to pieces, once to clean it and the second time to replace the cross wires. On each occasion it was re-calibrated and both times with the same result within the probable error of the determinations. The constant of the compensator, i. e., the factor by which its readings must be multiplied in order to reduce them to degrees, deduced from the above readings is 40·11. The position of the central fringe (zero point of the compensator) was found to vary slightly with temperature but otherwise was constant. The maximum variation observed was 0·035 turns. The scale on the compensator is so placed that its direct readings yield the supplement of the angle of phase difference rather than the angle itself.

The observations of the phase difference and the angle of restored polarization were made in the following manner in every case: (1) With both the telescope and collimator arms level and the surface-cleaning apparatus lowered out of the way, the zero point of the compensator was determined as the mean of at least twelve settings taken coming up from both directions. (2) With the two arms set to give an angle of incidence $\phi = 60°$, the mirror was brought into position, adjusted and cleaned in the manner which has been described. (3) With the polarizer set to give light vibrating in a plane inclined at an angle of 45° to the plane of incidence, the displaced position of the central fringe was observed (again as the mean of at least twelve settings from each direction), and the position of the analyzer making the fringes blackest was determined. For this last at least twenty-four settings were made in each case. (4) With the polarizer set to give light vibrating in the other 45° plane, the compensator and analyzer positions were again determined and with the same number of readings for each. (5) Finally, with the arms brought back into line, the zero point was again determined as in (1), so as to be able to take account of any temperature change in the compensator. The reflecting surface was renewed, of course, as often as might be necessary in the course of a set of observations.

The phase difference is obtained from the difference of the compensator readings of (3) and (4) and those of (1) and (5). The double angle of restored polarization is the difference of the positions of the analyzer in (3) and (4).

There were made, in all, nine complete sets for Δ and 2ψ as described above: four in air, three in water, and one each in the HCl and turpentine. The results are shown in the following table. In the first column are given the observed values of the displacement of the center fringe in terms of turns of the compensator screw, and in the second the directly observed values of 2ψ (or $2\psi_0$).

	Comp.	2ψ or $2\psi_0$
Air	0·7538 ± 0·0041	81·04° ± 0·35°
"	0·7549 ± 0·0018	81·54 ± 0·19
"	0·7550 ± 0·0017	81·32 ± 0·54
"	0·7548 ± 0·0052	81·46 ± 0·23
" (av.)	0·7546 ± 0·0017	81·34° ± 0·18°
Water	0·9975 ± 0·0035	81·65 ± 0·48°
"	0·9935 ± 0·0010	82·05 ± 0·35
"	0·9934 ± 0·0039	81·74 ± 0·20
" (av.)	0·9948 ± 0·0020	81·81° ± 0·16°
HCl	1·0030 ± 0·0099	81·91° ± 0·35°
Turpentine	1·0035 ± 0·0069	82·08° ± 0·34

From the average values above, the values of $\pi-\Delta$ (or $\pi-\Delta_0$) are computed by multiplication with the compensator constant, while the values of Q (or Q_0), P (or P_0), S (or S_0), δ, and n' are calculated by equations (3), (6), and (8). The results of the computations are given in the next table.

	Δ or Δ_0	Q or Q_0	P or P_0	S or S_0	δ	n'
Air	149·73° ± 0·07°	73·19°	148·63°	5·343		
Water	140·10° ± 0·08°	77·38°	139·40°	4·055	0·0084	1·329 ± 0·005
HCl	139·73° ± 0·40°	77·58°	139·10°	4·024	0·0086	1·340 ± 0·015
Turpentine	136·35° ± 0·28°	78·61°	135·78°	3·693	0·0127	1·465 ± 0·011

Finally, samples of the liquids used were put in a hollow prism and their indices determined in the usual way from the angle of the prism and the angle of minimum deviation. The values thus obtained for n_0 were:

	n_0
Water	1·3320
HCl	1·3375
Turpentine	1·4690

These values are certainly correct to the third place.

Discussion of the Results.

An inspection of the tables just given shows that in the case of each of the liquids examined $n' = n_0$ within the limits of error of the observations. In view of what has been said in the introduction and in the discussion of the theory of the experiments, this result indicates that there was present no appreciable film or layer of any description; and consequently, for these liquids at least, the transition layer which has been inferred from the phenomena of the reflection in air is not independent of the medium with which it is in contact. In other words, the transition layer is to be regarded as a true region of interpenetration of two media; and the fact that it is appreciable in liquids and not in solids must be attributed to the greater freedom of molecular motions in the case of the former, and not to any change in physical properties at the surface brought about by the force of surface tension.

The liquids chosen for this investigation include those for which the previous observations have yielded values of n' less than n_0, and one for which a value of n' greater than n_0 has been found. As the result of this work goes to show that both of these sorts of discrepancy vanish when all possible extraneous films are removed, it would seem a fair inference that all of the discrepancies which have been found previously are to be attributed to the same causes, and that the conclusion deduced from these experiments is a general one.

Sheffield Scientific School of Yale University,
New Haven, Conn., April, 1911.

Art. X.—*Recent Gravity Work in the United States;*[*] by William Bowie.

This paper gives a summary of the gravity work done by the Coast and Geodetic Survey during the past few years. This work comes under two general heads. First, the instruments and the field work and methods; and, second, the reduction and discussion of the observations.

In 1891 the Survey began the use of two sets of half-second pendulums.[†] They proved to be economical in their operation in the field and gave accurate results in the relative determination of the intensity of gravitation. The pendulum is essentially a flat stem, supporting a bob, with devices at the other end of the stem (called the pendulum head) to support the whole upon an agate knife edge fastened to the pendulum case. In the head is fastened rigidly an agate plane which rests upon the knife edge. As originally designed, the knife edge was in the head and the plane attached to the case. By having the plane in the head a more nearly invariable length of pendulum was secured, for any wear on the planes would have negligible effect on the period of oscillation.

Before beginning a swing of a pendulum the air in the case is practically exhausted (to about 60 millimeters of mercury). With a low air pressure a long period of swinging may be had with a small arc of oscillation. By means of a break-circuit chronometer, a flash apparatus and two mirrors, one on the case and the other fastened to the pendulum head, the observations are made by noting the time of a coincidence between the beat of the pendulum and that of the chronometer. If two such coincidences are observed, one can then obtain the period of the pendulum with reference to the chronometer time. The pendulum is so made that its period is slightly greater or less than a half second and a coincidence between the beat of the pendulum and that of the chronometer occurs every five or six minutes. The rate of the chronometer is obtained by observations with an astronomic transit on stars as they cross the meridian. Another piece of apparatus now in use is the interferometer. This is used instead of the static method formerly employed to get the flexure or movement of the pendulum case due to the horizontal force applied by the swinging pendulum. The case moves with the pendulum and tends to lengthen the period of oscillation.

The use of the interferometer to determine flexure was proposed by Mr. John F. Hayford while he was Inspector of

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[*] Read before the Philosophical Society of Washington, May 6, 1911.

[†] See Appendix 15, C. and G. S. Report for 1891, and Appendix 1, Report for 1894.

Geodetic Work. The necessary investigations and experimental work were done by former Assistant William H. Burger, in the fall of 1907, assisted by Mr. Hayford and Mr. E. G. Fischer, the Chief of the Instrument Division. The instrument was made in 1908 at our office. The interferometer has been used successfully during the past five seasons in the field. A monograph on this subject, written by Mr. Burger, appears as Appendix 6 of the report of the Superintendent for the fiscal year 1909–10, which is now available for distribution.

Previous to the year 1909 the relative intensity of gravitation had been determined at 47 stations in the United States; 37 were established by former Assistant G. R. Putnam, 3 by Assistant Edwin Smith, 4 by former Superintendent Dr. T. C. Mendenhall, and 1 by the late Assistant E. D. Preston. One of the 47 is the station at the Coast and Geodetic Survey Office, and another at the Smithsonian Institution.*

Each of the stations is referred to the pendulum pier at the Coast and Geodetic Survey Office as the base. The value for this station is 980·111 dynes and was determined relatively in 1900, using Potsdam, Germany, as the base.† The value at Potsdam was determined by the absolute method, using the reversible pendulum. Additional gravity work was taken up in 1909. It was started under the direction of Mr. Hayford, as Inspector of Geodetic Work, with Mr. Burger in immediate charge of the party making the observations. When Mr. Hayford left the Survey in the fall of 1909, the work was continued under the speaker. Mr. Burger has established 35 stations, Assistant H. D. King 21 stations, and the field work is now being done by Aid T. L. Warner, who will make observations at from 15 to 20 stations.

The field work during the present campaign will end at the close of this calendar year, by which time the value of the intensity of gravitation will have been determined at about 75 stations during the three years, 1909–11. These, with the 47 old stations, make a total of about 120. In making the selections, uniformity of distribution has been the principal aim, but consideration has also been given geology, elevation, erosion, and deposition of material. With the exception of the introduction of the use of the interferometer in measuring the flexure, the methods of conducting the recent work are practically those used by former Assistant G. R. Putnam.‡

Three pendulums, constituting a set, were used at each station.

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* The results are published in Appendix 15, Report for 1891; Appendix 1, Report for 1894; Appendix 6, Report for 1897; Appendix 4, Report for 1899.

† See p. 355, Appendix 5, Report for 1901.

‡ See Appendix 1, Report for 1894.

The General Instructions for Gravity Determinations state, in part:

(1) The determination of the intensity of gravitation shall commence with standard determination of time, and shall end with a second determination of time, made not less than 42 hours later than the first. Between these time determinations the pendulums shall be kept swinging as nearly continuously as is feasible.

(2) A standard determination of the intensity of gravitation shall consist of not less than six swings of which the probable error of the mean result is not less than ± ·004 dyne.

(3) Each pendulum shall be swung in the direct position only, and two successive swings are ordinarily to be made with each pendulum. The standard conditions for each swing shall be a pressure (reduced to zero degrees centigrade) of 60 millimeters, and total arc at beginning 5 millimeters. These standard conditions are to be approached as closely as is feasible without the expenditure of extra time for that purpose.

(4) The latitude of each gravity station must be determined within 1′.

(5) The elevation of each gravity station must be determined within 50 feet, unless to secure this degree of accuracy would require the expenditure of much time and money.

Such computations were made in the field as were necessary to ascertain whether the required degree of accuracy was obtained.

If it is assumed that there is no error in the value 980·111 dynes for the intensity of gravitation at the base station, then the average actual error in the values for the other stations is about ·003 dyne, with a maximum error, in rare cases, of about ·010 dyne. The probable error of the absolute determination of gravity at Potsdam is ± ·003 dyne. The probable error of the determination of the value for the Coast and Geodetic Survey station, relative to Potsdam, is about ± ·002. Hence, the probable error of the base station is about ± ·004 and the average probable error of the other stations in the United States is ± ·005 dyne. It is interesting to compare this accuracy with that of the stations determined at sea by Dr. Hecker. It is probable that the uncertainty in the value of the intensity of gravitation at an ocean station is, in some cases, as much as ·10 dyne.

Hayford applied Pratt's hypothesis of isostasy in his investigations of the figure of the earth. It is a well-known fact that the plumb line is attracted by the known excesses of mass above the theoretical sea surface, and is repelled by the defect of mass in the oceans. Hayford showed by solution B, in his "Supplemental Investigation in 1909 of the Figure of the

Earth and Isostasy" that the apparent deflections are increased by considering only the attraction, positive and negative, of the topography alone. In his solution H the effect of the negative attraction of the defect of mass under the continents was applied in addition to the effect of the topography, as was also the positive attraction of the excess of mass under the oceans, and the deflections were greatly reduced.

The theory of isostasy postulates that each topographic feature is compensated for by a variation from the normal density below sea level. The crust of the earth under a land area has a deficiency of mass and that under a water area has an excess of mass. It is assumed that the mass is the same in each unit column extending from the actual surface of the earth, land or water, to a certain depth below sea level. This statement is based upon the theory that there is complete local compensation uniformly distributed with respect to depth. Of course, the actual condition deviates somewhat from this ideal. The compensation for a feature, a separate mountain mass for example, is not necessarily directly under it, nor is the compensation distributed absolutely uniformly and absolutely limited by a certain depth. The second investigation of the figure of the earth by Hayford gave 120·9 kilometers as the most probable limiting depth. He predicted that "future investigations will show that the maximum horizontal extent which a topographic feature may have and still escape compensation is between one square mile and one square degree. The introduction of the theory of isostasy to the investigations doubled the weight of the resulting value for the flattening of the earth, which was found to be 1/297·0±·5.

Having met with such success in the investigations of the figure of the earth, it was decided to apply the theory of isostasy in the reductions of the gravity stations in the United States. This was done for 56 stations by Hayford in 1909. A preliminary report upon the results of his investigation was read at the meeting of the International Geodetic Association at London and Cambridge in 1909.*

The intensity of gravitation increases with the distance from the equator, it decreases with the increase in elevation above sea level and is affected by the topography of the world and its compensation.

The gravity for any latitude is given by Helmert's formula of 1901:

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*Published in Comptes Rendus des Séances de la seizième Conférence générale de L'Association Géodésique Internationale réunie à Londres et à Cambridge du 21 au 29 Septembre 1909. Rédigés par le Secrétaire perpetuel H. G. Van de Sande Bakhuyzen. I^{er} Volume : Procès-verbaux et rapports des Délégués sur les travaux géodésiques accomplis dans leurs pays, pp. 354–390.

$$\gamma_0 = 978{\cdot}046(1 + {\cdot}005302 \sin^2\phi = {\cdot}000007 \sin^2 2\phi).$$

The value sought is γ_0. The constant 798·046 is the theoretical value of the intensity of gravitation at sea level at the equator, unaffected by topography. The coefficient ·000007 was adopted by Helmert from the theoretical investigations of Weichert and Darwin, while the coefficient ·005302 resulted from a discussion by Helmert of about 400 selected gravity stations. These stations were selected from a total of about 1600 stations and were those which showed the smallest anomalies. In latitude 39°, approximately that of Washington, there is a change of ·0013 dyne for 1 minute change in latitude.

The formula $C_H = -{\cdot}0003086$ H, in which H is the elevation above sea level in meters, is used to get the correction for elevation of the stations. It follows that a change of ·001 dyne is caused by changing the elevation about 3 meters.

The corrections for latitude and elevation, only, are used in the Free Air reduction, which ignores the attraction of the topography altogether. In this reduction it is implied that there is complete isostatic compensation at the depth zero.

The Bouguer reduction applies corrections for latitude, elevation, and for the topography without compensation. The new, or Hayford, method applies these three corrections and also a correction for the isostatic compensation.

It is not necessary to discuss in detail the formulæ used to obtain the attraction of the topography and compensation. They are based upon the fundamental principle that the attraction of any elementary mass *dm* for a mass of one gram at the station of observation is in dynes $\frac{kdm}{D^2}$, where k is the gravitation constant, in the C. G. S. system, namely, 6673 (10^{-11}).* All other quantities must, therefore, be expressed in that system. D is the distance from the station to the elementary mass. The vertical component at the station of this attraction is

$$kdm \frac{\sin\frac{\theta}{2}}{4r^2 \sin^2\frac{\theta}{2}},$$

in which r is the radius of the earth, considered as a sphere (6370 kilometers), and θ is the angle at the center of this earth subtended between the station and the elementary mass (the station and the elementary mass being considered at sea level).

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*See page 153 of "The Century's Progress in Applied Mathematics" by R. S. Woodward, in Bulletin of the American Mathematical Society, vol. vi, No. 4, pp. 133–163.

The attraction at the station of an elementary mass which is higher than the station is given by the expression

$$kdm\frac{\sin\frac{\theta}{2}-\sin^{-1}\dfrac{h\cos\frac{\theta}{2}}{\sqrt{D^2+h^2+2Dh\sin\frac{\theta}{2}}}}{D^2+h^2+2Dh\sin\frac{\theta}{2}}$$

In this h is the difference in elevation between the elementary mass and the station.

The attraction at the station of an elementary mass which is lower than the station is given by the expression

$$kdm\frac{\sin\frac{\theta}{2}+\sin^{-1}\dfrac{h\cos\frac{\theta}{2}}{\sqrt{D^2+h^2-2Dh\sin\frac{\theta}{2}}}}{D^2+h^2-2Dh\sin\frac{\theta}{2}}$$

For masses near the station the following formula was used, which gives the attraction of a mass having the form of a right cylinder, upon a point outside the cylinder and lying in its axis produced:

$$\text{Attraction in dynes} = k2\pi\delta\left\{\sqrt{c^2+h^2}-\sqrt{c^2+(h+t)^2}+t\right\}.$$

δ is the density of the material, c is the radius of the cylinder, t is an element of the cylinder and h is the distance from the attracted point, the station, to the nearest end of the cylinder.

For a mass which has the form of a cylindrical shell, which is the difference in the effect of two solid cylinders of the same length, having different radii c_1 and c_2, this expression was used:

$$\text{Attraction in dynes} =$$
$$k2\pi\delta\left\{\sqrt{c^2_2+h^2}-\sqrt{c^2_1+h^2}-\sqrt{c^2_2+(h+t)^2}+\sqrt{c^2_1+(h+t)^2}\right\}.$$

In order to apply the formulæ to the computation of the effect of topography and the compensation, the whole surface of the earth was divided into zones, each having the station as the center. Each zone was divided into equal compartments by radial lines from the station. The division adopted is shown in the following table:

Designation of zone	Inner radius of zone. Meters	Outer radius of zone. Meters	Number of compartments
A	0	2	1
B	2	68	4
C	68	230	4
D	230	590	6
E	590	1280	8
F	1280	2290	10
G	2290	3520	12
H	3520	5240	16
I	5240	8440	20
J	8440	12400	16
K	12400	18800	20
L	18800	28800	24
M	28800	58800	14
N	58800	99000	16
O	99000	166700	28

	Degrees, minutes and seconds	Degrees, minutes and seconds	
18	1° 29′ 58″	1° 41′ 13″	1
17	1 41 13	1 54 52	1
16	1 54 52	2 11 53	1
15	2 11 53	2 33 46	1
14	2 33 46	3 03 05	1
13	3 03 05	4 19 13	16
12	4 19 13	5 46 34	10
11	5 46 34	7 51 30	8
10	7 51 30	10 44 00	6
9	10 44 00	14 09 00	4
8	14 09 00	20 41 00	4
7	20 41 00	26 41 00	2
6	26 41 00	35 58 00	18
5	35 58 00	51 04 00	16
4	51 04 00	72 13 00	12
3	72 13 00	105 48 00	10
2	105 48 00	150 56 00	6
1	150 56 00	180 00 00	1

It was found most convenient, in making the computations, to have the radii of some zones in meters and others in degrees and minutes of a great circle. All of the zones combined together cover the earth completely. For each zone a special reduction table was prepared, giving the relation between the mean elevation of each compartment of that zone, and the effect of the topography and compensation in that compartment upon the intensity of gravitation at the station. The mechanical part of the computation was performed by the use of transparent celluloid templates on which the boundary lines of the various zones were drawn. These templates, made to proper scale, were superimposed on the contour maps.

The following are condensed tables for zones E and K, which are hollow cylinders. The corrections are given in the fourth decimal place in dynes.

Zone E. Inner radius, 590 meters. Outer radius, 1280 meters. Eight compartments.

		Correction for elevation of station.									
		Station above compartment.					Station below compartment.				
Mean elevation. Fathoms	Correction	200 feet	600 feet	1000 feet	1800 feet	3000 feet	200 feet	600 feet	1000 feet	1800 feet	3000 feet
−500	−17	−1									
−400	−13	−1	−3								
−300	− 9	−1	−3	−4							
−200	− 4	−1	−2	−4	−4						
−100	− 1	−1	−2	−2	−3						
− 50	− 1	0	−1	−1	−2	−1					
Feet											
0	0	0	0	0	0	0					
400	+ 1	+1	+2	+3	+ 4	+ 3	−1				
800	+ 3	+1	+4	+6	+ 6	+ 5	−1	−5			
1200	+ 7	+2	+4	+7	+ 7	+ 4	−2	−7	−12		
2000	+16	+2	+5	+7	+ 6	+ 1	−2	−9	−16	−30	
3000	+28	+2	+4	+5	+ 2	− 4	−2	−9	−17	−35	−56
4000	+37	+1	+3	+3	− 1	− 9	−1	−7	−14	−32	−60
5000	+45	+1	+2	+1	− 4	−13	−1	−6	−13	−29	−57
6000	+51	+1	+1	0	− 6	−16	−1	−5	−11	−26	−51
8000	+60	0	−1	−2	− 9	−20	0	−4	− 9	−22	−43
10000	+66	0	−1	−3	−10	−22	0	−4	− 8	−19	−38
15000	+73	0	−1	−4	−12	−24	0	−3	− 6	−16	−32

Zone K. Inner radius, 12400 meters. Outer radius, 18800 meters. 20 compartments.

		Correction for elevation of station.							
		Station above compartment.				Station below compartment.			
Mean elevation. Fathoms	Correction	600 feet	1800 feet	4200 feet	7200 feet	600 feet	1800 feet	4200 feet	7200 feet
−1200	+1	−1	−1						
− 800	+1	0	−1	−1					
− 400	+1	0	−1	−1	− 1				
Feet									
0	0	0	0	0	0				
1000	−1	0	0	+1	+ 1	0			
2000	−1	0	+1	+1	+ 2	0	−1		
6000	−2	+1	+2	+3	+ 6	0	−2	−4	
10000	−1	+1	+2	+6	+ 9	0	−2	−6	−11
13000	+1	+1	+3	+7	+11	−1	−3	−8	−13
15000	+3	+1	+3	+7	+12	−1	−4	−9	−14

The first column of the table for zone E gives the mean elevation of the compartment in fathoms or feet, the second the correction for topography and its compensation, assuming the station to be at the same elevation as the compartment, the third to seventh columns give a correction to the values in column 2 due to the elevation of the station above the compartment, and the last five columns the correction to the quantities in the second column should the station be below the mean elevation of the compartment. The tables for the other lettered zones are practically the same in form as those for zones E and K, while the tables for the numbered zones are materially different owing to the absence of any correction for elevation of the station above or below the compartments, and due also to the fact that they are computed by a different formula.

The following table gives the values for the separate zones for six typical stations :

Correction for Topography and Isostatic Compensation—Separate Zones.

Zone	Kansas City. No. 39	Pike's Peak. No. 43	Colorado Springs. No. 42	Grand Junction. No. 46	Beaufort. No. 18	San Francisco. No. 54
A	+2	+2	+2	+2	+1	+2
B	+64	+72	+68	+68	0	+48
C	+97	+157	+160	+160	0	+35
D	+72	+310	+306	+282	0	+15
E	+30	+540	+408	+336	0	+1
F	+16	+602	+331	+239	0	0
G	0	+512	+192	+120	0	0
H	0	+443	+127	+66	0	0
I	0	+412	+78	+33	0	0
J	−16	+201	−11	−7	0	−2
K	−20	+79	−71	−65	0	−1
L	−24	−32	−147	−132	0	−7
M	−53	−290	−369	−391	0	−14
N	−47	−334	−342	−374	+4	+15
O	−55	−329	−339	−349	+45	+99
18	−10	−68	−68	−74	+14	+24
17	−10	−68	−69	−73	+16	+21
16	−10	−68	−69	−72	+20	+20
15	−11	−64	−68	−66	+27	+19
14	−11	−59	−62	−65	+34	+17
13	−20	−83	−81	−101	+52	+25
12	−13	−48	−48	−55	+36	+23
11	−14	−30	−30	−34	+29	+21
10	−14	−17	−17	−15	+19	+14
9	−8	0	0	+3	+14	+10
8	−1	+9	+9	+11	+14	+15

Correction for Topography and Isostatic Compensation—Separate Zones.
(Continued.)

Zone	Kansas City. No. 39	Pike's Peak. No. 43	Colorado Springs. No. 42	Grand Junction. No. 46	Beaufort. No. 18	San Francisco. No. 54
7	+ 8	+ 7	+ 7	+ 7	+ 5	+10
6	+ 9	+ 9	+ 9	+ 9	+ 6	+ 9
5	+11	+ 9	+ 9	+ 9	+ 8	+ 9
4	+ 7	+ 8	+ 8	+ 8	+ 7	+ 8
3	+ 5	+ 5	+ 5	+ 5	+ 6	+ 5
2	+ 3	+ 3	+ 3	+ 3	+ 3	+ 4
1	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1
Total,	−12	+1891	− 68	−511	+361	+446

The six stations in the above table were selected as representing typical classes. Kansas City is an inland station, far from the coast of the continent and not in a mountainous region. Pike's Peak is a station on a high mountain summit in the interior of the country. Colorado Springs is a station near the foot of the same mountain and at the edge of a great plain. Grand Junction is a station in the interior of the continent in a deep valley among high mountains. Beaufort and San Francisco are coast stations near deep water.

It is a most interesting fact and one brought out for the first time by Hayford, that there is a change of sign in the combined effect of topography and compensation near zone J, outer radius about 12 kilometers. This change is due to the fact that the effect of the compensation for more distant zones is greater than that of the topography. It will be seen that the effect of the distant topography and its compensation, beyond zone J for example, is in some cases entirely too large to be neglected. At Pike's Peak, it is — ·136 dyne and at San Francisco it is + ·034 dyne.

The results of the computations for certain stations are shown in the following two tables. In the first ϕ is the latitude, λ is the longitude, and γ_0 is the theoretical value for the latitude computed by Helmert's formula. H is the elevation of the station above sea level in meters. The other headings are self-explanatory. It will be noticed that the effect of topography and compensation at some stations is very small, zero in two cases, and large at others. For Pike's Peak it is nearly ·200 dyne.

Number of station	ϕ	λ	H meters	γ_0	Correction for elevation	Correction for topography and compensation
25	40 21·0	74 39·5	64	980·212	— ·020	+·013
26	40 44	74 02	11	980·248	— ·003	+·008
27	40 48·5	73 57·7	38	980·254	— ·012	+·011
28	42 16·5	71 48·5	170	980·386	— ·052	+·018
29	42 21·6	71 03·8	22	980·393	— ·007	+·013
30	42 22·8	71 07·8	14	980·395	— ·004	+·010
31	45 11·2	67 16·9	38	980·649	— ·012	+·010
32	42 27·1	76 29·0	247	980·402	— ·076	+·005
33	41 30·4	81 36·6	210	980·317	— ·065	·000
34	39 08·3	84 25·3	245	980·105	— ·076	+·002
35	39 28·7	87 23·8	151	980·135	— ·047	+·001
36	41 47·4	87 36·1	182	980·342	— ·056	+·007
37	43 04·6	89 24·0	270	980·458	— ·083	+·003
38	38 38·0	90 12·2	154	980·061	— ·048	+·001
39	39 05·8	94 35·4	278	980·101	— ·086	—·001
40	38 43·7	98 13·5	469	980·069	— ·145	—·004
41	38 54·7	101 35·4	1005	980·085	— ·310	·000
42	38 50·7	104 49·0	1841	980·080	— ·568	—·007
43	38 50·3	105 02·0	4293	980·079	—1·325	+·189
44	39 40·6	104 56·9	1638	980·153	— ·505	—·015
45	38 32·6	106 56·0	2340	980·053	— ·722	—·001
46	39 04·2	108 33·9	1398	980·099	— ·431	—·051
47	38 59·4	110 09·9	1243	980·092	— ·384	—·043
48	39 50·8	111 00·8	2191	980·168	— ·676	+·024
49	40 46·1	111 53·8	1322	980·250	— ·408	—·041
50	44 43·3	110 29·7	2386	980·607	— ·736	+·038
51	44 44·2	110 42·0	2276	980·608	— ·702	+·031
52	44 33·4	110 48·1	2200	980·592	— ·679	+·028
53	47 39·6	122 18·3	58	980·872	— ·018	—·020
54	37 47·5	122 25.7	114	979·986	— ·035	+·045
55	37 20·4	121 38·6	1282	979·947	— ·396	+·120
56	47 36·5	122 19·8	74	980·867	— ·023	—·018

The second table gives the number and name of the station, the computed gravity at the station, the observed gravity and the anomaly.

Number and name of station	Computed gravity at station g_c	Observed gravity at station g	$g-g_c$
25 Princeton, New Jersey	980·205	980·177	—·028
26 Hoboken, New Jersey	980·253	980·268	+·015
27 New York, New York	980·253	980·266	+·013
28 Worcester, Massachusetts	980·352	980·323	—·029
29 Boston, Massachusetts	980·399	980·395	—·004

Number and name of station	Computed gravity at station g_c	Observed gravity at station g	$g-g_c$
30 Cambridge, Massachusetts	980·401	980·397	—·004
31 Calais, Maine	980·647	980·630	—·017
32 Ithaca, New York	980·331	980·299	—·032
33 Cleveland, Ohio	980·252	980·240	—·012
34 Cincinnati, Ohio	980·031	980·003	—·028
35 Terre Haute, Indiana	980·089	980·071	—·018
36 Chicago, Illinois	980·293	980·277	—·016
37 Madison, Wisconsin	980·378	980·364	—·014
38 St. Louis, Missouri	980·014	980·000	—·014
39 Kansas City, Missouri	980·014	979·989	—·02
40 Ellsworth, Kansas	979·920	979·925	+·005
41 Wallace, Kansas	979·775	979·754	—·021
42 Colorado Springs, Colorado	979·505	979·489	—·016
43 Pike's Peak, Colorado	978·943	978·953	+·010
44 Denver, Colorado	979·633	979·608	—·025
45 Gunnison, Colorado	979·330	979·341	+·011
46 Grand Junction, Colorado	979·617	979·632	+·015
47 Green River, Utah	979·665	979·635	—·030
48 Pleasant Valley Junction, Utah	979·516	979·511	—·005
49 Salt Lake City, Utah	979·801	979·802	+·001
50 Grand Canyon, Wyoming	979·909	979·898	—·011
51 Norris Geyser Basin, Wyoming	979·937	979·949	+·012
52 Lower Geyser Basin, Wyoming	979·941	979·931	—·010
53 Seattle, Washington (Univ't'y)	980·834	980·732	—·102
54 San Francisco, California	979·996	979·964	—·032
55 Mount Hamilton, California	979·671	979·659	—·012
56 Seattle, Wash'gton, High School	980·826	980·724	—·102

As the mean with regard to sign of 54 of the 56 stations (the two Seattle stations were rejected on account of their very large anomalies) was — ·008 dyne, a correction of this amount was applied to the constant (978·046) of Helmert's formula. For all of the 56 stations considered as a single group the means for the three reductions are as follows:

	Anomaly		
	(New Method)	(Bouguer)	(In free air)
Mean with regard to sign	—·004	—·056	·000
Mean without regard to sign	·018	·066	·030
With the two Seattle stations omitted the means are:			
Mean with regard to sign	·000	—·053	+·005
Mean without regard to sign	·015	·064	·027

It is seen that the anomalies by the new method are decidedly smaller than by the two older methods of reduction.

An analysis of the anomalies showed that there is only slight, if any, connection between the size and sign of the anomaly and the topography. The nearly complete disappearance of the association between anomalies and topography is a proof that the condition called isostasy exists, and that the assumption that the compensation is complete and uniformly distributed with respect to depth from the surface to a depth of 113·7 kilometers is a close approximation to the truth. This value for the limiting depth of compensation was used instead of 122 kilometers (the latest value) as the computations were begun before the latter value was available.

The facts and conclusions stated above are for the 56 gravity stations in the United States used in the reduction made by Mr. Hayford in 1909. He and the speaker have nearly completed an enlargement of the first investigation with the addition of 33 stations, making 89 in all. It is expected that the results of this investigation will be published by the Coast and Geodetic Survey during this year. This investigation will verify the conclusions arrived at from the first one. Certain new features have been added. One is a study to show whether the theory of local distribution of the compensation is nearer the truth than what may be considered regional distribution. Another is an analysis of the anomalies to show whether there is any connection between the size and sign of the residual and the geologic formation. Though the number of stations is too small to justify the statement that there is a positive connection, yet the evidence is strong that there is a relation. This is especially the case with regard to the oldest and most recent formations.

It has been found that the results from the gravity investigations are in almost perfect harmony with those of Hayford's investigations of the figure of the earth and isostasy. Those who have read his second publication may remember the illustration on which are shown by ovals certain areas of excessive and defective mass, as indicated by the anomalies of the deflections. Gravity stations have been established in many of these areas and in each case the gravity anomaly by the Hayford method is of the same sign as that indicated by the deflections.

To sum up—the work done by the Coast and Geodetic Survey proves conclusively that a close approximation to the condition of complete isostasy exists. The introduction of the theory of isostasy into the reduction of gravity observations has made the anomalies very small. Further investigations of deflections of the vertical and of gravity observations may show how the compensation is distributed and how nearly it is complete. With increased knowledge of the distribution of compensation the figure and size of the earth can be more accurately determined.

United States Coast and Geodetic Survey, Washington, D. C.

ART. XI.—*Crystal Forms of Pyromorphite*; by O. BOWLES.

DURING the past winter a detailed study was made of the crystal forms of the mineral pyromorphite, the museum and laboratory of the University of Minnesota affording a number of excellent specimens from various localities. In addition to these, examination was made of a number of loaned specimens obtained through the kindness of the Foote Mineral Company of Philadelphia.

In 1876 H. Baumhauer,[*] by etching pyromorphite with nitric acid, obtained depressions possessing the symmetry of pyramidal hemihedrism, and for this reason the mineral was placed in the hexagonal bipyramidal class. Up to the present time no evidence has been presented, other than that supplied by etch figures, for placing it in this class. The present investigations, however, supply corroborative evidence and establish the mineral in its crystallographic class on the basis of morphology. This is made possible through the observation of many crystal faces representing a prism of the third order, and a small number of faces of a bipyramid of the third order.

Measurements of about forty crystals were made by means of a Goldschmidt two-circle goniometer of the 1910 model.

Several aggregates of pale, wax-yellow crystals were from the well-known locality, Ems, Nasseau, Germany. The largest crystals are approximately three to five millimeters in diameter, and five to ten millimeters in length, and are somewhat barrel-shaped. The most perfect crystals are smaller, more tabular in habit, and show most prominently the forms $\{10\bar{1}0\}$, $\{10\bar{1}1\}$, and $\{0001\}$. In many cases the form $\{11\bar{2}0\}$ is well developed, and on such crystals distinct third-order prism faces are usually present.

The latter form occurs at times as mere line faces, or may be as fully developed as the second order forms. Fig. 1 illustrates a crystal with four distinct faces of this form. It is $1{\cdot}7^{mm}$ in diameter and 1^{mm} in length. Care has been taken to represent accurately the relative size of each face. The form was observed on many crystals, and, for about fifty per cent of the faces observed, the reflection figure in the goniometer was clear and definite, giving reliable readings. The results obtained point conclusively to the symbol $\{21\bar{3}0\}$. The average of readings for eighteen faces gives a value of 19° 11′ for the angle ϕ, the calculated angle being 19° 06′.

The most perfect crystals of pyromorphite yet observed by the writer are those obtained from the Broken Hill Mines of

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[*] Neues Jahrbuch für Mineralogie, 1876, p. 411.

New South Wales. They are pale brown in color, of prismatic habit, and are frequently doubly terminated. The prominent forms are $\{10\bar{1}0\}$, $\{10\bar{1}1\}$, and $\{0001\}$; while in many cases the form $\{11\bar{2}0\}$ is of equal importance. The bipyramid $\{20\bar{2}1\}$ occurs frequently with narrow faces, while extremely small faces of the form $\{11\bar{2}1\}$ occur sparingly.

A new form observed is the bipyramid of the third order $\{21\bar{3}1\}$. A number of undoubted third-order faces were present, but owing to curvature only a small number of these gave reliable readings. For the most distinct face an average of thirty readings at the point of maximum luster gave ϕ 18° 58′, and ρ 66° 02′.

Fig. 1.

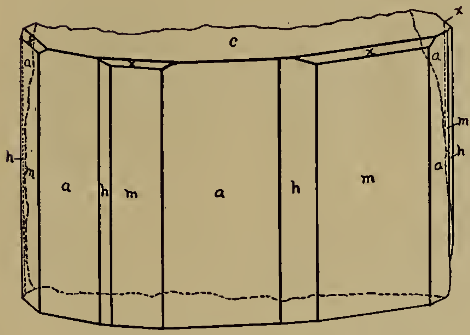
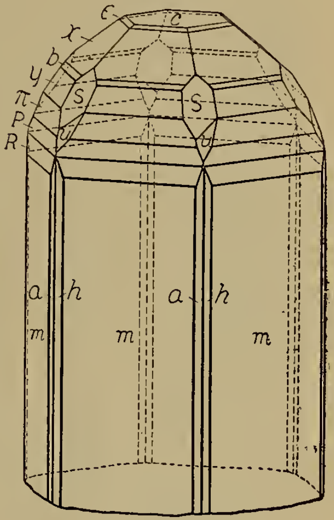


Fig. 2.



Figs. 1, 2.—Pyromorphite.

The irregular moss-like aggregates from Phœnixville, Pa., afforded rather unsatisfactory material for crystal study. Narrow faces, which are evidently third-order prisms, are present, but are too indistinct to give readings from which symbols may be determined.

The most noteworthy feature of crystals from Devonshire, England, is their peculiar habit, many of them being funnel-shaped and attached at the smaller end. The broader termination shows usually a rim of basal pinacoid with a cavity in the center. Occasionally the crystals are obliquely terminated owing to the extreme development of one pyramidal face as shown by a brightly reflecting border, the center being usually hollow. The prismatic faces give fairly definite reflection figures in the goniometer, and hence the convergence toward the point of attachment is not due to curvature, but is attained by a series of steps. The forms $\{10\bar{1}0\}$, $\{0001\}$, and $\{10\bar{1}1\}$ were observed.

The observed and calculated angles of the new forms are given below in tabular form.

	ϕ		ρ	
Form	Observed	Calculated	Observed	Calculated
h $\{21\bar{3}0\}$	19° 11′	19° 06′	89° 55′	90° 00′
u $\{21\bar{3}1\}$	18° 58′	19° 06′	66° 02′	66° 02′

Fig. 2 represents all the known crystal forms of pyromorphite, and the following table gives the characteristic angles. Those for which no reference is given are taken from Goldschmidt's "Krystallographische Winkeltabellen."

Table of Angles.

Form	ϕ	ρ	Form	ϕ	ρ
c $\{0001\}$	----	0° 00′	*y* $\{20\bar{2}1\}$	0° 00′	59° 32′
m $\{10\bar{1}0\}$	0° 00′	90° 00′	π $\{40\bar{4}1\}$	0° 00′	73° 36′
a $\{11\bar{2}0\}$	30° 00′	90° 00′	P $\{80\bar{8}1\}$§	0° 00′	81° 38′
h $\{21\bar{3}0\}$*	19° 06′	90° 00′	R $\{90\bar{9}1\}$‡	0° 00′	82° 34′
ϵ $\{30\bar{3}4\{$†	0° 00′	32° 31′	*s* $\{11\bar{2}1\}$	30° 00′	55° 49′
x $\{10\bar{1}1\}$	0° 00′	40° 22′	*u* $\{21\bar{3}1\}$*	19° 06′	66° 02,
b $\{15.0.\bar{1}\bar{5}.14\}$‡	0° 00′	42° 37′			

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University of Minnesota,
Minneapolis, Minn., May 4, 1911.

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* New forms.

† Bowles, this Journal, vol. xxviii, p. 40.

‡ Lacroix, Bulletin de la Société Minéralogique, 1894, p. 120.

§ Lacroix, Minéralogie de la France, iv, p. 394.

ART. XII.—*Some New Mechanical Quadratures*; by GEORGE F. BECKER.

MECHANICAL quadratures are in some circumstances unavoidable, but they are usually shunned as clumsy and troublesome. Were the formulæ neater and their applicability better defined, they might be of great use in experimental physics and might compete with other integrations by series in the computation of functions. This paper is intended as a contribution to that end.

There are three distinct systems of mechanical quadrature each depending upon the integration of a general formula for interpolation. By integrating Newton's interpolation formula Simpson's rule, Weddle's rule, and some others can be found. These depend upon the assumptions that the increments of the abscissa are constant and the differences above a certain order are negligible. It is said that if the attempt is made to include in quadratures of this species differences above the sixth, the formulæ become unmanageable, but this I have not tested. It is possible to base quadratures on Stirling's and Bessel's interpolation formulæ, but as these are not applicable at the beginning or the end of a series of values their usefulness is limited, and since these modes of interpolation are founded on Newton's, the quadratures are not essentially different.

Gauss used as the basis of his method of quadratures Lagrange's interpolation formula. When after integration the increment of the abscissa is assumed to be constant, Cotes's numbers result, but Gauss showed that, by a proper selection of unequal increments of the independent variable, formulæ can be deduced whose convergence is very rapid. Unfortunately most of the increments are surds, rendering the application of the method very laborious in spite of its elegance.

Interpolation by means of Taylor's series has several advantages over methods depending upon finite differences and its limitation to continuous functions is rarely of any moment. In dealing with known functions the methods of infinitesimal calculus are habitually employed excepting for interpolation, while finite differences constitute a distinct algorithm. Since Taylor's series is the very foundation of analysis, its application to interpolation is both more consistent and more elegant than that of finite differences, while, if needful, the final results can be expressed in terms of finite differences without the least trouble. Similarly so-called mechanical quadratures founded on Taylor's series in its application to interpolation are quadratures obtained by integration of a differential equation and thus do not differ essentially from integrations by series. The expressions for quadrature to which Taylor's theorem leads are in some cases semi-convergent series, yet the error involved may be reduced ad libitum. Although convergent series would yield results of absolute accuracy were an infinite number of terms to be computed, this accuracy is purely theoretical and computation terminates when the error becomes negligible. The distinction between convergent and semi-convergent series is clear, yet there is no difference between the results obtainable by their use in effecting quadratures.

The quadrature founded on Taylor's series was first given by Euler in 1732–3, but his paper was not printed until 1738. It was discovered independently by Maclaurin who published it in 1742.* The very essential discussion of the remainder was left to Poisson, Jacobi and others. The formula for mechanical quadratures commonly given in text-books, and ordinarily ascribed to Laplace, is merely Euler's equation with the substitution of finite differences for derivatives.

It is easy so to transform Taylor's series as to express an integral in terms of a sum of the ordinates and sums of the successive derivatives. The function to be integrated and its derivatives can be similarly expressed. From the system of equations thus developed the sums of the derivatives can be eliminated and the result taken between limits is a definite integral expressed in terms of the sum of the ordinates, together with the derivatives at the limits. This is Euler's quadrature.

Let h be the constant increment of x and B_1, B_3, B_5 . . . . . be Bernoulli's numbers; for brevity let also

$$v^k = f^{[k]}(x_n) - f^{[k]}(x_0)$$

or the difference of the kth derivative at the two limits.

Then Euler's equation may be written thus:

$$\int_{x_0}^{x_n} y\,dx = h\left(\frac{y_0}{2} + y_1 + y_2 + \ldots\ldots + \frac{y_n}{2}\right) - \frac{B_1h^2v'}{2\,!} + \frac{B_3h^4v'''}{4\,!} - \ldots + \mathrm{R}.$$

Of course

$$h = \frac{x_n - x_0}{n}$$

and h may be any integral factor of $x_n - x_0$. The total number of ordinates is $n+1$ and they divide the area to be integrated into n parts each of width h.

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* Euler's formula, based on Taylor's theorem, will be found in Commentarii Acad. Sci. Imp. Petrop., vol. vi, ad annos 1732 et 1733; 1738, page 68, Maclaurin gives it in his Treatise of Fluxions, 1742, page 672.

Euler's formula is capable of some transformations which do not seem to have been noticed and a variety of special forms can be deduced from it. For this purpose it is convenient to make certain changes in notation. The first term of the second member is a polygon bounded by the axis, the extreme ordinates and chords connecting the extremities of all the ordinates. Let this polygon of chords be denoted by C_1 and let

$$C_2 = 2h\left(\frac{y_0}{2} + y_2 + y_4 + \ldots + \frac{y_n}{2}\right)$$

$$\ldots = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$C_m = mh\left(\frac{y_0}{2} + y_m + y_{2m} + \ldots + \frac{y_n}{2}\right)$$

in which case n must be divisible by m. Evidently these are also polygons of chords and there is an Eulerian equation corresponding to each of them, obtainable by merely substituting mh for h. Let also

$$T = 2h\,(y_1 + y_3 + y_5 + \ldots y_{n-1}) = 2C_1 - C_2.$$

Here T may be a polygon of tangents or of tangents with portions of the ordinates. It consists of $n/2$ portions each of width $2h$. In any case the integral sought will be an area intermediate between T and C_m irrespective of the particular value of m. It is evident from the identity $T = 2C_1 - C_2$ that

$$\int_{x_0}^{x_n} y\,dx = T + (2^2 - 2)\frac{B_1 h^2 v'}{2!} - (2^4 - 2)\frac{B_3 h^4 v'''}{4!} + \ldots . + R.$$

Suppose n, or the number of strips into which the area is divided, to be a multiple of two. Then the integral is expressible by each of two or more Eulerian equations. If each of these is multiplied by an arbitrary multiplier and if the sum of these multipliers is unity, the sum of the equations will be a new expression for the integral. Furthermore, for every polygon of chords involved it will be possible to eliminate the coefficient of one difference of derivatives, or v. Thus if $n = 4$ the integral may be expressed in terms of T, C_2, or C_4. Multiplying by arbitrary coefficients and adding the three equations makes it possible to impose three conditions, viz.: that the sum of the multipliers shall be unity and that the coefficients of v' and v''' shall disappear. This transformation leaves the integral expressed in terms of the three polygons and of derivatives of the fifth and higher orders for which finite differences may be substituted if necessary.

So far as mere elimination is concerned there appears to be no limit to this process. Thus if $x_n - x_0$ were to be divided into 60 parts, eleven coefficients could be eliminated and the integral would be expressed in terms of T and eleven polygons of chords, only the 23d and higher derivatives or differences appearing in the remaining portion of the series. For certain classes of functions this might be advantageous, but on account of the semi-convergence of Euler's series the desirable limit will in many instances be lower.

I have carried out the process only as far as $n = 12$, which permits of the elimination of all the derivatives below the eleventh. The equations themselves show the appropriate factors, while the coefficient of the one derivative term retained is the sum of the coefficients in the several Euler series each multiplied by one of these factors. The following six formulas are thus obtained:

$$(1)\quad \int_{x_0}^{x_n} y\,dx = \frac{2\mathrm{T}+\mathrm{C}_2}{3} - 2h.\,\frac{h^3v'''}{360} + \dots. \qquad (n \geqq 2)$$

$$(2)\quad = \frac{32\mathrm{T}+12\mathrm{C}_2+\mathrm{C}_4}{45} - 4h.\,\frac{h^5v^{\mathrm{v}}}{1{,}890} + \dots. \qquad (n \geqq 4)$$

$$(3)\quad = \frac{648\mathrm{T}+81\mathrm{C}_2+112\mathrm{C}_3-\mathrm{C}_6}{840} - 6h.\,\frac{h^7v^{\mathrm{vii}}}{5{,}600} + \dots. \qquad (n \geqq 6)$$

$$(4)\quad = \frac{2{,}048\mathrm{T}+704\mathrm{C}_2+84\mathrm{C}_4-\mathrm{C}_8}{2{,}835} - 8h.\,\frac{2h^7v^{\mathrm{vii}}}{4{,}725} + \dots. \qquad (n \geqq 8)$$

$$(5)\quad = \frac{35{,}000\mathrm{T}+14{,}375\mathrm{C}_2+528\mathrm{C}_5-7\mathrm{C}_{10}}{49{,}896} - 10h.\,\frac{10h^7v^{\mathrm{vii}}}{12{,}096} + \dots \qquad (n \geqq 10)$$

$$(6)\quad = \frac{1{,}492{,}992\mathrm{T}-174{,}960\mathrm{C}_2+585{,}728\mathrm{C}_3}{1{,}801{,}800}$$
$$- \frac{104{,}247\mathrm{C}_4+2{,}288\mathrm{C}_6-\mathrm{C}_{12}}{1{,}801{,}800} - 12h.\,\frac{691h^{11}v^{\mathrm{xi}}}{750{,}750} + \dots \qquad (n \geqq 12)$$

The derivatives in the last or corrective terms of these equations may be expressed in terms of finite differences should the latter be more convenient. The transformation is well known, but its most essential features may be noted here to save a reference. The kth derivative of a function, $f\,(x^{(k)})$, multiplied by the kth power of the constant increment of x, here denoted by h, is expressible in terms of the kth finite difference and differences higher than the kth. For the purpose in hand Newtonian differences should be employed because they are applicable at the beginning and at the end of a series of values. When the derivatives and differences are so large that higher derivatives and differences also require consideration the transformation is somewhat complex, but if the kth difference is technically "small," so that the $(k+1)$st difference is negligible, then

$$h^k f(x^{(k)}) = \Delta^{(k)}$$

where Δ denotes finite difference. In the formulæ v is employed to indicate the difference of the derivatives at the limits of the area to be integrated, x_0 and x_n. Using a corresponding notation for the finite differences and assuming that the $(k+1)$st difference is inconsiderable

$$h^k v^k = \Delta_n^{(k)} - \Delta_0^{(k)}$$

and this substitution may be made in the corrective terms of the formulæ.*

Not all of these equations are wholly new. The first term of (1) is only Simpson's rule in a new notation and if n is limited to 2 it is also identical with Cotes's rule for $n = 2$. Omitting the derivatives, equations (2) and (3) also coincide with Cotes's rules for $n = 4$ and $n = 6$, but if in these equations n is taken at any multiple of 4 and 6, numbers quite distinct from Cotes's result. All of the equations can be expressed in the same form as Cotes's, but this mode of statement seems undesirable because it masks the vital fact that a reduction of the value of h increases the accuracy of the result. Now, no one would think of getting a considerable quadrature by Simpson's rule with the minimum value of $n = 2$, because this rule with $n = 10$ gives a result the error of which approaches a 625th of that incurred by taking n at 2, while if in (6) n is taken at 24 instead of 12 the error is reduced approximately to 1/4096 of its maximum value.

So far as I know, equations (4), (5), and (6) are new, and Cotes's numbers for $n = 8$ and 10 do not fit into the system of quadratures here discussed.

The derivative term in each of the six equations may exceed the value of the remainder. If the difference of derivatives in this term is denoted by v^r, this is to be regarded as the definite integral of $f(x^{(r+1)})$, which, like any other function of real variables to be integrated, must preserve the same sign between the limits of integration. If the sign does not change, and if also (as Poisson and Jacobi showed) the $(r+1)$st derivative does not pass through a maximum between the limits, then the final term of the equations exceeds in absolute value the remainder of the series. In any case whatever let λ be the maximum value of $f(x^{(r+1)})$ between the limits, then the total area represented by the definite integral, v^r, must be less than $\lambda\,(x_n - x_0)$, and this substituted for v^r in the corrective term

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* A discussion of the relations subsisting between derivatives and finite differences may be found in Smithsonian Math. Tables, 1908, page xxxvi, or elsewhere.

gives a quantity greater than the remainder of the Eulerian series. It is usually practicable so to select or subdivide the limits of integration that the $(r+1)$st derivative neither changes sign nor passes through a maximum and then the corrective term of the equations approximately defines the error of the quadrature.

It is possible still further to reduce the limits of the remainder provided that certain assumptions are made with respect to succeeding differential coefficients, but this proviso implies an inquiry which in most instances would be laborious, more so than the division of h into two or more parts.*

It will be observed that even in (6) the coefficients are numbers of manageable magnitude not exceeding 7 places. If the attempt were made to eliminate a larger number of derivative terms it is not improbable that the formulæ could be dealt with only by 10-place logarithms or computing machines.

The most accurate of the equations given above involves the division of $x_n - x_0$ into some multiple of 12 parts.

Such a division may be inconvenient, for example in dealing with a function which is already tabulated to a decimal argument. This difficulty, however, may be avoided with little trouble; for, if 100 values of y are available, the quadrature from the first to the 96th may be effected by equation (6) and that of the remaining 4 items by equation (2). When experimental data are to be dealt with observations can usually be so arranged as to fit a duodecimal formula and when time is the independent variable duodecimal division is of course most convenient.

In dealing with some functions one or two derivatives are readily calculated, or are perhaps already tabulated, while the higher derivatives are troublesome. It is worth while to observe, therefore, that it is as easy to eliminate the coefficients of the higher derivatives as of the lower ones, and that a formula similar to (6) could be found in which v' and v''' should be retained but v^{xi} and v^{xiii} cancelled.

Odd values of n lend themselves less readily than even ones to the elimination of derivatives from Euler's series because of their limited divisibility. If $n = 3$ the quadrature may be written

$$\int_{x_0}^{x_n} y\,dx = \frac{9C_1 - C_3}{8} - 3h.\frac{h^3\, v'''}{240},$$

and the first term of this formula was given by Newton.†

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* The remainders in formulæ (1) to (6) arise from the remainders in the system of Taylor's series on which Euler's equation is based, and the published discussions of the remainder in Taylor's series would make a stout volume. No elaborate consideration of this subject seems needful for the purpose of this paper.

† Opuscula, Methodus differentialis, prop. vi, Scholium.

Comparison with (1) shows that it is somewhat less accurate than Simpson's rule. Newton's rule is derivable also from the integration of his interpolation formula, and if $3h$ is taken as unity it coincides with Cotes's rule for $n=3$. The lowest odd number with two divisors is 9, so that with $n=9$ two derivatives could be eliminated, but such a formula would be of small value.

It is noteworthy that the simpler rules for quadrature are derivable from any one of the three fundamental interpolation formula.

Other formulas could be obtained by eliminating fewer coefficients than the divisibility of n permits. In general that would be a waste of opportunities, but two examples are worth noting. With $n=6$, I find from T, C_2, and C_3

$$\int_{x_0}^{x_n} y dx = \frac{15T + 3C_2 + 2C_3}{20} - 6h.\frac{h^5 v^{v}}{5{,}040} + \dots.$$

which is Weddle's rule with a corrective term. Under normal circumstances it is considerably less accurate than (3), as can easily be shown by applying each of the equations to the same portion of the exponential curve.

Curiously compact and accurate is a formula derived from T, C_2, C_3, and C_4, in which the coefficient of C_2 turns out to be zero. Of course n must be 12 or a multiple thereof. It may be written

$$\int_{x_0}^{x_n} y dx = \frac{1}{5}\left(4T + \frac{8C_3 - C_4}{7}\right) - 12h.\frac{h^7 v^{vii}}{25{,}200} + \dots (7).$$

Here the denominator of the corrective term is remarkably large, or the remainder very small, so that (7) may approach (6) in accuracy. Its simplicity makes it convenient for laboratory use. Economy of labor depends to some extent on the arrangement of computation, and for that reason I give in a footnote* (p. 124) the details of the quadrature by (7) of a portion of the ascending exponential. It will enable the reader to perceive that no advantage is obtained by stating the formulæ in terms of the ordinates instead of the polygons, even when the division of the area to be integrated is limited to the minimum value of n.

It is needless to say that the integrals (1) to (6) without the corrective terms are rigorous for finite series with $n+1$ constants whose highest terms contains x^n. In any other case two distinct means exist for reducing the error of the result below a given tolerance, viz., a proper choice of the number of derivatives to be eliminated and a subsequent reduction of h so far as this may be needful. Even if Euler's series ultimately becomes divergent for a given function or class of functions, the earlier part of the series is convergent and there is some term after the first at which divergence begins; in other words, the best results for a given value of h is attainable by integrating a certain number of terms of Euler's series. This amounts to a choice between formulæ (1) to (6) or others similarly derived. Thereafter the only question is how small a value of h must be adopted to give the required accuracy. Any quadrature by series assumes a fictitious curve more or less nearly coinciding with a real one. For the quadratures under discussion the number of derivatives eliminated determines the order of the contact of the two curves at the extremities of the arc to be integrated and also a minimum number of common points on the two curves. By division of h the number of common points is increased in simple proportion to the number by which h may be divided, but the order of contact at the extremities is

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* Find $\int_{-1}^{+2\cdot6} e^x d\,x$ with $n = 12$, or $h = 0\cdot3$. taking values of y from Smithsonian Math. Tables, by (7).

x		y	T	C₃	C₄
$x_0 =$	$-1\cdot0$	$y_0/2$		0·183 9397	0·183 9397
x_1	$-0\cdot7$	y_1	0·496 5853		
x_2	$-0\cdot4$	y_2			
x_3	$-0\cdot1$	y_3	0·904 8374	0·904 8374	
x_4	$+0\cdot2$	y_4			1·221 403
x_5	$0\cdot5$	y_5	1·648 721		
x_6	$0\cdot8$	y_6		2·225 541	
x_7	$1\cdot1$	y_7	3·004 166		
x_8	$1\cdot4$	y_8			4·055 200
x_9	$1\cdot7$	y_9	5·473 947	5·473 947	
x_{10}	$2\cdot0$	y_{10}			
x_{11}	$2\cdot3$	y_{11}	9·974 182		
x_{12}	$2\cdot6$	$y_{12}/2$		6·731 869	6·731 869
Σ			21·502 439	15·520 134	12·192 412
Factor................			$2h$	$3h$	$4h$
Product			12·901 4634 = T	13·968 1206 = C₃	14·630 8944 = C₄

These values substituted in (7) give for the answer 13·095 858. The true value of the last figure is 9.

For $n = 12$, but not for any multiple of 12, (7) can be written

$$\int_{x_0}^{x_n} ydx = \frac{h}{5}\left\{\frac{10}{7}(y_0 + y_{12}) + 8(y_1 + y_5 + y_7 + y_{11}) + \frac{80}{7}(y_3 + y_9)\right.$$

$$\left. + \frac{24}{7}y_6 - \frac{4}{7}(y_4 + y_8)\right\}.$$

No arithmetical work is saved by adopting this method of statement.

not affected by this process. The remainder, on the other hand, is inversely proportional to a power of the number by which h is divided, a power greater by one than the order of the retained derivative.

In order to test the accuracy of formulæ for mechanical quadrature it is clearly necessary to take a difficult example, for otherwise all reasonably good formulæ would show insignificant errors. For this purpose Bertrand selected

$$\int_0^1 \frac{\log(1+x)\,dx}{1+x} = \frac{\pi}{8}\log 2 = 0{\cdot}27219\ 826.$$

The curve in this case rises sharply from the origin, passes through a maximum at $x = 0{\cdot}7825\ldots$ and then approaches the x-axis asymptotically. In general form it resembles the energy curve of the spectrum.

I have taken the same example using 8-place natural logarithms and an 8-figure computing machine, and get the following table of results, in which I stands for the computed integral:

Formula	n	$I = \frac{\pi}{8}\log 2 +$
1	2	$+\ 0{\cdot}00181\ 206$
2	4	$-\ 0{\cdot}00002\ 363$
3	6	$-\ 0{\cdot}00000\ 545$
4	8	$-\ 0{\cdot}00000\ 154$
5	10	$-\ 0{\cdot}00000\ 060$
6	12	$\pm\ 0{\cdot}00000\ 000$
7	12	$+\ 0{\cdot}00000\ 001$

The results for (6) and (7) are very satisfactory, while those for the earlier formulæ could be greatly improved by taking n at a multiple of its minimum value. According to Bertrand, Gauss's formula for $n=4$ gives a result which is too small by 3 units in the seventh place, and thus tested it is intermediate in accuracy between (5) and (6).*

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* Rather curiously Weddle's rule applied to Bertrand's problem gives somewhat better results than (3). Furthermore, as this rule is deduced from Newton's interpolation formula, it appears to err only by a small fraction of the sixth difference, when the seventh difference is negligible. As here deduced from Euler's equation, the error should include fifth differences. While these facts are not incompatible, the relations seem to need confirmation, and I have integrated $e^x dx$ from $x=-1$ to $x=2{\cdot}6$, taking $h=0{\cdot}6$ and using values of e^x with 7 significant figures. By a separate computation I find the true value of the integral to be 13·09585 85938. Weddle's rule gives a value which is too great by 0·00064, while the value of the corrective term given in this paper for his rule is 0·00073, or about 9/8 of the real error. Formula (3) gives a value 0·00016 too great or 1/4 of the error of Weddle's rule and 2/3 as great as the value of the derivative term in (3).

As an application of the formulæ here developed I may mention the double integral of the probability curve. By any of the more accurate formulæ (2) to (7) it may be shown that

$$\int_0^x dx \left[1 - \frac{2}{\sqrt{\pi}} \int_0^x \epsilon^{-x^2} dx\right] = \frac{1}{\sqrt{\pi}}$$

or

$$\int_0^x dx \int_x^x \epsilon^{-x^2} dx = \frac{1}{2}.$$

In computing it 7-place values from Burgess's table were taken and the result obtained coincided with $1/\sqrt{\pi}$ accurately to 7 places. This integral is of interest in the analysis of diffusion.

Values of the probability integral itself are commonly arrived at by a somewhat intricate process, better fitted to yield a related set of values than a single one. By the formulæ given in this paper applied to tables of ϵ^{-x} isolated values of the probability integral are readily determined.*

To many experimental physicists calculus is a thorn in the flesh and a weariness to the spirit, partly, no doubt, because they so constantly have to deal with functions whose mathematical expression is unknown or uncertain. I take leave to suggest that mechanical quadratures may serve them to reach conclusions which mathematicians would obtain more elegantly but in a less obvious way.

But it appears to me that there is also room for a methodical examination by mathematicians of the applicability of formulæ such as are developed in this paper to the integration of functions which can not be integrated in "finite terms." In such an inquiry the main point would be to determine for each class of functions the limits of convergence of Euler's series and the nature of the substitutions most conducive to increase in convergence. I hope somebody may pursue the matter further.

Washington, D. C., April, 1911.

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* For $x=0{\cdot}7$, Burgess's table (Trans. R. S. Ed., vol. xxxix, 1900, p. 257) gives a value of the probability integral greater by 2 in the seventh place than that assigned to it in Encke's table (Asst. Jahrbuch, Berlin, für 1834). This is founded on Kramp's table (Analyse des réfractions astronomique et terrestres. Leipsic et Paris, an VII [1779]), and has been adopted by Airy, Kelvin, and others. A physicist not familiar with the history of these tables might wish to ascertain which value is correct, and this may be accomplished by the help of (5). With $h=0{\cdot}07$, seven-place values of $y=\epsilon^{-x^2}$ may be taken out of Smithsonian Math. Tables. Integrating by (5) and multiplying by $2/\sqrt{\pi}$ gives the required integral at 0·6778012, which is Burgess's value. If a computing machine is available, the arithmetical work is no more extended than in the example worked out in a previous footnote, and it requires no mathematical knowledge beyond that required for interpolation to one additional place in the table of the exponential, so that a schoolboy can do this "sum" on a single page of note paper.

Art. XIII.—*The Comparative Age of the Recent Crinoid Faunas;* by Austin Hobart Clark.

There is no point of more importance in the study of recent zoögeographic areas than the determination of their relative antiquity. Such a study must necessarily be based upon theoretical grounds; but there appear to be certain principles by which we may, if we are sufficiently cautious, be safely guided. These principles, as here stated, have been worked out chiefly through a study of the crinoids, though they appear to be applicable to the other marine groups, and probably also to many terrestrial forms. They concern the faunas solely in their physiological phylogenetic aspect, disregarding the external influences of immediate environment.

It must be borne in mind that faunal values vary very greatly in each class of animals, and often in the several orders in each class, as a result of varying reactions to physical, chemical and general economic environment. For instance, sessile or fixed animals would in each locality pass through a definite faunal cycle, such as we see indicated by the crinoids. Among pelagic animals, on the other hand, or among animals with a long free-swimming larval stage, faunal areas comparable to those delimited by the crinoids scarcely exist, and where they are indicated faunal cycles cannot be shown with any degree of certainty. This is due to the continual replenishing of areas, either directly or, as it were, by relays of generations, from a distant source, which, at least in some cases, is probably correlated with a back current carrying to the original source the young of animals which for many generations have lived in a distant area. Thus any change affecting the animals in any particular area would be extremely slow in affecting the species as a whole, for it would be dissipated over such an extent of faunal territory that its influence would be largely counteracted before it could acquire any headway.

Many species inhabiting deep or cold water are recognized as the deep or cold water forms or varieties of other species living in shallow water near shore. It is probable that at least in some of these cases the difference may be caused by physiological changes due to a deep or to a cold environment acting upon the developing young of a single generation, something as the color pattern of butterflies is changed by exposure to heat or cold at the time of pupation. If this were true, such deep or cold water species would have no faunal significance, no matter how great the significance of species associated with them might be, for their character and development would not be due to anything inherent within themselves, but would be quite dependent upon the development of the parent species under the more normal conditions.

Every marine fauna is composed of more or less permanently fixed animals (the most strictly sessile being the crinoids), purely pelagic animals, and animals representing all the intermediate stages. Each class probably has a special faunal cycle of its own independent of all the others, and independent of the systematic affinities of each of the species included in it.

Therefore, to apply the principles governing the development of faunas to a given fauna, we must first of all be familiar with the life history of each of the component types, and of the scope of its tolerance to changed conditions, most weight being given to the facts indicated by the most strictly sessile animals and those most intolerant of any change in their environment (among recent forms the crinoids), and the least to those pelagic species which appear capable of existing anywhere.

Faunas, like individuals, species and genera, pass through a period of youth, of adolescence, of maturity, and of senescence.

In a very young fauna the various genera are represented by several species each, and each of these species is very variable; all of the species are near the mean in their respective genera, none being highly specialized and none retrogressive.

Introduced species which become acclimated and thrive in their new surroundings are found to be, where they have been studied, exceedingly variable. This is equally true in regard to fish, birds, mammals, molluscs and insects, and probably holds good throughout the animal kingdom. We have numerous illustrations of this in such animals as have been introduced into North America from Europe, Africa and Asia.

A young fauna is in effect a fauna composed of species all of which are recently introduced, and all of which, maintaining themselves under optimum conditions, with a minimum of parasites and a maximum of food, are able greatly to increase their coefficient of variation.

Such a fauna we appear to have in the Bering Sea. The crinoids of the shallower waters here are abundant, but all the species, which are very variable, belong to the genus *Solanometra*, an intrusion from the antarctic regions. Of the other echinoderms the starfish present a wealth of forms maddening to the systematist; the number of varieties and incipient and valid species produced from the *Ctenodiscus*, *Hippasteria*, *Solaster*, *Henricia*, and other types, is almost incredible. Conditions are the same among the echinoids, and among the ophiuroids, and apparently among many, if not most, other animal groups as well. Yet with all this variability there is but a slight tendency to produce pathological, defective, or unbalanced types, types which depart widely from the genera mean as calculated from a study of the same genera in other areas.

Although the Bering Sea fauna is the nearest approach to a young fauna which can be found, yet there are a few distinctive genera which show an approach to the next epoch of faunal existence.

So far as the crinoids are concerned, the antarctic region is very young; here we have *Solanometra* and *Promachocrinus* (the latter merely differing from it in the doubling of all the radials), each with several very variable species, though none so variable as the Bering Sea representatives of the same group.

Adolescent faunas exhibit a comparative stability of specific types, coupled with the incipient formation of new genera as a result of a growing tendency of the species to depart widely from the generic mean.

The crinoid fauna of southern Japan might be considered as an adolescent fauna; here we find many genera including several species, each very stable and showing comparatively little variation, such as *Catoptometra*, *Comanthus*, *Dichrometra*, *Parametra*, *Pectinometra*, *Thaumatometra*, and *Pentametrocrinus*, while *Erythrometra*, *Nanometra*, *Calometra*, *Carpenterocrinus* and *Phrynocrinus* are not known elsewhere, though the two last, being from deep water, probably occur to the southward.

In mature faunas the species are fixed, save only for the species at the mean of each genus, which always remains variable, and new generic types are found which have become separated off from the parent genera through the suppression of intermediates, or have arisen by discontinuous variation. As a result of the formation of these new generic types, the number of species in each genus is diminished, and the species are found to approach more or less closely the means of the original genera, or the means of the genera newly formed.

The West Indian crinoid fauna appears to be approximately a mature fauna. It contains a number of peculiar genera, such as *Hypalometra*, *Coccometra*, *Leptonemaster*, *Comatilia*, *Microcomatula*, and *Analcidometra*, while almost all of the East Indian genera which occur here have become more or less differentiated from the original stock, forming new genera parallel to the original East Indian types. In several cases single East Indian genera have given rise to two or more West Indian genera, as *Comissia*, from which *Comatilia*, *Microcomatula*, and *Leptonemaster* appear to have been derived, as well as two other genera which up to now have remained undescribed.

Senescent faunas have lost a considerable proportion of the genera which they possessed at maturity; the genera which remain include aberrant species in which certain characters have become greatly exaggerated, giving those species a curiously unbalanced appearance. There is typically but a single species in each genus; but there may be two or more, each with a different set of characters exaggerated, in which case they are usually treated as aberrant monotypic genera.

The Australian crinoid fauna is a perfect example of a senescent fauna. It includes about fifty species, nearly all of which are remarkable for the grotesque exaggeration of their specific characters. Even in certain wide-ranging forms, as *Comatula solaris*, Australian specimens have their characters greatly increased over those from other regions.

Some examples of this exaggeration of the specific characters which make the Australian crinoid fauna unique are: the secondary development of biserial arms, indicated in *Comatulella brachiolata*, but not known outside of that genus, which is confined to southern Australia; the development of excessively short cirrus segments and pinnules, also peculiar to this genus; the development of very slender cirri in a comasterid, only found in *Comanthus trichoptera* from southern Australia; the development of twenty armed species of the normally ten armed genus *Comatula;* the occurrence of heterotomous arm division, unique among the comatulids, in the same genus; the development of enormous processes on the pinnule segments, seen in *Comanthina belli* and *Oligometra carpenteri*, representing two widely different families; the development of a very large centrodorsal bearing cirri irregularly arranged in a genus of Thalassometridæ, *Ptilometra;* excessive reduction of musculature in the same family, illustrated by the same exclusively Australian genus; incipient suppression of side, covering, and other perisomic plates, seen in the same genus; extraordinary development of interradial plates in adult comasterids, as seen in *Comanthina belli* and *Comaster multifida;* complete plating of the disk, dissociated from the development of side and covering of plates, as seen in *Zygometra elegans*, *Z. microdiscus* and *Z. multiradiata;* greatly enlarged lower pinnules in a zygometrid, as seen in *Z. miciodiscus;* very small lower pinnules in a zygometrid, as seen in *Z. multiradiata;* aberrant zygometrid arm division, as seen in *Z. elegans.*

A pathological fauna may resemble a senescent fauna in its general facies; but in a pathological fauna all the species, besides being aberrant, are excessively variable, which is never the case in a senescent fauna. Pathological faunas occur usually on the limits of faunal areas, or on the boundary between two very different faunal areas, and are composed in the latter of intrusive species from both the adjacent areas. Many of the animals in Massachusetts Bay, at least in the southern part, indicate a pathological fauna. This is shown by a study of the local species of almost any of the echinoderms, which exhibit an unusually large proportion of abnormalities and aberrant variants of all sorts.

Occasionally faunas are found which combine the characteristics of two or more of the stages described above; these are rejuvenated faunas, faunas which have progressed to the extreme point indicated (or perhaps slightly further) and then have been subjected to some change in environmental conditions which has served as a stimulus, and set a greater or lesser part of the fauna some distance back along the phylogenetic faunal path.

Such a fauna we find indicated by the crinoids about the shores of the large East Indian Islands; some of these approach, in the exaggeration of their specific characters, the Australian species, while others are very generalized, with several closely related species. The crinoid fauna of western Europe is also a rejuvenated fauna; it is composed of two genera, *Antedon* and *Leptometra*, both very close to East Indian genera, the former with five species, three highly specialized and two primitive, the latter including two species, one specialized and one more primitive; in each case the more primitive species occur in the Mediterranean.

It is possible to analyze a fauna on the basis of a single character in a group. Let us take, for instance, the character of the centrodorsal in the Comasteridæ. This organ differs in the several genera and species composing the family only in the degree of specialization, the developmental lines being everywhere the same. In some species, as in *Comanthus bennetti*, the centrodorsal always remains essentially as in the young, but increases in size throughout the life of the individual. Usually, however, resorption takes place at the dorsal pole which is gradually planed off, as it were, so that the centrodorsal changes from the primitive hemispherical form and becomes discoidal, the rows of cirri dropping off as the sockets are resorbed. In extreme cases the resorption results in reducing the centrodorsal to a thin stellate plate, without any traces of cirrus sockets, countersunk within the center of the dorsal surface of the radial pentagon.

We may arrange all comasterid centrodorsals in a linear series, calling the least developed (*Comanthus bennetti*) type A, and the atrophied stellate disk D, B, and C denoting intermediate stages.

Now the species of the Australian fauna have centrodorsals which run from A to D, but with especial emphasis on the D; the species of the East Indian fauna also run from A to D, but the emphasis is between B and C; the Japanese species run from A to C, with especial emphasis at B; the West Indian and east African species are confined between B and C. This holds good regardless of the subfamily or genus to which the species may belong, and exactly the same thing may be worked out in regard to other characters in this family, and with other characters in other families.

The recents crinoids of the Australian coasts are evidently senescent; they unmistakably indicate very great age. So complete, in fact, is this senescence that almost every species is affected. The crinoids of Australia came from the northward, from the great East Indian archipelago; but here continual changes in the distribution of the land and sea have constantly rejuvenated the fauna so that none of its component species has been permitted to drift into the peaceful old age so obvious in almost all the species along the Australian shores.

The fossil crinoids of Europe (belonging to genera still existing) appear to be senescent; but they are no more so, if as much, as are the recent crinoids of Australia. Judging from the evidence offered by the recent forms alone, the European crinoids reached the European seas by passage from what is now the Bay of Bengal north of what is now India. It was probably before this that the same genera spread southward from the parent central East Indian region to Australia.

The crinoids of southeastern Africa represent a comparatively young fauna; they must have reached their present habitat by passage southwestward from Ceylon along a land bridge since submerged; but few of them have as yet entered the Arabian Sea.

The West Indian fauna is younger again than that of the southeastern shores of Africa, from which it was derived. It must have reached the West Indies by following a land which extended from Madagascar to the Antilles, north of what is now southern Africa.

The fauna of southern Japan is very young, apparently younger than that of the West Indies.

The central sea connecting the Bay of Bengal with central Europe had an arm stretching northward across Russia. Certain adaptable genera, becoming acclimated, followed this arm northward and gave rise to the present arctic fauna. More recently one of these arctic genera has spread southward over the north Atlantic.

At a considerably later date a connection was formed whereby the East Indian crinoids, becoming slowly acclimated, reached the antarctic regions. There was also a connection between the antarctic regions and southern South America, whereby these forms secured a foothold on the western coast of that continent, spreading rapidly northward to the Aleutian Islands (dipping downward into deep water when passing under the tropics), and thence southward along the eastern coast of Japan, as far as Tokyo Bay.

This antarctic fauna is apparently the youngest of all the recent faunas, and the evidence of youth increases as we go northward along the west American coast.

U. S. National Museum, Washington, D. C.

Art. XIV.—*A Study of Some American Fossil Cycads. Part V.* Further Notes on Seed Structures*; by G. R. Wieland.

[Preliminary publication by permission of the Carnegie Institution of Washington.]

Mainly in recent years through the continued study of the wealth of fossil plants in the remarkable calcareous nodules or "coal balls" of the Coal measures of England by the English group of Paleobotanists, has the list of ancient seeds illustrated in detail become a long one. In fact, material has so augmented as to make the investigation of fossil seeds a subject of considerable scope and even unique fascination and promise.

So far, however, the best known old seed types are chiefly gymnospermous and Paleozoic with the notable exception of the Mesozoic Cycadeoideas. But fortunately whatever the latter lack by reason of isolation they more than make up by abundance and exquisite preservation in a half dozen different species. Not only is the structural representation ample, but the number of mature strobili now runs into the thousands. In fact the subject of Cycadeoidean seeds has assumed a continuous interest. For in addition to the mature seeds we have the seeds well outlined in many young strobili varying in size all the way from a pea to a small pear, as well as a proembryonic stage, considered present in one form (*Cycadeoidea Macbridei* ? Y. S. 131); while the fully developed dicotyledonous embryos are finely conserved and have now been seen by thousands!

Yet for a number of years following Carruthers' (1) description of *Bennettites Gibsonianus* such material seemed exceedingly rare, and it was not until 1894 that the isolated fruit *Bennettites* (Williamsonia) *Morièrei* (found by Morière in 1865) was finally described by Lignier (3) in a memoir which still retains its place as the most accurate detailed account of the Cycadeoidean seeds so far given. Five years later the first observation of seed cones on American trunks was announced by Ward (5) and Wieland (6), while in the latter's volume on American Fossil Cycads (8) a glimpse was had for the first time of the great extent and variety of ovulate fructification in the American species.

And now, as if nature designed for the student of gymnospermous seeds "a beauty beyond compare," there has recently been found near Hermosa in the eastern Black Hills Rim, by Doctor Darton of the U. S. Geological Survey, half of a truly monocarpic trunk now in the collections of the U. S. National

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* Parts I-III of these studies appeared serially in this Journal for March, April, and May, 1899, and Part IV in June, 1901.

Museum. Even as illustrated by Professors Coulter and Chamberlain in their new book on the Morphology of Gymnosperms, in only a single small text figure this specimen shows something of its extraordinary characters. But on inspecting the original, one can have but the single first thought—that the fossil record can become rich indeed!

From the sections of the Boulder (Colorado) trunk *Cycadeoidea nigra*, made some years ago, it was determined that a peduncle was present in every leaf-base axil, but the fruits had protruded beyond the zone of silicification. The general resemblance of this form to the Italian *Cycadeoidea Masseiana* was pointed out in my American Fossil Cycads; and more recently we have been enabled, through the interest of Capellini, to cut sections from this Italian type proving that it belongs to the series with fruits in every leaf-base axil, except that these fruits are very young. So, too, it was pointed out that in *Cycadeoidea Stantoni* axillary buds complement the entire leaf-base series. But though it was thus observed that in Italy, in the Black Hills, in California trunks of monocarpic habit were characteristic members of the Cycadeoideæ and doubtless could be conserved with all their fruits, none of the known localities gave much promise of yielding such an unique and marvellous fossil.

However only a casual examination of the Darton specimen showed it to have small-sized but evidently quite mature seed cones but little different from those of *C. Wielandi*, in the axil of most leaf-bases far up towards the apex of the trunk, and apparently occupying all of the lateral trunk surface that ever would be available for the production of fruits. At least no trunks are known with old peduncles in the basal region and a clearly young series of fruits above, while the trunk *C. turrita*, illustrated in American Fossil Cycads, Plate V, fig. 5, with the regularity of its leaf-base spirals disturbed by but a single ovulate cone was at once recalled.

On plotting the lateral surface of the Hermosa specimen it at once became evident that even the half trunk as collected bears from 500 to 600 ovulate cones, thus exceeding all records in fossil plants; and on cutting sections from a portion of the armor, which I was kindly permitted to break away for examination, so far as bearing on my comparative studies, the conclusion from the microscopic examination was fully confirmed.

That the armor portion selected, though completely coated over with lime, must contain concealed fruits was confidently expected. None the less the surpassing beauty of the sections obtained was scarcely anticipated. The first section cut, a transverse one, showed the entire lateral surface to be occupied by strobili, as it revealed three entire and two nearly entire axillary ovulate strobili, with but two of the five complementary leaf-bases; and with the cones thus located an equatorial armor section was at once cut through the summits of three adjacent ovulate cones. In all the cones the mineralization is, after the manner of silicification, not so distinct as calcification, but yet excellent, and nearly every seed contains a mature embryo, not so well conserved as those of Yale trunk 131,* but yet showing quite satisfactorily the character of the embryonic tissues. Especially valuable for purposes of comparison are these embryos, because little shrunken, and with the epidermal cells nearly always more or less distinct. Other sections of *Cycadeoidea* embryos showing more of detail we have in abundance, but none more beautiful than these.

In continuing the elaboration of material for the volume on the Taxonomy of the American Fossil Cycads, now in course of preparation under the auspices of the Carnegie Institution of Washington, many new strobili have been cut during the past year. Also, in addition to the strobili cut from the new Black Hills trunk, I have made seed sections of *Bennettites Gibsonianus* of the Isle of Wight, and already had at hand the sections of *Bennettites Morièrei* obtained from Professor Lignier as related in my American Fossil Cycads. In short, there has thus been brought together a representation of all the forms so far known; and on the basis of this complete representation it has been found very desirable to simplify ideas of the structure of the testa in the Cycadeoideæ, not alone for the purpose of forwarding present studies, but of making the paleobotanic text on this subject short and satisfactory.

As is always inevitable in the case of a complex fossil plant structure, the different types of mineralization, in this instance nature's own variation of her staining and imbedding methods (!), result in slightly different interpretations in the hands of different investigators. What with this factor and different modes of illustration or study of areas and features seldom taken from the same region of a seed, or showing variation of a given region in one and the same seed, it becomes all too easy to suspect greater differences in even a small group of species than actually exist; while meantime certain salient features are likewise easily overlooked. So it has proven in the case of the cycads, though of simple enough structure on closer study. In order, consequently, to bring out a fundamentally clear comparison of all the seeds, American as well as European, showing the best testal conservation, camera lucida drawings have been made of longitudinal sections at a

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*Illustrated in American Fossil Cycads, Plate XXII.

point about one-third of the distance from the base to the tip as reproduced in figures 2 and 4. Before taking up these, however, it is highly desirable to briefly recall the several interpretations of the *Cycadeoidea* testa.

According to Carruthers' (1) original study given forty years ago:

> "In *Bennettites Gibsonianus* . . . Two envelopes enclose the albumen and embryo. The outer envelope or testa, consists of a thin layer of delicate elongated cells; the inner is composed of a single layer of oblong cells arranged with the longest diameter at right angles to the walls, and indurated by a considerable amount of secondary deposits. . . . two coverings were produced upwards into a tubular exostome or styliform process . . . spread out like a stigma in the upper surface of the pericarp."

In this description and illustration of the general features of the seed the layer of collapsed fleshy cells immediately beneath the indurated layer is not mentioned, Carruthers then going on to say that,

> "Enclosed by these envelopes is the nucleus with its membranous covering and abundant albumen . . . the subrectangular cells of which are obvious in several seeds. . . . The albumen was solid behind the embryo but was divided from top to bottom down its center, in front of the embryo."

Here we have unmistakably clear allusion to embryonic features and tissue; for the supposedly albuminous "subrectangular cells" are simply the cotyledonary epidermis and mesophyll, uniform in appearance and peculiarities of preservation, in the embryos of *Bennettites Gibsonianus*, *B. Morièrei* and several American specimens, all known in satisfactory detail.

In the next description of these cycad seeds, that of Solms-Laubach (1890), the embryos were, however, clearly recognized, and the testal structure described as follows:

> "Three distinct testal regions are to be noted, a basal, middle and apical.
>
> "In the middle region of the seed the testa is closely appressed to the nucular membrane, and wherever well conserved three distinct layers may be recognized, the middle layer of which is simply a single stratum of short prismatic palisaded thick-walled, dark-brown cells; while the inner and outer layers consist in several thicknesses of rather small thin-walled tissue.
>
> "The tissue of the inner layer is mostly crushed and indistinct, while that of the outer layer appears as a light area following the palisade layer, and finally passes over into more or less distinctly confluent growth with the walls of the seed cavity. At least a distinct boundary appears but discontinuously. . . .

"In the apical region of the seed the testal layers were found most difficult to delimit owing to a lack of sections traversing the long and slender micropylar tube in the true median longitudinal position, and the large amount of pyrite investing the peripheral tissues of the strobilus in irregular areas."

In no form are the testal features conserved with more of diagrammatic clearness than in the French specimen *Bennettites Morièrei*, Lignier's description of which soon followed that of Solms as already mentioned. In fact the seeds of this isolated strobilus are conserved in such unrivalled perfection as to leave nothing more to be desired except the recovery of a second example, and make us anxiously ask if French collectors have really sought for further material in the original locality as diligently as they might. From the description of Lignier (1894) which enters into much detail we need not, however, quote in full in the absence of a series of photomicrographs. Though before passing on to the American seeds it should be mentioned that the limiting region between the seeds and surrounding scale-formed seed pit, which as we have just seen Solms found difficult to see in *B. Gibsonianus*, is always distinct in *B. Morièrei.* In any of the sections from the latter one may clearly see that the appearance, as of a peripheral confluent growth of the seed wall with the interseminal scales, is due to appression and the failure of the scales in places to develop their epidermal layer continuously. There thus arises a *pinching out* into a single ribbon-like layer of interseminal epidermis appressed closely to the very outermost cells of the seed. The condition does, however, show how, as the result of close growth and suppression of epidermal cells, a form of intergrowth could easily arise. Quite the only structural feature of the testal wall that Lignier leaves in doubt is the nature of the middle layer, whether stony, or, as he is inclined to believe, fleshy. On this point it is, however, reserved for the American species to throw a clear light, and to comparisons with them we may now turn.

*Comparison of testal structure in the American and European Cycadeoidean seeds.**

On comparing the descriptions of the testa already quoted, namely those of Carruthers (1), Solms (2), and Lignier (3), with each other, and with those given for the American seeds by the writer, a most substantial agreement within strict generic limits will be found and the differences due to conser-

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* In these comparisons the names of testal features and seed parts proposed by Oliver and Salisbury (11) are employed, having been found convenient and usable, while a close reading of the present text will disclose one or two extensions of this necessary *nomenclature of use.*

Fig. 1.

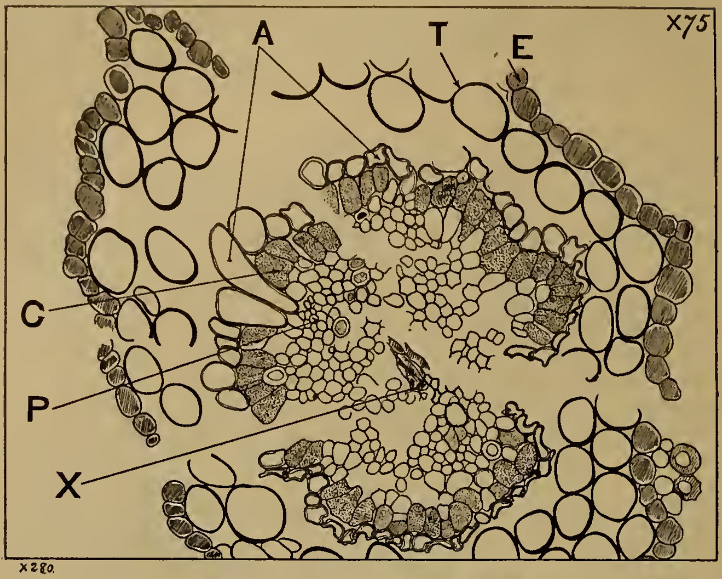

Fig. 1. *Bennettites Morièrei* type (Sap. et Mar.). × 75.

Transverse section of seed stem traversing point of greatest constriction exactly where expansion into the hilo-chalazal region begins (Camera lucida drawing reduced from × 280).

X, xylem or central tracheid region surrounded by stem ground tissue;

P, small celled outer ground tissue;

C, stained layer = "*assize colorée*";

A, imbricate to pleated layer = "*assize plissée*";

T, tubular cells of cortical region forming exterior of seed stem, and basal husk of seed;

E, outer woody layer of the enveloping interseminal scales.

As connoted the layer *E* is the ligneous epidermis of the five to six interseminal scales which completely enclose the seed-stem, being thus no true part of the testa, though often splitting off with the seed, and sometimes approximating a confluent growth.

The elements of the testa here appear in their simplest form, the section passing precisely through the transition region where the radio-symmetric seed-stem bundle passes over into the seed-base and testal structures. The xylem (*X*) is exactly on the point of expanding to form the cup-shaped base of scalariform tracheidal tissue supporting the nucellus, though still deeply enclosed by the fundamental tissue of the seed stem. In the mass of the latter, however, various resin cells characteristic of coniferous seed-base tissue (*Sequoia*, etc.) begin to appear, and peripheral groups of small cells basal to the inner flesh lie next to the conspicuous zone of resin filled cells (*C*). The latter gives origin to the middle zone of the testa and is strictly homologous with the gymnospermous "middle stone," though taking precisely the same mineral stain as the resinous cells scattered in the ground tissue about *X*. The third concentric layer, *A*, also a single cell in thickness, must be the continuation of the endodermis of the seed-stem bundle; it gives rise to the true outer flesh analogue, in this seed none other than the so-called "blow off" layer of the Carboniferous seed ferns. Finally the rapidly thinning and fraying zone of large, stringy tubular cells (*T*) is noted as the well-conserved continuation of the cortical region of the seed stems, which takes origin on the strobilar receptacle as a much thicker zone of small cells.

(From a section cut by Professor Lignier.)

vation will fully appear, if these two explanatory paragraphs be borne in mind:

Firstly.—The comparative study of all the known *Cycadeoidea* seeds and a fairly extensive list of existing gymnosperm seeds, shows that the middle layer of the seed wall is essentially a stony, rather than a merely indurated or suberous layer, and much thicker in *Bennettites Morièrei* than in any American species. Professor Lignier's description of this layer as fleshy was given with some reservation, and it is merely necessary to note that the stony layer shows varying degrees of induration in allied species, throughout the gymnospermous series.

Secondly.—In referring to the writer's own descriptions of testal structure, as given in his American Fossil Cycads with too few figures, all stress must be laid upon the fact that the seed is there spoken of as it probably appeared on splitting loose—as a shed seed—and that the form primarily dealt with is *Cycadeoidea Wielandi*, which has only traces of ribbing and now proves to have the most reduced testal structure known, being almost, or wholly, without an outer fleshy, or "blow off layer." Better sections from cones of other species show well-marked ribbing and a heavy "blow off" to be commonly present in the Black Hills Cycads. But so far there is no instance in which this structure shows the fine detail in any silificied specimens that it always exhibits in the ferrized *B. Morièrei.* In fact, the middle or indurated zone appears to have been far more susceptible to preservation by silicification, whereas the outer or "blow off" layer of the seed is infinitely better stained and conserved by iron carbonate. We think no one who sees the original preparations can fail to be struck by this complementary reaction of the outer flesh and middle stone to these two types of mineralization, as seen in the Calvados strobilus and the Black Hills fruits.

This explanation, then, entirely clears the way to a complete understanding of the similarity of testal development in the American and European fossil cycads. The seeds of the Cycadeoideæ containing embryos vary from one centimeter in length in *Amphibennettites Renaulti* of Fliche (4), to three or four millimeters in length in the smallest American forms, and there is a remarkable homogeneity in the testal features of the entire group. In fact, short of close study, the only differences discernible are in the ribbing and size of the seeds with some variation in the thickness of the tissue zones of the seed wall, which is normally three layered with a distinct middle stone. The outer flesh alone may, however, exhibit, aside from peculiarities due to the unusual manner in which the seed is completely encased in the solid husk of interseminal scales, marked reduction or even elimination.

Fig. 2.

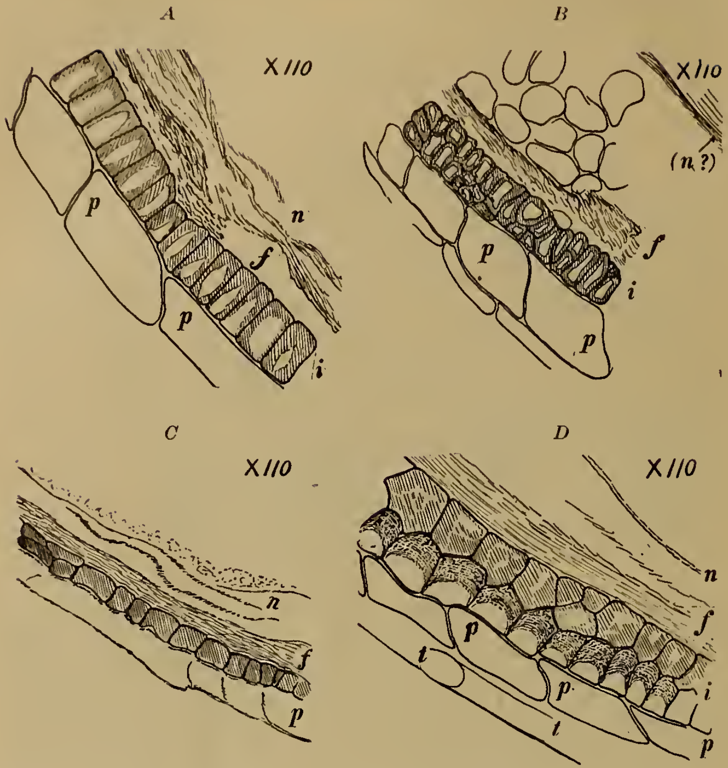

Fig. 2. Longitudinal section of Cycadeoidean testas at point two-fifths of distance from base to apex. × 110.

A. and *B.*—*Bennettites Gibsonianus* (type). Two seeds from one and the same cone. Lower Greensand, Isle of Wight.

C.—*Cycadeoidea* sp. (*not C. Wielandi*). Wealden equivalents (Lakota) of the Black Hills.

D.—*Bennettites Morièrei* (Sap. et Mar.). The type from Oxfordian or more likely Lower Cretaceous (cf. Lignier) of Calvados, Normandy. *Cf.* Fig. 3*B*.

i, indurated layer arising from *c* of fig. 1;
p, the outer fleshy or "blow off" layer arising from A of fig. 1 and expanding into five or six alæ near apex, sometimes forming horns;
f, collapsed tissue of inner flesh;
t, tubular cells forming lax or frayed husk, whence these cells may or may not appear in the longitudinal section; =*t*, fig. 1.
n, the nucellar sack tissue, always quite susceptible to silicification.*

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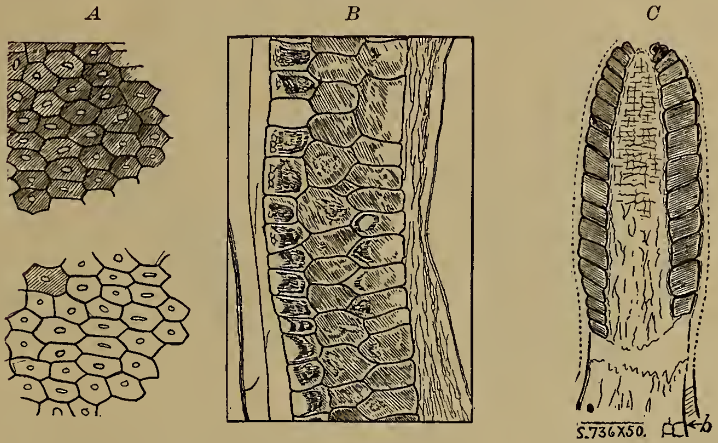
* Between the inner flesh (*f*) in various American seeds, and the nucellar sack (*n*), as well as in the seed of *Bennettites Gibsonianus* (B) often occur loosely compacted large cells, supposed to be nucellar contents (pre-embryonal tissues). In the initial course of silicification collapse of the

Of the several species *B. Morièrei* has distinctly the heaviest walls, *B. Gibsonianus* walls of intermediate thickness, and some of the American seeds the thinnest walls of all, though there is essential agreement in testal structure extending to the cell types of the three component layers.

To show this structural similarity and to further bring out minor details proving that in *Cycadeoidea* we deal with a genus of world-wide distribution and long persistence in time, I have made the series of camera lucida drawings shown in

Fig 3.



A.—Cycadeoidea turrita (?). Tangential section through the sclerotesta. × 88. The basal walls of these cells are far thicker than the lateral and tangential walls; the cell interior varies much in appearance, or only the solid base may appear. Again, the outer face may show a marked central concavity.

B.—Bennettites Morièrei (Sap. et Mar.) type. × 88. Longitudinal section of testa traversing valley below the shoulder where ribs first become prominent. Compare with fig. 2D.

C.—Cycadeoidea Wielandi. S. 736. T. 393. × 50. Longitudinal section of micropylar tube in seed type without distinctly developed "blow off." Palisaded wall in continuation from middle stone. Interior space filled with soft squarish cells, in bulk producing somewhat cancellated appearance. Dotted line shows limit of exterior surface, the thin outer layer failing of conservation.

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inner flesh would favor rupture of the nucellar sack with more or less dispersion of such rounded cells, but this explanation is tentative.

The close agreement of the two European species and the American forms retaining the "blow off" layer is noteworthy, while the two seeds of *Bennettites* showing difference in the indurated layer, as seen in about the same region of the testa, suggest the character of longitudinal fluting, and completely bridge the slight structural gap between the commoner American form C, and *Bennettites Morierei,* no more than mere specific differences appearing.

text figures 2, 4, from the equatorial region of the seed. These include all the best known forms, the seeds of *Cycadeoidea dacotensis* and of *C. excelsa* and *Jenneyana* excepted, as these have not so far been found well enough conserved to permit such drawings; though it can be seen from their general form and amount of testal development, which are well known, that they too agree within generic limits.

In comparing these drawings it must always be remembered that the seed wall is a more or less appressed one, as the result of enclosure by the five or six to as many as eight or ten interseminal scales forming the pocket in which the seed lies. Also both outer flesh and stone normally thicken markedly toward the shoulder and about the basal region of the micropylar tube to form a ribbed or even-tentacled *corona*. But while these *coronal ribs* may tend to disappear in some species, or may somewhat conform to surrounding scales, *an original and fixed number is in reality always present and representative of the species.* Furthermore the ribs may even send up a low crown of tentacle-like projections about the base of the micropylar tube, though it is only after studying the sections very attentively that one comes to see this feature, which, could one see a loose seed, would be very distinctive indeed. In short, we have to do with somewhat appressed vestigial lobes as unmistakable as those of *Physostoma.*

Lateral Testal Envelopes.—As already observed the "*enveloppe tubuleuse*" of Lignier, or cup-like husk formed by the extension of the cortex of the seed pedicels all round the seed base, tends to disappear. The really complex structure of this envelope has been conserved with diagrammatic clearness in *B. Morièrei,* where it is clearly seen to consist in an underlayer, the "*assize plissée,*" really the base of the "blow off," and a distinctly tubular outer layer which is not found continuous all over the surface of the seed, though its cells are markedly susceptible of preservation. But in strong contrast and clearly proving reduction, fig. 4A is an accurate enough drawing of an American seed in which too few tubular cells to show appear to rest on the middle stone, while there is no appreciable preservation of the inner part or "*assize plissée*" and its apical continuation as a strongly palisaded tissue, "*assize rayonante*" or "blow off." This condition is, however, exceptional, but one species showing so much reduction.

Once more in examining transverse sections of American species a doubt may arise as to whether the outer layer of the seed is not actually confluent with the interseminal scales as Solms supposed it might be in places ("Stellenweise") in *Bennettites Gibsonianus.* But this, it is thought, may be due in part to the fact that there are in the interseminal scales

Fig. 4.

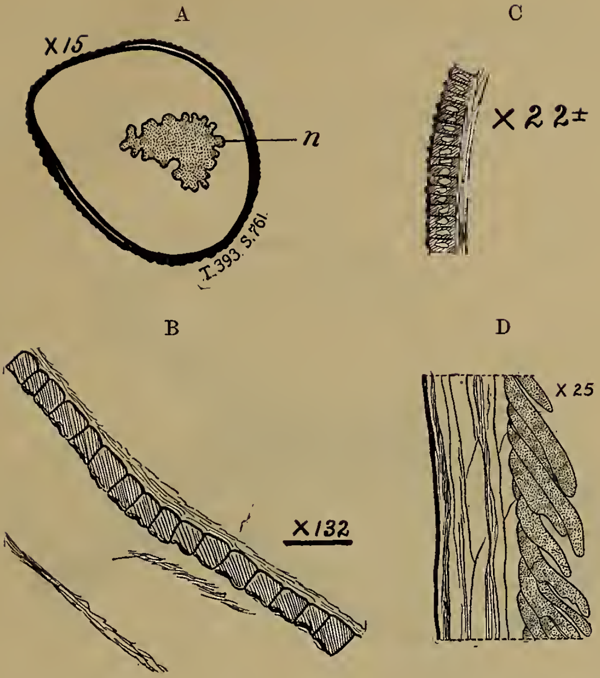

Fig. 4. Seed walls of *Cycadeoidea* (*A* and *B*), *Lagenostoma Lomaxi* (*C*), and *Physostoma elegans* (*D*), contrasted.

A.—Cycadeoidea Wielandi. This seed as described is without an outer fleshy or "blow off layer," although the inner flesh and the middle sclerenchyma have precisely the same development as in the other *Cycadeoidea* seeds.

B.—Cycadeoidea Macbridei (?), with thick blow off layer very poorly conserved. The sclerenchyma layer of squarish cells with their inner basal wall heavy, and the flattened inner flesh zone correspond to the outer notched and inner smooth line of *A*.

C.—Lagenostoma Lomaxi. Longitudinal section from above the cupule showing the inner flesh and mid-sclerenchyma with peg-like projections on tangential wall suggesting that an outer "blow off layer" may have failed of conservation. The structure is essentially similar to that of the most reduced of the *Cycadeoidea* seeds as shown at *A*, although about in proportion to the size of the seed both flesh and sclerenchyma are much thicker. (Redrawn from Scott.)

D.—Physostoma elegans. Longitudinal view of seed wall exactly showing the "blow off layer" as stippled-in cells to the right, but slightly generalizing the complex fleshy tissues between this layer and the nucellar sac which appears as a dark line to the left. Original drawing introduced to show the droop of the "blow off layer" as a peculiarity also seen in *Cycadeoidea*. In other respects interesting as a seed of ancient and complex character, between which and *Lagenostoma* there is in actuality a much greater structural gap than between this latter and the *Cycadeoidea* seed type, although the seeds of all three must be regarded as having analogous structures.

groups of sub-epidermal cells much like the tubular cells of the seed cortex or outer "enveloppe tubuleuse" and that moreover there is often next the seed an exceedingly thin extension of the epidermal layer of the interseminal scales. There can be no final doubt as to where the seed wall ends and the enclosing scales begin.

Middle Stone.—Following interiorly to the outer flesh analogue or "blow off" layer as so much subject to variation

FIG. 5.

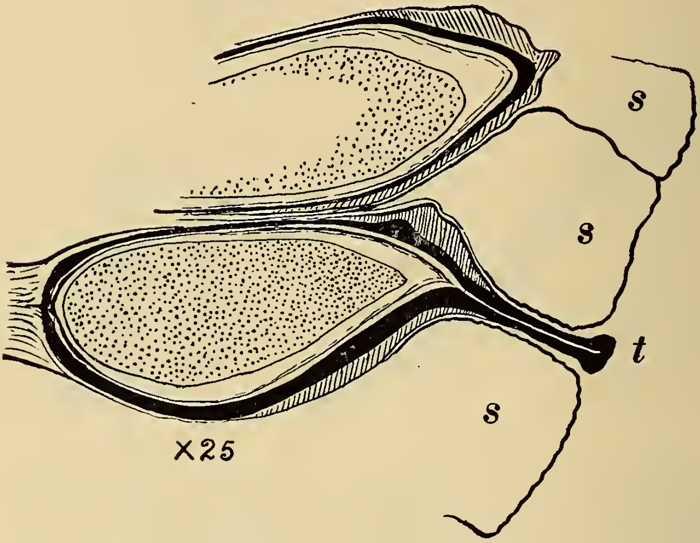

FIG. 5. *Cycadeoidea turrita* (?). Black Hills. × 25.

Longitudinal section through ovulate cone traversing two adjacent seeds. The upper seed is cut tangentially, and the lower one in the nearly true median vertical plane. The micropylar tube is here accurately cut throughout its entire length, and the section passes through two opposite ribs. Only at the seed base is the section a little eccentric, but owing to the small size of the seeds only a few out of a great number will be found so nearly cut in the median plane as the present seed and that in the following fig. 6 *A*.

to form ribs and coronal appendages characteristic of the various species, the middle stone is found far more constant; yet the figures 2A and 2B from seeds of one and the same cone of *Bennettites Gibsonianus* at once show that this layer also shares in rib formation and regionally varies much in the size of its cells. Its thickness as dependent on ribbing varies from one cell in the lateral region to several or more cells as the ribs form in the upper and shoulder region of the seed and converge towards the micropylar base.

In the American species the stone layer is usually very thin, but quite distinctly indurated,—silicification in reality showing density of walls better than other types of conservation. The cells of the stone superficies appear to have had a very thin tangential wall, even subject to collapse, so as to sometimes simulate a series of flattened hexagonal cups with very heavy bottoms and sides thinning a little toward the top. In the French specimen it is the cell contents rather than the cell walls that appear to have " taken the stain," and this produces a certain appearance as of a decidedly fleshy tissue especially in the outer cells bearing the "*blow off*." But what the true nature of the tissue is cannot rest in any doubt; for it is as we see often highly indurated in the American specimens, and nearly as much so in the Isle of Wight specimen. While, as I fully believe, the slightly less indurated condition seen in *Bennettites Morièrei* is quite exactly paralleled by the middle layer in *Pinus resinosa.* In considering any mineralized tissues, moreover, it is occasionally necessary to note that the staining could exhibit the cell contents rather than the cell walls, which might finally fail of clear outline and be replaced by structureless mineral.

Inner Flesh.—The inner fleshy layer or tissue region lying between the stony region and the nucellar sack is of about the same breadth as the stony region in all the Cycadeoideæ, bearing in mind the reduced testa in the American *C. Wielandi* where both these coats are very thin. In no instance, however, is the inner flesh distinctly enough conserved in the lateral region of the seed to permit camera lucida drawings, or even photomicrographs showing it other than as a clearly outlined zone of soft crushed tissue. But in the Normandy seeds preservation is often diagrammatically clear near the seed base where this zone is from three to about seven cells deep, with the outer cells elongate, and flat squarish to rounded forms on the interior. The nature and succession of the testal elements is clearly illustrated in the transverse section through the radiosymmetric seed base shown in fig. 1, where the relation to the central bundle is still clear and the layers appear in their initial and simplest form. That the ancestral endosarcal bundle system is not entirely eliminated is probable, though final determination of this point still depends on favorably located rib-angle sections of exceptionally conserved seeds.

Homologies of the seed coats in Cycadeoidea.

In my American Fossil Cycads (p. 174) the view was taken that *Lagenostoma* presents the nearest known analogy to the seed wall structure of *Cycadeoidea* of any form existing or

FIG. 6.

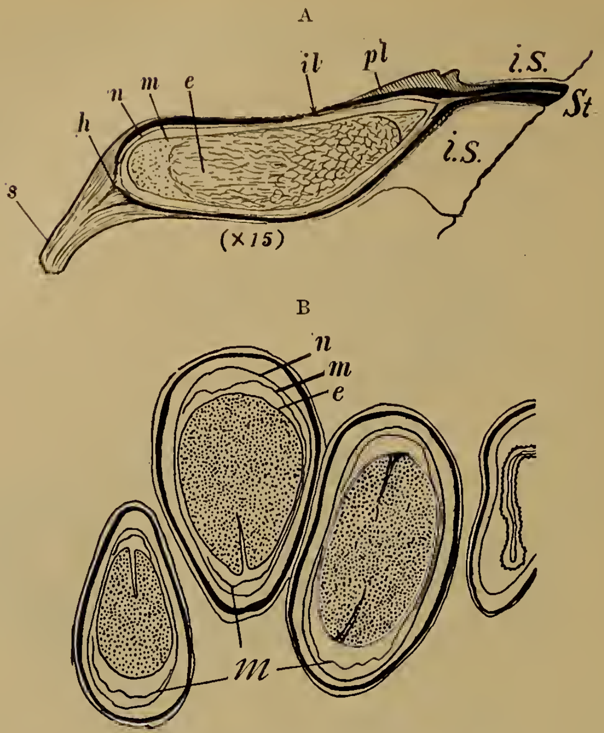

FIG. 6. *Cycadeoidea turrita* (?). Black Hills.

A.—Longitudinal section of seed. × 15.

s, seed pedicel:
h, hilum;
n, nucellar sack;
m, megaspore membrane;
e, embryo;
il, interior layers of testa;
pl, exterior covering or "blow off layer";
is, interseminal scales;
st, micropylar tube ending as a slightly flanged style.

B.—Oblique section of four adjacent seeds. × 25.

n, nucellar sack; *m*, megaspore membrane; *e*, embryo.

In *A* all the basal portion of the section traverses thin "blow off" tissue, which strongly thickens into a *five rib series* at the shoulder, these ribs even prolonging themselves tentacle-like into a sort of corona. The solid black line represents the middle stone or sclerenchyma, the narrow blank space between it and the nucellar sack the inner flesh, and the outer barred area the exterior soft tissue or blow off layer. In this seed a rib is cut on the upper side and a furrow is traversed on the lower side. Only in the micropyle does the diagram fail of accuracy, as the middle sclerenchyma does not give origin to all the micropylar wall.

In *B* the nearly complete occupation of the megaspore membrane by the embryo is seen to repeat itself normally. Occasionally in sections cutting many seeds a third cotyledon is indicated. In the seed to the right no embryo developed and the nucellar sack and megaspore membrane floated to the center and collapsed, whence an extra line appears as the boundary of the inner flesh.

extinct. And no reason is now seen to recede from this view. For in reality *Lagenostoma* offers in the retention of reduced inner flesh bundles, or an endovascular condition, an intermediate stage between the large thick-walled amphivascular seeds of existing cycads and the reduced or even truly monovascular *Cycadeoidea* seeds; while the archaic features in the apical region of the latter must be of far more significance than would be the retention of bundles, which were without a shadow of doubt anciently present. And the closer we study *Cycadeoidea* the clearer does it become that despite an enclosed position and despite reduction the seed apex is after all of the ancient multilobate type. Further, we think it can be accepted that the stony palisaded layer of *Lagenostoma lomaxi*, though following ripening and shedding of the seed the external one in all the lateral region of the seed, is none other than a middle stone. The small tubercles of this layer (cf. fig. 4C) were thought by Oliver and Scott (8) to have supported an outer layer of thin-walled cells, while in the *Cycadeoidea* seeds one may plainly see that the thin outer wall of the outer cells of the stone layer has to do with its function as a bearing wall for the "blow off" layer. In comparisons with *Lagenostoma* it may be remembered, too, that various species are known, and that in *L. ovoides* for instance, where both cell form and preservation suggest decided resemblance to *Cycadeoidea*, the indurated layer is several cells thick, so that this layer can vary much in thickness and development in both these genera as already known. To some the *Lagenostoma* cupule may seem to prevent comparison, but it should be recalled that this structure must have been under way of reduction, whereas the tubular layer which occupies the same region in *Cycadeoidea* and serves the same essential function as a basal cup or husk, is evidently a last remnant of some ancestral leafy structure.

So far as now recalled *Polypterospermum* of the French Paleozoic is the only other ancient seed which has ever been suggested as offering a distinct likeness to the Cycadeoidean seed structure. Professor Lignier (3) in studying the four (occasionally five) ribbed *Bennettites Morièrei*, after pointing out marked testal resemblance to *Gnetopsis*, attached too much significance to apical appendages, reaching the conclusion that the latter seed presented no true analogy. But he went on to guardedly name an apparently related form *Polypterospermum* as probably much nearer to *Cycadeoidea* than other ancient types, a suggestion of relationship which seems to have been little heeded. It is likely, however, that restudy of the apical region of the seeds of *Bennettites Morièrei* in conjunction with *Polypterospermum* will be well worth while, since this region is not sufficiently known even in *Bennettites Gib-*

Fig. 7.

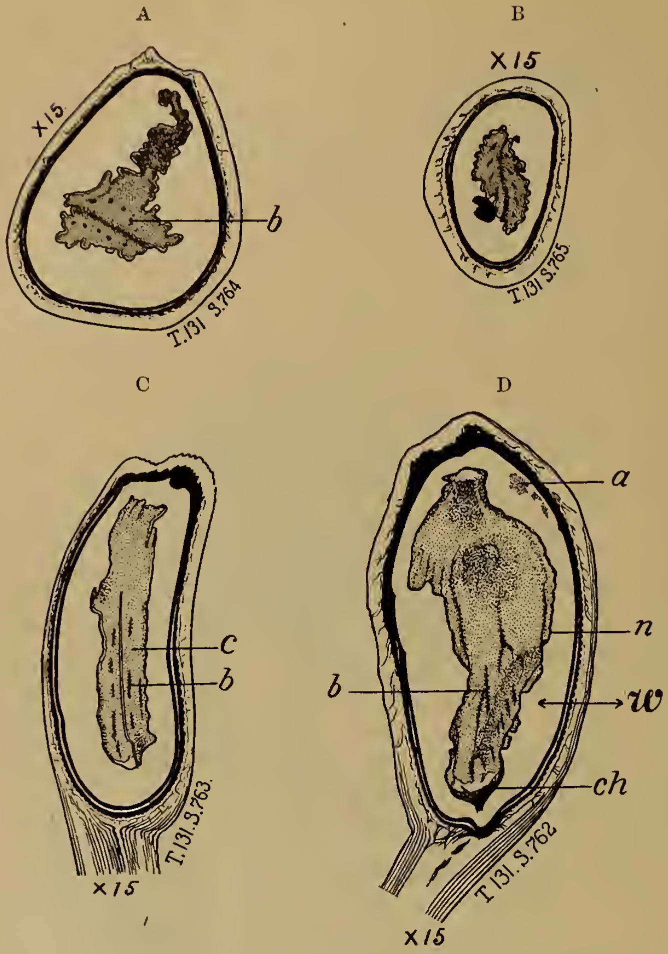

Fig. 7. *Cycadeoidea Macbridei* (?).

Four characteristic subtransverse to sublongitudinal sections of seeds containing embryos from as many different thin sections (Nos. 762–765) cut from one of the various strobili of the Minnekahta cycad trunk Y. S. No. 131 : all × 15.

A.—Subtransverse section. Passes near the "shoulder" of the seed as indicated by the apical ribs on the upper side, but below the radical since the two cotyledons with their bundles (*b*) plainly appear. In the upper cotyledon which must be cut near the cotyledonary node but four bundles are traversed, approach to the maximum number of five or six lamina bundles appearing on the lower or more basal side.

The somewhat convolute prolongation above is most readily explained as a remnant of proembryonic tissue exactly like that persisting or but slowly made over into the true embryo tissue in the very similar dicotyledonous embryo of *Ginkgo.*

sonianus, and is difficult of study in the silicified American specimens. Again, the French Paleozoic seeds are scarcely known to us in that closer detail which present methods of fossil seed study are rapidly bringing to light.

But meanwhile further interesting comparisons with ancient seeds have been made possible by the instructive interpretations of Paleozoic seed structures and noteworthy study by Oliver and Salisbury (11) of the two species *Conostoma oblongum* and *C. anglogermanicum.*

In the species of *Conostoma* no cupule obscures the exosarcal features, but the seeds have the small size of those of *Cycadeoidea*, in consequence of which they present much difficulty of study due to dependence on chance sectional planes. Nevertheless, by plotting about a score of sections of *Conostoma anglo-germanicum* and nine sections of *Conostoma oblongum*, and then constructing models from the estimated planes of the sections, nearly concise restorations of both

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B.—More nearly transverse and basal section than the preceding in which the dark staining mass clinging to the lower left cotyledon must be an endosperm remnant rather than a tissue like the convolute extension just noted in *A*.

C.—Sublongitudinal section. Passes through lateral hilum and emerges at the seed "shoulder," traversing nearly the entire length of the embryo with its two cotyledons (*c*) and their lamina bundles (*b*).

D.—More nearly longitudinal section than the preceding, cutting *chalazal tracheid stem* or goblet, and passing beyond the "shoulder" near to base of micropylar tube. The embryo is here especially instructive as showing the forking (*b*) of the cotyledonary bundles in both lamina as well as the apical proembryo folds and endosperm or albuminous remnants (*a*). Taking this section at *W* the characteristic proportion and appearance of the seed wall layers is indicated distinctly. On the inside next the embryo to which the nucellar sack clings is a considerable empty space left in part by shrinkage of the embryo, in part by collapse or failure of preservation of the spongy enclosing cells of the nucellus, and in part finally by the invariable flattening out of the cells of the inner flesh, indicated by the inside solid black line.

The inner flesh clings closely to the middle sclerenchyma, also shown in solid black but notched on the outer border, this being the artist's method of indicating the cup-shaped appearance of the component cells due to preservation of the thick inner or basal wall and thinning out of the lateral walls without easily detected conservation of the very thin tangential wall. Exteriorly comes the outer flesh, or more exactly the "blow off layer" strictly homologous to that of Carboniferous Cycadofilicinean seeds, *Physostoma*, etc. But in strobili of trunk 131 and in most American Cycadeoidean seeds the very thin cell walls of this layer are indistinct, though their characteristic palisade-droop, so pronounced in *Physostoma*, cf. figure 4 *D*, is plainly in evidence. Finally, the strongly lined outer basal tissue is that of the cortical husk.

[These sketches of seed sections are diagrammatic in the best sense, since they are in reality the artist's excellent drawings *just as he saw them* in these particular seeds, but to be seen over and over in seeds of other strobili cut from trunk 131. This trunk was referred by Professor Ward to the species *C. Wielandi* as best represented by Yale Cycads Nos. 77 and 393, but cannot be of that species. Not only are there leaf base differences but in the seeds of 77 and 393 the "blow off layer" is virtually eliminated.]

FIG. 8.

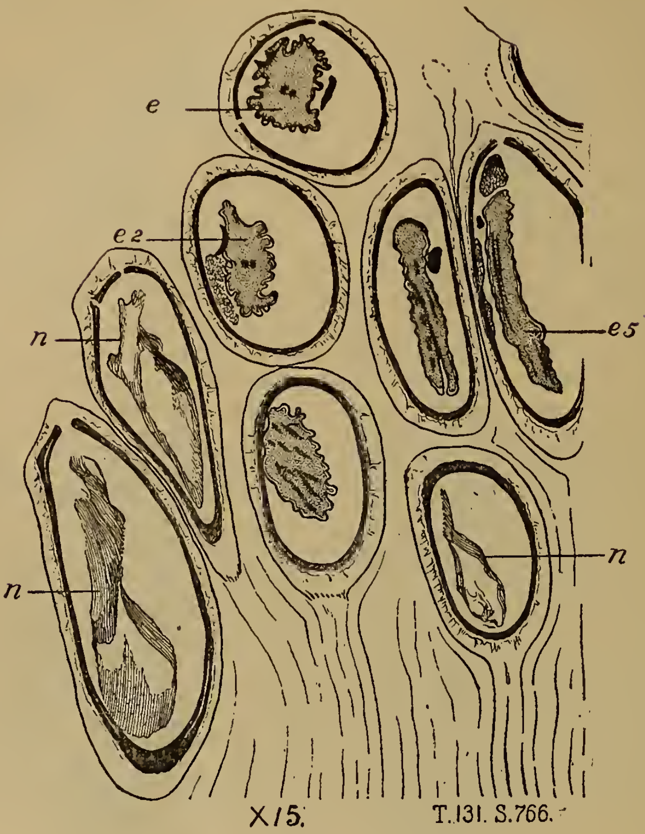

FIG. 8. *Cycadeoidea Macbridei* (?).

Part of a somewhat oblique section through a strobilus of Y. T. 131 cutting nine seeds at angles varying from nearly transverse (*e*, *e2*) to tangential longitudinal (*e5* and *n*) and illustrating the embryos and embryo bundle system. The position of the several sections is quite obvious:—*e* with its embryo is cut high up just where the cotyledonary node gives off the two supply bundles for the cotyledons; *e2* passes lower but is still rather near the cotyledonary plate since neither radical nor sinus between the lamina appears; while in the seed *below e2* the upper part of the pedicel is cut and the forking of the bundles in the tips of the cotyledons is evident; *e5* and the seed alongside it are decidedly tangential, though in each both cotyledons appear.

In each of the seeds *e–e5* a lateral deeply stained mass of endosperm (?) appears beside the embryo. In three of the seeds the embryo fails wholly of preservation, but the nucellar sacks (*n*, *n*, *n*) are wholly distinct, collapse and folding of this sack as here so clearly to be seen being of much interest in connection with various forms of nucellar sack rupture in many *Cycadeoidea* seeds.

species have been obtained. Both are endovascular, the inner fibrous flesh being traversed by six bundles in the angles of as many simple ribs in *C. oblongum*, and four bundles in the angles of the four major or wing ribs which initially alternate with as many minor ribs in the somewhat more complex *C. anglo-germanicum.* Both species thus agree with *Cycadeoidea* in size and in being coronate radiospermic ribbed and winged forms with essentially the same wall structure, barring retention of the endosarcal bundles, traces of which are, however, yet likely to be found in the Cycadeoideæ.

Indeed, truly essential testal and apical differences, rather than likenesses, remain to be established now that we know *Cycadeoidea* to be a characteristically four- and five-ribbed and lobate, winged, tentacled seed which also shows some tendency to alternation of major and minor ribs.

Evidently *Cycadeoidea*, though of composite type, has, as befits its Mesozoic extinction, a clear title to admission into the great groups of Paleozoic gymnospermous seed types retaining indisputable evidence of a yet more ancient multiple integument. And this is yet more strongly indicated when we turn to the fuller lobed *Neuropteris heterophylla* seeds described as attached to their foliage by Kidston, if, indeed, these are true megaspores. Especially so, if we further consider that most remarkable six-lobed microspore-bearing fruit *Codonotheca* of quite the same size and outer aspect as the reputed *Neuropteris* seeds, and on the score of association strongly suspected to be of Neuropterid affinity when first described (7).

Reëxamination of this fossil by the writer has so far failed to establish the presence of sporangial structures on the inner surfaces of the campanular lobes where much loose and extraordinarily large-sized pollen may be seen, seemingly in quite the position in which it grew.* But while the general appearance at first seemed to preclude the drifting in from the outside of pollen attaching itself to sticky inner surfaces of free

* These Codonothecan or Neuropterid microspores or *prothallate pollen* grains are the largest known, even greatly exceeding *Stephanospermum*, and it remains quite probable that by some modification of Nathorst's collodion method some evidence of extensive prothallial tissue may be found.

The characteristic make up of the seed wall again appears as in the preceding figure as well as the important additional fact that breaks or gaps in the inner flesh and middle sclerenchyma quite regularly occur near the shoulder and conclusively indicate that these seeds of *Cycadeoidea* are as truly ribbed tentacular or apically lobate as any members of the *Langenostoma* group.

[It is probable that these embryos have undergone some shrinkage, though the cell structure is often clear and does not show much evidence of collapse. However, various remnants about the sides of the embryos indicate unused parenchyma. The appearance does not entirely reconcile itself with the great size of the proembryo, *seen in another species.*]

apical lobes of a small central seed and there undergoing prothallial growth, such an interpretation is, because of the peculiar spindle-shaped and possibly ovulate base, not easily dismissed. Should this prove to be the true interpretation of *Codonotheca*, it is the most leafy of known seeds. But any one is free to work out various alternative interpretations for himself. And certainly this singular fruit would be at once explained by many, or most, as some entirely primitive form of giant microspore case had not the ubiquitous staminate disks of Mesozoic times led us to expect to find circular emplacements of sporophylls in process of reduction in ancient plants, and in particular taught us to see, that in such disks spores once borne ventrally may easily become falsely dorsal. In any case, however, the study of such forms must ultimately shed much light on the nature of gymnospermous testal structure, the essential and primitive elements of which already begin to appear.

Fig. 9.

Fig. 9. *Cycadeoidea Macbridei* (?).

Diagrammatic reconstruction of the dicotyledonous embryo showing approximate position of the bifurcation of the node (*bf*) and the probable bundle distribution in the cotyledons. The two branches leading into the cotyledons must run parallel further than here appears because the laminæ are shown as if arbitrarily flattened out.

But yet another comparison of the seeds of *Cycadeoidea* may be made with forms far nearer at hand that might have been thought of before. Through the great kindness of Professor R. B. Thomson, whose excellent demonstration of the megaspore membrane of the gymnosperms is well known, I have come into possession of a beautiful though limited series of longitudinal sections of existing gymnospermous seeds; and the attentive study of these shows that the smaller seeds, especially of the Abietineæ present a clear analogy to *Cycadeoidea* in all that pertains to lateral wall structure. In *Pinus resinosa* there is, taking the lateral wall, a noteworthy parallel, and if one had before him a complete series of both transverse and longitudinal sections of the Abietineous species it is likely that traces of apical ribbing would be found and that a composite exceedingly like *Cycadeoidea* could be observed.

And this line of study promises much interest; for the Abietinean series was always regarded as a quite modern side branch rather than an old gymnosperm stem terminal, until the possession of really ancient structures was pointed out by Hollick and Jeffrey.* These writers in their admirable study of Cretaceous conifers show *Pinus* to be archaic and demonstrate a new genus *Prepinus* of more primitive structure than any other conifer living or extinct, while Jeffrey now insists without reservation that the Abietineæ are the oldest tribe of conifers.† The decided resemblances in the seed wall structure to *Cycadeoidea* lend further color to such views if any value can be assigned to present-day features of gymnosperm seeds in trying out questions of ancient relationships amongst great groups of gymnosperms, using the name in any wide sense.

Some closing remarks.—To anyone interested in the subject of fossil seeds, it will not be necessary to say that even in the case of seeds as well represented as are those of *Cycadeoidea* finality in description cannot easily be reached. To secure more exactly oriented sections, to illustrate these adequately by both photomicrographs and drawings and gain an accurate idea of the precise form and structure of the various species of seeds is a work of time and perforce the task set for further publication in connection with other features. But meanwhile, it may be stated that, regarding our view that a proembryonic tissue occupying all of the nucellar cavity is present in one species of *Cycadeoidea*, we still have no other explanation to offer. Though it can be said that whatever the nature of this tissue it seems to have been much given to bursting from the nucellar sack. Scarcely better photomicrographs showing the usual character and position of this tissue can be given than that of the transverse section Plate XXX (9), where the slight filmy tissue traversing irregularly the mass of rounded cells is none else than the much wrinkled and collapsed nucellus, though we were not at first prepared to believe that the nucellus had so frequently collapsed, ruptured and floated about in shreds amongst these cells as is now seen to be the

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*Hollick, Arthur, and Jeffrey, E. C.—Studies of Cretaceous Coniferous Remains from Kreischerville, New York. Mem. N. Y. Bot. Garden, vol. III, 138 pp. with 29 plates. New York, 1909.

†Jeffrey, E. C.—A new Prepinus from Martha's Vineyard. Proc. Boston Soc. Nat. Hist., vol. 34, No. 10, pp. 333–338, pl. 33. Boston, 1910.

case. Others who have seen the sections are at least certain that the tissue is not endospermous; and to the objection that a proembryonic tissue would not be likely to thus occupy quite all of the nucellar cavity it is replied that such a condition is in reality only one of degree, and that it is readily conceivable as having been present in Cretaceous gymnosperms. Though it is of interest that conformably to the lesser degree to which the embryos shown in figure 7 fill up the nucellar cavity as compared with those of figure 6, far more distinct traces of endosperm are present.

The sections, which may be seen at the Yale Museum, are not only being constantly added to, but meanwhile receiving careful attention and comparison, and it is intended to give features displayed the best possible illustration. Meanwhile ink drawings of various seeds are appended in the present text figures 7 and 8 illustrating the strobili of Yale Cycad 131. This trunk is one of those referred to *C. Wielandi* by Professor Ward, but cannot be of that species as represented by trunks 77, 393, and various other specimens constituting a distinct and unmistakable group. Trunk 131, which bears strobili with not infrequent finely conserved embryos—indeed quite the best so far known—may be provisionally referred to *C. Macbridei.* The chief vegetative differences from *C. Wielandi* are exhibited by the sections through the cortical parenchyma, showing the leaf traces and the leaf bases of both to be of much larger size than in the *C. Wielandi* trunks, while the main differences in testal development are exactly noted in the legends of the respective figures, 4 C, 7, etc.

The present drawings all show the position of the young embryo bundles to agree with that seen in both *Bennettites Gibsonianus* and *B. Morièrei*, as shown by the scheme of the embryo bundle pattern, figure 9, which must closely approximate the true form. From this it is evident that a pattern a little more reduced than that of the living cycads, but not so much as that of conifers, is present. In fact, the bundle pattern is the same composite one seen in *Ginkgo biloba*, to the general form and structure of the entire embryo of which there is a very close analogy, extending to the occasional occurrence of three cotyledons instead of the normal dicotyledonous condition.

Finally, the fact that seed and embryo of these fossil cycads are of the most generalized gymnospermous type can escape no one; while the retention of pronounced cycadofilicinean features further favors inclusion in the Cycadales. Though for the present letting classifications evolve themselves as they may, it is most interesting to observe that not only were the primitive seed characters of the Cycadeoideæ little obscured by appression in the peculiar strobilar type so much affected by the group throughout the Mesozic, but even so much the more surely conserved as to permit the freest comparison with the ancestral singly borne multilobate leafy seeds of Paleozoic times.

Yale University Museum,
New Haven, Conn.

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ART. XV.—*A New Locality of Pyrrhotite Crystals and their Pseudomorphs*; by C. H. SMYTH, Jr.

THE rebuilding of the old "Seneca Turnpike" through Central New York, during the summer of 1907, led to considerable opening up of new and old quarries along the line of the highway. Among these, is a small quarry in Clinton rocks, whose location is clearly marked on the Oriskany Sheet of the U. S. Geological Survey, being at the point where a small stream crosses the highway about half-a-mile east of Lairdsville.

While searching the quarry for celestite and strontianite, which occur here in small quantity, the writer found a small rusty-brown hexagonal crystal which, on being touched, went to pieces along basal cleavage or parting planes. Without a magnifier, the mineral looked much like weathered mica, but the geological conditions precluded the possibility of such being the case. Further search was rewarded by the finding of a number of crystals in much better condition, and it was apparent that the mineral was pyrrhotite.

The crystals range in size from microscopic up to about 5^{mm} in greatest diameter, and while some of them have the normal bronze-yellow color of pyrrhotite, they are more commonly tarnished or superficially altered to limonite, and range from yellowish brown to black in color, often with strong iridescence.

The crystals are, for the most part, exceedingly simple, consisting of the prism and base, with no other faces developed, but they show three rather distinct habits. The most common of these is prismatic, the length of the prism being three or four times the diameter of the base. Some of these crystals are tapering and probably have the form described by Dana,* or one closely related, but the faces are too imperfect to permit a determination. Another habit, shown by the largest crystals found, is tabular parallel to the base, thus being of the type most common for this species. In this type, the basal diameter is from two to six times the length of the prism. In both of the foregoing types the prism faces are deeply striated parallel to the base.

Finally, the pyrrhotite is scattered over the surfaces of associated minerals in minute, very thin scales, looking almost like dust, but when magnified showing the normal hexagonal shape, and thus constituting an extreme case of tabular habit, resembling micaceous hematite. Many of these minute scales are of irregular shape and sometimes are in arborescent groups. There are no differences of association, age or condition of

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* Dana, E. S., this Journal, xi, p. 386, 1876.

formation apparent to account for these differences of habit, their cause or causes being entirely a matter of speculation.

The ordinary basal cleavage of the species is well shown, and the magnetic character is marked, all specimens tested being strongly attracted by a rather weak magnet.

The rock in which the pyrrhotite occurs is a very calcareous sandstone associated with the upper ("fossil") ore bed of the Clinton, and the mineral is found in small secondary cavities, of irregular shape, lined with quartz and some calcite and dolomite. The order of crystallization appears to be dolomite, quartz, calcite and pyrrhotite. As stated above, celestite and strontianite are present in small amounts, as is also a pale green chloritic mineral, whose quantity is too small to admit of a careful study.

The placing of the pyrrhotite with reference to the other minerals present affords a very pretty instance of selective precipitation which is particularly marked in the case of the minute hexagonal plates. When a cavity contains calcite, the pyrrhotite is deposited upon this mineral almost exclusively. Calcite, which to the naked eye looks dusty, is shown by the microscope to be sprinkled over with beautiful hexagonal plates of pyrrhotite, and the latter often occupy depressions in the calcite, looking as though they had been pressed down into it when it was in a plastic condition, although, of course, such is not the case, the phenomenon being due to solution.

When calcite is lacking in a cavity, dolomite supports the pyrrhotite, and it is only when the crystals of the latter become large or very abundant that they rest upon quartz. Whether the influence of the carbonates is chemical, physical, or both, is not entirely clear, but the frequent occurrence of pyrrhotite plates in cavities of the calcite and dolomite is strongly suggestive of chemical action. It is worthy of note that no primary pyrite was found associated with the pyrrhotite, although the former mineral is rather frequent in the Clinton rocks, and at a quarry only half-a-mile distant, and in the same horizon, occurs in good crystals up to an inch in diameter. Seemingly the iron sulphide usually precipitated as pyrite in the Clinton rocks was, by some peculiar condition, in the particular locality under consideration, crystallized as pyrrhotite. The associated minerals show no corresponding peculiarities to indicate the causes leading to the formation of pyrrhotite, and as in their conditions of original deposition, as well as in subsequent history, these rocks must be practically identical with the rocks of adjacent quarries, the modifications needful to produce pyrrhotite instead of pyrite must have been so slight as to leave no means of tracing them. This is not, perhaps, surprising in view of the close similarity in the chemical composition of the two minerals and yet it is a fact that, in spite of this similarity, their geological relationships are somewhat different. Pyrrhotite is essentially a mineral of the igneous and metamorphic rocks, and to some extent of metalliferous veins, while pyrite though occurring in all of these associations is also widespread in the sedimentary rocks.

Lacroix[*] gives five modes of occurrence for pyrrhotite: in eruptive rocks; in contact-metamorphosed sediments; in meteorites; in metalliferous veins; and in crystalline schists; the normal sediments not appearing at all in the list. This latter type of occurrence is represented by the instance under consideration, which is thus somewhat exceptional. Of course, there is a certain similarity between the secondary cavities lined with minerals deposited from solution and the true metalliferous veins, and it is with the latter class of occurrences that the pyrrhotite here described has more in common. Nevertheless, the conditions represented in the Clinton rocks, though leading to a considerable rearrangement of constituents, are very different from those associated with the formation of typical metalliferous veins, with their high temperatures and pressures, and immensely potent chemical agents. To place the present occurrence of pyrrhotite with the metalliferous veins would be wholly unjustifiable, its proper classification being in association with sedimentary rocks, corresponding to Lacroix's[†] fourth mode of occurrence for pyrite.

The finding of these crystals recalled a similar occurrence noted many years ago, but never recorded, and of which but one specimen is at hand. The locality is Clinton, N. Y., some four miles east of the one described above, and the horizon is the oölitic iron ore, about twenty feet below the fossil ore of the preceding locality. In this oölitic ore a few small cavities lined with pyrrhotite have been found. The mineral is in very thin hexagonal plates, resembling closely the third habit described above, with a dark-bronze, or tarnished surface. The crystals are always small, hardly exceeding a millimeter in diameter and are implanted upon the edges. As a further instance of crystallized pyrrhotite in sedimentary rocks they are of interest, though of little consequence as specimens of the mineral.

Here again there is a complete absence of evidence as to why pyrrhotite was formed instead of pyrite, which occurs in much greater quantity, though not found thus far in direct association with the pyrrhotite.

Pseudomorphs.

The alteration of pyrrhotite to limonite mentioned above runs all the way from a slight superficial change to complete

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[*] Min. de la France, II, pt. 2, p. 564.

[†] Ibid, p. 578.

pseudomorphism, the form of the pyrrhotite alone remaining, in the substance of the limonite. In such cases, the resultant crystal is usually honeycombed and cavernous, though often having a nearly complete external shell. Sometimes the shell is quite hollow, though extremely smooth and lustrous on the surface. There is a complete analogy with the pseudomorphs described by Lacroix,* except in the matter of magnitude, the crystals here considered being much smaller. But the analogy does not cease here since Lacroix's pseudomorphs of pyrite and marcasite are paralleled by instances of pseudomorphs of pyrite after the pyrrhotite. In every case noted, these pseudomorphs are either hollow, consisting of a mere shell of pyrite preserving the form of pyrrhotite, or are partly filled with cavernous limonite.

While the typical limonite pseudomorphs often preserve the forms of the pyrrhotite crystals very precisely, even to the striation of the prism faces, the pyrite pseudomorphs always have a rather rough, irregular surface. Apparently, the process begins with the growth of a coating of pyrite crystals upon the pyrrhotite, the latter mineral being subsequently more or less completely decomposed and removed, leaving a hollow shell of pyrite. The individual crystals of pyrite are very minute, and their form can be seen only with the microscope, and then imperfectly, but enough octahedral faces are shown to warrant the conclusion as to the nature of the mineral. In a few cases the pyrite has built up the edges of the pyrrhotite, forming pronounced ridges, with the faces as depressions between them. On account of the small size of the secondary crystals, it is impossible to determine whether or not they are definitely oriented with reference to the pyrrhotite, but apparently they are not. For the same reason, no final conclusion can be reached as to the possible presence of marcasite in addition to the pyrite. It might well be present and escape detection.

Evidently limonite pseudomorphs have sometimes formed directly from the pyrrhotite and, again, they have followed upon the conversion of the latter mineral into pyrite, the former case giving more perfectly formed pseudomorphs.

While there seems to be no doubt as to the general tendency of pyrrhotite to alter into marcasite and pyrite, the conditions leading to such changes are not clear, particularly in the case of pyrite. The latter mineral has the greater specific gravity, and higher grade of symmetry, favoring its formation under deep-seated conditions, and Van Hise† concludes that "doubtless when the necessary chemical reactions can take place there

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* Loc. cit.

† Van Hise, C. R., Treatise on Metamorphism, Monograph 44, U. S. Geol. Survey, p. 216.

is a tendency in the lower zone for pyrrhotite to alter to pyrite."

It is a fact that both minerals form readily under deep-seated conditions, but it is also true that pyrite often is deposited near, or at, the surface, being a common constituent of sedimentary rocks; while on the other hand pyrrhotite is distinctly rare in such environment, and apparently tends to pass over into pyrite as it comes within the influence of surface conditions. Thus while it may be that pyrrhotite changes into pyrite at great depth, it certainly does so nearer the surface, although the comparatively rare occurrence of crystals causes a correspondingly limited number of determinable examples of the change.

Marcasite, on the other hand, is a mineral of moderate depth, changing under the deeper seated conditions into the denser and more symmetrical pyrite. As a pseudomorph after pyrrhotite, it would ordinarily represent more superficial conditions, and might well result from a second stage of alteration, the first being the alteration of pyrrhotite to pyrite, the second the alteration of pyrite to marcasite. Thus pyrrhotite, formed originally at considerable depth, when brought under the influence of more superficial conditions becomes unstable and tends to pass over into such compounds as would naturally form under these conditions, and we have pseudomorphs of pyrite and marcasite, sulphides that readily form at moderate depths. This is in harmony with the molecular volume relations of the three minerals, the molecular volume of pyrrhotite, pyrite and marcasite being respectively, 19·1, 23·2 and 25·4, as quoted by Grubenmann* from Becke.

Finally, under distinctly superficial conditions, with abundance of oxygen, the last stage of the series is the formation of limonite, a most stable product under these conditions.

While, in some cases, all of these stages of alteration might be passed through, in other cases only part of them would be represented, as determined by local conditions, and any stage might be partial or complete. In the particular instance here described, it is quite clear that there has been a partial alteration of some crystals to pyrite followed by a more or less complete change of the pyrite to limonite. In other crystals the pyrite stage is apparently lacking, the passage from pyrrhotite to limonite being direct. Finally, many crystals are quite fresh and unchanged. As before stated, it is impossible to determine whether or not any marcasite has been formed.

The unusual feature of the case lies in the fact that the first stage in the whole series of operations, that is the formation of the pyrrhotite, represents geological conditions quite different from those under which this mineral is usually developed.

Princeton University.

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* Grubenmann, U., Die Kristallinen Schiefer, I, p. 37.

ART. XVI.—*Ferritungstite, a New Mineral*; by WALDEMAR T. SCHALLER.

A SAMPLE of tungstic ocher was collected in the State of Washington by Mr. Howland Bancroft, of the U. S. Geological Survey. The exact locality is the Germania Tungsten Mine, Deer Trail mining district, northeastern part of the State of Washington. Mr. Frank L. Hess, also of the U. S. Geological Survey, suggested that the tungstic ocher might prove of sufficient interest to warrant careful study. On microscopic examination, the earthy looking ocher was found to be well crystallized and pure and chemical tests showed that the ocher was a hydrous ferric tungstate, entirely different from ordinary tungstic ocher, called tungstite, which, as Walker* showed, has the formula $WO_3H._2O$. For the privilege of describing this interesting new mineral, I am indebted to the two gentlemen above named.

Examination under the microscope shows that *ferritungstite* crystallizes in hexagonal plates, evenly developed but very minute. Those lying flat on the base are isotropic under crossed nicols, but are too small to exhibit any interference figures. Such crystals as are partially tilted, show decided double refraction on their edge. A small quantity of gangue, mostly quartz, is mixed with the mineral but limonite stains are almost absent, though occasionally a little can be seen.

Ferritungstite results from the oxidation of wolframite and is associated with that mineral in massive quartz. The cleavage, hardness and density of *ferritungstite* could not be determined. The color is pale yellow to brownish yellow when pure. It gives off water in a closed tube, and is decomposed by acids, yellow oxide of tungsten separating out.

Only a few tenths of a gram of pure material were available for analysis. Two samples were collected at different times from the same specimen. Qualitative tests showed the absence of MoO_3,SO_3,P_2O_5, and, in general, of substances other than those given in the analyses. The analyses of the two samples are given below.

Analyses of ferritungstite.

	1	2
WO_3	37·1	35·8
Fe_2O_3	26·6	27·3
H_2O(Ign.)	18·6	20·9
Insol.	14·7	[16·0]
	97·0	100·0

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* This Journal (4), xxv, 305, 1908.

The ratios deduced herefrom are shown in the following table:

Ratios of analyses of ferritungstite.

	1			2		
WO_3	·16	or	·94	·15	or	·88
Fe_2O_3	·17	"	1·00	·17	"	1·00
H_2O	1·03	"	6·06	1·16	"	6·82

These ratios are close enough to 1 : 1 : 6 to show that the formula for *ferritungstite* is $Fe_2O_3.WO_3.6H_2O$. Below are shown the two analyses with the insoluble matter deducted and recalculated to 100 per cent, compared with the theoretical values calculated from the formula $Fe_2O_3.WO_3.6H_2O$.

Comparison of analyses with calculated composition.

	Analysis 1	Analysis 2	Calculated
WO_3	45·1	42·6	46·4
Fe_2O_3	32·3	32·5	32·0
H_2O	22·6	24·9	21·6
	100·0	100·0	100·0

The mineral is different from any described and the new name proposed, *ferritungstite*, shows its chemical relation to ordinary tungstic ocher or tungstite.

Chemical Laboratory,
U. S. Geological Survey.

ART. XVII.—*A Method of Removing Tests from Fossils;* by S. S. BUCKMAN.

THE following remarks apply especially to brachiopods; but there is reason to believe that the method may be extended with advantage to other classes of fossils. Among brachiopods natural casts are not frequently met with, except in a few favored localities; and the natural casts are often unsatisfactory. Therefore a method of making artificial casts by removal of the test becomes of value when it is desired to study internal characters. The following is the method:

Choose specimens which are not crystalline, and preferably those which are likely to have a coarse-grained, hard internal core. Heat them to redness and then drop into water. Much of the test will then fall off; what remains can sometimes be wholly removed by brushing. If not, the delicate use of a sharp penknife will separate the rest. Care must be employed in using the penknife to prevent scratching of details of muscle marks, ovarian area, or vascular markings.

Heating may be done in an ordinary fire, but it is not altogether satisfactory; the specimens may be burnt too much. Heating by means of a bunsen flame, or a spirit lamp, or for larger specimens a gas or spirit blow-lamp, is more satisfactory. As the test is most adherent over the muscle areas, they should be heated most; that is, the specimens should be held beak downwards in the flame in the case of brachiopods.

Experiments so far have been chiefly with Mesozoic brachiopods, and of these the Rhynchonellids come out most satisfactorily, presumably on account of their fibrous test; some of them make very beautiful casts, showing all details excellently, but, of course, much depends on the state of fossilization. The Dallininæ have also yielded satisfactory results, but for some reason the Terebratulids do not come out so well, and the proportion of spoilt specimens is considerable.

In the case of rare specimens the method should only be employed after careful consideration: there is, of course, a risk of destroying the specimen altogether, and in any case details of test, of beak, deltidial plates, etc., will be lost.

The method was suggested by receiving, for description, from the Geological Survey of India a series of brachiopods from Burma, which had been burnt by Mr. T. D. La Touche for the purpose of extracting them from a rather intractable matrix. Many showed as a consequence good internal details, and that fact suggested burning other species to compare with them.

Thame, Oxon, England.

Art. XVIII.—*On the Decomposition of the Cerium Earth Double Sulphates with the Alkali Sulphates by Fusion with Charcoal*; by Philip E. Browning and Philip L. Blumenthal.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxxii.]

Among the best known and chief sources of the cerium earths are their insoluble double sulphates with the alkali sulphates obtained as a by-product in the process for the separation of these earths from the earths of the yttrium group. The problem which has to do with the conversion of these insoluble sulphates into soluble salts of the cerium earths is therefore an important one. The procedure in general use brings about this result by treating the double sulphate with sodium or potassium hydroxide until the cerium earths are converted to the hydroxides when the alkali sulphates may be removed by washing. The hydroxides are then dissolved in any convenient acid. This method is at best tedious both in the preparation of hydroxides and the removal by washing of the alkali sulphates. The double sulphates are sometimes digested with hydrochloric acid and then treated with water, but here also the process is slow in yielding soluble cerium earth material. Or, the double sulphates are treated with large volumes of water, frequently stirred, a method even more time consuming than the others.

The work to be described was undertaken to test the application of the reduction by carbon to this problem. This method has been applied to the preparation of soluble barium and strontium salts from barite and celestite* and, as we discovered late in our work, is mentioned in connection with some work on cerium over fifty years ago.† As this early work gave no details or numerical results and contained some statements which our work would hardly bear out we have thought best to give our results.

The material which we used was a crude double sulphate, a technical by-product carrying appreciable amounts of calcium and iron salts together with some sand.

In order to obtain a standard to which to refer results, five portions of one gram each were dissolved in from 300–400$^{cm^3}$ of water by frequent stirring for several hours and the solutions were precipitated in faint acidity by oxalic acid. The oxalate was ignited and the oxide weighed, yielding 0·3897 grm.

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*Introduction to Chemical Preparations, Erdmann-Dunlap, first edition, pages 27 and 30.

† Berzelius and Hisinger (1804), Ann. Chim. phys., L, 259; Beringer (1842), Liebig Ann., xlii, 135; Schmidt (1852), Liebig Ann., lxxxiii, 329.

Four portions of 1 grm. each were thoroughly mixed with 2 grm. of charcoal and heated in a covered porcelain crucible over a bunsen flame for from 30–45 minutes. After cooling, the mass was treated with about 4^{cm^3} of strong hydrochloric acid and 10^{cm^3} of water when the solution of the cerium earths took place with the abundant evolution of hydrogen sulphide. The residue of the charcoal was filtered off and the cerium earths in the filtrate were precipitated by oxalic acid in the usual manner. The average of these results, agreeing within a few milligrams, was 0·3908 grm. Three determinations each with 5 grams of the material and 5 grm. of charcoal heated 45 minutes gave an average result of 2·021 grm.; and four portions of 10 grm. heated with from 8–15 grm. of charcoal from 15–35 minutes yielded an average of 4·37 grm. of the oxides. Finally a portion of 100 grm. was mixed with 200 grm. of charcoal and heated in a battersea crucible in a furnace for about one hour. The yield of this experiment was a little over 40 grm. of the oxides.

The conclusion from this work is that the double sulphates of the cerium earths with alkali sulphates are readily decomposed by heating with charcoal into a form easily attacked by hydrochloric acid with the formation of soluble chlorides.

In course of this investigation it was found that the reduction of the double sulphates to sulphides by charcoal was not complete although the product was readily attacked by hydrochloric acid. Accordingly several experiments were made to determine the best conditions for forwarding the reducing action. The results appear in the table and were obtained by determining the amount of sulphate present in the hydrochloric acid extract after carbon fusion, by precipitation with barium chloride.

	Amount of double sulphate taken	Amount of charcoal used	Time of fusion	Per cent sulphate reduced
	grm.	grm.	mins.	
(1)	1	2	30	60·5
(2)	1	2	60	70·5
(3)	1	2	120	91·0
(4)	1	2	140	84·6
(5)	1	2	240	80·6
(6)	1	4	30	59·0
(7)	1	4	60	75·4
(8)	1	4	30	70·8
(9)	1	4	30	64.0
(10)	1	4	60	93·7

In experiments 1–9 the heating was carried on in a covered crucible over a bunsen burner, and experiment 10 in a furnace. In experiment 8 the heating was conducted in a current of hydrogen and in experiment 9 in an atmosphere of carbon dioxide.

The best conditions seem to involve a moderate excess of charcoal with about an hour's heating.

May, 1911.

SCIENTIFIC INTELLIGENCE.

I. Geology and Mineralogy.

1. *La Granodiorita de Concepcion del Oro en el Estado de Zacatecas, y sus Formaciones de Contacto;* por A. Bergeat. Bol. del Inst. Geol. de Mexico, No. 27; 1910. 4°, pp. 109, 9 plates.—After a general description of the region, with a brief account of the stratified rocks, the author describes the principal mass of granodiorite with petrographic details and chemical analyses. After mention of schlieren and inclusions he then takes up the subject of the contact metamorphism, both endomorphic and exomorphic. The former consists partly in a change of grain and partly in the intense absorption of lime from neighboring limestones, whereby an intermediate zone of garnet rock is produced. In the latter the limestones are converted into marble, filled in places with garnet, wollastonite, vesuvianite and other minerals. In some places at the contact are deposits of pyrite and chalcopyrite, in others hematite and magnetite, with blende and tennantite with quartz, which are referred to emanations from the magma. These various features, with the mines, are described in detail, the whole forming a valuable contribution to Mexican geology, and to our knowledge of the occurrence of ore deposits.

L. V. P.

2. *Fourteenth Annual Report of the Geological Commission of the Cape of Good Hope for 1909.* Pp. 116, vi. Cape Town, 1910.—This report is comprehensive in character and presents the results obtained by the Director, A. W. Rogers, working in conjunction with A. L. du Toit. The geology of Kenhardt, Prieska, and Carnarvon, is fully described; this is the region extending from the Orange River to Upington and southward to near Carnarvon. The most important part of the work has to do with the old formations referred to under the so-called Kheis series and the granitic rocks associated with them. Some new facts are also given in regard to the bowlder beds of the Dwyka series, and the Kimberlite pipes and dikes in Carnarvon and Victoria West.

Two sheets of the geological map have also recently appeared: these are No. 11, Clanwilliam, and No. 13, Beaufort West–Fraserburg.

3. *Norwegian Geological Survey.*—The following important publications have been recently received:

Nr. 50. Norges Geologi; av Dr. Hans Reusch. Pp. viii, 196.

Nr. 56. Rennebu: Fjeldbygningen inden Rektangelkartet Rennebus Omraade; af Carl Bugge. Pp. 42, with geol. map.

Nr. 57. Aarbok for 1910; utgit av Dr. Hans Reusch. In four parts, pp. 20, 49, 67, 24; with plates, charts and text figures.

4. *State of Tennessee—State Geological Survey.* Geo. H. Ashley, State Geologist.—The following are recent publications:

Bulletin 4. Administrative Report of State Geological Survey, 1910; by Geo. H. Ashley. Pp. 59. Nashville, 1911.

Bibliography of Tennessee Geology, Soils, Drainage, Forestry, etc., with subject index; by Elizabeth Cockrill. Pp. 119. Extract from Bulletin 1.

5. *Handbuch der Mineralogie;* von Dr. Carl Hintze. Erster Band, vierzehnte Lieferung, Pp. 2081–2240, Leipzig, 1911 (Veit & Comp.)—This is the twenty-sixth part of Hintze's Handbuch, and although more than twenty years have passed since Part I was issued, the author's work is no less careful, accurate and thorough than at the beginning. The species halite, or rock salt, occupies nearly 230 pages, or practically the whole of the present issue.

6. *Catalogue of the Minerals of Tasmania.* Pp.221. Hobart, 1910.—A second edition of the Catalogue of Tasmanian minerals, by W. F. Petterd (see vol. iii, 352, 1897), will be welcomed because of the remarkable variety of species which the island has afforded. Three hundred and fifty-six species are discussed in this pamphlet of more than 200 pages, and among these we note the following names which have not appeared in the Journal: *Batchelorite* (p. 22) is a hydrated silicate of aluminium occurring in green foliated or slaty masses, as nodules in schist, at the Mt. Lyell mine. Hardness = 4; specific gravity = 3·3. An analysis by G. F. Beardsley gave: SiO_2 49·4, Al_2O_3 45·1, H_2O 5·6 = 101·1.—The name was given by J. W. Gregory in 1905 after W. T. Batchelor; it had been called pyrophyllite. *Stichtite* (p. 167) is a hydrated carbonate of magnesium, chromium, iron, named after Mr. Robert Sticht. It forms foliated to compact masses of a lilac color occurring in serpentine at Dundas near the Adelaide mine. It had passed earlier under the name of kämmererite. In addition to much interesting information in regard to many different species, is to be noted a full account of the remarkable crocoite of Tasmania, with mention of several new crystal forms.

7. *The Minerals of Guanajuato, Mexico.*—Dr. E. Wittich has given a list of the large number of species occurring in the mining district of Guanajuato. Among the points of interest brought out may be noticed the existence of bismuth in the Sierra

de Santa Rosa, and also of the lead tungstate, raspite, which has only been known hitherto from the original locality in New South Wales and from Brazil.—*Soc. Geol. Mexicana,* and *Mem. Alzate,* xxviii.

8. *Minerals from the Belgian Congo.*—Dr. H. Buttgenbach gives an account of the Congo minerals in the *Annales du Musée du Congo Belge.* Among the points of special interest may be noticed the diamonds in Katanga, the various copper minerals including chalcocite, dioptase and azurite, also of strontianite from Kindu.

9. *Die Anwendung der stereographischen Projektion bei kristallographischen Untersuchungen;* by H. E. Boeke. Pp. viii, 58; 1 plate and 57 text-figures. Berlin, 1911 (Gebrüder Borntræger).—This little book has been written with the object of furnishing German students of crystallography a description of the principles of the stereographic projection together with illustrations of the various uses to which it can be put. The protractor which it describes is the stereographic net devised by Wulff. This consists in a net which shows the projection of all great and small circles drawn for every two degrees. The drawing of the stereographic projection is made on transparent paper and then by placing it above the stereographic net in the proper position any desired angle can be measured, etc. It is to be regretted that the book did not also describe the transparent protractors and the stereographic scales devised by Penfield. The book is well written and illustrated and should serve to extend the use of this valuable method of projection. W. E. F.

II. Miscellaneous Scientific Intelligence.

1. *A Second Course in Algebra;* by Prof. H. E. Hawkes, Columbia University, and W. A. Luby and F. C. Touton, Central High School, Kansas City. Pp. vii, 264. Boston and New York, 1911 (Ginn & Co.).—The present work, together with the First Course in Algebra by the same authors and the Advanced Algebra by Professor Hawkes, completes a series adapted to the use of a very large body of students and already extensively used. The volume now under review is admirable for clearness of presentation and freshness of statement. Graphical methods are used more freely and effectively than in any work on algebra known to the writer of this notice. Historical notes are also inserted with great frequency and add much to the interest and value of the book. It may, we think, be fairly said that no treatise on algebra now before the public is likely to produce as vivid an interest in that science in so many students. W. B.

2. *Les Progrès et L'Evolution de L'Astronomie;* par J. Mascart (Estract from Astronomia Popolare, Turin). Pp. 18. —An estimate, thoughtful and suggestive, of the best lines of development in observational astronomy, and of the possibility of increased efficiency through the coördination of work and the coöperation of the workers. W. B.

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SCIENTIFIC INTELLIGENCE.

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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XIX.—*The Probable Influence of the Soil on Local Atmospheric Radioactivity*; by James Cox Sanderson, B.A.*

Introduction.

Through the investigations of Elster and Geitel† attention was first called to the fact that the ordinary atmosphere normally contains radioactive constituents which can be collected by suspending a negatively charged wire for some time in the open air. Their experiments also showed that the air of cellars and caves contains a relatively greater proportion of radioactive material than the free air above ground, which suggested the possibility that the radioactive substances in the air might be of subterranean origin. The work of other investigators along the same lines has contributed largely to the extension of our knowledge of the nature and origin of atmospheric radioactivity.

Bumstead‡ collected the active deposit upon a long wire, stretched in the open air and charged to a high negative potential. He was the first to show conclusively that the atmospheric radioactivity was due in part to the presence of radium emanation and its disintegration products, and in part to the emanation and the disintegration products of thorium.

Gockel§ has examined the problem from the meteorological point of view and has found very considerable variations in the atmospheric radioactivity to exist with rising and falling

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* Thesis presented to the Faculty of the Graduate School of Yale University, June, 1911, for the degree of Doctor of Philosophy.

† Phys. Zeitschr. ii, 590, 1901.

‡ This Journal, xviii, p. 2, 1904.

§ Phys. Zeitschr., iv, 604, 1902–3; v, 591, 1904; ix, 304, 1908; ix, 907, 1908.

barometer, varying direction and velocity of winds, etc. The radium emanation is evidently the one which is affected by such changes in atmospheric conditions, since it has a comparatively long half-value period, can be carried great distances and diffuses to great heights before completely disintegrating. The thorium emanation, on the other hand, with its comparatively short life, will only be found near the surface of the earth. Dadourian* and W. Wilson† used the method of the negatively charged wire to determine the ratio of the amounts of radium and thorium emanations in the atmosphere. Kurz,‡ using much the same method, obtained accurate curves, as well as some quantitative data, for the active deposits.

Since the emanations present in the atmosphere must have their origin in the soils and rocks of the earth's surface, a study of the radioactive properties of the underground air might be expected to furnish valuable data on the nature and origin of atmospheric radioactivity.

Ebert,§ Dadourian‖ and Blanc¶ have investigated the radioactivity of the underground air. In each instance the active deposit was collected upon a negatively charged electrode over which underground air was drawn, or which was allowed to stand in a vessel filled with underground air. Blanc placed a large vessel, opened at the bottom, upon the ground and collected, upon a negatively charged electrode, the active deposit, produced by the emanation diffusing into it. He plotted the decay curve of this active deposit and, from the curve, deduced the amount of thorium active deposit initially present. He then allowed thorium emanation to diffuse into the same vessel from a tube containing a known amount of thorium hydroxide mixed with sand. On comparing the amounts thus obtained, he concludes that there must be at least $1{\cdot}45 \times 10^{-5}$ gram of pure thorium per gram of vegetal earth in Rome.

In one of the earlier experiments of Elster and Geitel,** the underground air was drawn continuously into the electroscope for an hour. The rise of the activity, due to the production of active deposit, was measured and, when this had reached a maximum, the current of air was stopped and the decay of the activity followed for many hours. They afterward devised and employed the method of collecting the active deposit on a negatively charged electrode which is subsequently placed in the ionization vessel. An examination of the literature of the subject has failed to disclose any other instance where the

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* This Journal, xxv, 335, 1908.

† Phil. Mag., xvii, 321, 1909.

‡ Phys. Zeitschr., ix, 177, 1908.

§ Phys. Zeitschr., iv, 162, 1902–3.

‖ This Journal, xix, 16, 1905.

¶ Phys. Zeitschr., ix, 294, 1908; Phil. Mag., xviii, 146, 1909.

** Phys. Zeitschr., iii, 574, 1901–2.

radioactive properties of the underground air have been studied by drawing a current of air directly through an electroscope.

The object of the present investigation was to determine, by an elaboration of the early experiment of Elster and Geitel just cited, the character and amount of the gaseous radioactive constituents of the soil.

The general scheme of the investigation was as follows:

A current of underground air was drawn from a small iron vessel, buried about 120 centimeters beneath the surface of the earth under the basement floor of the Physical Laboratory, and was conducted through the ionization chamber of a gold leaf electroscope. Immediately following the introduction of the air there was a rise in the activity to about eighteen times the natural leak of the electroscope. This was due to radioactive emanations in the underground air. The activity continued to rise, at first rapidly, and then more slowly, for about three hours, as the result of the production of the radium active deposit. The air current was continued and a very gradual rise in the activity was noted for about three days, when it reached a maximum. If, at this stage, the flow of air was suddenly stopped, a sharp falling off of the activity was noticed which continued for five or six minutes and then reached a minimum. This part of the activity fell to half value in about one minute and was easily identified as thorium emanation.

A relation was found between the amount of thorium emanation set free per cubic centimeter of the soil and the corresponding activity as measured in the electroscope. It was thus possible to compare the amount of thorium emanation set free per cubic centimeter of the soil with that liberated by a known amount of thorium.

The case of the radium emanation is more simple; since the half value period of radium emanation is comparatively long, it suffers no appreciable loss of activity in the time taken to reach the electroscope. It is therefore only necessary to standardize the electroscope by introducing the radium emanation in equilibrium with a known amount of radium and determining the rate of leak after the emanation has stood for three hours.

Some additional experiments were made on a number of soils, sands and minerals, with a view to comparing their emanating power.

Apparatus.

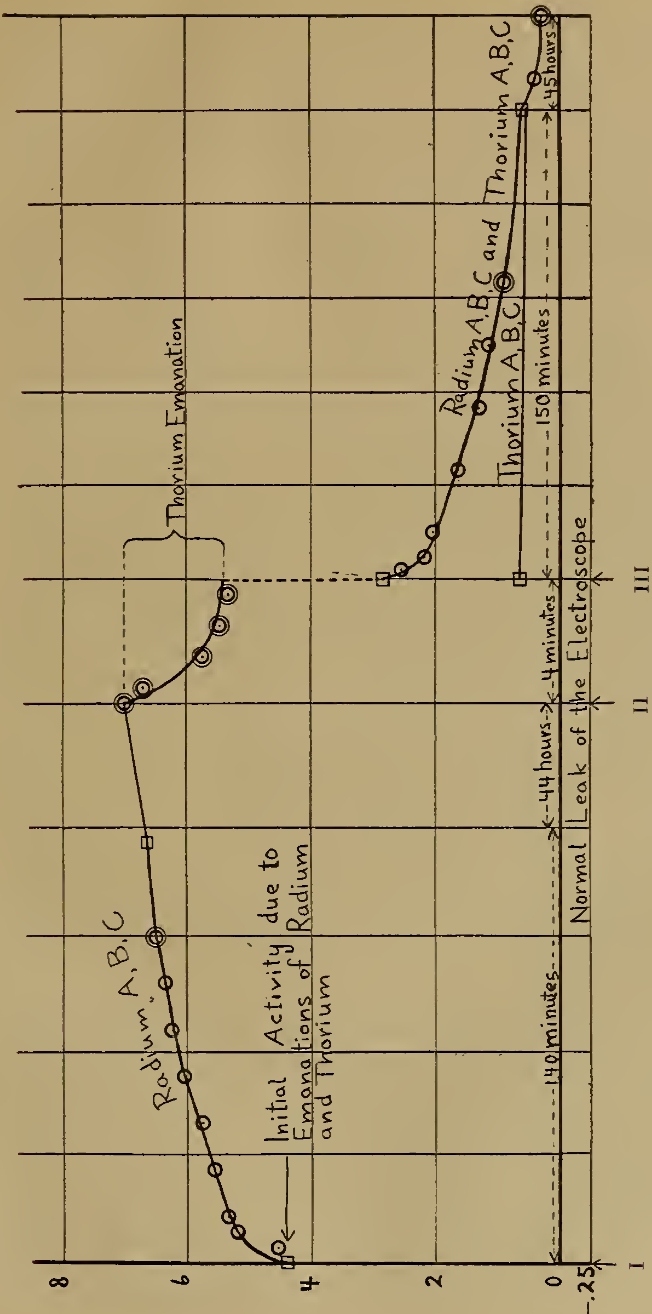
The electroscope consisted of two cylindrical metal vessels, 30 centimeters high and 13 centimeters in diameter, placed one above the other. The lower vessel, or ionization chamber, was provided with a central electrode which extended, through sealing wax insulation and guard ring, into the upper vessel, and served to support the gold leaf. The guard ring was kept charged to −300 volts. The walls of both vessels were grounded, while the gold leaf and central electrode were charged negatively. The source of potential was a battery of small storage cells. The position of the gold leaf was read by means of a telemicroscope through mica windows in the case of the upper vessel. A small tube near the bottom of the ionization vessel admitted the current of air, which was drawn out through a similar tube near the top.

To get the underground air, several bricks were removed from the cellar floor and a deep hole dug in the sandy soil beneath. An iron cylinder, 13 centimeters in diameter and 30 centimeters high, with many holes drilled in its top, bottom and walls, was fitted with a brass tube, 130 centimeters long and 0·4 centimeter in diameter, and, after being wrapped in a covering of cheese cloth, was buried deep in the hole, so that, when the earth had been filled in, only two or three centimeters of the tube protruded vertically above the surface. Connection was made with the inlet of the ionization vessel by a rubber tube and a glass bulb containing glass wool, to act as a dust and ion filter. The outlet of the ionization vessel was connected with a filter pump through rubber and lead tubing. Suitable pinchcocks were placed at the outlet and inlet of the ionization vessel.

Radioactivity of the Underground Air.

After the normal air leak of the electroscope had been determined, the current of underground air was started and readings were taken every ten or fifteen minutes, over thirty divisions of the scale, for an hour and forty-five minutes. As will be seen later, these readings, when plotted, fitted almost perfectly the curve showing the increase of the amount of ionization due to α-particles from radium A and C. The current of air was maintained for about forty-four hours, when the active deposit of thorium was fifteen-sixteenths of its equilibrium value and practically the maximum activity was attained. At this point, the current of air was stopped exactly on the minute, and readings taken every minute for the next four minutes. This was repeated a number of times. As will be shown later, these readings approximated closely to the decay curve of thorium emanation. Finally the underground air connection was removed and the emanations swept out by drawing the air from the room through the electroscope. Readings were taken, at first every few minutes and then at longer intervals, which, when plotted, showed the dis-

FIG. 1.



I. Current of underground air flowing.
II. Current of underground air stopped.
III. Underground air swept out.

integration of radium A and C, and finally, of thorium B and C. Figure 1 shows graphically the growth and decay of the activity due to the presence of radium and thorium emanations in the underground air. The ordinates are activity in scale divisions per minute and the abscissas represent time; for convenience, the scale of the abscissas is different in different parts of the curve, as indicated.

From the accepted values of λ for radium A and C, a curve was plotted showing the increase with time of the ionization due to the a-rays from radium A and C. The number of ions produced by an a-particle of each kind was taken as proportional to its range. The ordinates were percentages of the total activity. Assuming that the curve passed through the point obtained empirically at 105 minutes, it was successively made to include five or six of the preceding points and in each case the value of the total activity due to radium A and C deduced. The mean of these values was taken, and from this mean the value of the ordinate when $t = o$ was obtained. This represented the combined activities of radium and thorium emanation.

The part of the curve showing the disintegration of thorium emanation is plotted from the accepted value of λ for that substance. The observed values are in good agreement with those calculated; readings had to be taken at time intervals so short that certain irregularities in the motion of the gold leaf became very apparent and were an obvious source of error.

In plotting the rise of the activity of radium A and C, the active deposit of thorium was neglected, because the first disintegration product of thorium emanation is rayless. In the last part of the curve, however, thorium A, B and C are in equilibrium with the emanation, and in the curve for the decay of the activity due to radium A and C, their contribution to the total ionization had to be taken into consideration. The initial values of the activity, in scale divisions per minute, for the active deposits of thorium and radium, were deduced as follows:

At 35 minutes and 95 minutes after the emanations had been swept out, the total activity was 1·65 and 0·90 scale divisions per minute respectively. At 35 minutes the radium A and C was 46·7 per cent of its initial value; the thorium B and C, 96·4 per cent. At 95 minutes the values were 14·5 per cent and 90·5 per cent, respectively. If x be the initial value of the radium A and C, and y the initial value of the thorium B and C, we have: $·467\,x + ·964\,y = 1·65$ and $·145\,x + ·905\,y = 0·90$ which give, $x = 0·64$ and $y = 2·22$ scale divisions per minute. During the disintegration of radium A and C, the curve for thorium B and C is practically a straight line and is so drawn in the figure. The decay curve for radium A and C is superposed on this straight line to show the combined activities.

The values in the last part of the curve correspond to a half-value period for thorium active deposit of about 12 hours, which is in sufficiently good agreement with the accepted value, namely 10·6 hours.

Points surrounded by circles are observed points; those with double circles are mean values of two or more readings; a point in a square is one which was extrapolated from the curve.

Standardization of the Thorium Emanation.

In order to compare the thorium emanation in the underground air with that produced by a known amount of thorium, it was necessary to obtain a relation between the amount of emanation produced per cubic centimeter of the earth or sand and the corresponding rate of leak of the electroscope. The calculation was simplified by substituting for the mercury flask and connecting tube a brass tube, 140 centimeters long and with an internal diameter of about 0·4 centimeter. This tube was provided with a sharp, conical head of iron, 3 centimeters long, with a shank which fitted snugly in the tube and a shoulder which rested firmly against its end. The tube was driven into the earth with a heavy mallet until only a centimeter or so remained above ground. It was then withdrawn a short distance and the conical head driven out with a blow from a long iron rod passed into the tube. The ionization chamber of the electroscope was then connected to the brass tube by a length of rubber tubing and observations were made as follows:

The filter pump was started (running about 3 liters per minute) and the current of air continued for several minutes until the ionization vessel was filled with underground air. The pump was then shut off, and the vessel with the underground air allowed to stand for half an hour, when the supply of air was renewed by running the pump for another short interval. This operation was repeated every half hour. At the end of about three hours the radium A, B and C had come into equilibrium with the emanation and the radium part of the observed activity had attained a constant value.

With the pump running, a series of readings was then made which gave the combined activities of radium emanation, radium A, B, C, and thorium emanation. The pump was stopped and five or six minutes allowed for the thorium emanation to decay. A series of readings then gave the constant radium part of the activity alone. The difference between the activity with the pump running and the activity when the air was at rest was due to the thorium emanation.

It is easily seen that all the thorium emanation is drawn from a sphere whose radius $R = \sqrt[3]{\frac{3qT}{4\pi P}} = 23{\cdot}5$ centimeters, where q = cubic centimeters per second drawn by the pump (50); T, the number of seconds required for thorium emanation to decay practically completely (420); and P, the volume of air per cubic centimeter of the earth or sand (·366). This is the radius of the sphere from which all the air is drawn in seven minutes and any emanation originating beyond this sphere will entirely decay before reaching the electroscope. Since the tube was driven into the soil a distance equal to about six times the radius of this sphere, no variation in the concentration of thorium emanation was to be expected. The radium emanation, on the other hand, with its longer half-value period, was drawn from a sphere of relatively enormous size, but, in standardizing the radium, the underground air current was never running for lengths of time aggregating to more than twenty minutes and in this time all the air was drawn from a sphere of only about 32 centimeters radius.

Let n be the amount of thorium emanation in equilibrium per cubic centimeter of the earth. Then $\frac{n}{P}$ is the amount of emanation per cubic centimeter of underground air, and this will be its concentration whether at rest or in motion, until it leaves the earth to enter the tube. If k_1 is the total volume of the brass tube and all connections, up to the ionization chamber, $\frac{k_1}{q}$ is the time taken to reach the ionization chamber and the concentration will there have the value $\frac{n}{P}e^{-\frac{\lambda k_1}{q}}$, where λ is the decay constant for thorium emanation. The time taken to pass through the ionization chamber is $\frac{k_2}{q}$, where k_2 is the volume between the inlet and outlet. The activity measured is proportional to the mean concentration of the emanation in its passage or

$$N \propto \frac{1}{T}\int_0^T e^{-\lambda t}dt = \frac{1}{\lambda T}\left(1-e^{-\lambda T}\right) = \frac{q}{\lambda k_2}\left(1-e^{-\frac{\lambda k_2}{q}}\right)$$

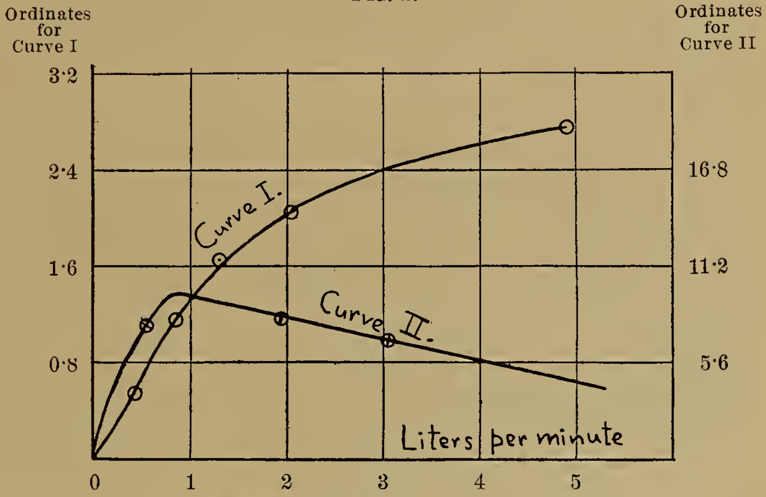
Hence the concentration

$$\text{(I.)} \qquad N = \frac{nq}{P\lambda k_2} e^{-\frac{\lambda k_1}{q}} \left(1 - e^{-\frac{\lambda k_2}{q}}\right)$$

where k_1 = 101·5 and k_2 = 2750.

To test the accuracy of the measurements involved in this equation, a series of readings was made with the pump running at different speeds; i. e. for different values of q. By taking the mean of several measurements, the activity when q = 34·5 (pump fully on) was found to be 2·06 scale divisions per minute.

FIG. 2.



Ordinates represent scale divisions per minute.

The corresponding value given by the equation was 1·64 n. This ratio was used to determine the ordinates of equation I, which was plotted for values of q from zero to 5 liters per minute. The other observed values of the activity corresponding to different values of q were then plotted directly and it will be observed that they fit the curve very closely. (Curve I, figure 2.) Since 1·64 n gave a rate of 2·06 scale divisions per minute, one scale division per minute must indicate a mean concentration in the electroscope of 0·80 n per cubic centimeter.

The Thorium Standard.

In selecting a standard for comparison with the amount of thorium emanation obtained with the underground air, a number of difficulties are apparent. No one as yet has devised a method by which either all or a definite fraction of the thorium emanation in equilibrium with a known amount of a thorium salt may be obtained with certainty. It may reasonably be assumed, however, that if the thorium salt could be obtained in the form of a sufficiently thin coating on the surface of some neutral material, all of the emanation produced within it would escape. For this reason the thorium solution was thoroughly mixed with a considerable quantity of neutral sea sand so that each grain was covered with a very thin film of radioactive material.

Another point which must be taken into consideration is the requirement that all the disintegration products of thorium, preceding the emanation, shall be present in equilibrium amounts. In the present experiment this was accomplished by taking a solution of a thorium mineral containing a known proportion of thorium.

The mineral chosen was thorite, containing 52 per cent of ThO_2 in the form of a silicate. When this mineral was dissolved in hydrochloric acid, diluted and mixed with a granular neutral material, a thin gelatinous film of free silicic acid, containing the $ThCl_4$, was formed on each grain, and it was thought that such a film would possess a very great emanating power, an assumption which was amply justified by comparison with thorium in other forms. By adopting as a standard the most emanating form of thorium which could be found, it was assured that the results obtained for the thorium content of various materials were very nearly minima. The standard was prepared by dissolving 0·1 gram of thorite in a little hydrochloric acid. It was then diluted and intimately mixed with 884 grams of white beach sand, which had been previously tested and found free from any measurable radioactivity. This mixture was thoroughly dried and then moistened with 12 cubic centimeters of water. The standard thus prepared was placed in a vertical tin cylinder, about 35 centimeters high, closed at its lower end, except for a brass connecting tube, and provided with a cover having a small inlet hole in its center. About a centimeter from the bottom was a platform of wire gauze on which was placed a disk of cotton. The air was sucked in at the top, through the sand, out at the bottom and thence, through a rubber connecting tube, to the ionization chamber.

The theoretical considerations governing this case are much the same as before. When the underground air was drawn directly into the brass tube, it retained its equilibrium concentration up to the instant of entering the tube. In the case of the cylinder, a horizontal layer of air enters the sand practically devoid of thorium emanation and passes through it in a time $\frac{k_3}{q}$, where k_3 is the volume of air in the interstices of the sand. Each layer will therefore acquire a concentration $\frac{n}{\mathrm{P}}(1-e^{-\frac{\lambda k_3}{q}})$ before leaving the sand, where n is the emanation per cubic centimeter of sand and P the volume of air in one cubic centimeter of sand. The terms relating to the decay in transit and the mean value in the ionization chamber will keep the same form. Hence

$$\text{(II.)}\quad \mathrm{N} = \frac{nq}{\lambda \mathrm{P} k_2}\left(1-e^{-\frac{\lambda k_2}{q}}\right) e^{-\frac{\lambda k_1}{q}} \left(1-e^{-\frac{\lambda k_3}{q}}\right)$$

where $k_1 = 347$, $k_2 = 2750$, $k_3 = 201$, $\mathrm{P} = {\cdot}366$.

With the pump drawing 3·03 liters per minute the rate of the electroscope was 6·865 divisions per minute; for the same value of q, equation II, gives 0·0886 n. This ratio was used to determine the ordinates, and equation II was plotted (v. curve II, figure 2). Two other observed values of the activity, for different values of q, fell near enough this curve to show the correctness of the assumptions.

Since 6·865 scale divisions per minute correspond to a concentration of 0·0886 n, we see at once that one scale division corresponds to a concentration of 0·0129 n. But n is the emanation in equilibrium with $\frac{0{\cdot}52 \times 0{\cdot}1}{545}$ gram of $\mathrm{ThO_2} = 9{\cdot}45 \times 10^{-5}$ gram $\mathrm{ThO_2}$, and hence one scale division per minute corresponds to a concentration equal to the emanation in equilibrium with $1{\cdot}22 \times 10^{-6}$ gram of $\mathrm{ThO_2}$ or $1{\cdot}07 \times 10^{-}$ gram of pure thorium under the conditions specified.

Other Materials.

A larger cylinder, made from a section of galvanized iron pipe, with a diameter of 17·6 centimeters, a height of 71 centimeters, and a capacity of about 15 liters, was provided with a gauze screen and cotton pad, as before, and used to test the thorium content of other materials.

The earth under the cellar floor consists of about 85 per cent disintegrated red sandstone, none of which disintegrated in situ, but which was carried by streams from a melting glacier. The grains were worn and rounded in transit. The remaining 15 per cent consists of fragments of trap rock and various crystalline gneisses and schists. The sample designated "Sandstone II" was taken from some excavations about a mile from the physical laboratory. This earth has the same constituents as the above, but disintegrated where it was found and was not carried by glacial streams.

A sample, called "surface soil," was of the same general nature as the earth under the laboratory floor, but contained a considerable proportion of loam. It was a specimen of the soil in the rear of the Laboratory, and was removed from just beneath the surface.

The results of the measurements of the different specimens were of the same general character, although, as might be expected, the earth taken from near the surface was less active than the material lying deeper. This is probably due to the leaching action of the surface water.

A test on white beach-sand showed no activity. This was significant and made it seem probable that the activity of soil is due for the most part to the material covering the separate grains and not to mineral constituents of the grains themselves. To test this point some cellar earth was heated with fairly strong hydrochloric acid, filtered and washed. The sand thus obtained was thoroughly dried and placed in the larger cylinder, which it half filled. As will be seen from the table, fully half of the activity was removed by this process. This specimen is called "treated earth" in the table.

A solution was prepared by dissolving 0·8135 gram of thorianite, containing 78 per cent ThO_2, in a little concentrated nitric acid with gentle heating, evaporating to dryness, dissolving and diluting to 50 cubic centimeters with distilled water. 10 cubic centimeters of this solution was diluted still further and mixed with 884 grams of neutral beach sand in the same manner as has been described in the case of thorite. As is shown by the results given in the table, the emanating power of the thorium nitrate thus prepared is noticeably less than that of the thorium chloride contained in a gelatinous film of silicic acid.

Another experiment was made in which a volume of 10 cubic centimeters of the thorianite solution was freely diluted and thoroughly mixed with 15 liters of the cellar earth. The normal activity of the earth was subtracted from the reading obtained, and this gave the activity due to the thorianite alone. The table shows that in this condition the thorium is slightly more emanating than when mixed with sand, but the difference is not so striking as in the case of thorite. In the table this specimen is designated "enriched earth."

Measurements were also made of the amount of thorium emanation escaping from the thorium minerals monazite (5 per cent ThO_2) and thorianite (78 per cent ThO_2). The monazite was in the form of fine sand, and the thorianite in the form of cubical crystals about 3 millimeters on a side. About 500 grams of each were placed in a glass cylinder and held in place by glass wool. Air was drawn through and readings taken as before.

In all the foregoing experiments the relation between the amount of thorium emanation per cubic centimeter and the activity as measured in the electroscope was deduced from equation II by substituting the proper values for the constants k_1, k_3, and P.

The experiment designated "surface diffusion" was made by placing a rectangular metal plate of about 2400 square centimeters, one centimeter above a leveled surface of cellar earth and drawing air, into the electroscope, through a tube soldered in the middle of the plate. In this way the air was made to pass slowly over the surface of the soil, which was quite moist. An experiment was also made with rather large fragments of broken red sandstone. The fifteen-liter cylinder was filled with this material and air drawn through it as before. It is obvious that equation II does not apply in either of these cases.

The third column gives the amounts of the thorium in one cubic centimeter of sand, under the specified conditions, which will liberate the same amount of emanation as one cubic centimeter of the material considered. The fourth column gives the amount of thorium present in one cubic centimeter of the material, in those cases where this was known.

Material tested	Activity in scale divisions per minute	Thorium equivalent in grams per c. c.	Am't of Thorium actually present per c.c.
Cellar Earth	2·06	$1{\cdot}35\times10^{-6}$	--------
Surface Soil	1·13	$1{\cdot}08\times10^{-6}$	--------
Sandstone II	1·41	$1{\cdot}35\times10^{-6}$	--------
Sea Sand	0·00	$0{\cdot}00\times10^{-6}$	--------
Surface Diffusion	0·20	--------	--------
Broken Sandstone	0·55	--------	--------
Thorianite Sand	12·32	$1{\cdot}50\times10^{-4}$	$2{\cdot}04\times10^{-4}$
Monazite	6·86	$2{\cdot}04\times10^{-4}$	1240×10^{-4}
Thorianite	95·2	$3{\cdot}58\times10^{-4}$	30400×10^{-4}
8 Liters of treated earth	0·50	--------	--------
8 Liters of cellar earth	1·01	--------	--------
Enriched earth	6·48	$5{\cdot}15\times10^{-6}$	$7{\cdot}00\times10^{-6}$

It will be seen from the table that the thorium in the sand treated with thorianite solution is about four hundred and twenty times as emanating as the thorium in monazite, and about six thousand, one hundred times as emanating as the thorium in thorianite.

The Radium Standard.

The radium emanation obtained on dissolving 0·0907 gram of North Carolina uraninite (containing 76 per cent of uranium) was introduced in the electroscope. After standing for about three hours, the rate of leak of the electroscope was 110 divisions per minute. Taking $3{\cdot}4\times10^{-7}$ gram as the amount of radium in equilibrium with one gram of uranium, the amount of radium in the sample was $2{\cdot}34\times10^{-8}$ gram. Approximately 14 per cent of the radium emanation escapes from the specimen of (powdered) uraninite taken as a standard,* and therefore the emanation introduced into the electroscope was in equilibrium with only 86 per cent of $2{\cdot}34\times10^{-8}$ gram, or $2{\cdot}0\times10^{-8}$ gram of radium. One scale division per minute therefore corresponded to the ionization produced by the emanation, radium A, B, and C, in equilibrium with $1{\cdot}82\times10^{-10}$ gram of radium.

The mean of several measurements of the activity of the radium emanation, in equilibrium with radium A, B, and C, contained in the underground air was five scale divisions per minute. The total amount of radium emanation present in the volume of underground air necessary to fill the electroscope was therefore equal to that in equilibrium with $5\times1{\cdot}82\times10^{-10}$ or $9{\cdot}1\times10^{-10}$ gram of radium. The volume of the ionization chamber of the electroscope was 3,800 cubic centimeters and therefore each cubic centimeter of underground air contained radium emanation equivalent to that in equilibrium with $2{\cdot}4\times10^{-13}$ gram of radium. The porosity of the earth was 36·6 per cent, that is to say each cubic centimeter of earth contained 0·366 cubic centimeter of air. Therefore the amount of radium emanation produced by one cubic centimeter of earth was equal to $2{\cdot}4\times10^{-13}$ times 0·366 or $8{\cdot}9\times10^{-14}$ gram of pure radium.

Discussion of Results.

The results of experiments conducted by a number of independent investigators have clearly demonstrated that the radioactive properties of the normal atmosphere near the surface of the earth are due to the presence of very small amounts of the emanations of radium and thorium and the disintegration products of these substances. It is necessary to assume that these emanations are formed by thorium and radium compounds present in the solid material constituting the surface of the globe. The radium emanation because of its relatively slow rate of disintegration might be expected to reach the surface by diffusion from considerable depths and to escape from the interior of masses of rock having a slight porosity. In contrast to this, however, the thorium emanation disintegrates so rapidly that the process of diffusion alone is insufficient to bring any appreciable quantities of this to the surface, except from the uppermost layers of a light and porous earthy covering. It is in the

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* Boltwood, this Journal, xxv, 281, 1908.

free surface of such a covering that by far the greater proportion of the thorium emanation which ultimately enters the atmosphere must originate, and its dissemination through the lower strata of the air must be greatly facilitated by winds and other air currents.

It is, moreover, evident that the actual quantities of either emanation which can obtain access to the free atmosphere under the most favorable conditions of exposure, etc., will be much less dependent on the actual amounts of thorium and radium present in the surface materials than on the physical and chemical conditions in which these elements exist and which determine their emanating properties. If the thorium and radium are in the form of compounds which permit the escape of a large proportion of the emanation formed within them, their contribution to the local atmospheric radioactivity will be much more pronounced than that of much larger quantities of the parent radioactive elements existing in a non-emanating form.

Sand and earth consist essentially of disintegrated rock which has undergone more or less chemical decomposition. For facilitating the escape of the emanations the advantage derived from the mechanical subdivision alone is apparent. The decrease in the thorium emanating power of a specimen of earth treated with dilute hydrochloric acid, which was observed in the course of the experiments described in this paper, also justifies the assumption that a considerable proportion of the thorium emanation which escapes originates in the superficial coating covering the separate grains of the specimen of sand examined. It is, therefore, highly probable that the thorium in this surface coating exists in a chemical form which readily permits the escape of emanation.

Since by far the greater proportion of the land areas of the globe are covered with soil of some description, it is apparent that the part played by this in contributing to the radioactive constituents of the atmosphere must be much greater and much more important than the part played by the rocks which underlie it. It is, therefore, to be expected that an examination of the radioactive properties of the soil and the underground air in different localities will afford valuable data for explaining the differences in the radioactivity of the atmosphere already observed in certain instances.

As the average of results of measurements conducted during a period of a year at Montreal, Eve* found the amount of radium emanation present per cubic centimeter of atmospheric air to be equivalent to that in equilibrium with 6×10^{-17} gram

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* Phil. Mag., xvi, 622, 1908.

of radium. This is one four-thousandth the amount found for underground air here at New Haven. The average of Joly's values* for the thorium content of many common rocks is approximately ten times the value found from the emanating power for the thorium content of the earth at New Haven, while his value for the radium content is about one hundred times that found for New Haven earth by the method employed in this paper.

Summary.

A determination has been made of the amount of radium emanation in the underground air in the neighborhood of the Sloane Physical Laboratory. It was found that one cubic centimeter of underground air contains radium emanation equal to the amount in equilibrium with $2{\cdot}4\times10^{-13}$ gram of radium. This is equivalent to the production, per cubic centimeter of earth, of radium emanation in equilibrium with $8{\cdot}9\times10^{-14}$ gram of radium.

A method has been devised by which the amount of thorium emanation present in underground air can be directly measured in an electroscope and compared with the emanation evolved by a known weight of thorium salt. In this manner it was found that the earth in the neighborhood of the Laboratory emits per cubic centimeter thorium emanation equivalent to that produced by $1{\cdot}35\times10^{-6}$ gram of thorium under the standard conditions.

The important bearing of the emanating power of the soil on the radioactive properties of the atmospheric air in different localities has been pointed out, and a method has been suggested by which the emanating power of the soil and the radioactive character of the underground air can be determined in any given locality.

In conclusion, I wish to acknowledge my very great indebtedness to Professor B. B. Boltwood, and express my thanks for his assistance and advice.

Sloane Physical Laboratory, May, 1911.

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* Phil. Mag., xviii, 140, 1909.

ART. XX.—*On the Mineralization of the Gold-bearing Lode of Passagem, Minas Geraes, Brazil;* by ORVILLE A. DERBY.

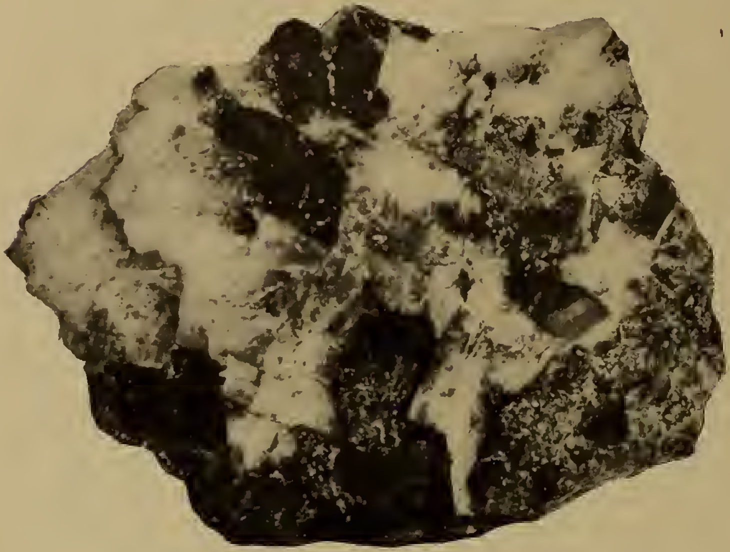
IN an article published in the *Zeitschrift für praktische Geologie* for Oct., 1898, on the gold-bearing lode of the Passagem mine near Ouro Preto, State of Minas Geraes, Brazil, Dr. Eugene Hussak concluded from a detailed mineralogical and petrographical study of the contents of the lode and of the immediately adjacent portions of the country rock, that it is of eruptive origin representing the ultra-acid phase of a pegmatitic apophysis from a neighboring mass of granite. Since the lode is, in all essential respects, a typical quartz-pyrite one, this conclusion has attracted considerable attention on account of its bearing on the general question of the genesis of ore-bearing bodies of this character.

With regard to the metalliferous portion of the lode (the ore proper, consisting of a mixture in varying proportions of arsenical, magnetic and common pyrites with traces of various other sulphides, associated with a large amount of tourmaline) Hussak expressed somewhat reservedly the opinion that it should be classed among the primary constituents of the lode. This opinion was based on the constant and characteristic association of the metallic sulphides with the tourmaline, which was regarded as a contact mineral and thus practically contemporaneous with the intrusion of the granitic apophysis. A fine suite of specimens recently presented to the Geological Service of Brazil by Mr. Arthur J. Bensusan, the able superintendent of the mine who is always on the alert for new developments that promise to be of scientific interest, suggested the hypothesis that the lode might possibly have become mineralized by an introduction of sulphides and tourmaline subsequent to its formation; and to gather additional evidence on this important point, an examination *in situ* of a recently opened section of the mine that revealed certain features not hitherto observed, was made by Mr. Jorge Ferraz of the staff of the Geological Service.

A drift now being driven through sterile quartz in search of an ore shoot, begins to show on one of the walls and in the heading a beginning of mineralization in the form of small patches and streaks of massive tourmalinized quartz accompanied by a small amount of arsenopyrite, and at the same time a porphyritic appearance due to isolated polyhedral inclusions of a greenish mineral sharply defined in a white or black groundmass according as they occur in the sterile or in the mineralized portion of the lode. The occurrence (see fig. 2), in the broken-down material, of pieces of stratified quartzite shows that the wall of the drift must be in close proximity to the contact of the lode with the country rock, although the plane of contact is not yet clearly exposed in the working. This circumstance suggests that the inclusions may possibly represent a contact mineral developed locally in the marginal zone of the lode, rather than an original constituent, but for the purpose of the present study this question is immaterial.

The accompanying figures present, about half natural size, four of the most significant slabs of the lode rock that came to hand. No 1 is a mass of typical glassy vein quartz studded with inclusions which in part show sharp cut crystalline outlines, while fig. 2 shows a corresponding part in the central zone (B), flanked on one side by a zone (A) of country rock and on the other by a zone (C) of highly tourmalinized quartz with a certain admixture of pyrites.

Fig. 1.



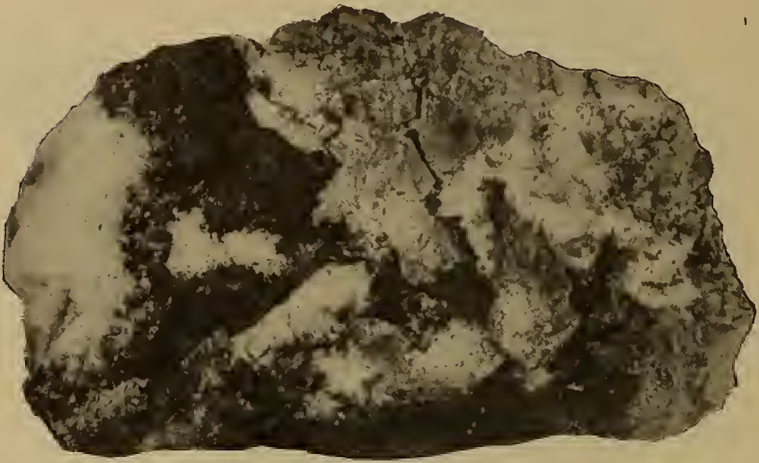
The inclusions consist of sericitic mica, in place quite coarsely crystalline, in milky white flakes (as in the central and left portions of the one at the middle of the lower border of fig. 1), but for the part in cryptocrystalline masses of a light greenish color. In places the characteristic luster and cleavage of an original feldspathic mineral are preserved, but for the most part even in these cases the microscope reveals only a micaceous aggregate which treatment with the acid shows to be heavily charged with calcite. A single inclusion only (3 in fig. 2) amongst the score or more examined retains the feldspar substance in a sufficiently fresh condition to permit of a satisfactory microscopic and chemical examination. The microscopic sections show in great perfection the characteristic twinning bands of a plagioclase feldspar with an extinction angle indicative of a nearly normal oligoclase, and an approximate analysis confirms this reference, as does also the external form, since with careful work many of these inclusions can be completely detached from the matrix in ideally sharp-cut crystals.

Fig. 2.

These inclusions are, therefore, original feldspars that have become sericiticized by some agency that has reached them through an apparently impervious involucre of dense vein quartz. In their immediate vicinity the quartz shows fissures large and small, filled with tourmaline and pyrites which have evidently been introduced by solutions, or gases, carrying boron, sulphur and arsenic along with iron and, rarely, gold, silver, copper, bismuth, lead and probably tellurium. A relation between the two phenomena of the sericitization of the feldspar and the mineralization of the lode, with boron and sulphur compounds, is at once suggested and fortunately definite evidence on this point is at hand.

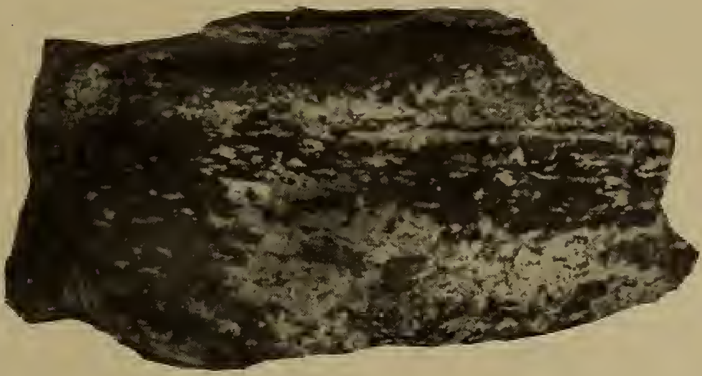
The almost absolutely fresh feldspar crystal (3) in fig. 2 lying in the quartz band *B* is, on the face photographed, completely surrounded with quartz free from tourmaline and pyrite, in a zone of the width of two centimeters or more, while at the back of the block scattered crystals of these minerals can be traced up to its margin, and here a portion of the crystal shows incipient sericitization. Its neighbor 2 is still comparatively fresh, while 1, which abuts directly on a strongly mineralized part of zone *C*, is so completely altered that all traces of the original cleavages have been obliterated. In many cases it is clear that the mineralizing agent has only reached one face of the feldspar crystal and that this contact has been sufficient to effect the alteration of the latter. This is well shown in fig. 1 in the case of the two grouped crystals at the middle of the upper margin in which narrow bands of pyrites (distinctly seen in photograph) are interposed between the two feldspar individuals and between the left-hand one and the quartz, while at the right the contact between the quartz and the inclusion is perfect. All the other inclusions on this slab show the same phenomena of a narrow, almost linear, mineralized strip (with pyrite predominant over tourmaline) along one face and a sharp cut contact with the quartz on the others. Evidently the mineralizing agent entered through small fissures which, on meeting a feldspar crystal, passed along one of its faces, which, in the case of all those shown in fig. 1, was always on the same (left) side.

Fig. 3.



The specimen represented in fig. 3 exhibits some other phases of the mineralization process. The fissures of the fractured quartz-feldspar rock are here of considerable width and the filling is exclusively of tourmaline with only here and there a small isolated crystal of pyrite, of which not more than a dozen can be counted on the considerable surface here shown. The feldspar is completely sericitized and it is thus clear that this effect was produced by the agent that introduced the tourmaline rather than the one that brought in the metallic sulphides. It is also evident that two distinct agents were involved and that, in places at least, these acted quite independently one from the other. In the lower part of this specimen the tourmaline has a small admixture of granular quartz giving a friable *tourmalinfels* with a slight development of a schistose structure. Elsewhere on this and the other specimens figured, the vein quartz is impregnated with tourmaline, giving, as Hussak has already remarked, a massive rock resembling the luxullianite of Cornwall.

Fig. 4.



The block of ore represented in fig. 4 shows a mass of distinctly schistose *tourmalinfels* charged with arsenopyrite (white in the figure) which clearly fills fractures along planes of schistosity, and across the intervening plates of rock. This case completes the evidence, suggested by figs. 2 and 3, of the independence of the tourmalinization and the sulphuritization of the original vein rock, and shows that the former process preceded the latter. Other specimens showing larger fissures filled with a somewhat spongy mass of a granular arsenopyrite have scattered needles of tourmaline with every appearance of having been formed *in situ*, so that it is tolerably certain that the sulphide invasion took place before the complete cessation of the formation of tourmaline.

A partial analysis of one of the sericitic masses, made with the view of determining the constituents that cannot be referred to the original feldspar crystal, gave 4·14% of combined water, 4·1% of carbonic acid (combined with lime as calcite) and distinct traces of fluorine, and it is thus evident that these elements played a part in the tourmalinization of the original pegmatitic vein and in the alteration of its feldspathic contents.

The Passagem lode thus presents evidence of three distinct processes of filling, and the succession of events in its formation may be summarized as follows:

First—An extensive fissure opened by stress along (above, below and across) a bed of brittle rock (quartzite) enclosed between more tenacious schists, was closed by an invasion of pegmatite running off into clear quartz. At this stage the lode contained only the minerals characteristic of a granite magma such as is represented in the neighborhood by a boss of granite; or, possibly, some others that may have been formed near the contact through reactions with the country rock.

Second—A subsequent stress, acting in substantially the same place and manner as the first, fractured this pegmatitic quartz, rendering it accessible to a pneumatolitic action characterized by silica, boron, water vapor, carbonic acid and fluorine ("after effect" of the granitic eruption ?), which filled its fissures with tourmaline, sericiticized the feldspar of the pegmatite wherever fissures, often quite minute, permitted access to it, and probably produced the characteristic contact phenomena noted by Hussak.

Third—A third stress, coming near the end of the second phase of the lode, fractured the tourmaline filling and gave access to a pneumatolitic action characterized by sulphur, arsenic, metallic oxides and metals (gold and silver), which filled the fissures of the lode, invading to some extent its preexisting portions, and probably also some of the adjacent and enclosed country rock.

Serviço Geologico e Mineralogico do Brasil,
Rio de Janeiro. May 8, 1911.

Art. XXI.—*A Notable Brazilian Diamond;* by Orville A. Derby.

A diamond of large size and of certain interesting peculiarities of form and surface recently appeared in Rio de Janeiro from the river Bagagem district, in the southwestern part of the state of Minas Geraes, in the headwater region of the river Paraná. This district, in which diamonds were first discovered about the middle of the last century, became famous in 1853 through the finding of a stone that took the name of Star of the South and which is until to-day the largest well authenticated diamond known from Brazil. Its weight in the rough is given as 52·276 grams, or 254½ Paris carats (=255 international carats). It was found in or near the river Bagagem, a few kilometers below the town of the same name, and a few months later and in about the same place a second large stone, known as the Dresden diamond, was found which weighed in the rough 119·5 carats or 24·1172 grams. The present stone, to which the name of Estrella de Minas (Star of Minas) has been given and which weighs 35·8754 grams (175 international carats of 205 milligrams), is reported to have come from or near the same spot.*

The shape and size of the present stone could be very approximately represented by quartering an elliptical rubber ball representing a medium-sized hen's egg, and then distorting

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* The upper Paraná diamond field and the neighboring one of the river Abaeté on the opposite side of the Paraná-São Francisco watershed are the only ones in Brazil that have afforded diamonds of over 100 carats weight. In the older Diamantina field, which has been worked continuously since 1728, a stone of an *oitava* (an eighth of an ounce, the most frequently used Portuguese unit for precious metals and stones) was considered such a rarity that in the days of slave labor liberty was given to the finder. Apparently only some scores, or at most a few hundreds, of such stones were found in this field, and those of a weight of 50 to 100 carats can be counted on the fingers. The same is the case in the productive Bahia field, in which, however, black diamonds or *Carbonados* of hundreds and even thousands of carats (the largest known weighed 3148 carats or about 120 carats more than the famous Cullinan diamond) appear. According to information that is considered reliable, the largest diamond ever found in Brazil was destroyed in 1906 by the stupid sledge and anvil test for hardness. It was found in the river Verissimo district in southern Goyaz adjacent to the Bagagem district and is reported to have been of about the size and shape of an ordinary matchbox, that is to say a parallelopipidon of 60x36x16 millimeters. On this basis its weight was calculated as over 600 carats, or roughly between two and three times that of the Star of the South. A parcel of powder and fragments which one of the interested parties had saved as his share was shown me by a local lapidary who had taken pains to gather reliable information regarding the matter. The parcel when purchased by him contained something over 100 carats and from the largest fragment he cut a stone of 8 carats.

one of the pieces in such a way as to produce an obtuse ridge extending diagonally across the curved face from end to end, but without distorting, except in shape, the two plane faces. The accompanying figures, all of natural size, represent very accurately, in Nos. 1 and 2, the two plane faces; but, owing to light effects, the curved faces shown in Nos. 3 and 4 present an appearance of being made up of subordinate faces (suggestive of distorted dodecahedral crystallographic planes) that do not appear on the stone itself.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Greatest length	38^{mm}
" width	22^{mm}
" height	23^{mm}

As is well shown in these figures, all the faces, both plane and curved, are covered by sharp-cut lines and depressions similar to those produced by etching, though in this case it seems much more probable that they are features of crystalline growth. The large semi-circular depression in the middle of the base line of fig. 1 is, however, an artificial fracture due to a blow that raised a thin scale along a plane of octahedral cleavage characteristic of the mineral. The small cleavage face thus produced is parallel to the main face and to several subordinate platform-like faces that rise above its general surface. The face shown in fig. 2 also shows, with still greater distinctness, several parallel platforms as well as a sharply defined pit with coarsely ridged walls, suggestive of an external mould of the point of an octahedral diamond crystal of the size of about a carat.

According to the description and figures given by Dufrenoy* the Star of the South was in the rough a semi-ellipse and thus strikingly similar in general form to the present stone.† It is also on record that the original form of the Dresden stone was such that it suggested the hypothesis that it and the Star of the South were cleavage fragments of an original elliptical (distorted dodecahedral) unit. It is thus highly probable that the three stones, representing a limited area of diamond-bearing ground, were characterized by a quite similar original shape, that is to say, a vaguely defined combination of curved faces constituting a dome rising from a plane face. In the case of the stone here noted a considerable portion of the ideal dome is cut away by a second plane face, and judging from No. 2 of Dufrenoy's figures, this was also the case with the Star of the South. Without entering into crystallographic considerations, a comparison may be suggested with fig. 7, pl. 1, of Rose and Sadebeck's memoir on the crystallization of the diamond,‡ which represents a dome-shaped diamond with a flat base which is interpreted as a case of hemimorphism.

An interesting question, which must, however, be left to crystallographers, arises as to the significance to be given to the plane faces and to the surface markings of this diamond. The first and most natural impression is that the plane faces are cleavage planes, and the fact that a small artificial fracture shows that one of them is strictly parallel to an octahedral cleavage seems to confirm this view. In this case, however, they represent a superinduced feature, and the superficial markings on them must also be posterior to the formation of the crystal and thus can only be attributed to etching; a process which is difficultly conceivable in the case of the diamond. If, on the other hand, the markings are an original (growth) feature, the plane faces must also be original, since the markings on them must have been produced at the same time as on the curved faces. In the Star of the South, which

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* Traité de mineralogie, 2d ed., vol. 2, p. 95, pl. 225, figs. 1, 2 et 3.

† It is to be strongly suspected that the sharply defined dodecahedral faces shown in Dufrenoy's figures 1 and 2 are the crystallographer's interpretation of such obscure indications of crystalline faces as are seen on our figures 2 and 3, and thus might receive a materially different interpretation from another observer.

‡ Abh. d. K. Akad. d. Wissensch. in Berlin 1876.

according to his description had everywhere a *chagriné* surface, Dufrenoy thought that evidence of adhesion to a matrix was to be found on a part of the flat face, but in view of the present stone this explanation is evidently inapplicable. Equally inapplicable seems to be the explanation of such features as the pit shown in fig. 2 (three such are reported on the Star of the South) as due to the imprint of smaller diamonds which have fallen away. It is for crystallographers to say if the hypothesis of hemimorphism above suggested is admissible or not to such dome-shaped diamonds as are here discussed and perhaps also to the great Jagersfontein and Cullinan stones as well.

Serviço Geologico e Mineralogico de Brasil,
Rio de Janeiro, May 20, 1911.

ART. XXII.—*Association of Rutile and Cyanite from a New Locality;*[*] by THOMAS L. WATSON and JOEL H. WATKINS.

Introduction.

THE occurrence of rutile in association with cyanite is known from a number of localities in this and foreign countries,[†] but the literature contains scarcely more than the mere statement that the two minerals are observed in association. The known localities in the United States in which rutile and cyanite occur together are Graves Mountain, Lincoln County, Georgia, and Crowder and Clubb mountains, Gaston County, North Carolina. The European localities include Horrsjöberg and Dicksberg, Sweden, and near Petschau, Bohemia. In Brazil, Derby[‡] has described a cyanite schist occurring at Serro do Gigante composed mainly of cyanite, chlorite, sericite, quartz, and rutile, with an analysis by Hillebrand, which shows 4·93 per cent TiO_2. The occurrence of rutile in these localities is of more scientific interest than of commercial value.

This paper describes briefly field observations made in a small area of metamorphic crystalline rocks, containing rutile and cyanite in intimate association, and results of microscopic study of thin sections of specimens collected from the area. The area lies 12 miles northwest of Charlotte Courthouse, in the extreme northwest corner of Charlotte County, Virginia. The chief object of these notes is to direct attention to the mode of occurrence and relations of rutile and cyanite in this locality, and to note the manner of alteration of the cyanite, which is pronounced and we believe of interest. Cyanite is more abundant than rutile, and the latter is only of scientific interest in the Charlotte County area.

Lithologic Characters.

The accompanying map, fig. 1, comprises a very small area in the extensive belt of metamorphic crystalline schists, designated pre-Cambrian in age on the recent geologic map[§] of Virginia. Within the area mapped two types of the schist are recognized in their principal differentiated parts, but are regarded as probable variations of a single type, since they appear to grade into each other in the field, and with the excep-

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[*] The discovery of rutile in the area described in this article was made by the junior author, who has supplied the field notes and map.

[†] Dana, E. S. A System of Mineralogy, 1900, pp. 501, 799. Hintze, C. Handbuch der Mineralogie, 1906, p. 1595; 1907, pp. 1617-1619.

[‡] Derby, O. A. This Journal, vol. vii, p. 343, 1899.

[§] Geological map of Virginia. Virginia Geological survey, 1911.

tion of cyanite the principal minerals are the same in both. The rocks have a strike of N. 30° E. and an average dip of about 45° southeast, becoming vertical in places. No igneous

Fig. 1.

Fig. 1. Map of rutile-cyanite area, Charlotte County, Virginia,

rocks are found within the area, and it is distant about 15 miles from the exposed western margin of the granite and granite-gneiss belt. From the composition and texture of the schists it is inferred they were derived from original siliceous and argillaceous sediments under anamorphic•conditions.

The principal rock type is a thinly foliated quartz-sericite schist of light color when fresh and of medium coarse grain. It is composed of quartz and sericite as essential minerals, with occasional grains of rutile and other accessory minerals as microscopic inclusions. Thin sections show granulation and optical disturbance of the quartz, the former (granulation) being pronounced in the hand specimens.

The second rock type is a cyanite schist of variable texture according to whether quartz or cyanite predominates. Some specimens show a fine-granular nearly white rock composed almost entirely of sugary quartz, with occasional cyanite and sericite. The other extreme is represented by a coarse aggregate of greenish cyanite in flat prismatic individuals measuring 2 inches long by ½ inch wide, and containing but little quartz. Between these two extremes many gradations are traceable. The principal minerals are quartz, cyanite, and sericite, with a goodly sprinkling of rutile in places. Under the microscope the effects of dynamo-metamorphism are shown in granulation, fractures, and optical disturbance of the quartz. Cyanite occurs in prismatic form having good cleavage development parallel to the vertical axis, and contains some inclusions. It is distributed irregularly through the rock and at times forms the dominant mineral, ranging in size up to 2 inches long and from green and blue to colorless. Rutile as grains and crystals occurs with few exceptions in the substance of both cyanite and quartz. Black tourmaline and garnet are noted in places.

Rutile.

The principal occurrence of rutile is in the cyanite schist although occasional grains are observed as microscopic inclusions in the quartz-sericite schist. The rutile is frequently observed megascopically as minute grains in the hard rock and in the sands derived from the decay of the schists. It is red to reddish brown in color, very faintly pleochroic, and the larger grains sometimes show cleavage. It is quite generally fresh and very seldom shows incipient alteration peripherally to leucoxene. It is associated with both quartz and cyanite, more often with the latter, in euhedral and anhedral crystals, single and twinned, and sometimes in aggregates. In several thin sections the rutile appeared to be as abundant in the quartz as in the cyanite.

Microscopically the rutile is usually inclosed in the substance of the cyanite and to some extent in the quartz, without orientation. It is sometimes observed formed along the boundaries of the cyanite and quartz, frequently cutting into their

Fig. 2.

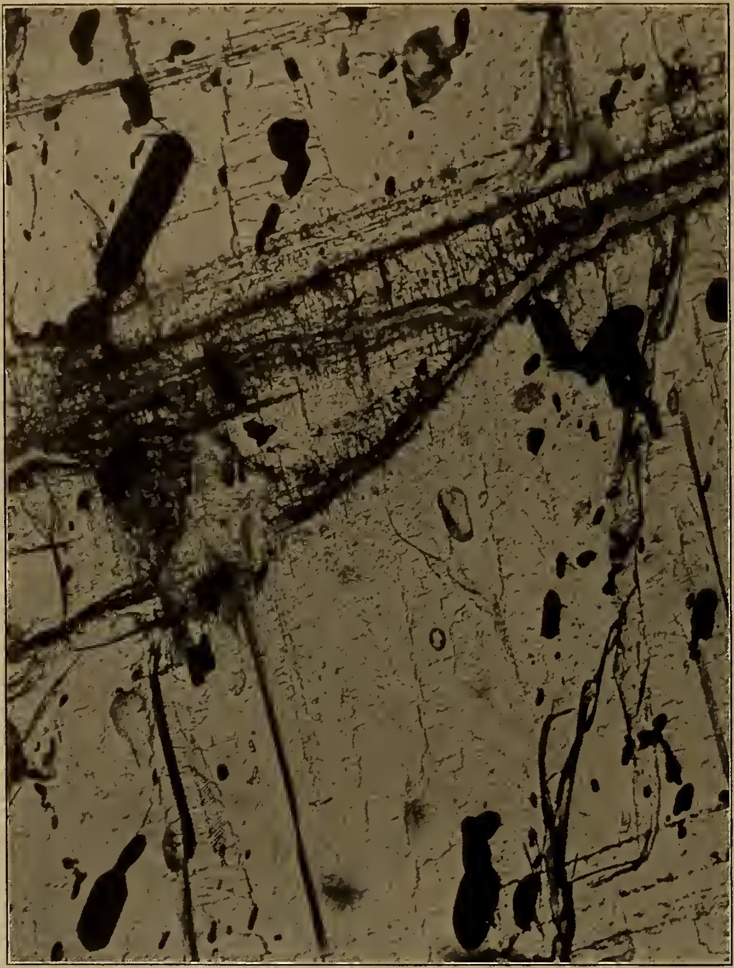

Fig. 2. Photomicrograph of cyanite showing inclusions of rutile crystals (in black). Other occasional light-colored inclusions are shown. Fracture and cleavage in the cyanite are indicated. Magnified 105 diameters.

substance; along cleavage directions in the cyanite; and occasionally along irregular fractures, but in the latter case the fracture in the cyanite sometimes passes through the larger grains of rutile, indicating that the rutile formed prior to the fracturing of the cyanite. The relations of the rutile to the cyanite and quartz are such as to preclude its formation subsequent to that of the associated minerals, cyanite and quartz (figs. 2 and 3). Figure 3 is a microphotograph showing rutile inclosed in secondary muscovite derived from the alteration of cyanite, without change of the rutile in the original mineral cyanite.

FIG. 3.

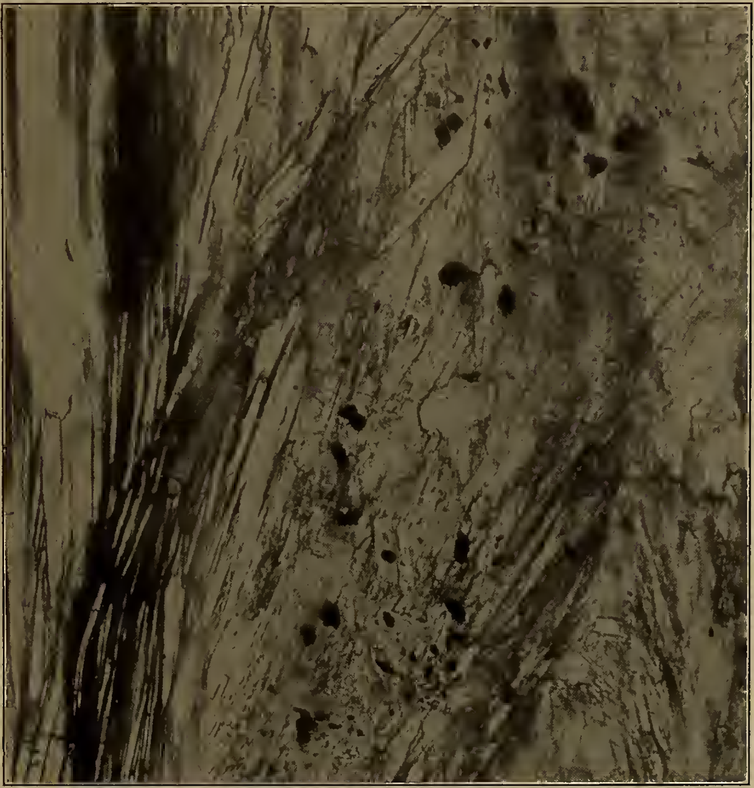

FIG. 3. Photomicrograph of cyanite altered to muscovite folia. Inclusions of rutile crystals are shown. Magnified 105 diameters.

Cyanite.

Cyanite, in the schist described above, ranges in amount from a predominant to a very subordinate constituent, in size up to 2 inches long and ½ inch wide, and from colorless to green and blue. It is in long bladed and coarsely columnar crystals, flattened parallel to 100, and without terminal planes. Fractures crossing the longer directions of the crystals (100) are rather common.

The cyanite is colorless in the thin sections but in some of the strongly colored individuals weak pleochroism (colorless to faint blue) is noticeable. Cleavage parallel to 100 is usually well developed and is sometimes observed parallel to 010. It contains inclusions of quartz, rutile, and some feldspar (?), sufficiently large and conspicuous as to give a micropoikilitic texture to the cyanite.

The most interesting feature of the cyanite is its alteration to muscovite. Some specimens of a coarse aggregate of columnar individuals of deep green color are easily scratched with the knife and on close examination are seen to be composed mostly of scales and shreds of muscovite. Other specimens show the alteration to be accompanied by the formation of much deep red to yellowish-brown iron oxide. Thin sections under the microscope indicate an aggregate of muscovite shreds, discolored from iron oxide, and sometimes inclosing grains of rutile which show little or no alteration (fig. 3). The early stages of alteration progress partly along cleavage and fracture directions, indicated usually by a somewhat darker color along these directions.

The literature contains a few references to the alteration of cyanite. Among the more recent ones are Van Hise[*] and Dana,[†] who remark that cyanite alters to muscovite (damourite) and talc (steatite). Clarke[‡] says the reported alteration of cyanite to talc and steatite is most questionable, and remarks that probably a compact muscovite (damourite) has been mistaken for talc. The reactions involved in the change of cyanite to muscovite (damourite) are those of hydration and are therefore characteristic of the zone of katamorphism.[§]

Genesis.

The mineral association in the area described is one of quartz and sericite with the heavy minerals cyanite, some rutile, and less tourmaline and garnet. Van Hise[‖] has pointed out that the conditions favorable for the development of gar-

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[*] Van Hise, C. R. A Treatise on Metamorphism, Mono. xlvii, U. S. Geological Survey, pp. 318-319, 1904.

[†] Dana, E. S. A System of Mineralogy, p. 501, 1900.

[‡] Clarke, F. W. Bull. 330, U. S. Geological Survey, p. 528 (footnote), 1908.

[§] Van Hise, C. R. Loc. cit., p. 318.

[‖] Van Hise, C. R. Ibid., p. 300.

net, cyanite, tourmaline, and other heavy metamorphic minerals are heat, moisture, and high pressure; that they are produced by processes of silication, and are formed normally in the zone of anamorphism. Emmons* adds rutile to the list of those minerals sometimes formed under conditions of dynamic regional metamorphism. Following Emmons† and Lindgren‡ in the genetic classification of minerals, garnet, rutile, and tourmaline are regarded as occurring under igneous conditions, in pegmatite veins, in contact metamorphic deposits, in deep vein zones, and under conditions of dynamic regional metamorphism. Cyanite is not known to occur as a pyrogenetic mineral nor as a product of the deep vein zones. In the area described cyanite is regarded as having formed contemporaneous with the metamorphism of the rocks.

The rocks of the small area described are metamorphic crystalline schists derived from original sediments under anamorphic conditions and the area so far as known is removed from igneous rocks and therefore from igneous contact positions. Pegmatites and veins are not known to occur. The heavy metamorphic minerals are regarded, therefore, as having been produced under conditions of dynamic regional metamorphism.

Brooks Museum,
University of Virginia.

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* Emmons, W. H. Economic Geology, vol. iii, p. 621, 1907.
† Emmons, W. H. Ibid., pp. 619, 621, 622.
‡ Lindgren, Waldemar. Ibid., vol. ii, pp. 122-125, 1906.

ART. XXIII.—*Seventh Paper on the Heat of Combination of Acidic Oxides with Sodium Oxide*; by W. G. MIXTER.

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

THE heat effects of the reactions of the heavy metals of the first group and their oxides with the oxides of sodium have been studied. Large errors in the experimental work were unavoidable. The results, however, show that the higher oxides of copper, silver and gold combine with sodium oxide with considerable heat effect to form compounds which are stable at high temperatures.

Copper in the form of a powder burned poorly in sodium peroxide. The oxide, because it was more finely divided than the metal used, answered better. The reaction between the oxide and the sodium peroxide may have been incomplete and the result low. The cupric oxide for the two following tests was prepared by heating basic copper carbonate to 500°. It was in the form of a bulky powder.

Experiment 1.—Cupric oxide 5·025, sulphur 1·000, sodium peroxide 16 grams. Thermal result for 1 gram of cupric oxide, 130^c.

Experiment 2.—Cupric oxide 4·93, sulphur 1·000, sodium peroxide 13 grams. Thermal result for 1 gram of cupric oxide, 124^c.

The fusions were good, dark green, and left when treated with water a black residue which set free chlorine from hydrochloric acid, showing that a peroxide of copper was present. The mean of the thermal results is $10,110^c$ for one gram molecule of cupric oxide. Assuming that the CuO was all oxidized to CuO_2 and adding $19,400^c$ for the heat required to reduce Na_2O_2 to Na_2O and O, we have for the heat effect of

$$CuO + O + Na_2O = 29,500^c.$$

Since the fusions were green it is evident that a compound of a copper oxide and sodium oxide was formed.

Silver.

Silver in the form of fine powder was prepared by precipitating the metal by copper from a solution of the nitrate, washing it with water and ammonia and drying. The following determinations were made :

	1	2
Silver	10·000 grams	10·000 grams
Sulphur	1·000 "	1·000 "
Sodium peroxide	17· "	13· "
Heat observed	5424^c	5596^c
Heat of oxidation of S and Fe	5320^c	5320^c
	104^c	276^c
For 1 gram of silver	10^c	28^c

The mixture in experiment 1 did not fuse but only sintered together and the product contained no fused particles of silver. The fusion of 2 was good and it left when digested with water and acetic acid 6·8 grams of metallic silver, most of which was in a fine powder. A few particles of fused silver were present, showing that the temperature of the fusion was high. The first result is low because the fusion was not good. Sodium peroxide in water reduces silver oxide, hence it is impossible to determine how much of the silver in the mixture of experiment 2 was attacked and it is best to consider that all of it was. On this assumption the heat effect of 1 gram of silver reacting with sodium peroxide is 28^c and of 2 gram atoms it is $6{,}000^c$.

Silver Oxide.

The silver oxide used in the investigation was made by adding potassium hydroxide to a solution of the nitrate. It was thoroughly washed, dried in the air and then heated for two days at 200° to 220° and finally the temperature was raised and kept at 280° for several hours. The preparation contained 92·8 per cent of silver; Ag_2O containing 93·1 per cent. It was not quite free from carbonate, but gave off very little gas when dissolved in nitric acid. It was preserved in a stoppered tube. The experimental work was as follows:

	3	4
Silver oxide	6·200 grams	4·897 grams
Sulphur	1·500 "	1·500 "
Sodium peroxide	15· "	14· "
Heat observed	8526^c	8358^c
Heat of S and Fe	7955^c	7955^c
	571^c	403^c
For 1 gram of Ag_2O	92^c	81^c

Some gas was given in experiment 3 in the combustion but none in 4. Both fusions left a few minute particles of fused silver when they were disintegrated by water and the fine sediment floated off. The mean of the two results is 87^c.

This number multiplied by 231·76, the molecular weight of Ag_2O, gives 20,000^c for the heat effect of $Ag_2O + Na_2O_2$.

Silver oxide, Ag_2O, does not exhibit, so far as known, any acidic property towards strong bases or basic oxides. Moreover only the higher oxides of metals are as a rule acidic oxides. Hence it is probable that a compound of silver peroxide, Ag_2O_2, with one or more molecules of sodium oxide is formed. On this assumption the following are derived from the experimental data:

$2Ag + 2Na_2O_2 = Na_2O.Ag_2O_2 + Na_2O +$ .... 6,000^c
$2Na_2O + 2O = 2Na_2O_2 +$ .... 38,800^c

$2Ag + 2O + Na_2O = Na_2O.Ag_2O_2 +$ .... 44,800^c

$Ag_2O + Na_2O_2 = Na_2O.Ag_2O_2 +$ .... 20,000^c,
$Na_2O + O = Na_2O_2 +$ .... 19,400^c

$Ag_2O + O + Na_2O = Na_2O.Ag_2O_2 +$ .... 39,400^c
$2Ag + O = Ag_2O +$ .... 5,400^c

Considering the unavoidable errors, 5,400^c found for the heat of formation of silver oxide agrees fairly with Thomson's result of 5,900^c.

Gold.

Fernand Meyer* observed that precipitated gold reacts violently with molten sodium peroxide with formation of sodium aurate. Determinations of the heat effect of the reaction and also that of $Na_2O + Au_2O_3$ have been made and it has been found that both reactions are attended with very considerable heat.

Gold powder required for the investigation was prepared by throwing down the metal from a dilute solution by sulphurous acid. The brown precipitate obtained was washed, dried and then rubbed through a sieve having 50 meshes to the inch. The sodium peroxide used was also sifted through the same sieve and the heat of one gram of sulphur burned in the peroxide was found to be 5276^c. The heat effect of the iron wire used for ignition was taken to be 44^c. The following are the experiments:

	1	2	3	4	
Gold	5·000	5·000	5·000	5·000	grams
S	1·000	1·000	1·000	1·000	"
Na_2O_2	14·	12·4	13·	13·	"
Heat observed	5650^c	5774^c	5675^c	5725^c	
" due to Fe and S	5320^c	5320^c	5320^c	5320^c	
	330^c	454^c	355^c	405^c	
For 1 gram of gold .	66^c	91^c	71^c	81^c	

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*C. R. 145, 805, 1907.

The mixture of gold, sulphur and peroxide fused and left on cooling a compact mass. When the fusions were disintegrated in water part of the sodium aurate hydrolyzed with separation of auric hydroxide and at the same time the sodium peroxide present reduced considerable gold. Hence the metallic gold in the insoluble portions of the fusions should not be deducted from the amount taken. In experiment 1 the residue left by water was treated with hydrochloric acid to remove auric hydroxide and the gold remaining was 2·7 grams. In the second experiment, where less peroxide was used than in the first, the gold from the fusion was only 0·8 gram. A small amount of gold in the form of minute fused particles was observed in the residues left by water in experiments 1 and 3.

The wide differences in the results obtained are due, in part, to variable but small amounts of gold not attacked and in part to unavoidable small errors all of which affect the small values for gold. The mean of the result is 77^c for one gram of gold reacting with sodium peroxide. For two gram atoms it is $77^c \times 197{\cdot}2 \times 2 = 30{,}400^c$.

Auric Oxide.

The attempt to make pure auric oxide for this investigation led to a study of auric hydroxide.* It was found that the hydroxide loses oxygen before all of the water is expelled. The substance taken from the calorimetric work was preparation B described in the paper referred to. In composition it corresponded closely to the formula Au_3O_4. Although it was a mixture of auric oxide and metallic gold it will be considered as auric oxide in the calculations and the following experiments:

	5		6	
Auric oxide	4·004	grams	3·811	grams
Sulphur	1·000	"	1·000	"
Sodium peroxide	10·	"	10·	"
Observed heat	6216^c		6206^c	
Heat due to S and Fe	5320^c		5320^c	
	896^c		886^c	
For one gram of Au_2O_3	224^c		232^c	

The mean, 228^c, multiplied by 442·4, the molecular weight of auric oxide, gives $100{,}900^c$ for the heat effect of $3Na_2O + Au_2O_3$. The result is low since both fusions contained a little metallic gold and correction is not made for the

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* Auric hydroxide formed on a gold anode. Deportment of auric hydroxide when heated. J. Am. Chem., xxxiii, 688.

metallic gold mixed with the auric oxide used. It should be stated that oxygen was not liberated by the fusions.

The heat of formation of auric oxide is derived as follows:

$2Au + 3Na_2O_2 = 3Na_2O.Au_2O_3 +$ .... $30{,}400^c$
$3N_2O + 3O = 3Na_2O_2 +$ .... $58{,}200^c$

$2Au + 3O + 3Na_2O = 3Na_2O.Au_2O_3 +$ .... $88{,}600^c$

and

$Au_2O_3 + 3Na_2O = 3Na_2O.Au_2O_3 +$ .... $100{,}900^c$

hence

$2Au + 3O = Au_2O_3 -$ .... $-12{,}300^c$

Apparently these results are fair since $-12{,}300^c$ found for the heat of formation of Au_2O_3 agrees well with Thomson's, which is $2Au + 3O + Aq = Au_2O_3Aq - 13{,}200^c$. The experiments with gold and auric oxide show conclusively that the heat of formation of sodium aurate is very large.

The heats of the formation of the peroxides of copper and silver are not known. They are probably negative and small. Assuming the amounts of these heats to be negligible, we have

$Cu_2O_4 + (Na_2O)_x =$ .... $59{,}000^c$
$Ag_2O_2 + (Na_2O)_x =$ .... $39{,}000^c$
$Au_2O_3 + 3Na_2O =$ .... $101{,}000^c$

The peroxide of copper is taken as Cu_2O_4 so that it may for comparison contain two atoms of metal. In previous papers it has been shown that the heats of combination of acidic oxides with sodium oxide is closely related to the atomic weights of the elements of a sub-group. In the case of the peroxides of copper, silver and gold this relation is lacking. The heat of $Ag_2O_2 + (Na_2O)_x$ is much less than corresponds to the atomic weight of silver. The explanation appears to be this: Silver is more basic than copper and gold, and its peroxide contains only one atom of oxygen to one of silver, while the other two oxides contain more than one atom of oxygen to one of copper or gold.

Art. XXIV.—*On the Rates of Solution of Certain Metals in Dissolved Iodine, and their Relation to the Diffusion Theory*; by R. G. Van Name and Rowland S. Bosworth.

[Contribution from the Kent Chemical Laboratory of Yale Univ.—ccxxiii.]

In a recent paper* it was shown that the metals mercury, cadmium, zinc, copper, and silver, all dissolve at the same rate in a solution of iodine in potassium iodide, a result which seems to prove that the velocity of the reaction is determined by the rate of diffusion of the iodine rather than the actual rate of combination of the iodine with the metal. Moreover, it was found that when the concentration of the potassium iodide is changed, or when bromine or cupric bromide is substituted for the iodine, the reaction velocity is altered in the direction which would be expected from the rates of diffusion of the active substances.

The present investigation is an extension of the work of Van Name and Edgar, intended to further test the applicability of the Diffusion Theory to this type of reaction. It covers, (1), a comparison of the rates of solution of several more metals in iodine; (2), a study of the effect of substituting other metallic iodides for potassium iodide; and (3), of the effect of varying acidity.

The method and apparatus employed were substantially the same as those used and described by Van Name and Edgar, but with several minor modifications which increased the regularity and reproducibility of the results. Disks of the different metals, of like size, were held in a fixed position in the iodine solution with the plane of the disk vertical and close to the path of the blades of a propeller-shaped glass stirrer revolving at a known rate. The velocity of the reaction was measured by removing samples of the liquid from time to time and titrating with 0·02 normal thiosulphate.

Two points in which the procedure differed from that of Van Name and Edgar are worthy of mention; first, the special precautions, described below, which were employed to insure uniformity in the size of the metal disks, and second, the use of a holder for the disks made entirely of platinum. The latter eliminated a source of trouble and uncertainty present in the earlier work owing to the occasional breakage of the glass holder, since it was necessary, and by no means easy, to repair the holder without appreciably altering its dimensions. This new holder, which was identical in shape with the glass ones, was constructed of stiff heavy platinum wire. To prevent

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* Van Name and Edgar, this Journal, xxix, 237, 1910.

metallic contact between disk and holder, the three horizontal projecting arms which grasped the disk at three points on its circumference were coated with a heavy layer, renewed from time to time, of a commercial pyroxylin preparation known as "New Skin." The slight spring of the platinum wire sufficed to hold the disk firmly in place.

Variations in the diameter of the disks, since they affect the surface area to a relatively large extent, were avoided in the following way. The metals used were carefully rolled out to a uniform thickness of $0·5^{mm}$ and cut into pieces slightly larger than desired. A pair of specially prepared patterns in the form of thick circular disks of hardened steel were then clamped in concentric position on opposite sides of the metal sheet, and the edges of the latter carefully trimmed and filed away to exact coincidence with the circumference of the patterns. The diameter of the disks so prepared was $38·3^{mm}$ with a maximum variation of about $0·05^{mm}$. Before using, the disks were always cleaned with hot caustic alkali and then slightly etched with acid to insure uniform action over the whole surface.

The velocity constant was calculated from the expression $K = 2·3 \frac{v}{t_2 - t_1} \log \frac{c_1}{c_2}$, in which v is the total volume of the liquid, and c_1 and c_2 are the amounts of thiosulphate needed to titrate a 20^{cc} sample at times t_1 and t_2.

The rate of stirring was the same in all the experiments here recorded, 170 revolutions per minute. Variations in the rate seldom exceeded ± 1 per cent, and as great care was taken to adjust the *mean rate* to 170 revolutions, the fluctuations affected chiefly the single values of the constant, and must have had an almost negligible effect upon the final result, i. e., upon the average value of the velocity constant for the given experiment.

In many of the experiments a further precaution was taken. With the aid of a stop-watch, and of a bell connected with the speed indicator so as to ring after every 100 revolutions, it was possible without interfering with the experiment to accurately determine the mean rate of stirring for the whole of each separate reaction period. The corresponding values of the velocity constant were then corrected to 170 revolutions on the assumption that the value of the constant is proportional to the 4/5 power of the rate of stirring.* Although this procedure gave greater security against possible variations in the stirring, the effect of the corrections upon the final result

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* This relation was shown to hold approximately by the work of Van Name and Edgar.

proved in many cases to be wholly negligible, and in only one experiment out of about thirty did it amount to five units in the second decimal place (about 0·7 per cent), thus showing that for most purposes the simpler method was sufficiently accurate.

Experiments with Cadmium.

A preliminary series of experiments showed that cadmium would be a more suitable metal for the purposes in view than mercury, the metal used by Van Name and Edgar in the majority of their experiments. It is worthy of mention that the rates of solution of these two metals were found to be the same within the error of experiment, thus confirming the conclusion reached in the earlier paper.* The values obtained were as follows:

Mercury (Disk of gold, heavily amalgamated)						
with $n/1$ KI,	(4 exps.)	7·41	7·36	7·46	7·47	Mean, 7·43
" $n/1$ NaI,	(3 exps.)	6·86	6·56	6·72		Mean, 6·71
Cadmium						
with $n/1$ KI,	(2 exps.)	7·46	7 54			Mean, 7·50
" $n/1$ NaI,	(1 exp.)					6·83

Substitution of sodium for potassium iodide lowers the rate of solution of both metals, and by the same amount. Details of these experiments are omitted both because the results are inferior in accuracy to those later obtained with the improved apparatus and method, and because the constants are not directly comparable with the later ones on account of subsequent changes in the dimensions of the apparatus.

Except in the above preliminary work, the iodide solutions used were invariably 0·5 equivalent normal with respect to iodide (1/2 KI, 1/4 BaI$_2$, etc.). The change to a more dilute iodide solution brought with it the same phenomenon observed with zinc in the earlier work,†—a tendency for the metal disk to become coated with hydroxide owing to hydrolysis of its iodide. To avoid this the solutions were in all cases made slightly acid, generally 0·02 equivalent normal, with sulphuric or hydrochloric acid. It will be shown later that up to over 0·1 normal the degree of acidity has no appreciable effect upon the reaction velocity. The fact that hydrolysis of the cadmium iodide did not occur when the concentration of alkali iodide was normal or above is no doubt due to the extensive formation of the double salt of the type K$_2$CdI$_4$ in the stronger solutions.

The metallic cadmium used was of Kahlbaum's preparation. To ascertain whether possible impurities in the metal were

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* This Journal, xxix, 237.

† This Journal, xxix, 245.

affecting the results a portion of about 200 grams was subjected to two successive distillations in a current of hydrogen, but the redistilled metal showed on trial no perceptible difference in behavior from the original sample. Thereafter the Kahlbaum cadmium was used without further attempt at purification.

In Table I are the results of sixteen duplicate experiments with cadmium, the first six recorded in detail. No corrections for variations in the rate of stirring have been applied in this series. The volumes of the solution are given for experiment 1 only, but the same values apply to all the experiments of

TABLE I.

Metal : CADMIUM. Stirring, 170 revs. Temperature 25°.
KI 0·5 normal. H_2SO_4 0·02 normal.

1.	$v =$		580		560		540		520		500		480^{cc}		
	$\Delta t =$		10		10		10		12		11		10^{min}		
	$c =$	19·76		17·58		15·58		13·74		11·79		10·11		8·78	
	K=		6·78		6·75		6·78		6·63		6·97		6·77		Average, **6·78**
2.	$\Delta t =$		11		10		11		10		10		10		
	$c =$	20·01		17·70		15·76		13·77		12·21		10·68		9·33	
	K=		6·45		6·49		6·63		(6·24)		6·68		6·48		Av. **6·55**
3.	$\Delta t =$		10		10		10		10		10		10		
	$c =$	20·13		17·92		15·93		14·05		12·39		10·80		9·36	
	K=		6·74		6·58		6·77		6·53		6·87		6·86		Av. **6·73**
4.	$\Delta t =$		10		10		10		10		10		10		
	$c =$	21·46		19·11		16·90		14·94		13·13		11·45		9·92	
	K=		6·71		6·88		6·64		6·71		6·84		6·88		Av. **6·78**
5.	$\Delta t =$		10		10		11		11		10		10		
	$c =$	19·52		17·34		15·37		13·33		11·42		10·00		8·68	
	K=		6·87		6·74		6·99		(7·29)		6·63		6·79		Av **6·80**
6.	$\Delta t =$		10		10		10		10		10		10		
	$c =$	18·81		16·73		14·81		13·11		11·53		10·10		8·80	
	K=		6·79		6·81		6·58		6·67		6·61		6·61		Av. **6·68**
7.	K=		6·80		6·81		6·68		6·59		6·79		6·62		Av. **6·72**
8.	K=		6·66		6·90		6·76		6·77		6·79		6·66		Av. **6·76**
9.	K=		6·56		6·70		6·72		6·52		6·88		6·52		Av. **6·65**
10.	K=		6·46		6·44		6·48		6·49		6·52		6·64		Av. **6·51**
11.	K=		6·80		6·77		6·72		6·85		7·01		6·79		Av. **6·82**
12.	K=		6·59		6·85		6·88		6·65		7·04		6·64		Av. **6·78**
13.	K=		6·52		6·69		6·73		6·53		6·79		6·67		Av. **6·66**
14.	K=		6·64		6·98		6·85		6·76		6·88		6·70		Av. **6·80**
15.	K=		6·71		6·68		6·78		6·67		7·00		6·68		Av. **6·75**
16.	K=		6·56		6·77		6·82		6·49		6·90		6·57		Av. **6·69**
															Average of all, **6·72**

this paper; 580^{cc} for the first reaction period, and 20^{cc} less for each succeeding one. Values of c, the iodine concentration, are expressed in cubic centimeters of an approximately 0·02 normal thiosulphate solution required by 20^{cc} of the liquid. Δt is the time interval ($t_2 - t_1$ page 208) in minutes. A few abnormal constants, indicated by parentheses, have been omitted in calculating the averages.

Table II shows the effect of varying acidity. Corrections for fluctuations in the stirring have been applied by the method described above, r being the mean rate of stirring during the given reaction period. In experiments 4 to 11 the correction data have been omitted for the sake of brevity, but the average given in each case is that of the corrected constants.

A necessary readjustment of the apparatus between this series and that of Table I has slightly altered the value of the constant. A proper comparison is obtained by comparing experiments 2, 3, and 4, which are closely concordant, and whose average is K = 6·86, with the 6·72 of Table I.

The close agreement between the first five experiments of Table II shows that a change in acidity between the limits of 0·002 and 0·1 normal has no appreciable effect upon the results. Further increase in the acidity diminishes the rate of solution by an amount which increases with the concentration of the acid. A comparison of experiments 3 and 4 shows that the substitution of hydrochloric for sulphuric acid does not appreciably alter the constant.* A similar agreement between the effect of hydriodic acid and of sulphuric acid at 0·5 normal concentration will appear later.

TABLE II.

Metal: CADMIUM. KI 0·5 normal. Temperature 25°.

1. H_2SO_4 0·002 normal.

v =		580		560		540		520		500		480		460	
Δt=		10		10		10		10		10		10		10	
c =	19·65		17·51		15·50		13·61		lost		10·41		9·05		7·80
K=		6·68		6·83		6·78				6·83		6·72		6·82	
r =		170·5		170·0		169·3		169·5		171·1		168·9		169·5	
K (corr.) =		6·67		6·83		6·80				6·82		6·75		6·84	
															Av. **6'79**

2. H_2SO_4 0·02 normal.

Δt=		10		10		10		10		10		10		
c =	19·92		17·71		15·68		13·74		12·09		10·51		9·09	
K=		6·82		6·81		7·12		6·65		6·99		6·96		
r =		171·3		170·1		171·0		170·2		170·9		168·8		
K (corr.) =		6·78		6·81		7·09		6·64		6·96		7·00		Av. **6'88**

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*Compare also, in Table III, experiments 1 and 2, and in Table VI, experiments 8 and 9.

TABLE II.—*Continued.*

Metal: CADMIUM. KI 0·5 normal. Temperature 25°.

3. H_2SO_4 0·02 normal.

$\Delta t=$		10		10		10		10		10		10		
$c =$	39·62		35·19		31·13		27·37		24·00		20·96		18·15	
K=		6·87		6·85		6·94		6·83		6·76		6·90		
$r =$		170·5		170·6		170·3		169·5		169·3		169·5		
K (corr.) =		6·85		6·83		6·93		6·85		6·78		6·92		Av. **6·86**

4. HCl 0·02 normal.

$\Delta t=$		10		10		10		10		10		11		10	
$c =$	39·79		35·43		31·50		27·72		24·27		21·13		18·01		15·50
K=		6·72		6·58		6·89		6·90		6·92		6·96		6·90	

K (corr.) av. **6·83**

5. H_2SO_4 0·1 normal.

$\Delta t=$		10		10		10		10		10		10	
$c =$	19·93		17·70		15·68		13·79		12·09		10·50		9·13
K=		6·87		6 79		6·92		6·84		7·04		6·70	

K (corr.) av. **6.86**

6. H_2SO_4 0 33 normal.

$\Delta t=$		10		10		11		10		12		10	
$c =$	20·01		17·88		15·90		13·90		12·28		10·47		9·11
K=		6·51		6·57		6·59		6·43		6·64		6·67	

K (corr.) av. **6·64**

7. H_2SO_4 0·5 normal.

$\Delta t=$		10		10		10		11		10		10	
$c =$	20·20		18·10		16·11		14·30		12·50		10 98		9·63
K=		6·36		6·52		6·43		6·35		6·47		6·29	

K (corr.) av. **6·40**

8. H_2SO_4 0·9 normal.

$\Delta t=$		10		10		11		10		12		13	
$c =$	19·27		17·32		15·49		13·64		12·11		10·35		8·69
K=		6·19		6·23		6·24		6·18		6·54		6·45	

K (corr.) av. **6·31**

9. H_2SO_4 1· normal.

$\Delta t=$		10·05		10		10		10		10		10	
$c =$	20·46		18·34		16·34		14·57		12·89		11·30		9·86
K=		6·29		6·45		6·19		6·36		6·58		6·54	

K (corr.) av. **6·39**

10. H_2SO_4 1· normal.

$\Delta t=$		10		10		10		10		10		10	
$c =$	21·11		18·97		16·97		15·08		13·36		11·80		10·31
K=		6·19		6·23		6·37		6·29		6·20		6·47	

K (corr.) av. **6·34**

11. H_2SO_4 1· normal.

$\Delta t=$		10		10		10		10		10		10	
$c =$	20·54		18·48		16·56		14·72		13·08		11·57		10·14
K=		6·12		6·13		6·36		6·14		6·13		6·33	

K (corr.) av. **6·17**

With the more strongly acid solutions it is necessary to prevent oxidation of the iodide by the air. All experiments of the present investigation in which the acidity of the solution was greater than 0·1 normal were therefore carried out in an

Table III.

Metal: Iron. KI 0·5 normal. Temperature 25°. $r = 170$.
H_2SO_4 0·02 normal (except in experiments 1, 10, and 11).

Common Wrought Iron.																	
*1.	v =		580		560		540		520		500		480				
	Δt=		10		10		11		10		11		10				
	c =	19·96		17·67		15·67		13·50		11·83		10·12		8·77			
	K=		7·07		6·71		7·32		6·85		7·09		6·87				Average, **6·99**
2.	K=		6·82		7·01		6·89		7·01		7·15		7·02				Av. **6·98**
Swedish Iron.																	
3.	K=		6·75		6·76		7·08		6·58		6·93		6·82				Av. **6·82**
4.	K=		6·68		6·90		7·19		6·64		7·00		7·08				Av. **6·92**
"American Ingot Iron."																	
5.	Δt=		10		10		10		10		10		10				
	c =	20·18		17.95		15·91		14·02		12·38		10·81		9·44			
	K=		6·78		6·75		6·83		6·46		6·77		6·49				Av. **6·68**
6.	Δt=		10		10		10		10		10		10				
	c =	18·97		16·83		14·92		13·18		11·57		10·10		8·79			
	K=		6·94		6·74		6·69		6·77		6·79		6·66				Av. **6·77**
7.	Δt=		10		11		13		13		17		20				
	c =	17·95		16·03		14·04		11·99		10·17		8·14		6·18			
	K=		6·56		6·73		6·55		6·58		6·54		6·50				Av. **6·59**
8.	Δt=		14		10		10		13		12		24				
	c =	20·54		17·40		15·43		13·59		11·54		9·77		6·98			
	K=		6·87		6·71		6·86		6·53		6·93		6·72				Av. **6·77**
9.	Δt=		10		10		12		10		10		5		13		
	c =	19·40		17·25		15·25		13·04		11·45		lost		9·29		7·68	
	K=		6·80		6·89		7·04		6·76				6·87		6·72		Av. **6·85**
10.	H_2SO_4 0·1 normal.																
	Δt=		10		10		10		10		10		10				
	c =	19·55		17·40		15·39		13·55		11·93		10·48		9·00			
	K=		6·75		6·86		6·87		6·61		6·46		(7·31)				Av. **6·71**
11.	H_2SO_4 0·1 normal.																
	Δt=		10		10		11		10		10		10				
	c =	19·35		17·25		15·30		13·28		11·74		10·24		8·91			
	K=		6·66		6·71		6·94		6·40		6·83		6·67				Av. **6·70**

* HCl 0·02 normal, instead of H_2SO_4.

atmosphere of carbon dioxide, obtained by conducting a rapid current of the gas into the upper part of the reaction vessel throughout the experiment. Blank tests showed that this method, when properly carried out, reduced the oxidation to a negligible amount. In one case, however, experiment 6, a failure of the generating apparatus allowed some oxidation to occur, the amount of which was roughly estimated, and a calculated correction of 0·07 added to the final result. The value of "K (corr.)" for experiment 6 as given in the table includes this correction.

Experiments with Iron.

The disturbing effect of impurities in the metal used is well illustrated by the experiments with iron recorded in Table III. In experiments 1 and 2 the disks were of common sheet iron, which in dissolving set free a considerable quantity of carbon. Swedish iron, supposed to be of fairly high purity, was used in experiments 3 and 4. The rest were carried out with "American Ingot Iron,"* which, according to the advertised analysis, is about 99·9 per cent pure. That this last material was comparatively free from carbon was evident from the bright surface which it maintained in dissolving, and the clear solution produced.

It is seen in the table that the common and Swedish iron gave higher constants than the purer metal. A possible effect of the presence of carbon in the iron is illustrated by the results of certain experiments in which metallic contact existed between the disk and its platinum holder. This occasonally happened owing to the wearing through of the layer of pyroxlin on one of the arms supporting the disk, and was indicated by an abnormally high rate of solution as shown by the two following experiments with cadmium in the presence of barium iodide:

A.	9·22	9·13	9·20	9·04	9·05	9·25	Av. 9·15
B.	8·73	8·49	8·82	8·21	8·27		Av. 8·50

The normal value of the constant under the prevailing conditions was 6·45. In both cases a plainly visible point of contact between the cadmium and platinum was found.

It is easy to account for the high constants in such cases. Contact between the two metals establishes a short-circuited cell of which platinum is the cathode. This affects the results in two ways: first, the nascent hydrogen evolved on the platinum reduces iodine, thus causing an apparent increase in the reaction velocity; second, the rate of movement of the iodine diffusing toward the disk in the form of I_3' ions is accelerated by the superposition of an electrical force upon the osmotic

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* From the American Rolling Mill Co., Middletown, Ohio.

force, thus actually increasing* the rate of solution of the disk. In view of these facts it seems reasonable to conclude that a particle of carbon or of a more negative metal adhering to the disk might have a similar effect, so that in many cases (not necessarily in all) an impure metal would give a higher constant than a pure one, as in the present instance.

In comparing these results with those obtained with cadmium, only those experiments need be considered in which the purest iron was used. Experiments 5, 6, 7, 8, and 9 carried out at 0·02 normal acidity, give an average value of K of 6·74; experiments 10 and 11, at 0·1 normal acidity, an average of 6·71, thus again proving that the rate of solution is independent of the acidity when the latter is not too high. Since these experiments were carried out before the readjustment of the apparatus† they are to be compared with the value 6·72 for cadmium. The agreement is excellent.

TABLE IV.

KI 0·5 normal. H_2SO_4 0·02 normal. Temperature 25°. $r = 170$

Nickel.

1.	$v =$	580	560	540	520	500	480		
	$\Delta t =$	10	10	15	10	10	10		
	$c =$	20·03	17·82	15·81	13·12	11·55	10·09	8·77	
	K=	6·78	6·70	6·71	6·61	6·75	6·72		Average, **6·71**
2.	$\Delta t =$	10	10	10	10	10	10		
	$c =$	19·84	17·69	15·69	13·84	12·17	10·59	9·18	
	K=	6·64	6·71	6·77	6·67	6·95	6·86		Av. **6·77**

Cobalt (Impure).

3.	K=	6·24	6·00	6·15	5·72	5·83	5·73	Av. **5·95**
4.	K=	6·47	6·25	6·33	6·05	6·37	6·18	Av. **6·28**

Cobalt (Electrolytic).

5. Disk 38·76 × 0·075^{mm}

$\Delta t =$	10	10	11	11	10	11	
$c =$	39·40	34·68	30·38	26·26	22·59	19·64	16·70
K=	7·39	7·41	7·15	7·11	6·99	7·07	

K (corrected for stirring) av. **7·15**

K, with further correction for size of disk, **6·90**

6. Disk 38·64 × 0·068^{mm}

$\Delta t =$	10	10	11	10	10	10	
$c =$	39·54	34·92	30·58	26·70	23·39	20·37	17·48
K=	7·19	7·43	6·65	6·88	6·90	7·34	

K (corrected for stirring) av. **7·01**

K, with further correction for size of disk, **6·83**

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* A greater increase would be produced by the discharge of the much more numerous I′ ions, but as this would not directly affect the free iodine concentration it would not appear in the results.

† See page 211.

Experiments with Nickel and Cobalt.

No special tests for purity were applied to the sample of nickel used, but the fact that in dissolving in acid or iodine solution it retained a bright surface and gave no residue may be accepted as an indication that it contained very little carbon. The velocity constants obtained agree very closely with those for iron and cadmium.

The first two experiments with cobalt, Nos. 3 and 4 in the table, were carried out with a comparatively impure sample of the metal, which on treatment with acids or iodine solution soon acquired a black, closely adherent coating. This cobalt was proved by chemical tests to contain a good deal of nickel and iron together with traces of copper. The results obtained with this sample of cobalt are much lower than with iron or nickel.

For experiments 5 and 6 disks of pure electrolytic cobalt were used, obtained by depositing the metal on a disk of platinum of the standard diameter from a solution of carefully purified cobalt chloride containing sodium formate and a slight excess of formic acid. Very smooth and compact deposits of ample thickness were thus obtained, using a current density of 0·4 amp. per sq. dm. The purification of the cobalt chloride was based on two successive precipitations as potassium cobaltinitrite.

These disks retained a perfectly clean surface in dissolving. Before using they were measured with a micrometer and the constants obtained were corrected for the difference in surface area from that of the standard size (38·3^{mm} diam. and 0·5^{mm} thick).

Since experiments 5 and 6 were performed after the readjustment of the apparatus they are to be compared with the value 6·86 of Table II. The agreement is evidently all that could be desired.

Experiments with Tin, Magnesium, and Aluminum.

The results obtained with tin are of particular interest since they show the nature of the disturbances to be expected in the case of a metal which may give two different soluble iodides. As compared with the metals previously considered the velocity constants for tin were found to be, on the average, about 15 per cent higher. This can not be attributed to impurities, for the sample of tin used was of the highest purity which could be purchased, and was further purified for this special purpose by decomposing it with nitric acid, washing the metastannic acid, and finally reducing with cane sugar. The probable explanation is as follows: Iodine reacts with a stannous salt according to the equation

$$Sn^{++} + I_2 = Sn^{++++} + 2\ I',$$

TABLE V.

Metal: TIN. KI 0·5 normal. Temperature 25°. $r = 170$.
HCl 1· normal in experiments 1, 2, 3, and 4.

1.	$v =$		580		560		540		520		500		480		
	$\Delta t =$		10		10		10		10		10		10		
	$c =$	20·52		18·16		15·92		13·67		11·71		9·93		8·05	
	K=		7·08		7·37		8·21		8·04		8·25		(10·06)		Av. **7·79**
2.	$\Delta t =$		6		6		5		7		10		7		
	$c =$	20·79		19·22		17·74		16·51		14·95		12·69		11·36	
	K=		7·58		7·47		7·77		7·36		8·18		7·59		Av. **7·66**
3.	$\Delta t =$		10		14		11		14		15		21		
	$c =$	20·95		18·60		15·60		13·54		11·04		8·76		5·71	
	K=		6·90		7·03		6·94		7·57		7·70		(9·77)		Av. **7·27**
4.	K=		7·07		6·99		6·99		7·50		8·11		(9·56)		Av. **7·33**
5.	HCl 0·33 normal.														
	K=		7·87		6·83		7·30		7·52		7·08		7·39		Av. **7·33**
6.	HCl 0·25 normal.														
	K=		7·43		7·49		7·71		8·18		7·69		8·67		Av. **7·86**

the change from left to right being nearly complete.* At the actual surface of the metal the iodine concentration is practically zero, and the tin will therefore dissolve as stannous iodide. As this diffuses through the "unstirred" layer it will encounter an ever increasing concentration of iodine, and will therefore soon be converted into stannic salt. The diffusion path for the iodine so used will be less than the thickness of the diffusion layer, thus causing a more rapid consumption of iodine than in a normal case and giving the high velocity constants actually observed.

To prevent hydrolysis of the tin salt and the resulting accumulation of hydroxide on the disk, the solutions were made at least 0·25 normal with hydrochloric acid. Oxidation was prevented by the use of carbon dioxide as described above.

In the experiments with metallic magnesium, hydrogen was always evolved from the disk, thus introducing a disturbing factor of a new kind. None of the metals discussed above had evolved hydrogen in visible amounts even at the highest acidity employed, but with magnesium hydrogen was produced to some extent even in neutral solution, and when enough acid was present to keep the disk free from hydroxide, the gas evolution became very marked.

There are two obvious ways in which the gas evolution would affect the results; first, the adhering gas bubbles would

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* The use of this reaction as a quantitative method of estimating iodine has been proposed by Spring, Jour. Am. Chem. Soc., xix, 809.

TABLE VI.

Metal :—CADMIUM. Iodides all 0·5 normal. Temp. 25°. $r = 170$.

Hydrogen Iodide.

1. HI 0·5 normal. No other acid.

$r =$		580		560		540		520		500		480		460	
$\Delta t =$		11		11		13		13		11		12		18	
$c =$	36·75		32·55		28·73		24·80		21·16		18·34		15·59		12·00
K=		6·39		6·36		6·09		6·35		6·50		6·49		6·68	

K (corr.) av. **6·45**

Sodium Iodide.

2. H_2SO_4 0·02 normal.

$\Delta t =$		10		10		10		10		11		10	
$c =$	38·59		34·46		30·63		27·09		23·87		20·69		18·01
K=		6·56		6·59		6·62		6·56		6·49		6·67	

K (corr.) av. **6·59**

3. H_2SO_4 0·02 normal.

$\Delta t =$		12		11		10		11		10		12	
$c =$	51·78		45·31		39·84		35·32		30·77		26·98		22·91
K=		6·45		6·54		6·50		6·51		6·57		6·53	

K (corr.) av. **6·53**

Lithium Iodide.

4. H_2SO_4 0·02 normal.

$\Delta t =$		10		12		11		11		10		10		10	
$c =$	39·91		35·34		30·83		27·07		23·65		20·80		18·18		15·81
K=		(7·04)		6·36		6·38		6·38		6·41		6·46		6·42	

K (corr.) av. **6·40**

5. H_2SO_4 0·02 normal.

$\Delta t =$		10		11		12		11		10		11	
$c =$	39·97		35·79		31·56		27·39		23·91		21·04		18·10
K=		6·39		6·40		6·37		6·41		6·39		6·55	

K (corr.) av. **6·41**

Barium Iodide.

6. HCl 0·02 normal.

$\Delta t =$		10		10		10		12		11		11		11	
$c =$	39·32		35·19		31·30		27·78		23·92		20·79		17·86		15·31
K=		6·43		6·56		6·43		6·47		6·37		6·62		6·43	

K (corr.) av. **6·47**

7. HCl 0·02 normal.

$\Delta t =$		10		10		10		10		11		12		10	
$c =$	39·16		35·09		31·29		27·81		24·61		21·36		18·18		15·74
K=		6·35		6·41		6·36		6·35		6·43		6·44		6·62	

K (corr.) av. **6·42**

TABLE VI.—*Continued.*

Metal:—CADMIUM. Iodides all 0·5 normal. Temp. 25°. $r = 170$.

Magnesium Iodide.

8. H_2SO_4 0·02 normal.
$v =$ 580 560 540 520 500 480 460
$\Delta t =$ 11 12 11 10 11 10 11
$c =$ 39·71 35·47 30·95 27·21 24·13 21·03 18·39 15·83
K= 5·95 6·35 6·32 6·23 6·25 6·43 6·26
K (corr.) av. **6·25**

9. HCl 0·02 normal.
$\Delta t =$ 10 10 10 10 10 10
$c =$ 40·35 36·27 32·42 28·92 25·62 22·61 19·79
K= 6·18 6·27 6·16 6·29 6·24 6·39
K (corr.) av. **6·25**

10. HCl 0·02 nornal.
$\Delta t =$ 10 10 10 10 10 10
$c =$ 40·96 36·81 32·90 29·32 26·00 22·94 20·11
K= 6·19 6·29 6·21 6·24 6·26 6·31
K (corr.) av. **6·25**

Calcium Iodide.

11. HCl 0·02 normal.
$\Delta t =$ 10 10 10 10 12 10
$c =$ 39·70 35·67 31·90 28·40 25·18 21·67 18·99
K= 6·20 6·25 6·27 6·24 6·25 6·34
K (corr.) av. **6·25**

12. HCl 0·02 normal.
$\Delta t =$ 10 10 10 10 10 10
$c =$ 40·19 36·19 32·38 28·81 25·57 22·56 19·79
K= 6·07 6·22 6.31 6·20 6·26 6·28
K (corr.) av. **6·21**

Cadmium Iodide.

13. HCl 0·02 normal.
$\Delta t =$ 10 10 10 11 15 10
$c =$ 22·17 19·64 17·47 15·40 13·41 10·66 9·34
K= 7·03 6·54 6·81 6·53 7·64 6·35
K (corr.) av. **6·80**

14. HCl 0·02 normal.
$\Delta t =$ 10 10 10 10 4 10 11
$c =$ 14·82 13·18 11·70 10·36 lost 8·56 7·42 6·29
K= 6·79 6·66 6·56 7·00 6·86 6·89
K (corr.) av. **6·78**

15. HCl 0·02 normal.
$\Delta t =$ 10 10 10 10 10 10
$c =$ 14·15 12·59 11·17 9·85 8·59 7·50 6·46
K= 6·78 6·68 6·79 7·10 6·78 7·16
K (corr.) av. **6·87**

reduce the available surface of the disk, and second, the breaking off of the bubbles would stir the diffusion layer, thus bringing the strong outside solution into direct contact with the metal. These two effects would act in opposite directions, but apparently the second predominates, for the constants obtained are high.

An experiment in the presence of 0·1 normal sulphuric acid, giving a brisk hydrogen evolution, resulted as follows:

A. 8·72 9·28 8·50 8·43 Average 8·73

In neutral solutions the disk remains free from hydroxide if a little ammonium chloride is present, but even under these conditions there is a very marked evolution of hydrogen. The two following experiments were performed in neutral solutions which were about 0·025 normal with respect to ammonium chloride:

B.	9·31	10·71	11·85	12·75	9·50		Av. 10·82
C.	9·19	9·76	10·06	13·12	7·50	8·90	Av. 9·76

The conspicuous irregularity of the constants is only what would be expected when we consider the large effect which would be produced by variations in the rate of formation or in the size of the gas bubbles, factors which it is very difficult to control.

A number of experiments were carried out with aluminum disks, but in every case the metal was so irregularly attacked by the iodine that no confidence can be placed in the results. The disk after use was always found to be pitted with small holes, with intervening spaces which appeared to have been attacked but little if at all by the iodine. The single experiments gave fairly regular constants but duplicate experiments did not agree at all closely. The values of the constants were low in every case except one, this being an experiment in the presence of normal hydrochloric acid which gave an evolution of hydrogen and a high constant, no doubt on account of the hydrogen. In the other cases the acidity was 0·25 normal or less. All of the results, however, were entirely compatible with the conclusion drawn from the inspection of the disks; namely, that a part of the surface of the metal was not attacked.

Cadmium in the Presence of Various Iodides.

It has been shown by Jakowkin* that iodine dissolved in a large excess of an iodide of an alkali or alkali earth metal in water solution is almost completely combined in the form of triiodide. We should expect, therefore, that the diffusion of iodine in such a solution would be determined chiefly by the

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* Zeitschr. phys. Chem., xx, 19.

rate of diffusion of the triiodide molecules, which in turn must vary with the nature of the positive ion. Hence the rate of solution of a metal in the liquid should be different in the presence of different iodides.

These differences in the rate of solution furnish the basis for an interesting and valuable test of the validity of the diffusion theory, and we have therefore carried out a series of parallel experiments with cadmium in the presence of a number of different iodides in equivalent concentration. These experiments were very carefully performed, and the results, given in detail in Table VI, are very concordant. The greatest fluctuation in the constants occurred with cadmium iodide, and is probably due to the low iodine concentrations which had to be employed, which magnified the errors of titration. Corrections for rate of stirring were applied in the manner already described. The magnesium iodide used contained a small amount, perhaps one or two per cent, of calcium iodide, but the effect of this impurity must have been negligible as the constants for these two iodides are practically equal. Values for potassium iodide, comparable with Table VI, are furnished by experiments 2, 3, and 4 of Table II. The agreement between experiment 1 of Table VI and experiment 7 of Table II shows that hydriodic acid alone has practically the same effect as sulphuric acid of the same concentration in the presence of an equivalent amount of potassium iodide.

Discussion.

A summary of all the results of previous tables with the exception of those obtained with impure metals is given in Table VII. Most of the values represent the mean of two or more experiments under the stated conditions.

Under A, are the mean values of the velocity constants for different metals in the presence of potassium iodide, for each degree of acidity tested. To facilitate comparison results obtained before the readjustment of the apparatus referred to on page 211 have been multiplied by the factor 6·86/6·72, thus reducing them to the later standard. Such values are indicated by stars.

The agreement between the metals cadmium, iron, nickel, and cobalt is very striking, and clearly proves that under like conditions these metals dissolve in iodine at the same rate. In the earlier investigation a like result was obtained with the five metals, mercury, copper, silver, zinc and cadmium. Eight metals in all have, therefore, been shown to possess the same rate of solution in iodine, a result for which there seems to be no satisfactory explanation other than that furnished by the diffusion theory.

Under B in Table VII are given the mean values of the velocity constants for the experiments with cadmium in the presence of different iodides. Considered from the standpoint of the diffusion theory, these figures must represent, at least roughly, the relative magnitudes of the rates of diffusion of iodine in the different solutions. An exact parallelism would not be expected, since this could only exist if the thickness of the diffusion layer were the same in each case, while in reality the thickness would vary somewhat with the properties of the liquid, especially its viscosity.

It would be extremely interesting to compare these velocity constants with the directly measured diffusion coefficients of iodine in the different solutions, but as yet none of the necessary diffusion coefficients have ever been determined, though it is likely that this deficiency will be remedied before long.* It is possible, however, by making certain assumptions, to obtain a rough estimate of the relative values of these rates of diffusion. For reasons already given (p. 221), they would be expected to depend chiefly upon the diffusion velocities of the triiodide molecule. As a first approximation we may assume that the rates of diffusion of the different triiodides would follow the same order as the corresponding iodides. Inspection of the existing data on the rates of diffusion of iodides shows clearly that potassium, sodium, and lithium iodides stand in the order named, while hydrogen iodide, by analogy with hydrogen chloride, should be highest of all. With the divalent iodides it is necessary to base the estimate chiefly upon the migration velocities of the positive ions, which are given in the third column of Table VII, B. The difference in the ionization of divalent and univalent iodides makes it unsafe to base any comparison between the two groups upon the ionic velocities. The diffusion data seem to show that the alkali earth halides diffuse slower than the alkali halides.

On referring to the values of the velocity constants for cadmium in the presence of different iodides, as given in Table VII, B, we find the alkali iodides in the order, potassium; sodium; lithium; as would be expected from the above considerations. Barium stands above both magnesium and calcium, as would be anticipated, but calcium is slightly below magnesium, thus deviating from the order of the ionic velocities.

There are two values, however, for which the above analysis gives no explanation. One is the high velocity constant for cadmium iodide, which in view of its abnormally low ionization and its tendency to form complex anions would be

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* Dr. Graham Edgar has kindly undertaken to carry out these measurements in connection with other experiments on diffusion which he is conducting at the University of Virginia.

TABLE VII.

Summary of Velocity Constants.

A.

Acidity	N/500	N/50	N/10	N/4	N/3	N/2	9N/10	N/1	NH_4Cl N/40
Cadmium	6·79	6·86	6·86	----	6·64	6·40	6·31	6·30	
Iron	----	*6·88	*6·85	----	----	----	----	----	
Nickel	----	*6·88	----	----	----	----	----	----	
Cobalt	----	6·87	----	----	----	----	----	----	
Tin	----	----	----	*8·02	*7·48	----	----	*7·67	
Magnesium	----	----	8·73	----	----	----	----	----	10·29

B.

Cadmium in presence of	K	Migration velocity of cation.		Viscosities of chlorides in N/2 sol. at 25°.
Potassium Iodide	6·86	K^+	64·9	0·987
Cadmium Iodide	6·82	1/2 Cd^{++}	47·4	1·063
Sodium Iodide	6·56	Na^+	43·6	1·047
Hydrogen Iodide	6·45	H^+	318·	1.034
Barium Iodide	6·45	1/2 Ba^{++}	55·1	1·057
Lithium Iodide	6·41	Li^+	33·4	1·067
Magnesium Iodide	6·25	1/2 Mg^{++}	45·9	1 094
Calcium Iodide	6.23	1/2 Ca^{++}	51·5	1·076

* Starred values have been multiplied by 6·86/6·72.

expected to stand at the bottom of the list or near it; the other is the value for hydrogen iodide, which is surprisingly low considering the high mobility of the hydrogen ion. It is evidently this peculiarity in the behavior of hydriodic acid which accounts for the observed effect of acidity in lowering the velocity constant.

Another factor besides the rate of diffusion, which would affect the rate of solution of a metal, is the viscosity, an increase in which would tend to increase the thickness of the diffusion layer and thus retard the reaction. In the absence of published data on the iodides, the viscosities of the corresponding 0·5-normal chloride solutions at 25°, referred to water at the same temperature as unity, are given for comparison in the last column of the table.† The order of increasing viscosity is K, H, Na, Ba, Cd, Li, Ca, Mg, which is nearer the order of the velocity constants than was the case with the ionic velocities, and explains in part the unexpected values observed with cadmium and hydrogen iodides. The inference to be drawn from the two anomalous velocity constants is that

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† According to measurements by J. Wagner, Zeitschr. phys. Chem., v, 31, and by Reyher, Zeitschr. phys. Chem., ii, 744.

iodine will probably prove to diffuse in cadmium iodide faster, and in hydrogen iodide slower, than the above considerations have led us to expect.

There is obviously nothing in the results of this investigation, as judged by the evidence at present available, which is incompatible with the diffusion theory. On the other hand, the results are in most respects in striking agreement with the predictions of that theory. A study of the temperature coefficient of the reaction between iodine and a metal has already been begun.

Summary.

1. The rates of solution of cadmium, iron, nickel, and cobalt in similar iodine solutions have been measured and found to be equal. This result extends the list of metals, which by the former article were shown to dissolve at the same rate, from five to eight: viz. Hg, Cu, Ag, Zn, Cd, Fe, Ni, and Co.
2. Tin gives a higher velocity constant than the above metals. This is what would be expected if the formation of the stannic iodide took place in two stages, as is probably the case.
3. Magnesium dissolves abnormally fast owing to the stirring action of the bubbles of hydrogen set free from its surface.
4. An increase in the acidity of the solution above 0·1 normal lowers the value of the velocity constant.
5. The rates of solution of cadmium in the presence of eight different iodides have been determined. Except in the cases of cadmium iodide and of hydriodic acid the relative values of the velocity constants roughly correspond with what would be expected from the probable rates of diffusion of the corresponding triiodides as estimated from the available data. Since the diffusion coefficients of iodine in the different solutions are still unknown, it is not yet possible to base a satisfactory test of the diffusion hypothesis upon these constants.
6. The results as a whole support the validity of the diffusion theory.

ART. XXV.—*Cross-bedding and Absence of Fossils Considered as Criteria of Continental Deposits ;** by EDWARD M. KINDLE.

IN recent years a marked inclination has developed in some quarters to question the marine origin of certain formations which have hitherto been classed as sea-laid deposits. The writer heartily approves of the close scrutiny which some of the earlier assumptions in this field are receiving. If, however, we are to make any permanent progress in this direction it is highly important that the newer views on this subject should themselves be something more than mere assumptions or conclusions based upon false premises. In some cases before the later opinions concerning the conditions of deposition can be accepted it will be necessary to submit more satisfactory criteria for discriminating nonmarine from marine deposits than those on which some authors appear to rely chiefly. If one may judge from the character of the evidence used in some recent papers for establishing the continental origin of formations, there is urgent need of clarifying our ideas concerning the criteria by which such deposits may be recognized. This note is intended to assist in this process by pointing out the fact that some of these criteria will not bear critical examination.

While some authors have furnished satisfactory evidence of the continental origin of certain deposits, e. g., the Triassic sandstone of Connecticut, others have not taken the trouble to tell us what criteria they use for discriminating continental from marine deposits, giving instead of evidence some such statement as "we have expressed the opinion that the sandstone was a continental deposit."† Prof. A. W. Grabau, however, has been sufficiently explicit in indicating two of the criteria which he considers available in such discrimination. The following quotation from Professor Grabau indicates the manner in which the general absence of fossils and the presence of cross-bedding is used as evidence of the nonmarine origin of beds which exhibit these features. In discussing the age and origin of certain sandstones he states :

> "In fact, the general absence of fossils, the frequent cross-bedding and other characters point rather to a continental origin of a part, at least, of this basal series, the agents of deposition being rivers or the wind. There is scarcely a geologist today who is satisfied with the complacent explanation, current only a

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* Published with the permission of the Director of the U. S. Geological Survey.

† Bull. N. Y. State Mus., No. 145, p. 122, 1910.

short time ago, that the absence of fossils in a sandstone is due to 'unfavorable conditions at the time of deposition,' or to subsequent destruction of the fossils, in some mysterious way or other. That fossils abound in marine sandstones of all kinds, and even in conglomerates, is a well-known fact, and that the sands along our modern sea-shores are rich in shells and other hard parts of organisms, is equally a matter of common knowledge. The argument that the absence of fossils in a rock which elsewhere carries them, indicates some peculiarity of the sea-shore at that point, capable of barring the life of the sea, is a laborious explanation to fit a preconceived notion of the origin of the formation in question."*

Professor Graban† has depended largely on the kind of evidence outlined in the above paragraph in suggesting a continental origin for the Queenston shale, the Medina sandstone, and the Esopus shale. Without raising the question of the merits of any particular case to which this class of criteria has been applied, the writer wishes to point out the fact that both the features named, absence of fossils and cross-bedding, may and do characterize both marine and nonmarine sediments. Hence their presence in any particular formation can not be regarded as evidence of continental origin. Not only is cross-bedding a common characteristic of marine sediments, but it is quite probable that it is often produced at considerable depths. There is reliable evidence, according to A. R. Hunt, "that at depths of about 40 fathoms in the English Channel and of 50 fathoms on the Banks of Newfoundland there is not only motion at the bottom, but strong motion, far exceeding the gentle oscillation of the water that is sufficient to ripple a sandy sea bed."‡ We have the testimony of Rear Admiral Sir W. J. L. Wharton§ that fine mud and sand may be moved to a depth of 80 fathoms by wave action and that there is evidence of the chafing of cables to a depth of 260 fathoms. It should be recalled in this connection that many ocean currents have in parts of their courses a velocity greater than most continental streams.

The above citations sufficiently indicate that vigorous agitation of the sea bottom occurs at considerable depths. For evidence that this submarine disturbance often produces cross-bedding we have only to go to the rocks themselves. Cross-bedding instead of being a characteristic peculiar to nonmarine or "continental deposits," is a common feature in almost if not all classes of marine sediments which have accumulated in

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* Physical and Faunal Evolution of North America during Ordovicic, Siluric and early Devonic time: Jour. Geology, vol. xvii, pp. 211–212, 1909.

† Idem.

‡ Proc. Roy. Soc. London, vol. xxxiv, p. 15, 1883.

§ Foundations of Coral Atolls: Nature, vol. lv, 1897.

waters of moderate depth. It occurs even in limestones. The writer has seen excellent examples of cross-bedding in the Spergen limestone of Indiana. We believe that no one, not even Professor Grabau, will question the marine origin of the Spergen limestone. If geologists will bear these facts in mind they will neither cite cross-bedding in rocks as an evidence of their origin in continental waters nor in extremely shallow marine waters as is often done.

Critical inspection of the other criterion of nonmarine sediments referred to by Professor Grabau shows it to be fully as untrustworthy as cross-bedding, as a means of discriminating nonmarine beds. Making use of the absence of fossils from any given bed, whether partial or total, as evidence of its nonmarine origin rests upon a serious misconception of the facts relating to the distribution of both extinct and living molluscan forms. Marine animals with hard structures were not uniformly distributed over the epicontinental sea bottoms in the past, nor is the present sea bottom within the life zone of the continental shelf occupied with anything like uniformity. Off some of our present coasts richly tenanted areas alternate with others which are barren of life. The occurrence of barren zones in both present and Paleozoic seas, instead of being an improbable or anomalous thing, as Dr. Grabau's remarks would indicate, is a fact which may be easily demonstrated. This fact requires no "laborious explanation," but is a corollary of the familiar principle that the distribution of marine life is controlled by environmental factors, among which are temperature, food, salinity, protection from destructive wave action, and transportation of larval forms. Ocean currents frequently control, partially or completely, one or more of these factors with the result that adjacent areas of the same sea may be on the one hand marine deserts and on the other areas teeming with marine life.

Among the factors controlling faunal distribution, least likely to impress the paleontologist with their great importance if his acquaintance with the seashore is limited, is the character of the bottom, depth, and exposure to storm waves. Mr. Godwin-Austen* has well said that a "drift sand zone" is wholly unfitted for marine life. It can be easily imagined that it would be as difficult for a molluscan fauna to secure a foothold on the shifting sands of some coasts as it is for terrestrial life to establish itself firmly in a sand-dune country. If, to the probability of being buried alive, we assume complete exposure to the direction of the heaviest gales and a depth which will give to storm waves their maximum destructive effect in pounding the bottom, we will have an environment in which no molluscan

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* Natural History of the European Seas, p. 233.

fauna could live. Professor Moseley has indicated the destructive nature of wave action on the sea bottom in the following words:

> "With respect to enemies, the waves themselves are, perhaps, the most formidable, as they attack and occasionally destroy whole colonies at once, whereas predatory foes rather affect the individual."*

As an example of an environment which doubtless some of the factors named above made uninhabitable by marine faunas we may cite one of the Carboniferous sandstones. The irregularity of the distribution of sea bottom life in the Paleozoic is illustrated in the Riverside sandstone of the "Knobstone" group of Southern Indiana. The most careful search over scores of square miles of outcrops of this formation, over a portion of its area of distribution, will fail to discover a single fossil. In other areas they occur in abundance. In the areas where fossils appear to be entirely wanting in this formation there is a total absence of cross-bedding or any other physical features which might suggest to some a continental origin. Both the fossiliferous and the barren areas are clearly marine beds and afford one of many possible examples of the "absence of fossils in a rock which elsewhere carries them."†

Another example which may be given of barren beds at a horizon which is abundantly fossiliferous in other areas occurs in central New York. Thus far 80 feet or more of the Genesee shale of the Cayugan section has failed to yield any fossils to the most persistent collectors.

The barren areas of the Paleozoic seas are duplicated in the present seas. They occur along various parts of the present coasts of North America. The writer has traversed several hundred miles of the northwestern and northeastern coasts of the continent in small boats which gave excellent opportunities for observing the contrasts between different areas of the coast with respect to the relative abundance of marine life. On the Alaskan coast contrasts are often abrupt and most striking. Along the beach at Nome one may search for hours without finding a single shell. In that vicinity the writer has scanned the bottom in depths of 6 to 15 feet from the side of a small boat, when the water was exceptionally smooth and favorable for observation, for miles without seeing a single sea shell. Northwest of Nome 100 miles, however, the abundance of marine life is such that the beach is strewn with thousands of shells. A special effort was made at Nome to secure representatives of the present marine fauna, but not a single mollus-

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* Else Reclus' New Physical Geography, vol. ii, p. 376.

† Jour. Geology, vol. xvii, 1909.

can shell was obtained. At Cape Prince of Wales, however, which is 100 miles northwest of Nome, the writer collected in two hours 45 species. Although the coastal waters at Cape Prince of Wales and various points to the northeastward support a rich and varied fauna, the nearly barren zone begins immediately south of the cape and continues unbroken, save by very rare examples of sea shells, for more than 100 miles along the southwest coast of the Seward peninsula.

On the northwest coast of Greenland the writer has used a dredge where on one side of a peninsula every haul brought up numbers of shells while on the opposite side not a single mollusk was secured.

Such facts as these, although they appear to be unfamiliar to some paleontologists, are in no wise exceptional or unusual, as will be seen from the following quotation from Godwin-Austen:*

> "There is a zone of clean sand in advance of most lines of coast which comes within the range of the tidal and wave disturbance of the water, where deposits are being formed, which, after a while, are broken up again, and which may be called the drift-sand zone. This is wholly unfitted for marine life, and the only organic forms it ever contains consist in the fragmentary shells and tests of other zones. I have dredged along a band of this kind for thirty miles on our own coast without finding a single living form."

The exploration of the sea bottom off the west coast of America by the Albatross in 1904 and 1905, although in much deeper waters than we are concerned with in epicontinental seas, has shown in a remarkable manner the effectiveness of an ocean current in controlling the distribution of marine life. This expedition, which was in charge of Alexander Agassiz, found that the bottom under the Humboldt current is crowded with organisms, whereas there is a sparsely inhabited submarine desert to the westward of the western edge of the current.

In view of the examples of synchronous barren and richly tenanted zones which have been cited in the seas of the present, it seems apparent that absence of fossils from any part of a formation can not be accepted as evidence of nonmarine origin. Since both barren beds and cross-bedding are occasional characteristics of both marine and nonmarine beds, it seems evident that neither of these features can be cited as evidence of either kind of origin. Cross-bedding affords decisive evidence of current or wave action, but it does not indicate whether the action occurred in marine or continental waters.

In the present stage of development of the criteria of continental deposits it will be wise to use with extreme caution any

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* Natural History of the European Seas, p. 233.

criteria for their recognition other than the occurrence of terrestrial fossils. The difficulty of furnishing entirely conclusive criteria for the discrimination of continental deposits is sufficiently indicated by the fact that the best general discussion of the subject which has appeared* expressly disclaims "the purpose to offer here criteria for finally and definitely testing the origin of any particular formation." Instead of depending upon any particular kind of bedding and the absence of organic remains as evidence of nonmarine conditions of deposition, the writer would urge the necessity of finding terrestrial or nonmarine fossils. It is true that procuring this kind of conclusive evidence often requires much hard work and sometimes long suspension of judgment till the evidence is secured. But a conclusion based on such evidence is worth waiting for.

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* Barrell, Joseph, Jour. Geology, vol. xiv, 1906, p. 447.

Art. XXVI.—*The Detection of Sympathetic Vibrations of Small Amplitude by Interference Methods;* by J. S. Stevens.

During the past few years a number of attempts have been made in the Physical Laboratory of the University of Maine to apply interference methods to the detecting of sympathetic and forced vibrations of small amplitude. The sensitiveness of the experiment has heretofore prevented the obtaining of any satisfactory results. During the past semester the experiment was assigned to Mr. R. M. Holmes, an assistant in the department, and a beginning was made toward solving the problem. It is well known that if two tuning forks of the same pitch are mounted side by side, the vibrations of one fork will cause sympathetic vibrations in the other. These may be detected by the sense of hearing, or if a small mirror is attached to the prong of the second fork a spot of light may be made to trace its path on a screen. The object of the work described in this note was to detect the presence of sympathetic vibrations of extremely small amplitude. A mirror was rigidly attached to the prong of one fork, and this mirror was used as the adjustable mirror of a Michelson interferometer. Another fork was adjusted so that it had nearly the same pitch as the first fork, and this was used as the exciting source. When the two forks were so nearly alike in pitch that no beats could be heard, the exciting fork was set in vibration and held near the fork which had the mirror attached. There was no contact between the two forks, and the vibrations of one passed through the air directly to the other. In this case vibrations were readily detected by rhymic motion of the fringes whenever the fork was struck. When the exciting fork was weighted, so that it had a velocity of 260·6 vibrations per second (the pitch of the mirror fork being 265), it was possible to produce vibrations in the second fork. To do this, however, it was necessary to give the first fork a great amplitude and hold it very close to the second fork. When its pitch was changed to 258·2 no vibrations could be detected.

It is suggested that here is a field of considerable interest. If the experiment were performed in a chamber from which the air could be exhausted, the relation between the power of the air to carry sound-waves and its density could be determined. The substitution of other gases for air would prove an interesting piece of work. The sensitiveness of the apparatus used is illustrated by various tests which were made by the two forks. The interferometer was mounted on a slate slab supported by a brick pier 15 feet from the ground. When the fork which was in unison with the mirror-fork was excited and touched to the bottom of the pier, corresponding vibrations were detected. If, however, the pitch of the fork was changed by three or four vibrations per second, no motion of the fringes could be observed. The passing of an electric car 300 feet distant caused a motion of the fringes; and work was practically impossible, except in the evening, when the building was unoccupied.

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SCIENTIFIC INTELLIGENCE.

I. GEOLOGY.

1. *Die Kristallinen Schiefer des Laacher Seegebietes und ihre Umbildung zu Sanidinit*; von R. BRAUNS. 4°, pp. 61, 18 tables; in case. Stuttgart, 1911.—The well-known ejected bombs of sanidinite, so called, which are found in the volcanic products of the Eifel, and especially at Lake Laach, like those from Vesuvius and other places, have had various origins ascribed to them. They have been chiefly regarded, either as agglomerations of early formed minerals, in a molten magma, or as fragments of some related igneous rock torn off and brought up by the magma. Professor Brauns, as the result of his studies, brings forward the idea that in reality they are fragments of the sedimentary gneisses, schists, etc., on which the lower Devonian of the area rests, changed by contact metamorphism. He adduces arguments in favor of this view, and shows by chemical equations how, for example, a biotite- muscovite-quartz schist, by a simple exchange of molecules, yields a rock consisting of sanidine, hypersthene, corundum, and cordierite. Thus by simple melting and recrystallization many cases could be explained; and to this origin, aided by the components of the alkalic magmas and their contained volatile constituents he is inclined to ascribe the other ejected masses with their varied minerals. The work is illustrated by many handsome half-tone plates of microphotographs explanatory of the text.

L. V. P.

2. *British and Foreign Building Stones*; by JOHN WATSON. 12°, pp. 483. Camb. Press, 1911.—One-half of this book, as indicated in the sub-title, is a descriptive catalogue of the rock specimens in the Sedgwick Museum at Cambridge. The first part of the work is, however, of a descriptive nature. The writer first considers the plutonic igneous rocks, giving a general account of British granites and their occurrences, and from this

passes on to those of other countries. He then takes up the volcanic rocks, and mentions the chief types of porphyries, basalts, etc., used for building purposes in Europe. The sedimentary rocks are treated in groups, according to the geologic epoch to which they belong. In all cases the observations are based especially on the material in the museum mentioned. The particular value of the work is, therefore, strictly local, for students in connection with the Cambridge collection ; but it may occasionally prove of service as a book of reference for localities. For its particular purpose the work appears well executed.

L. V. P.

3. *Die Kontaktmetamorphose im Kristianiagebiet;* von V. M. GOLDSCHMIDT. 8°, pp. 483, Videnskap. Skrift. 1. Mat. nat. v. Kl. 1911, No. 1.—It would be a natural expectation that a treatise on some phase of the geology of the Christiania region by one of Prof. Brögger's pupils and assistants, and under his general direction and advice, would be a notable contribution in the particular field to which it is devoted. This expectation is fully realized in the fine volume which is the subject of this notice, for we hardly recall any work on the subject of contact metamorphism which, based on a special locality, is of more general interest and importance. While want of space forbids us from giving it more than a general notice, the following features of the work may be mentioned:

The first part is devoted to a general geological description of the contacts, those of the middle portion of the region being the ones especially dealt with. After a general introduction a number of contact zones are described in full detail, and in this part a number of contact ore deposits are also treated.

The second part is given to the results of the petrographic study of the contact rocks, and is enriched with a large number of chemical analyses, which afford data for conclusions regarding the petrogenesis of the different types. As features of general interest some conclusions of the writer may be mentioned: There is no evidence of stress, of dynamic metamorphism, in the rocks ; the thickness of sedimentary cover was 1500 meters, giving a static pressure of 420 kilos per cm^2 ; under this pressure coarse granular hornfelses formed in the inner contact zone. The metamorphism took place without any melting of the sediments, as shown in several ways; and the author is inclined to think without much action from solutions, or gases. The action in the main took place before the solidification of the intruding magma. The temperature of the inner zone was between 1100° and 1200° C.; in the outer zone, where amphibole occurs, not over 550°. The author here points out that the use of quartz as a geologic thermometer is not justified unless we know something in regard to the pressure involved, for the inversion point between quartz and tridymite must be greatly raised by it. The writer then takes up the classification of the rocks and goes on to their consideration from the standpoint of modern physical chemistry.

He shows that Gibbs's phase rule applies to these, as well as to igneous rocks, and draws some interesting conclusions, which help in the scheme of classification adopted. The petrographical part closes with a description of the various types, of pneumatolytic varieties and of ores, etc.

The last part of the volume, consisting of about 250 pages, is devoted to a careful and thorough study of the minerals appearing in the contact zone; in round numbers some 90 species being considered. These are treated from crystallographic, chemical, optical, and genetic standpoints, the whole forming a notable contribution to mineralogy, especially of the region under consideration. In conclusion, it may be remarked that this work should be in every geological reference library, and will repay reading by the petrographer, mineralogist and student of the genesis of ore deposition. L. V. P.

4. *Grundzüge der Paläontologie* (*Paläozoologie*); by KARL A. VON ZITTEL. Part I, Invertebrata reworked by Ferdinand Broili; pp. 607 and 1414 text-figures. Part II, Vertebrata reworked by Ferdinand Broili, Ernest Koken and Max Schlosser; pp. 598 and 749 text-figures. Munich (R. Oldenbourg), 1911.—This well-known German text-book of Paleontology, the best one on the subject, has been thoroughly revised and brought up to date. The first edition appeared in 1895 in one volume, had 971 pages with 2048 text-figures and treated about 6800 genera. The present book in two volumes represents the third edition of the Invertebrata and the second edition of the Vertebrata, has 1205 pages with 2163 text-figures, and nearly 10,700 genera are discussed or classified. The first volume was reviewed in the January (1911) number of this Journal.

The fishes are revised by Professor Koken of Tübingen, and that the work has been well done is shown in the fact that 140 pages are devoted to them. Dr. Broili of the Alte Akademie at Munich has revised the Amphibia, while most of the matter treating of the Reptilia he has rewritten. Dr. Schlosser, also of the Alte Akademie, has revised the birds, and in good part rewritten the mammals, which are described on 260 pages. The classification throughout the book is conservative, and yet progressive.

No paleontologist can work without the book. C. S.

II. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Les Sommes des Pièmes Puissances Distinctes Egales à une Pième Puissances;* by EDOUARD BARBETTE. Pp. 153. Paris (Gauthier-Villars).—This treatise, as indicated by the title, discusses a generalization of Fermat's theorem, viz., the determination of the necessary and sufficient conditions for a sum of distinct pth powers to be equal to a pth power, p being any integer. The main topic suggests three subsidiary problems formulated by the author as follows :

Problem I: The sums of distinct pth powers of which the greatest is x^p, equal to a pth power.

Problem II: The sums of distinct pth powers equal to a given pth power.

Problem III: The sums of consecutive pth powers equal to a pth power.

Several other topics closely allied to the above are also considered. The work as a whole is divided into four parts, preceded by a short introduction.

In Part I the case $p=1$ is considered, the problem here reducing to a treatment of sums of integers. The latter half of this section contains a comprehensive discussion of prime and composite numbers, a number of methods being given for determining that a given integer is or is not a prime, together with the means, in the latter case, of resolving it into factors.

Part II treats the case of squares: three necessary and sufficient conditions that a sum of squares shall be a square are obtained. There are also several special topics, such as methods of solving the equation $y^2 + z^2 = x^2$, and identities relating to sums of squares.

The case, $p \geq 3$, is contained in Part III, where a generalization of the conditions of Part II are given. These are worked out in detail for $p = 3$, 4, 5, 6, 7, and 8. The work closes with a short chapter on polygonal numbers.

The whole treatment is most freely illustrated by examples making clear the methods of application of the various principles. In this connection it may not be amiss to mention the tables, which comprise the first 5,000 triangular numbers, the primes up to 10,000 and the powers and sums of powers up to the sixth of the numbers 1—30. Finally it should be remarked that the work is complete in itself, a feature which ought to commend it to readers. W. A. W.

2. *The Grammar of Science;* by KARL PEARSON. Part I.—*Physical. Third Edition, revised and enlarged.* Pp. xx, 394. London, 1911 (Adam and Charles Black).—The first edition of the present work appeared in 1892 and was followed by a second in 1899. The time which has elapsed since the last date has seen so rapid a development of science as to call for an extension of the field discussed by the author, and while the present volume deals with physical ideas and phenomena, a second is to follow having to do with living forms. The latter is expected to appear in the course of the present year. The present volume is thoughtful and suggestive and the every-day physicist accustomed to assume the reality of matter and force, of the ether, the law of cause and effect and the like, will find his ideas challenged and subjected to a critical philosophical scrutiny of the most searching kind. Thus, for example, the author remarks in his preface: "Beyond such discarded fundamentals as 'matter' and 'force' lies another fetish amidst the unscrutable arena of even modern science, namely, the category of cause and effect."

3. *Marriage, Totemism and Religion:* An Answer to Critics; by the RIGHT HON. LORD AVEBURY. Pp. ix, 243. London and New York, 1911 (Longmans, Green and Co.).—The present volume is based on a work by the same author on the "Origin of Civilization and the Primitive Condition of Man." This was delivered in lectures at the Royal Institution in 1868 and published in 1870. The special topics here discussed deal with the absence of marriage with primitive man, its origin and evolution; also totemism, witchcraft, magic, and religion. The author presents his views clearly, handling with vigor the criticisms which have been offered since the publication of his first work.

4. *Smithsonian Physical Tables. Fifth revised Edition;* prepared by F. E. FOWLE. (Publication 1944.) Pp. xxxiv, 318, with 335 tables and an index. Washington, 1910. Smithsonian Misc. Collections, vol. 58, No. 1. Publication 1944.—This is a radical revision of the physical tables compiled by Prof. Thomas Gray in 1896, embodying recent data and with many additions. There are now four independent series of Smithsonian tables occupying independent fields; viz., meterological, geographical, physical, and mathematical.

5. *Royal Academy of Sciences of Turin.*—The program in regard to the Vallauri prizes of the Royal Turin Academy announces that prizes will be given: (1) for the best critical work on Latin literature appearing between Jan. 1, 1911, and Dec. 31, 1914; and (2) for the most important and extensive work in the physical sciences published between Jan. 1, 1915, and Dec. 31, 1918. Each prize amounts to 26,000 Italian livres; the awards will be made without regard to nationality.

6. *Catalogue of the Lepidoptera Phalænæ in the British Museum.* Volume x. Plates CXLVIII–CLXXII. London, 1911.—This volume, continuing the excellent plates illustrating the Phaænæ of the British Museum, has recently appeared.

7. *Bureau of American Ethnology, Smithsonian Institution.*—BULLETIN 43. The following publications have recently appeared: Indian Tribes of the Lower Mississippi Valley and adjacent Coast of the Gulf of Mexico; by JOHN R. SWANTON. Pp. vii, 387; 32 plates, 2 figures.

BULLETIN 50. Preliminary Report on a Visit to the Navajo National Monument, Arizona; by JESSE WALTER FEWKES. Pp. vii, 35; 22 plates, 3 figures.

8. *The Sarawak Museum Journal.* Issued by the Sarawak Museum under the Authority of His Highness the Rajah. Vol. I, No. 1. Pp. 201. Sarawak, February, 1911.—This first number of the Journal issued by the Sarawak Museum contains, in addition to a series of papers on ethnological subjects, three others on insects and also a list of Sarawak minerals by J. S. Geikie.

9. *Rhodesia Museum. Eighth Annual Report.* Pp. 36. Bulawayo, 1909.—This report is accompanied by three appendices on the gold-bearing rocks, the minerals, and the batrachians and reptiles of Rhodesia.

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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXVII.—*Recent Stream Trenching in the Semi-arid Portion of Southwestern New Mexico, a Result of Removal of Vegetation Cover*;* by John Lyon Rich.

A conspicuous development of recent stream trenches in the valleys of many of the temporary streams of the western states is a feature of such widespread and common occurrence that it cannot be assigned to accidental causes, but calls for an explanation which shall have more than a local application. This trenching is particularly well developed in portions of southwestern New Mexico. Here it is apparently an effect of the removal of vegetation cover by excessive grazing. A brief description of the nature of the trenching and a statement of the evidence on which the above explanation of the phenomenon is based is the purpose of the following discussion.

The portion of New Mexico on which our study is particularly based is included within the Silver City quadrangle in the southwestern part of the state. The quadrangle may be roughly divided into two physiographic units, a mountainous portion and a desert plain formed by the accumulation of gravels derived from the mountains. Of the whole area of the quadrangle, about one-third is covered by these desert accumulations.

The climate is semi-arid, with an average rainfall in the neighborhood of 18 inches in the mountainous parts, and considerably less in the lower, desert portions. The precipitation comes mostly in the form of showers during the hot summer months, from about the middle of June until the latter part of September. General rains are not of common occurrence. As a result of these climatic conditions there are no permanent streams in the area outside the higher mountains, and even in

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

the mountains, the permanent streams are of small consequence except when swollen by the summer rains.

In the following discussion when we speak of streams we would be understood as referring to the temporary streams which carry water only during, or immediately after, a storm.

A conspicuous feature of the topography of the Silver City quadrangle, outside the more rugged mountains, is a pronounced stream trenching in all the valleys; a trenching of recent date which is evidently still in progress. Along the steep-walled mountain gorges this feature is, of course, not evident, but outside of the higher mountains it would be difficult to name a valley in which it is not conspicuous. The features shown in different parts of the quadrangle are so similar that a description of one of the most typical valleys will serve as a characterization of the general conditions throughout the area, and as a basis for a discussion of the causes of the trenching. For such a description the valley called Cane Spring Canyon, along which some of the accompanying photographs were taken, will admirably serve our purpose.

Fig. 1.

Fig. 1. View showing typical features along the course of the Cane Spring Canyon stream across the piedmont fan. The photograph shows recent trench in the foreground cut into alluvial valley filling, piedmont gravels in the middle distance along the sides of the valley, and mountains at source of the stream in background. Note the bowlders and flood débris spread out over the surface of the alluvial flat.

The stream, which is a temporary one, flowing only in times of flood, heads with several branches in a region of rocky hills of moderate height. Within the hills it has a drainage area of about seven square miles. After leaving the hills the stream flows with an average slope of 120 feet per mile for about 5 miles across a dissected piedmont gravel accumulation to the Mangas, a larger temporary stream which, about 15 miles below, empties into the Gila, a good-sized permanent stream.

The salient features of the Cane Spring valley in its course across the piedmont gravels are well shown in the accompanying photograph (fig. 1). There are first the steep-sided valley walls of partly cemented desert conglomerate from 50 to 150 feet high; then, forming the valley floor, comes an alluvial flat, nearly level in cross section; and finally, cutting sharply into the material of this flat, is the recent stream trench from 50 to 200 feet in width and from 2 to 15 feet in depth, and bounded, as a rule, by vertical walls of alluvium.

Fig. 2.

Fig. 2. Recent stream trench working back into the still undissected flat of a small tributary of Cane Spring Canyon. This picture was taken near the site of fig. 1.

The history of the valley as revealed by its cross section may be briefly summarized as follows: The valley was initiated on the surface of the piedmont desert fan. For some reason—an uplift of the land or a change in climatic conditions—the stream began cutting through the fan. This cutting continued until a valley from one-eighth to one-fourth mile in width and locally over 150 feet in depth had been formed. Following this period of cutting came one of filling, during which the alluvial flats in the valley were formed. Lastly, the streams began cutting again, forming the trenches whose origin we are seeking. These trenches are still working their way up the tributary valleys by headwater recession and sapping. This is well illustrated by fig. 2, which shows the trench working back into the still undissected flat of a small tributary.

The alluvial flats are composed of fine sandy loam and gravel. The latter occurs in the form of irregular lenses interspersed through the loam. Its component pebbles range in size up to 5, 6, or 8 inches in diameter, but seldom larger, and even these sizes are uncommon. Two or three inches in diameter would represent a fair average for the coarser gravel. From this there is every gradation down to fine sand. The stratification is indistinct, but may usually be made out. In characteristic exposure the material stands up in vertical bluffs. From its general make-up and composition there can be no doubt that it is a stream deposit of the type formed by aggrading temporary streams.

Fairly uniform conditions of deposition are shown by the nature of the sediment. That heavy floods were not common during the time of deposition is indicated by the lack of heavy bowlders in the deposit. The valley filling is not an ordinary flood plain such as may be formed along permanent streams, for, in the first place, the slope of the valley bottom, 120 feet per mile, is too great for the formation of a flood plain so wide and flat as the one we are considering; and in the second place, the surface of the flat is not a graded slope along the stream course. Alluvial fans from the valley sides form an integral part of the valley filling. Their prominence, and their effect in breaking the normal valley profile, indicate that a large proportion of the filling came from the sides down the short steep tributaries rather than down the main valley.

On the whole, then, the character of the valley filling indicates accumulation under conditions such that there was no permanent stream in the main valley, and such that accumulations from the sides were as important as those from the main stream. These conditions would be realized under an arid or semi-arid climate during the time of filling.

In the bottoms of the trenches and sometimes spread out over the surface of the flats above, there is *coarse* stream gravel with bowlders ranging up to two feet in diameter, and much of it evidently of very recent deposition. This coarse material presents a marked and significant contrast to the fine textured alluvial valley filling revealed in the side walls of the trenches. The significance lies in the fact that its transportation must have required a volume of water much greater than that of the finer alluvial material on which it rests. Its presence overlying the finer material and the fact that it is associated with flood débris in such a manner as to prove its deposition within a very few years at most, clearly indicates that, in recent times, the maximum volume of water coming down the valley in times of flood has been greater than while the alluvium was accumulating.

On the basis of such evidence of the increased volume of flood waters, we are justified in suspecting that the waters of these floods may have been responsible for the cutting of the stream trenches in question. In an endeavor to explain the trenching it is, therefore, necessary to look for the cause of the increased volume of the flood waters.

Such an increase may be the result of one or the other of two conditions or a combination of both. These conditions are: either an increase in the amount of water by increased precipitation, or a more rapid run-off with no increase in precipitation. An analysis of the results of each of these two conditions taken separately may serve to indicate which is most probably the responsible one in the case at hand.

Taking first the condition of increased precipitation, we will start with a semi-arid climate, such that the streams are not permanent and are silting up their valleys—in other words, with conditions as we conceive them to have been at the time of the formation of the valley fill of Cane Spring Canyon and other valleys of the region. There would undoubtedly be some vegetation which might serve as a fairly efficient cover and constitute an important factor in the absence of heavy floods. With an increase in precipitation we should expect the vegetation to become more luxuriant and more effective as a protective covering; in this way perhaps equaling or overbalancing the tendency of the stream toward cutting, resulting from the increased volume of water. Even though the storms became heavier, the run-off would be slower, so that it is likely that, until the time that the precipitation became so great that the streams became permanent, there would be little, if any, increased tendency toward cutting.

Considering next the second factor; if we have a semi-arid climate favorable to the formation of a fairly efficient vegetation cover, and the balance between erosion and deposition is so adjusted that the streams are silting up with fine material; with considerable rainfall at certain times of the year, prevented, however, by the vegetation cover from forming heavy floods, and if by some means we remove the vegetation cover without changing the amount or distribution of the rainfall, marked results of a different nature will follow. The rain, still as heavy as before, will fall on a bare surface unprotected by vegetation and with little capacity to hold in reserve the excess precipitation. A rapid run-off in the form of floods must result. These floods, rushing down the valleys, will have power to cut where before deposition was in progress. Good sized bowlders will be carried down and strewn along the stream courses and over the flats. The result of such floods would be manifest in the trenching of the valley bottoms and the spreading out over the flats of bowlders larger than those in the valley fill itself. They would produce conditions exactly the same as those we have described as characteristic of the valleys of the Silver City quadrangle.

Having been led to the belief that a removal of the vegetation cover would be competent to cause stream trenching, it becomes pertinent that we inquire whether there is evidence of such a removal of cover in the region under discussion. The answer is in the affirmative.

An efficient cause for the removal of such a vegetation cover is the excessive grazing to which the country has been subjected during the past few years. A good account of the former conditions of the region was given me by Mr. MacMillan, a rancher living in the Mangas valley, who has been a resident of the region since 1876. His statement of the early conditions is substantiated by that of all the old residents of the neighborhood with whom I had occasion to talk. According to him there was formerly much more timber than at present along the Mangas valley and on the piedmont desert fans, but probably never enough to modify materially the run-off of the water. More important than the timber, there was, along the valley bottoms, as well as on the hills and desert fans, a thick carpet of grass. This is reported to have been about knee high and quite thick. Along the valley bottoms it was thick enough to be cut for hay by the ranchers.

Such were the conditions in places where now scarcely a spear of grass can be found. The cattle, often forced to extremes of hunger so great that, sometimes, in a single season, as during the past year, they die by the hundreds of starvation alone, have kept the grass eaten so closely that there has been little opportunity for natural maturing and seeding, with the result that not only has the grass been kept closely cropped, but it has been to a large extent exterminated. The vegetation cover has been reduced from one of relatively high efficiency to almost nothing.

Coincident with the removal of the vegetation has come an increase in the violence of the floods. In the early days, according to MacMillan and others, heavy floods were rare. The storms were just as severe as now, but the run-off was slower. For instance, when a heavy storm occurred in the Burro Mountains, at the head waters of the Mangas, the water would continue to come down the valley for two or three days, whereas now it all comes at once in a single flood. When overstocking had reduced the vegetation cover the first floods began to come, and have been coming with increased frequency and violence every year since.

Having found from an inductive study that the trenching and other conditions of the valleys might be explained by a removal of vegetation cover, and having found from the his-

FIG. 3.

FIG. 3. Typical recent stream trench in the Mangas valley. Note the flat alluvial valley filling in which the trench is cut.

FIG. 4.

FIG. 4. Another view showing characteristic recent stream trenching. This is near the head of a small valley, but the trench is well developed.

torical evidence that such a reduction has actually taken place, with an accompaniment of increased floods, we may further test the theory by inquiring whether the formation of the trenches corresponds in time with the removal of the vegetation. On this point the testimony of the settlers is unanimous that, in the early days, there were few, if any, trenches in the valley bottoms, and that trenching has followed the appearance of the heavy floods. The deep trenches in the Mangas, one of which is shown in the photograph (fig. 3), have practically all been formed within the past 20 or 30 years, and are still deepening. The town of Silver City is built partly on an alluvial flat, such as those we have described. Running through the town is a trench or gulley cut through the alluvial valley filling to a depth of at least 20 feet and with a width of about 100 feet. A little over 15 years ago the site of this trench was one of the main streets of the town. During a severe storm the street was partly washed out and the trench begun. This trench has been cut deeper every year until the present condition has been reached.

From physiographic evidence of this sort, and from the testimony of the early settlers, there is good proof that the trenching is of recent date, corresponding in time with the removal of the grass by too close pasturing.

Our own observations, in so far as we had opportunity to make them in the short space of one summer, bear out the statements of Mr. MacMillan and others as to the normal vegetation conditions. In certain portions of the Silver City quadrangle, which were so far removed from water that the cattle seldom visited them, we found a fairly good cover of grass. These portions were on rocky hills of lava, never, at the best, fitted to maintain a great amount of vegetation, so that in the more fertile valley bottoms and on the gravel plains one would expect a good growth of grass. Within the Fort Bayard military reservation there is a tract of land which has been kept fenced for several years, and has been subjected to very slight grazing. Within this area the grass grows thick and often knee high. There can be no doubt that this grass as a covering is efficient, both in preventing a rapid run-off, and, on account of the sod which is formed, directly hindering stream cutting. Mr. MacMillan reports that in a watershed which he has kept fenced for several years and has not allowed to be closely pastured, the stream trenches which had begun to form before the fencing are gradually filling up.

The conspicuous nature of the physiographic results of overstocking of a region, and the rapidity with which they are brought about are surprising, and afford a striking illustration of the influence of man on geologic processes. If the grazing of a region for a period of 40 years, more or less, has produced so great results, it requires no great stretch of the imagination to picture the conditions in this section a few centuries hence if the same processes continue, as there is every reason to believe they will.

It is not alone within the area of the Silver City quadrangle that stream trenching is a conspicuous feature, for it is common in many parts of the west. In traveling through the states of New Mexico, Colorado and Wyoming, one finds that this trenched condition is widespread. The recency of the trenching is indicated by the fact that it is still in progress, and the gulleys are still working back towards the heads of the smaller tributaries.

In making a wider application of the principles of stream trenching which we have outlined, it is evident that, since the trenching is the result of the removal of vegetation cover, we will be likely to find it only in those regions whose normal climate is such that the normal vegetation would be luxuriant enough to become an important factor in the conservation of the rainfall, and in the protection of the valley bottoms from direct erosion. In such regions the overstocking, to which the west has been subjected, will have so reduced the cover as to cause increased floods with accompanying stream trenching. In regions normally too arid for the formation of an efficient vegetation cover the trenching should not be apparent.

Within the area of the Silver City quadrangle alone there is some evidence bearing on this point. The extreme southeastern corner of the sheet is lower and much more arid than the rest of the area, and it was noted that here the trenching is not so well developed as in the portions of the quadrangle which receive a greater precipitation. In order to thoroughly test the principle, comparison should be made between portions of the state, or of other states, which have climatic conditions similar to those of the Silver City region and other portions where climate is distinctly more arid, as, for instance, portions of southern New Mexico and Arizona.

Art. XXVIII.—*On the Qualitative Detection of Certain Elements which form Insoluble Sulphates: Barium, Strontium, (Calcium,) and Lead;* by Philip E. Browning and Philip L. Blumenthal.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxxiv.]

In the ordinary processes of qualitative analysis the alkali earth elements are usually separated by ammonium carbonate, after hydrogen sulphide and ammonium hydroxide have been used to remove the greater number of the bases. It has long been observed by those employing these processes that a considerable part of the alkali earth, especially barium and strontium, fails to appear when the ammonium carbonate is added. The reasons given for this loss have been the oxidation of hydrogen sulphide or other sulphides to sulphates and the consequent precipitation of the alkali earth sulphates, the formation in alkaline solution of carbonates and the consequent precipitation of the carbonates, and the tendency of the large amounts of ammonium salts which collect during the analysis to interfere with the precipitation of the alkali earth carbonates by ammonium carbonate. Various precautions have been suggested to avoid these sources of error, such as the prompt removal of the excess of hydrogen sulphide by boiling, the use of freshly prepared hydroxides free from carbonate, and the removal of the ammonium salts by ignition before attempting to precipitate the alkali earth carbonates.

The work to be described in this paper was undertaken to study, first, the effect of a direct precipitation of the insoluble alkali earth sulphates, after the removal of the mercury in the mercurous condition, silver, and the proportion of lead which may be precipitated by hydrochloric acid; and, second, the action of ignition with carbon upon these sulphates. For the work solutions were prepared containing to each cubic centimeter one milligram reckoned as the element.

Preliminary experiments showed that in a volume of 10$^{cm^3}$, 1^{mg} of Sr, 0·5^{mg} of Pb, and 0·1^{mg} of Ba gave distinct precipitates when treated with a few drops of dilute sulphuric acid and allowed to stand a few minutes, and 10^{mg} of Ca gave a precipitate on standing over night.

The action of ammonium acetate upon the sulphates of barium and lead was tried as follows: Two solutions containing 0·1 grm. of Pb and 4 grm. of ammonium acetate in 10$^{cm^3}$ of water gave no precipitate when a slight excess of sulphuric acid was added. On addition of more sulphuric acid the lead sulphate tended to precipitate. When ammonium sulphate was substituted for the sulphuric acid no precipitation took place even in the presence of an abundant excess of that reagent. To test the delicacy of the barium precipitation under these conditions 1^{mg} of Ba was added to a clear solution containing 0·1 grm. of Pb, 4 grm. of ammonium acetate, and 1 grm. of ammonium sulphate in 10^{cm^3} of water. The barium sulphate was precipitated at once. It is evident from these experiments that barium sulphate in small amounts may be precipitated in the presence of lead salts by insuring the presence of a sufficient amount of ammonium acetate, and that ammonium sulphate is to be preferred as the precipitant.

In a previous paper from this laboratory* we have discussed the application of fusion with carbon to the reduction of the difficultly soluble double sulphates of the cerium earths with the alkali sulphates, and mentioned the fact that this fusion process had been used for the preparation of soluble barium and strontium salts from barite and celestite. It is now our purpose to show the application of this process to the detection of the alkali earths when present as the sulphates.

Several solutions containing $0·5^{mg}$ of Ba were treated with sulphuric acid, the barium sulphate after filtration was treated directly on the filter paper with a little pure sugar carbon, and the paper containing the sulphate and carbon inserted in a closed glass tube and heated to full redness for a few minutes. After the ignition the mass was extracted by boiling with a little hydrochloric acid, and after filtration the extract was treated with sulphuric acid. In every case the precipitate was distinct, although in a few instances faint. Comparative tests were made by putting equal amounts of barium sulphate through the treatment just described, and through the well-known fusion process with sodium carbonate (fusing, washing with water, and dissolving the carbonates in hydrochloric acid), with possibly a little advantage in the carbonate process so far as concerns the amount of barium shown, but scarcely enough advantage to balance the saving of time in the employment of the carbon ignition method.

As the outcome of this work the following method is suggested.

About 10^{cm^3} of a solution which may contain mercury in the mercurous condition, silver, lead, barium, strontium, and calcium, besides other elements, is treated with hydrochloric acid in faint excess and the precipitated chlorides are filtered off. To the filtrate are added about 5 grm. of ammonium acetate and a 10 per cent solution of ammonium sulphate to complete precipitation. After gentle warming, the alkali earth sulphates are filtered off and washed with a saturated solution of ammo-

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* This Journal, xxxii, 164.

nium acetate until the washings give no test for lead by hydrogen sulphide. The filtrate and washings are reserved for treatment by the ordinary course of analysis. To the precipitated sulphates on the paper a small amount of pure sugar carbon is added, the paper is rolled up, and the mass placed either in a porcelain crucible with a cover or in a closed glass tube, and heated to full redness for a few minutes. The fused mass is treated with about 5^{cm^3} of 50 per cent acetic acid and warmed, when, if the alkali earth elements are present, an odor of hydrogen sulphide will generally be evident. The extract is thrown upon a filter and the residue washed with about 5^{cm^3} of water. The filtrate containing acid and water is treated with a few drops of a solution of potassium chromate to test for barium. The barium chromate is removed by filtration, and the filtrate boiled with sodium carbonate to precipitate strontium and calcium as the carbonates. If the precipitate of the carbonates is very small, it may be dissolved in hydrochloric acid and tested spectroscopically. If, however, it is not too minute in quantity, it should be dissolved in nitric acid after careful washing, and the strontium and calcium separated by dehydration with amyl alcohol.

The results follow in the table. All tests for strontium and calcium were confirmed by the spectroscope, and in (4) and (5) strontium was found by the spectroscopic test.

	Pb present grm.	Ba present grm.	Sr present grm.	Ca present grm.	
(1)	0·0500	0·0500	0·0500	0·0500	Good tests for all.
(2)	0·0250	0·0250	0·0250	0·0250	Good tests for Pb, Ba, and Sr. Ca faint.
(3)	0·0100	0·0100	0·0100	0·0100	Pb and Ba good. Sr fair. Ca doubtful.
(4)	0·0050	0·0050	0·0050	0·0050	Pb and Ba good. Sr fair.
(5)	0·0010	0·0010	0·0010	0·0010	Pb good. Ba fair. Sr faint.
(6)	0·1000	0·0050	----	----	Pb and Ba good.
(7)	0·1000	0·0010	----	----	Pb good. Ba faint.

From these results it would appear that these tests proposed for barium and strontium, effective to at least a milligram of each element, may with advantage precede the group precipitation by hydrogen sulphide in the ordinary course of qualitative analysis.

June, 1911

Art. XXIX.—*A Modified Procedure for the Detection of Silicates, Fluorides, and Fluosilicates*; by Philip E. Browning.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxxv.]

The method for the detection of silica depending upon the formation of the insoluble skeleton of silica in the metaphosphate bead is not always satisfactory in the hands of the average student, and the method which depends upon the observation of the jelly of silicic acid on evaporation with hydrochloric or nitric acid is of course available only when the silicate is decomposed by those acids.

The formation of silicon fluoride by the action of hydrofluoric acid or a fluoride and sulphuric acid upon a silicate is often applied to the detection of silica, since the silicon fluoride when acted upon by water gives a white precipitate of silicic acid. The usual procedure in making this test is to allow the gas to come in contact with a moistened glass rod, but the condensation of steam or sulphuric acid on the rod often makes the results uncertain.

The work to be described was undertaken to devise if possible a method by means of which the reaction could be made more delicate and trustworthy. It was found that when moistened black paper was brought in contact with the fumes of silicon fluoride the deposit of silicic acid was very easily detected. Accordingly the following method was tried.

A small lead cup about one centimeter in diameter and depth was made by running the melted metal into a mould, and a flat piece of lead with a small hole in the center was used as a cover. Into this cup a small amount of finely powdered calcium fluoride, generally about 0·1 grm., was placed together with the silicate, and the mixture covered with a few drops of concentrated sulphuric acid, added by means of a medicine dropper or fountain-pen filler. Upon the upper side of the cover a piece of moistened black filter paper was placed and upon this a small moistened pad of ordinary filter paper was laid to keep the black paper moist during a heating of about ten minutes upon a steam bath. At the conclusion of the heating a white deposit was found on the underside of the black paper over the opening in the cover, if silica was present in appreciable amount.

Talbot* has shown that very small amounts of fluorides may be detected by the etching test. The converse of the method just described for the detection of silicates was applied to the detection of fluorides, and while extreme delicacy cannot be claimed, the results are fairly satisfactory when a milligram of fluorine is present.

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* J. Amer. Chem. Soc., xxviii, 1437.

The detection of fluosilicates by this method is of course even simpler than that of either the fluorides or the silicates. The results follow in the tables:

I

Silicon Tests.

	Name and amount of silicate used grm.	Approximate % of SiO_2	CaF_2 present grm.	Result
(1)	0·1000 SiO_2	100	none	nothing
(2)	0·1000 "	"	0·1000	very good
(3)	0·0100 "	"	"	very good
(4)	0·0050 "	"	"	very good
(5)	0·0010 "	"	"	trace
(6)	0·0100 Kaolinite.....	46	"	very good
(7)	0 0050 "	"	"	very good
(8)	0·0010 "	"	"	trace
(9)	0·0100 Gadolinite....	24	"	very good
(10)	0·0050 "	"	"	trace
(11)	0·0100 Lepidolite	50	0·2000	good

II

Fluorine Tests.

	Name and amount of fluoride used grm.	Approximate % of F.	SiO_2 present grm.	Result
(1)	0·1000 CaF_2..........	49	none	nothing
(2)	0·0100 "	"	·0·0500	very good
(3)	0·0050 "	"	"	apparent
(4)	0·0010 "	"	"	trace
(5)	0·0100 Na_3AlF_6......	54	"	very good
(6)	0·0050 "	"	"	distinct

III

Fluosilicate Tests.

	Na_2SiF_6 present grm.	Result
(1)	0·0050..................	very good
(2)	0·0010..................	very good

From these results it is apparent that one milligram of silicon or fluorine may be detected by the method described.

When very small amounts of material are to be tested it is especially desirable to have the material very finely pulverized, and the delicacy of the test seems to be also somewhat furthered by warming the sulphuric acid before adding it to the mixture of the fluoride and silicate. When fluosilicates are to be examined these precautions are not necessary, as the reaction with the sulphuric acid takes place quite readily in the cold.

July, 1911.

ART. XXX.—*Hinsdalite, a new mineral*; by E. S. LARSEN, Jr., and W. T. SCHALLER.

Introduction.

THE new mineral here described was collected by one of the authors (E. S. L.) in the summer of 1910 while engaged in the areal mapping of the geology of the San Cristobal quadrangle, Colorado. It was found in considerable quantity at an elevation of about 9,950 feet, on one of the dumps of the Golden Fleece Mine, which is about three miles south of Lake City, Hinsdale County, Colorado. The name *hinsdalite*, proposed for the new mineral, is derived from the name of the county in which it is found. The chemical analysis showed hinsdalite to be a hydrous sulphate and phosphate of lead and aluminum with a little strontium replacing the lead. It is therefore the lead analogue of svanbergite or the aluminium analogue of corkite.

Occurrence.

(E. S. LARSEN.)

The country rock of the mineral occurrence belongs to the Picayune member of the Silverton Volcanic Series and consists of tuffs, lava flows, and intrusive bodies of rhyolite, latite, and andesite. The tunnel of the mine was not accessible, but judging from the material on the dump, the new mineral occurs as an original component of a vein whose chief constituents, in the order of their abundance. are quartz, hinsdalite, barite, pyrite. galena, tetrahedrite, and rhodochrosite. The vein material contains bands of almost pure, coarsely granular hinsdalite, an inch or more across. These bands are bordered by a finely crystalline aggregate of quartz and hinsdalite, in which are imbedded well-formed crystals, often a centimeter across, of the new mineral. Beyond the fine aggregate is nearly pure, granular quartz or quartz and barite. The galena and tetrahedrite and, to some extent, the pyrite, are concentrated in the quartz-hinsdalite aggregate.

Description of Mineral.

(E. S. LARSEN.)

The granular hinsdalite is rather coarsely crystalline and the mineral shows a strong tendency to develop crystal faces. Some of the larger imbedded crystals are rhombohedrons resembling cubes, with a perfect cleavage (basal) truncating one corner. The crystal faces are always dull and rough, so that accurate measurements were impossible. Several crystals, however, could be measured with a contact goniometer and gave for the angle $r \wedge r'$ the values: 91·0°, 91·3°, 91·2°, 91·7°, average 91·3° or 91° 18′. The value of the c axis, computed from this average angle, is 1·2677. Measurements of the angle between the cleavage and the adjacent rhombohedron varied from 56° to 59°, with an average of 57° 18′. The calculated value for the angle $c \wedge r$ is 55° 40′.

Fig. 1.

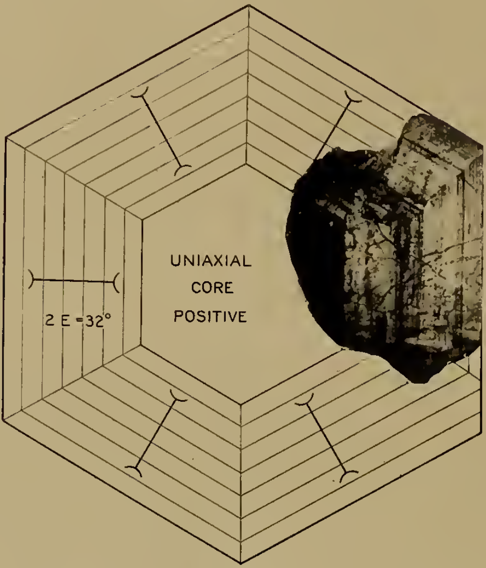

Fig. 1. Basal section of hinsdalite.

The faces commonly developed on the larger crystals are the unit rhombohedron r $\{10\bar{1}1\}$ and the base c $\{0001\}$. The smaller crystals are tabular, parallel to the base, and have both the positive and negative rhombohedrons. The basal sections are hexagonal, while the prismatic sections are lath-shaped, with pointed ends. The optical properties show, however, that the mineral is only pseudo-rhombohedral.

The perfect basal cleavage gives wavy and striated surfaces, and the striations are in some cases developed in three directions, forming hexagonal markings. The hardness of hinsdalite is about 4 1/2 and the density is 3·65. The streak is colorless. The luster is vitreous to greasy. The crystals are nearly colorless, with a greenish cast, but much of the mineral is dark gray from minute inclusions.

A microscopic study of thin sections revealed the fact that the larger crystals, at least, are strongly zoned. This zonal structure is easily seen in ordinary light, or even in the hand specimens. Some of the zones are much more subject to alteration than others. Between crossed nicols the different zones show slightly different interference colors.

On account of the zonal growth it is not possible to obtain accurate and consistent optical data. Cleavage pieces of the mineral are not isotropic, but are nearly normal to a positive, acute bisectrix. The values of 2E vary from nearly 0° to 40°. Dispersion of the optic axes was not perceptible. In many cases the core of the larger crystals is nearly uniaxial, and the most common value of 2E for the outer zone is 32°. The variation in the value of 2E is probably largely due to the zonal growths, though in some cases it is clearly due to overlapping of twin lamellæ. Basal sections of some of the crystals are divided into six radial segments and the plane of the optic axes for each segment is normal to the hexagonal prism edge and to the striations.

These relations are shown in fig. 1, where the diagrammatic part shows the optical relations and the photograph shows a basal section (under crossed nicols) of an incomplete hinsdalite crystal.

Accurate measurement of the angle between the segments was not feasible, though it approximates closely to 60°. Similar optical anomalies have been described for hamlinite* and for jarosite†, both members of the same series of minerals to which hinsdalite belongs (see paper in the number following).

The indices of refraction for hinsdalite were determined by the oil immersion method. The values of α and β are nearly the same and vary from 1·66 to 1·68, with an average value of 1·67; the value of γ varies from 1·678 to 1·700. The birefringence was measured by comparing the interference color of sections parallel to the plane of the optic axes with that of the same section of quartz. For the greater part of the hinsdalite crystal the value of 0·019 was obtained. Some of the narrow zones gave a value as low as 0·016. Therefore the indices of refraction for hinsdalite may be taken as: $\alpha = 1·670$, $\beta = 1·671$, $\gamma = 1·689$.

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* Bowman, H. L.: On Hamlinite from the Binnenthal, Switzerland. Mineral. Mag., vol. xiv, p. 389, 1907.

† Slavik, Franz: Mineralogische Notizen. Zeitschr. Kryst., vol. xxxix, p. 297, 1904.

Chemical Composition.

(W. T. Schaller.)

The new mineral is infusible, becomes blue when heated with cobalt nitrate, and gives a lead reaction when fused with sodium carbonate on charcoal. A little water is given off when it is heated in a closed tube. It is practically insoluble in acids.

After the qualitative analysis had shown what the essential components of the mineral were, a preliminary quantitative analysis was made, the approximately correct results not being here given. With a knowledge of the composition and the experience gained in making the preliminary analyses, the chemical composition of hinsdalite was determined on carefully selected and pure material. The results obtained, together with the ratios deduced therefrom, are shown below.

Analysis and ratios of hinsdalite.

PbO	31·75	·142	·172	1·93 or 2
SrO	3·11	·030		
CaO	trace	----		----
Al_2O_3	26·47	·260		2·92 or 3
SO_3	14·13	·177		1·99 or 2
P_2O_5	14·50	·102		1·14 or 1
H_2O	10·25	·570		6·40 or 6 (= 6 × 1·07)
	100·21			

The ratios agree well with the formula, $2PbO.3Al_2O_3.2SO_3.P_2O_5.6H_2O$, except that the P_2O_5 and H_2O are a little high. A comparison of the analysis with the calculated percentages is shown below. The sample analyzed consists of 82·56 per cent of $2PbO.3Al_2O_3.2SO_3.P_2O_5.6H_2O$, and 17·44 per cent of $2SrO.3Al_2O_3.2SO_3.P_2O_5.6H_2O$ (svanbergite).

Under 1 is given, in the table below, the analysis of the Colorado mineral; under 2, the calculated composition of $2PbO.3Al_2O_3.2SO_3.P_2O_5.6H_2O$; under 3, the composition calculated for a mixture of 82·56 per cent of the pure lead mineral and 17·44 per cent of the pure strontium mineral (svanbergite); and under 4, for comparison, the calculated composition of pure svanbergite.

Comparison of analysis with calculated composition.

	1	2	3	4
PbO	31·75	38·37	31·68	----
SrO	3·11	----	3·91	22·43
Al_2O_3	26·47	26·36	27·55	33·19
SO_3	14·13	13·77	14·39	17·32
P_2O_5	14·50	12·21	12·76	15·37
H_2O	10·25	9·29	9·71	11·69
	100·21	100·00	100·00	100·00

The Colorado mineral, or at least that sample of it which was analyzed, represents a strontium hinsdalite just as the only good analysis of svanbergite really represents a lead svanbergite.

The water of the mineral is all water of constitution, that is, it is driven off only at a high temperature. It was found that practically no water was expelled up to 390°, the following table showing the results obtained :

Loss of water.

Temp.	Total loss in weight
110°	0·02 per cent
170°	0·02 "
250°	0·08 "
390°	0·08 "
590°	9·24 "

The crucible was heated in an air oven for the temperatures up to 250° ; above this heat, an electric furnace was used. The results show that the water is lost between 400° and 600°, approximately.

In its relation to other members of the group, hinsdalite is best considered as the lead type of svanbergite. It may just as well be considered as an aluminous corkite, the formula for corkite* being $2PbO.3Fe_2O_3.2SO_3.P_2O_5.6H_2O$. The systematic place of hinsdalite is thus well fixed, and it adds another well-defined mineral to a group which already includes a considerable number of minerals (see paper in the number following). The relations of these minerals, closest related to hinsdalite, can be seen in the following tabulation:

Svanbergite	$2SrO$.	$3Al_2O_3$.	$2SO_3$.	P_2O_5.	$6H_2O$.	Rhomb., $c=1·2063$
Hinsdalite	$2PbO$.	$3Al_2O_3$.	$2SO_3$.	P_2O_5.	$6H_2O$.	Rhomb., $c=1·2677$
Corkite	$2PbO$.	$3Fe_2O_3$.	$2SO_3$.	P_2O_5.	$6H_2O$.	Rhomb., $c=1·1842$
Beudantite	$2PbO$.	$3Fe_2O_3$.	$2SO_3$.	As_2O_5.	$6H_2O$.	Rhomb., $c=1·1842$

United States Geological Survey,
Washington, D. C.

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* Compare Lacroix, Minéralogie de la France, vol. iv, p. 592, 1911.

ART. XXXI.—*The Hunton Formation of Oklahoma*; by

CHESTER A. REEDS, Bryn Mawr College.

[Contributions from the Paleontological Laboratory of Yale University.]

Introduction.

THE Hunton formation of the Arbuckle Mountains, Oklahoma, was briefly described by Mr. J. A. Taff in the Atoka Folio, 1902, Tishomingo Folio, 1903, and Professional Paper No. 31, 1904, of the U. S. Geological Survey. Drs. G. H. Girty and E. O. Ulrich collected and studied fossils in connection with the stratigraphic work of Taff.

Since 1905 the writer has examined with care all of the widely scattered outcrops of the Hunton. He has made, furthermore, three large collections of fossils from these beds, and has measured as many as 35 sections across the exposed edges of these tilted strata. After the completion of a comprehensive study of the collections and sections under the direction of Professor Charles Schuchert of Yale University, the writer prepared a paper entitled "The Stratigraphy of the Hunton Formation, with introductory chapters on the Physiography and Structure of the Arbuckle Mountains, Oklahoma." This report was submitted May 1, 1910, to the Faculty of the Graduate School of Yale University as a thesis, in partial fulfilment of the requirements for the degree of Doctor of Philosophy. The introductory chapters on the Physiography and Structure together with chapters on the Stratigraphy and Mineral Resources of the Arbuckle Mountains have since been published as Bulletin No. 3, 1910, of the Oklahoma Geological Survey.

In the following pages the writer proposes to submit only a summary of his stratigraphic and paleontologic studies of the Hunton, since the text and illustrations of the complete report will be published later as one of the U. S. Geological Survey publications.

As no maps accompany this article the writer refers the reader to the Ardmore, Tishomingo, Atoka and Stonewall topographic sheets, the Atoka and Tishomingo Folios, the map of the Arbuckle Mountains in Professional Paper No. 31 of the U. S. Geological Survey, and to the maps accompanying Bulletin No. 3 of the Oklahoma Geological Survey.

Problem stated.—As mentioned in the Tishomingo Folio, page 4, and Professional Paper No. 31, pages 29 to 30, the Hunton limestone may be divided into two categories: (1) lithologically, into 3 members: a basal limestone, a middle shale and an upper limestone; (2) paleontologically, into 4 faunal horizons: Clinton, Niagara, Helderberg and Lower Oriskany, the first and second assigned to the basal member, the third and fourth to the middle and upper members, respectively.

The writer does not accept this threefold lithologic and fourfold paleontologic subdivision of the Hunton. Instead, he proposes both a fourfold lithologic and paleontologic arrangement, the new units to have the rank of formations. From bottom to top they are (1) the Chimneyhill limestone (Silurian), (2) the Henryhouse shale (Silurian), (3) the Haragan shale (Devonian) and (4) the Bois d'Arc limestone (Devonian). These four formation names are new terms and have been approved by the Committee on Geologic Names of the U. S. Geological Survey. As may be seen from the correlation table, Table 1, the limits of the new subdivisions do not correspond exactly wlth those proposed by Taff, Ulrich and Girty.

This difference in the grouping of the beds has arisen, no doubt, from the unrealized very variable thickness of the Chimneyhill, Henryhouse, Haragan and Bois d'Arc formations from place to place, and also because the characteristic fossils which definitely define the limits of each had not then been determined. In Taff's type area at Hunton only three of the new formations here proposed, the Chimneyhill, Haragan and Bois d'Arc, are present, the Henryhouse having been eroded previous to the deposition of the Haragan. In the Lawrence anticline, however, some 15 to 20 miles northwest from Hunton the Henryhouse formation attains its greatest thickness, 223 feet, while the Haragan formation is wanting. There the Bois d'Arc rests disconformably on the Henryhouse while the latter is disposed similarly on top of the Chimneyhill. In the "White Mound" region 3 to 4 miles southeast of Dougherty, and many places elsewhere, the four formations are present, but varying in thickness from locality to locality. No two of the 35 sections made across the Hunton are alike. Not only are the entire sections of different thickness but also the amount of each formation present is variable. The cause for this variability is assigned to unequal rate and time of deposition from place to place, and also to differential erosion during and following sedimentation.

The writer's classification is based on both faunal and lithologic grounds but primarily on the faunal evidence. In localities where the Haragan shale rests on the Henryhouse shale, as in the exposures about Dougherty, it will be difficult, without a knowledge of the fossils, to separate one formation from the other. In localities where only one of these shale members is present, as near Lawrence and Hunton, there will be no difficulty in distinguishing three formations, lithologically as well as faunally. The fossils, however, are the only criteria that may be relied upon to determine which of the two shale formations is represented.

That the writer's conclusions may be substantiated and that the formations may be more completely defined, each formation, with its characteristic fauna, will be treated separately in the following pages.

Chimneyhill limestone (*Silurian*).

This formation corresponds to Taff's lower Hunton limestone. It varies in thickness from 0 to 53 feet, but it is persistent throughout all of the widely scattered exposures of the Hunton. It is named after Chimneyhill creek, which crosses

Table I.—*Correlation table of the Siluro-Devonian Rocks, Arbuckle Mountains, Oklahoma.*

Period	Series	Stage	Reeds 1911	Taff, Ulrich and Girty 1903–1904	
Devonian	Helderbergian	Becraft	Bois d'Arc limestone 0–90 feet, average 60 feet	Upper Hunton	Oriskany
		New Scotland	Haragan shale 0–166 feet, average 100 feet	Middle Hunton	Helderbergian
			Break		
Silurian	Niagaran	Bob & Lobleville	Henryhouse shale 0–223 feet, average 90 feet		
			Break		
	Alexandrian	Ohio Clinton	Chimneyhill limestone 0–53 feet av. 35 feet: Pink-crinoidal member, 0–39 ft., av. 15 ft. Glauconitic member, 0–25 ft., av. 15 ft. Oölitic member, 0–12 ft., av. 5 ft.	Lower Hunton	Niagara Clinton

the formation in the northeast corner of the Mountains. The type locality is at the confluence of three small creeks, Sec. 4, T. 2N., R. 6E. Since there were no geographic names in this region suitable for formation names it was necessary to change "South Fork of Jack Fork" creek to Chimneyhill creek. The Chimneyhill limestone rests unconformably on a blue, green or yellowish shale which Taff has named the Sylvan. Above, in most places, it is in contact with the Henryhouse formation, which rests unconformably on it. In other places, as at Hunton, it is in contact with the Haragan shale, the second shale formation, since erosion removed in that region all of the Henryhouse before the Haragan was deposited on the uneven surfaces of the Chimneyhill.

Lithology.—From a lithologic standpoint the Chimneyhill formation is divisible into three members: an oölitic limestone, a glauconitic limestone and a pink-crinoidal limestone. Each member has a variable thickness and extent throughout the mountains. They will be considered in the order named, which was also their order of deposition.

Oölitic member.—This member forms a bed of oölitic limestone ranging in thickness from 0 to 12 feet, at the base of the formation. Its best outcrop is in the northeast corner of the mountains in the vicinity of Lawrence. There it has an average thickness of 9 feet, and is well exposed for a distance of 5 miles as the cap-rock to the escarpment of the Sylvan shale. Although this member is generally present with the other members of this formation it is absent in 10 of the 35 measured sections and only 1 foot thick in 4 of them. Where it is only 1 foot thick the lower half is composed chiefly of crinoidal fragments while the upper 6 inches consists wholly of oölite. Where the member has an average thickness of 5 feet or more the lower 1·5 feet consist chiefly of crinoidal fragments. Other fossils are sometimes present. This narrow lower zone is often of the same color as the overlying oölite beds, but perhaps it is more frequently a brownish earthy crinoidal limestone. On fresh exposures the oölitic limestone in the upper zone is light gray to white in color, but where weathered it takes on a darker tone. In hand specimens the oölites themselves may be more or less uniform in grain, that is, fine, medium, or coarse, or, those varying from a pinhead to a pea in size may be associated together. This upper oölitic zone is chiefly unfossiliferous except for a few small specimens of *Favosites niagarensis*, and occasionally lentils of white limestone which contain a new species of *Clorinda*. In the Coal creek section a 6-foot yellowish shale bed, resembling the Sylvan, occurs between 3·5 feet of oölite below and 1 foot of oölite above. This is the only locality observed where a lentil of shale was intercalated in this member. Its presence indicates that the muddy water conditions of the Sylvan were resumed at this time and place. The presence of limestone lentils at other localities foreshadows the deposition of the overlying white glauconitic limestone or middle member.

Glauconitic member.—This member was found in all of the numerous exposures examined except one near Sheep creek where the pink-crinoidal member rests on the oölitic member. The 35 sections made across the Hunton show that it varies in thickness from 0 to 25 feet. It is a white to gray, granular to crystalline, generally massive bedded limestone, disseminated with green glauconitic grains. The presence of the green glauconite, white color and granularity readily distinguish it from the oölitic and pink-crinoidal members, between which it is intercalated.

Pink-crinoidal member.—This limestone constitutes the uppermost member of the Chimneyhill formation. Typical exposures are to be found in the Lawrence and Hunton anticlines and Franks syncline along the northeast border of the mountains between Lawrence and Bromide. The exposures in the vicinity of Dougherty in the west central part of the mountains are not so characteristic. Typically the member is a thin bedded, compact earthy to crystalline limestone containing numerous crinoidal fragments which have been stained pink by infiltrated iron and manganese. The member varies in thickness from 0 to 39 feet, with an average thickness of approximately 15 feet. This variation in thickness is accounted for chiefly by the differential erosion which affected the member previous to the deposition of the Henryhouse shale, and, in places where it has been completely carried away, by a second period of erosion, the one just previous to the deposition of the Haragan shale.

Fauna.—The fauna of the Chimneyhill limestone is roughly equivalent to that of the Ohio Clinton and Brassfield formations east of the Cincinnati axis in Ohio and Kentucky. It is still more closely related, however, to the Ohio Clinton west of this axis in Indiana, southern Illinois, Kentucky and Tennessee. In fact, as at present understood, the Chimneyhill was deposited in the same marine waters but near the opposite shore of a rather restricted geographical province, the Indiana basin.* It would thus be expected that the faunas are somewhat alike but not necessarily the same in every particular. The names and stratigraphic range of the characteristic species of the Chimneyhill formation are as follows:

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* Schuchert, C., Paleogeography of North America, Bull. Geol. Soc. Am., vol. xx, pp. 532–538, pl. 64.

CHARACTERISTIC SPECIES OF THE CHIMNEYHILL FORMATION (SILURIAN).

Oölitic member.

Atrypa n. sp., *Schuchertella* sp., *Rhipidomella* n. sp., *Cyclonema daytonensis.*

Glauconitic member.

Callopora magnopora, *Pachydictya bifurcata*, *Phenopora fimbriata*, *Phenopora magna*, *Rhinopora verrucosa*, *Plectambonites transversalis* n. var., *Strophomena* (?) *antiquata*, *Cyclonema ventricosa*, *Orthoceras* cf. *latanummulatum*, *Illænus ambiguas*, *Illænus* cf. *armatus.*

Pink-crinoidal member.

Pisocrinus sp., *Homœospira* n. sp., *Plectambonites tennesseensis* (cf. *quinquecostata* McCoy), *Spirifer radiatus*, *Stropheodonta corrugata*, *Triplecia* n. sp. (cf. *waldronensis*), *Whitfieldella* sp., *Delthyris* n. sp., *Conocardium* sp., *Hyolithes* n. sp., *Lophospira* sp., *Calymene* sp., *Cyphaspis clintonensis*, *Dalmanites arkansus*, *Illænus* 2 sp., *Lichas* n. sp., *Odontopleura arkansana*, *Prœtus corrugatus* ?, *Prœtus determinatus* ?, *Sphœrexochus* sp.

Oölitic and glauconitic members.

Orthis flabellites.

Glauconitic and pink-crinoidal members.

Stephanocrinus elongatus, *Conocardium* sp., *Strophostylus cyclostomus*, *Orthoceras rectum*, *Dalmanites* sp.

Oölitic, glauconitic and pink-crinoidal members.

Streptelasma cf. *bilateralis*, *Clorinda* n. sp., *Dalmanella elegantula*, *Hebertella fausta*, *Platystrophia biforata*, *Triplecia* cf. *ortoni*, *Hormotoma* sp., *Dalmanites werthneri*, *Illænus* cf. *daytonensis.*

Henryhouse shale (Silurian).

This formation varies from 0 to 223 feet in thickness. The thickest exposures occur in the Lawrence anticline on Chimneyhill creek in the northeast corner of the Arbuckles and again in the south limb of the Arbuckle anticline along the southwest border of the mountains from Springer to Poolville (Elk). Good outcrops may be seen on Henryhouse creek 3 miles east of Woodford. The formation takes its name from this creek. In the central part of the mountains in the vicinity of Dougherty the formation is not so thick and on the eastern side of the Arbuckles from Canyon creek south to Bromide (Sulphur Springs) it is altogether wanting.

Lithology.—Along Chimneyhill creek this formation is composed of bluish to yellowish, thin to moderately thick bedded earthy limestone and intercalated shale beds in the lower 180 feet, while the upper 43 feet is of white marly beds. In the type area, and also in the vicinity of Dougherty, alternating yellowish shales, shaly limestones and bands of reddish earthy limestone occur. The lower 180 feet of the Chimneyhill section is represented thus in the Henryhouse creek section. Faunally, it contains many of the same species but is less prolific in the number of individuals. The white marly beds and their coral fauna are not present at the top of the Henryhouse creek section. As may be seen the beds of the two sections are thus somewhat variable in character as well as in thickness. The sediments were evidently deposited in shallow oscillating seas which bordered an irregular coast-line of slightly uplifted land, or, possibly in a sea containing scattered islands.

Fauna.—The fauna of the Henryhouse shale is more prolific than that of the Chimneyhill formation below, although fossils are scant in the lower 120 feet. They may be collected, too, with greater ease from the weathered shale slopes of the Henryhouse than from the hard limestone ledges of the Chimneyhill. The contact between these two formations is sharper in the northeast part of the mountains in the Lawrence anticline, than in the vicinity of Dougherty and along the south side of the mountains, west of the Washita river. The fossils from the lower 120 feet of this formation correspond more closely to those of the Bob formation of Tennessee and this division may be known as the Lower Henryhouse. The fossils from the remaining 102 feet correspond most closely to the Lobleville beds and these beds represent the Upper Henryhouse. It may thus be seen that the unconformity between the Chimneyhill and Henryhouse formations is denoted by the absence of the Osgood, Laurel, Waldron, Lego, Dixon and Beech river formations as defined by Pate and Bassler.* The names and stratigraphic range of the diagnostic species of the Henryhouse formation are as follows :

CHARACTERISTIC SPECIES OF HENRYHOUSE FORMATION (SILURIAN).

Lower Henryhouse.

Glassia sp., *Scenidium insigne*, *Schuchertella* n. sp., *Stropheodonta* n. sp., *Strophonella prolongata*, *Platyschisma* n. sp., *Orthoceras* n. sp., *Bronteus* cf. *plana*, *Ceraurus niagarensis*, *Dalmanites* n. sp., *Encrinurus* n. sp.

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*Pate, W. F. and Bassler, R. S., Proc. U. S. Nat. Museum, vol. xxxiv, p. 410.

Upper Henryhouse.

Astylospongia præmorsa, *Amplexus shumardi*, *Aulopora repens*, *Calceola* sp., *Cladopora reticulata*, *Eridophyllum rugosum*, *Favosites niagarensis*, *Favosites venustus* n. var., *Heliophyllum radicula*, *Plasmopora folis*, *Thecia minor*, *Thecia major*, *Coccoseris micropora*, *Heliolites interstinctus*, *Heliolites subtubulatus*, *Pisocrinus milliganae*, *Synbathocrinus tennesseensis*, *Ascodictyon silurinense*, *Bythotrypa* cf. *distichia*, *Bythotrypa* cf. *squamata*, *Chilotrypa* 4 sp., *Crepipora* n. sp., *Fenestella* cf. *acuticosta*, *Fistulipora* 2 sp., *Hederella* sp., *Leptotrypa* n. sp., *Lioclema* 2 sp., *Nicholsonella* cf. *florida*, *Penniretepora* cf. *distichia*, *Rhopalonaria attenuata*, *Anastrophia* cf. *internascens*, *Anoplotheca saffordi*, *Atrypa* cf. *nodostriata*, *Camarotœchia* ? *neglecta*, *Hebertella fissiplica*, *Leptæna* sp. (European type), *Nucleospira* cf. *lentiformis*, *Pholidops* sp., *Rhynchonella* n. sp., *Rhynchospira globosa*, *Schuchertella subplanus*, *Spirifer crispus*, *Strophonella tenuistriata*, *Uncinulus* cf. *nucleolata*, *Uncinulus* cf. *stricklandi*, *Amphicœlia* sp., *Platystoma* sp., *Cyrtoceras subrectum*, *Orthoceras* sp., *Acaste* cf. *dowingiæ*, *Dalmanites* n. sp.

Lower and Upper Henryhouse.

Striatopora sp., *Lecanocrinus* n. sp., *Ceramopora* sp., *Fenestella* n. sp., *Fistulipora hemispherica*, *Pachydictya crassa*, *Anoplotheca saffordi*, *Bilobites saffordi*, *Camarotœchia whitei*, *Dalmanella crassa*, *Dictyonella gibbosa*, *Gypidula rœmeri*, *Gypidula rœmeri simplex* n. var., *Leptænisca adnascens*, *Merista tennesseensis*, *Pholidostrophia* n. sp., *Schuchertella subplanus rœmeri*, *Spirifer saffordi*, *Stropheodonta* n. sp. (1), *Strophonella laxiplicata*, *Calymene* cf. *camerata*.

Haragan shale (Devonian).

The Haragan shale varies in thickness from 0 to 166 feet, with an average thickness of about 100 feet. The fossils indicate that this variation in thickness is due chiefly to the unequal rate of deposition of the beds over an uneven surface. It is absent in the Lawrence anticline and Wapanucka syncline but is represented in most of the remaining outcrops of the Hunton. Excellent exposures may be found along the northeast border of the mountains from Canyon creek south to Hunton and Bromide. The prominent escarpment at the postoffice of Hunton is of this shale. Excellent exposures containing abundant fossils are to be seen in the "White Mound" region along Haragan creek 3 to 4 miles southeast of Dougherty. This is the type area, the formation taking its name from Haragan creek which flows westward across the strike of the formation about one-fourth mile north of "White Mound." The term Haragan, which is used here as the formation name, has been applied to an unnamed creek which may be seen on the Ardmore quadrangle in Sec. 17, T. 2S., R. 3E. The

Henryhouse and Haragan shales are both exposed here and when taken together constitute Taff's middle member.

Lithology.—The formation consists of alternating blue to white shales and thin bedded earthy limestones which weather into yellowish shales on long exposure. It resembles somewhat the Henryhouse formation, but instead of a tendency toward massive bedded alternating series of yellow and pink earthy limestones and some shale beds there is here a predominance of the shale members and only occasionally thin ledges of earthy or crystalline limestone. The most typical sections were made along Coal and Haragan creeks.

Fauna.—The fossils are numerous and easily obtained close to the streams where weathered shale slopes occur. The fauna contains a considerable number of species that are to be found in the New Scotland shale of the Helderbergian series in the lower Devonian of New York. The names of the species which have been identified that are peculiar to this horizon are the following:

CHARACTERISTIC SPECIES OF THE HARAGAN SHALE (DEVONIAN).

Favosites venustus, *Striatopora issa*, *Brachiocrinus* sp., *Edriocrinus* n. sp., *Callopora perelegans*, *Anoplia helderbergæ*, *Atrypa nodostriata* n.var., *Atrypina imbricata*, *Camarotœchia bialveata*, *Chonetes* sp., *Cyrtina dalmani*, *Dalmanella* n. sp., *Dalmanella subcarinata*, *Orthostrophia strophomenoides*, *Spirifer cyclopterus* n. var., *Stropheodonta crebristriata*, *Stropheodonta varistriata*, *Stropheodonta* n. sp., *Stropheodonta* cf. *planulata*, *Strophonella* n. sp., *Trematospira* cf. *costata*, *Conocardium* sp., *Megambonia* sp., *Diaphorostoma* n. sp., *Diaphorostoma ventricosa*, *Platyceras lamellosum*, *Platyceras unguiforme*, *Pleurotomaria* n. sp., *Tentaculites gyracanthus*, *Dawsonoceras* n. sp., *Dicranurus hamatus*, *Phacops logani*.

Bois d'Arc limestone (*Devonian*).

This formation corresponds to Taff's upper Hunton. It is present wherever the Chimneyhill, Henryhouse and Haragan beds are found except in the northeast limb of the Arbuckle anticline in the vicinity of Honey creek near the Washita river. There it was eroded previous to the deposition of the overlying Woodford chert. It varies in thickness from 0 to 90 feet but has a general average of 60 feet. In the type area along Bois d'Arc creek, Sec. 4, T. 2N., R. 6E., in the northeast corner of the Arbuckles, it has a maximum thickness of only 64 feet. Although the thickness is not as great as that to be found in the Dougherty anticline, or along Haragan creek, the fossils indicate that it is the higher portion of the section which is here represented. It may yet be determined that the uppermost 40 feet of the Bois d'Arc are Oriskany in age.

Lithology.—The Bois d'Arc limestone consists of thin bedded crystalline and non-crystalline limestone with occasional chert lentils and thin beds of intercalated yellowish shale. In the Coal creek and Goose creek sections a 6-foot bed of yellowish shale occurs near the middle of the formation. Where the crystalline ledges have weathered considerably the rock is readily worked for fossils, but the non-crystalline limestone instead is very hard and weathers into thin lenticular lenses.

Fauna.—The fossils indicate that for most places in the Arbuckles deposition was continuous from the Haragan shale into the Bois d'Arc limestone. The contacts, however, are sharp where the beds are gently inclined, but not always so where the beds are steeply tilted. This is due to the less effective power of the agents of weathering. In passing from the Haragan shale to the Bois d'Arc limestone, thin intercalated shale beds are to be found between the ledges of limestone in the lowermost 5 feet of the Bois d'Arc limestone. This is well illustrated in the thick sections across the Dougherty anticline and along Haragan creek. In the type area in the northeast corner of the mountains the Bois d'Arc limestone rests unconformably on the Henryhouse shale, for strangely enough the Haragan shale is not represented here. This suggests that the northeast corner of the Arbuckle Mountains was above sea level during Haragan times, and possibly that the Henryhouse was not affected much by erosion since the thickest section containing the highest horizon of the formation occurs a mile away on Chimneyhill creek. Since deposition was continuous in various places from the Haragan shale into the Bois d'Arc limestone, it is not surprising that the lower part of this limestone, in such places, has a New Scotland aspect. Since, however, there are a number of fossils that are characteristic of this limestone it is best treated as a separate formation. It is more nearly the Becraft than the New Scotland of the New York section. The names of the fossils which are peculiar to this formation are as follows:—

CHARACTERISTIC SPECIES OF THE BOIS D'ARC LIMESTONE (DEVONIAN).

Dendropora n. sp., *Favosites shriveri*, *Trachypora* n. sp., *Pisocrinus* sp., *Codaster* n. sp., *Cyrtina rostrata*, *Eatonia singularis*, *Leptostrophia magnifica*, *Leptostrophia oriskania*, *Meristella lævis*, *Meristella lentiformis*, *Rensselæria marylandica*, *Spirifer concinna*, *Spirifer cyclopterus*, cf. *hartleii*, *Stropheodonta becki*, *Strophonella cavumbona*, *Trematospira* n. sp., *Uncinulus* 2 n. sp., *Mytilarca* cf. *acutirostra*, *Orthonychia* cf. *plicatum*, *Platyceras* n. sp., cf. *tenuiliratum*.

Widely-ranging species. — After having listed separately most of the species which occur in each of the four formations under appropriate headings, it is well in order to make the faunal list complete to give now the names and range of the species which are not characteristic of any one formation and which have a stratigraphic range greater than that of a single formation. In a sense they are forms which bind together the faunas of the four formations. They have been arranged in tabular form under class headings, Table II. The list shows that some species which have heretofore been considered characteristic of certain horizons are no longer so. This is well exemplified by *Leptænisca concava*, which is restricted to a 4-foot horizon in the New Scotland of New York. In Oklahoma it ranges through more than 300 feet, starting in the Henryhouse (Silurian) and terminating in the Bois d'Arc (Devonian). Another diagnostic fossil of the New Scotland and Linden is *Camarocrinus ulrichi*. In the Arbuckle Mountains it has the same range as *Leptænisca concava*. The fauna of the Upper Henryhouse is prophetic of the Helderbergian, but it is still Silurian since it contains a larger number of associated Niagaran species. This is very interesting when it is remembered that none of the Cayugan series is represented. These and other points of interest will be treated in a more comprehensive manner in the complete stratigraphic and paleontologic report which will appear later as a U. S. Geological Survey publication.

Table of Silurian and Helderbergian formations.—When the Chimneyhill, Henryhouse, Haragan, and Bois d'Arc formations are arranged in tabular form opposite synchronous formations of the completed geologic column, it is at once apparent that they represent but a small part of the time from the beginning of the Silurian period to the close of the Helderbergian epoch of the Devonian. That the reader may have before him a graphic idea of this relation, a table of Silurian and Helderbergian formations is given in Table III. Except for the new terms here proposed, it has been compiled from the tables given by Schuchert in his Paleogeography of North America. In the various districts considered, the times of no deposition as well as eroded sediments have been indicated by the word "Break."

TABLE II.

The widely-ranging species of the Chimneyhill, Henryhouse, Haragan and Bois d'Arc formations, Arbuckle Mountains, Oklahoma.	Silurian				Devonian	
	Chimneyhill limestone			Henryhouse shale	Haragan shale	Bois d'Arc limestone
	Oölitic member	Glauconitic member	Pink-crinoidal member			
SPONGIA						
Hindia sphæroidalis	--	--	--	--	×	×
ANTHOZOA						
Enterolasma waynense	×	×	×	×	×	×
Favosites conicus	--	--	--	×	×	×
Favosites favosus	--	×	×	--	--	--
Michelinia lenticularis	--	--	--	×	×	×
CRINOIDEA						
Camarocrinus ulrichi	--	--	--	×	×	×
BRACHIOPODA						
Anastrophia verneuili	--	--	--	×	×	×
Anoplotheca concava	--	--	--	--	×	×
Atrypa reticularis	--	--	×	×	×	×
Cyrtina dalmani	--	--	--	--	×	×
Delthyris perlamellosus	--	--	--	×	×	×
Leptæna rhomboidalis	--	×	×	×	×	×
Leptænisca concava	--	--	--	×	×	×
Meristella atoka	--	--	--	×	×	×
Nucleospira ventricosa	--	--	--	×	×	--
Plectambonites transversalis	--	--	--	×	×	--
Rhipidomella emarginata	--	--	--	×	×	×
Rhipidomella oblata	--	--	--	×	×	×
Rhynchospira formosa	--	--	--	×	×	×
Schuchertella woolworthanus	--	--	--	×	×	×
Strophonella punctulifera	--	--	--	×	×	×
Uncinulus nucleolata	--	--	--	×	×	×
GASTROPODA						
Platystoma niagarensis	×	×	×	×	×	×
CRUSTACEA						
Phacops hudsonicus	--	--	--	--	×	×
Dalmanites pleuropteryx	--	--	--	--	×	×

TABLE III.—*Table of Silurian and Helderbergian Formations.*

Period	Series	Western New York		Eastern New York	East of the Cincinnati axis, Ohio	West of the Cincinnati axis, Ind., Ky., Tenn.	Arbuckle Mountains, Oklahoma
Devonian	Helderbergian		*Break*	Becraft New Scotland Kalkberg Coeymans		*Break* Linden *Break*	Bois d'Arc Haragan *Break*
Silurian	Cayugan	Monroe group		Manlius, 75 feet Rondout, 40 feet Cobleskill, 6 feet			
		Salina group	Bertie, 60 feet Camillus, 50–30 feet Syracuse } 600 feet Vernon } Pittsford, 20 feet	Rosedale Wilbur Binnewater High Falls Shawangunk			
	Niagaran		Guelph of Ontario Lockport, 130 feet Rochester 85 feet } Same fauna Irondequoit 14 feet }		*Break* Cedarville Springfield West Union Niagara shales 50–100 feet Dayton	*Break* Decatur 63–70 feet Louisville { Brownsport { Lobleville 17–76 feet Bob 15–75 feet Beech River 37–101 feet } Dixon 18–44 feet Lego 25–46 feet Waldron 2–9 feet } Saint Clair { Laurel 25–33 feet Osgood 10–22 feet } *Break*	*Break* Henryhouse 0–223 feet average 90 feet *Break*
	Anticostian or Alexandrian	Clinton of west'rn N.Y.	{ Williamson, 24 feet Wolcott (Furnaceville), 14 feet Sodus } *Small break* Medina (Oneida)		*Break* Ohio Clinton or Brassfield 20–150 feet *Break*	*Break* Ohio Clinton, 0–20 feet Edgewood, 0–4 feet Girardeau, 0–4 feet	*Break* Chimneyhill 0–53 feet, av. 35 ft. *Break*

ART. XXXII.—*A Study of the Time Interval in a Protective or Circuit Breaking Device;** by CALVIN NAFTZINGER WENRICH.

IN the ordinary plunger circuit breaker, the time between the starting of the iron core and the releasing of the spring is very short. This time is not appreciably affected by a change of current after the starting of the core. Such an interval in a breaker is called the "time element."

The fuse, when used as a breaking device, acts on the principle of an "inverse time element," that is, the greater the excess of current above the maximum amount which the fuse will permanently carry, the shorter is the interval before the circuit is broken. This is a desirable feature. The fuse, however, is non-adjustable in its time feature and very dangerous from the standpoint of ignition at its blowing temperature. These features make it undesirable as a circuit breaking device.

If a circuit breaker is to serve as a heat protector, it ought to operate on the principle of an "inverse time element." An automatic device should act quickly on a large overload and very slowly on a small overload, defining "overload" as the excess of current above the value at which the device would not operate during any length of time. From the standpoint of the definitions of "time element," "inverse time element," and "overload," a few of the most popular breakers will be examined.

The mounting of a copper or aluminium disc on a horizontal axis in a rotating field has been resorted to frequently for an inverse time feature. A weight is supported by a fine cord on the pivoted horizontal axis. The driving torque of the rotating field just balances the weight under normal conditions. In the case of an overload, the weight is raised by the driving torque and in its motion engages two contact points in the tripping circuit. The length of the cord finishes an adjustment for the time element, while the resultant driving torque gives the inverse time element. The magnitude of the weight lends the adjustment for the overload.

This method—the winding of a cord on a spindle, where the weight is the resisting force—has been used in a variety of ways.

The "clock type" of relay consists of a clock mechanism which is released by an armature suspended above the poles of a magnet. The magnet is energized by the time current.

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* Thesis presented to the Faculty of the Graduate School of the University of Pennsylvania in partial fulfilment of the requirements for the degree of Ph.D.

The circuit of the tripping element is completed when the armature is held down by the magnet and then only after the clock has unwound a predetermined amount. This contact, in the tripping circuit, effected by the unwinding of the clock, is made in many different forms. The magnet may be made to operate for any definite current depending on the distance between the poles and the armature. The time between the release of the clock mechanism and the making of contact in the tripping circuit is not determined or affected by any particular armature setting, but rather by the amount of unwinding. Here, then, we have no inverse time element.

The amount of unwinding for any particular release may be varied and easily adjusted for any specified time to trip. If the relay is set to release the clock mechanism at 200 amperes and the unwinding adjusted to make contact in 2 seconds after the release, the circuit will open in 2 seconds provided the line current remains at 200 or more for 2 seconds.

If, however, the line current falls below 200 before the 2 seconds are up, the armature goes back and hence no contact can be made to open the circuit. This is not a desirable relay. While it has the important feature of operating on both D. C. and A. C., it has no resetting element. After each time the contact is made, the clock must be wound. It gives little assurance of reliability in the clock mechanism stopping to unwind, if, during the predetermined time for tripping, the line current falls below the value necessary to effect a release.

Perhaps the most popular relay with an adjustable inverse time element is the bellows type. Here the actuating mechanism consists of an iron core in a solenoid compressing a bellows in its upward movement. The bellows is attached to the upper end of the iron core. There is an adjustable needle valve in the bellows for controlling the escape of air. A retarding force is furnished by the air pressure in the bellows. The inverse time element is controlled by the adjustable valve. The tripping circuit is completed by a ring on the iron core engaging two contact pieces in its upward motion. The time element adjustment is furnished by the distance between the engaging ring on the iron core and the contact pieces. For overload adjustments suitable weights are placed on the engaging ring. This is both a D. C. and A. C. relay. A variation from this particular form is the substitution of a dashpot for the air bellows. This shows that the ordinary plunger circuit breaker may be modified by attaching to the iron core a bellows or dashpot, thereby getting an inverse time element attachment. The tripping circuit is generally separated and energized by a storage battery. In this investigation, the aim was not only to study the time functions in circuit breakers now in use, but also to devise additional protective methods.

In the three devices described above the operating principle is that of magnetism.

With the exception of one or two devices where the expansion of metallic rods is used for completing a tripping circuit, no work, having heat for its operating principle, seems to be recorded. Attacking the problem from this point of view, the principle of the Nernst lamp was first used. The amount of current in the glower is some function of its temperature. If then the line current through the heater heats the glower, and at a certain temperature the glower allows enough current to pass through its shunt from the line to energize a tripping magnet, the system furnishes a good inverse time element. For the higher the current in the heater, the shorter will be the time necessary to heat the glower to the required temperature.

An old style of Nernst heater was obtained and the glower placed on the inside. Even with the glower in this position it took from 1½ to 2 minutes for ½ of an ampere to heat the glower to the temperature required for operating the tripping magnet. The glower and the magnet in series were placed in shunt with the heater. The time for heating the glower to the operating point was too long, and the current used too high, to give satisfaction.

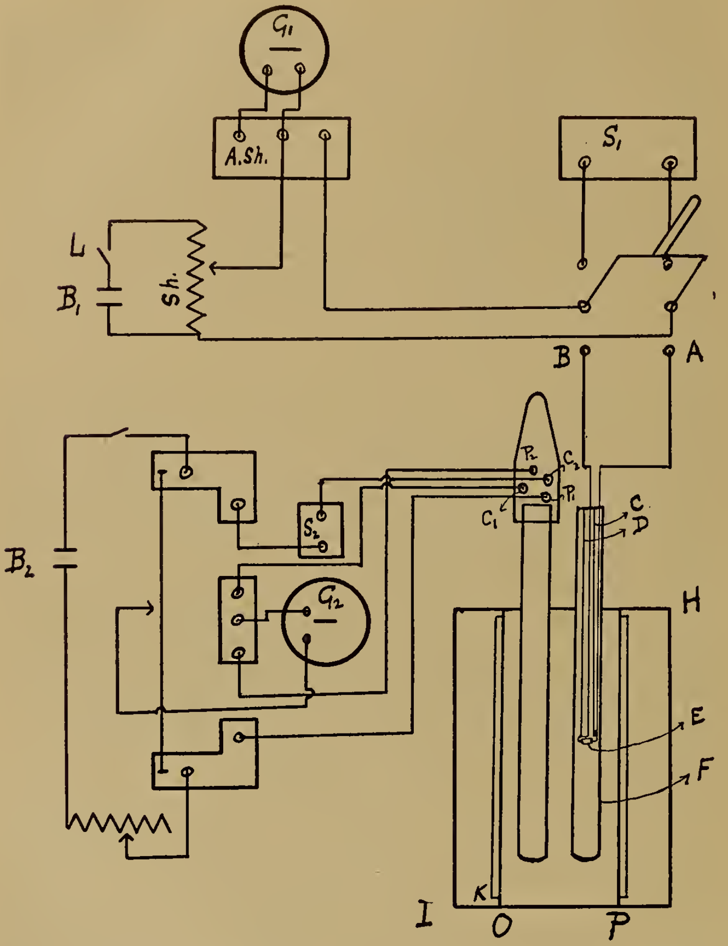
After an extensive search it was found that fused lead chromate has properties similar to those of the Nernst glower. In the same position as the glower, it took less time and current to operate the tripping magnet. The behavior of the chromate seemed very promising and hence it was thought profitable to plot a curve connecting its resistance with temperature.

The accompanying diagram (fig. 1) shows the connections of the apparatus used for obtaining the data.

HI is the electric furnace in which the chromate was heated. The temperature was determined by a compensating lead type of platinum thermometer. The thermometer was connected to the ordinary form of a slide wire resistance bridge as shown in the diagram. G_2 is a Leeds and Northrup testing galvanometer; S_2 is a variable standard resistance chosen very nearly equal to the platinum, so that the balance was obtained near the center of the bridge. P_1 P_2 C_1 C_2 are the terminals of the thermometer. The leads from these terminals to the bridge were specially constructed for this purpose, with the aim of making the bridge very symmetrical and more accurate.

The platinum of the thermometer was incased in a porcelain tube, and to have as nearly as possible a correct temperature of the chromate, this was mounted in a similar way. A porcelain tube F of about the same size as that of the thermometer was used. Into this tube a pipe-stem CD was projected to the distance shown in the diagram.

Fig. 1.



Two platinum wires were fused into a small cylindrical piece of well-fused lead chromate E. The piece was 0·5^{cm} long and 0·15^{cm} in diameter. This was suspended from the end of the pipe-stem with one wire coming through the stem to B and fastened with furnace cement to the lower end of the stem. The other wire was conducted out between the stem and the tube to A. The latter wire was fastened to the outside of the lower end of the stem with cement. This gave a firm suspension and prevented short-circuiting. The top of the tube was closed with cement, care being taken not to make it air-tight. The platinum wires were soldered to heavy brass bars just outside the tube.

A furnace was built especially for the purpose of heating the chromate. The construction is very similar to that described in the Bulletin of the Bureau of Standards (vol. vi, No. 2, p. 160, 1909). In building the furnace "Nichrome" ribbon was used instead of platinum. The method of measuring the resistance of the chromate was that of comparison.'

In the figure, G_1 is a Leeds & Northrup type K galvanometer which was used with a telescope and scale at a meter's distance. The sensibility of this instrument is 446 megohms with a resistance of 120 ohms. An Ayrton shunt was used in connection with it, as seen in the figure. S_1 is the variable standard with which the resistance of the chromate was compared.

The constants of the thermometer were determined and are recorded with Table I. The ordinary formula for calculating the temperature from the change of resistance and temperature coefficient was used.

It was noted that when the chromate was heated to a high temperature, it had a higher resistance after cooling than it had before heating it. On a second heating to a temperature considerably lower than the first, it showed little or no variation after cooling. At room temperature it was very stable.

The curve given in fig. 2 was obtained from a piece that had been heated twice for several hours with the range of temperature used for the curve. Through this range the chromate has a very large negative temperature coefficient. The points on the curve are somewhat irregular. It was impossible to determine the causes of all the variations which were observed for the whole range of temperature.

When the switch was on A and B with L open and the chromate at a temperature of about 350° centigrade, the galvanometer mirror swung to the extreme right of its zero position ; at about 400° to the extreme left ; at 475° to the extreme right again, and so on until at 800° there had taken place six distinct reversals. Some of these movements, especially at high temperatures, were quite violent and off the scale. On cooling, the reversals were repeated in reverse order at about the same temperatures.

The curve given in figure 2 was obtained by impressing an extra E.M.F. on the shunt marked *sh* in figure I. With this E.M.F. balanced with the unknown E.M.F. in the circuit, a zero position of the galvanometer was obtained. L was now closed and a reading taken.

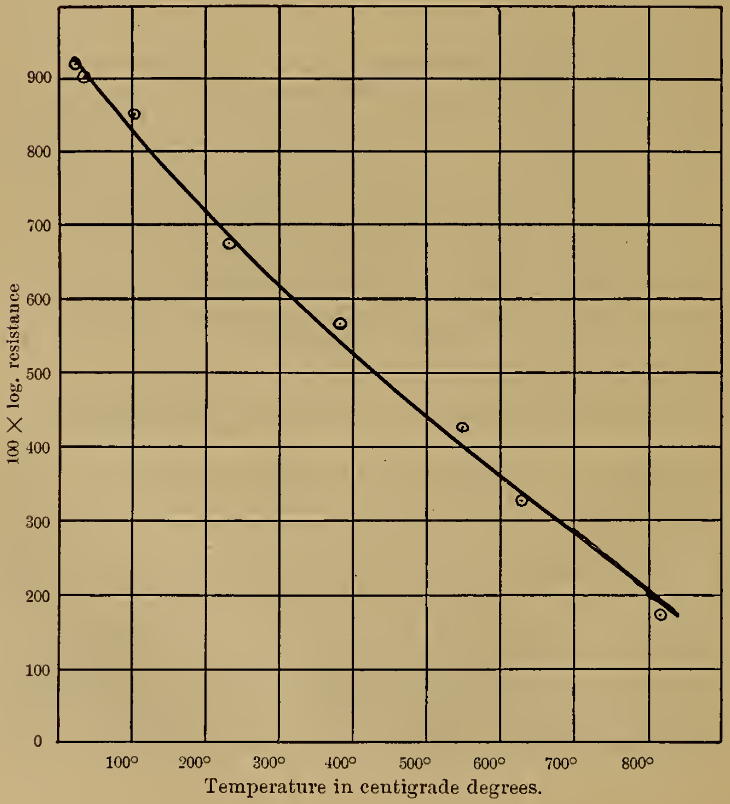
TABLE I (FOR FIG. 2).

Readings	Av. defl. in cm. for the chromate	Av. defl. in cm. for S_1	S_1	Calculated resistance of the chromate	Average reading on the bridge	S_2	Cal. resistance of ther.	Cal. temperature
1	0·23	81·0	$4{\cdot}917(10)^{6}$	$1{\cdot}7\bar{3}\ (10)^{9}$	48·99	3	$2{\cdot}88\bar{0}$	22·69
2	0·33	80·95	$4{\cdot}917(10)^{6}$	$1{\cdot}20\bar{6}(10)^{9}$	$50{\cdot}06\bar{5}$	3	$3{\cdot}00\bar{7}$	34·80
3	1·07	80·4	$4{\cdot}917(10)^{6}$	$3{\cdot}69\bar{4}(10)^{8}$	48·34	4	$3{\cdot}74\bar{6}$	105·4
4	6·69	8·08	$4{\cdot}917(10)^{6}$	$5{\cdot}93\bar{0}(10)^{6}$	50·46	5	$5{\cdot}09\bar{2}$	233·6
5	8·73	10·91	$3{\cdot}99\ (10)^{5}$	$4{\cdot}98\bar{6}(10)^{5}$	47·64	7	$6{\cdot}36\bar{9}$	355·3
6	12·43	$11{\cdot}71\bar{5}$	$2(10)^{4}$	$1{\cdot}88\bar{4}(10)^{4}$	51·22	8	$8{\cdot}40\bar{9}$	550·3
7	1·25	2·37	10^{3}	$1{\cdot}90\bar{0}(10)^{3}$	50·67	9	$9{\cdot}24\bar{4}$	629·4
8	12·57	6·785	10^{2}	$5{\cdot}39\bar{7}(10)$	50·525	11	$11{\cdot}2\bar{3}$	819·0

Constants of the Platinum Thermometer.

$R_0 = 2{\cdot}64\bar{2}$	Temperature of steam was 100·32°
$R_s = 3{\cdot}692$	Average barometer was 30·37 inches
$R_{100} = 3{\cdot}688$	Fundamental interval = $1{\cdot}04\bar{6}$
	Temperature coefficient = ·00397

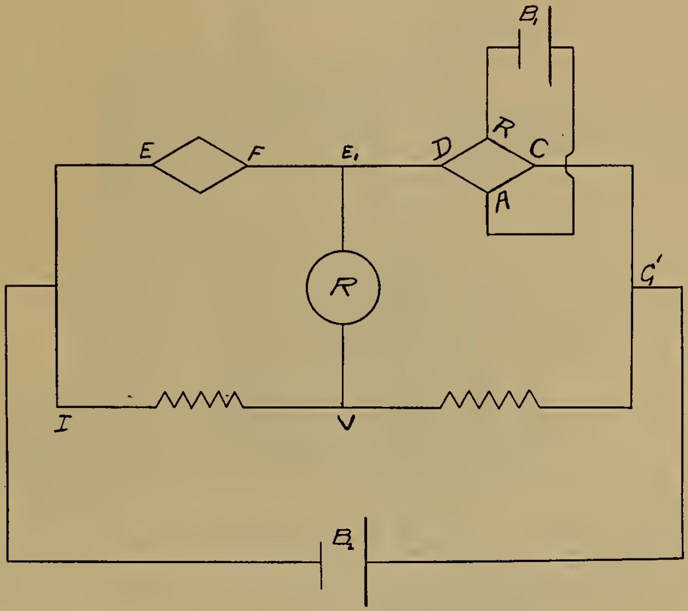
FIG. 2.



A piece of chromate similar to the one under test was prepared, and a current with considerable density was passed through it for about 18 hours. No trace of transformation or decomposition could be found. Time did not permit any further investigation of the causes for the unstable condition of the chromate at these temperatures, and since this behavior did not warrant its use for a protective device, the principle of the Nernst lamp was abandoned for the time being. The chromate will be examined again in the near future with the hope of obtaining more definite data.

The original problem was now attacked on the principle of the bolometer. Figure 3 shows the general plan of the apparatus. B_2 is the battery furnishing the bridge current. IV and VG′ are two resistances of about 10 ohms each adjusted very nearly equal. The eight arms in the bridges EF and DC were adjusted electrically equal as nearly as possible. Each arm consisted of about 10 ohms resistance. The bridge, then, as a whole, balanced for a wide range of current, and remained so for any variation of room temperature. B_1 is the source used to heat the small bridge DC, thereby unbalancing the large bridge, and consequently having a current through R. R is a relay which contains in its circuit a tripping magnet. If then the source B_1 were shunted off the line, and the line

Fig. 3.



connected with the tripping magnet, we would have a device for breaking a circuit for an overload in a time which was some inverse function of the current in the line.

On account of its high temperature coefficient, iron wire was chosen for EF and DC. The wire used was $0{\cdot}01^{cm}$ in diameter. "Advance" wire was chosen for IV and VG′ on account of its practically zero temperature coefficient. EF and DC were

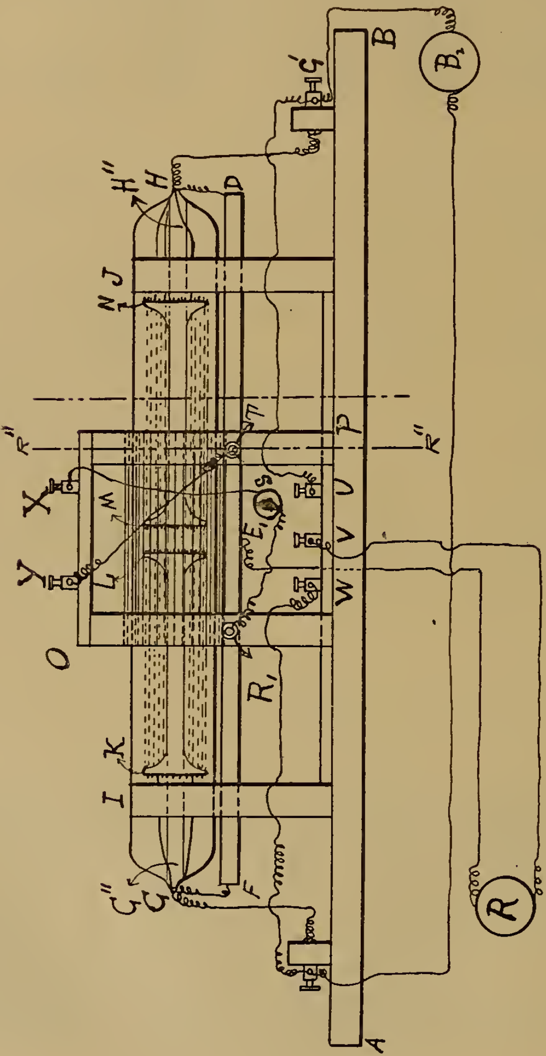
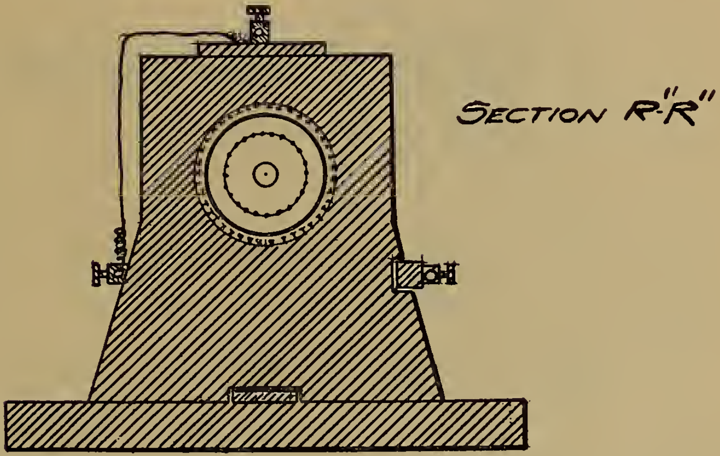


Fig. 4.

mounted as shown in figure 4. See also fig. 6 for an end view. Corresponding letters are used in figures 3, 4, and 6. K, L, M, and N, fig. 4, are 4 glass discs blown on the small tube G"H" which is contained in the larger exhausted tube GH. The discs are 3·8$^{\text{cms}}$ in diameter. The distance from K to L is 17·8$^{\text{cms}}$; from L to M 1·27$^{\text{cms}}$; and from M to N 17·8$^{\text{cms}}$. The whole length of the tube is 50·8$^{\text{cms}}$. The four arms in DC, figure 3, are strung on the discs M and N, figure 4, as shown by the dotted lines. Each arm taking up six lengths, has its terminals at N. An end view of the disc with the binding posts for these terminals is shown in figure 6. The brass binding posts E, R, etc. are fastened to a plate of mica which is cemented to the disc.

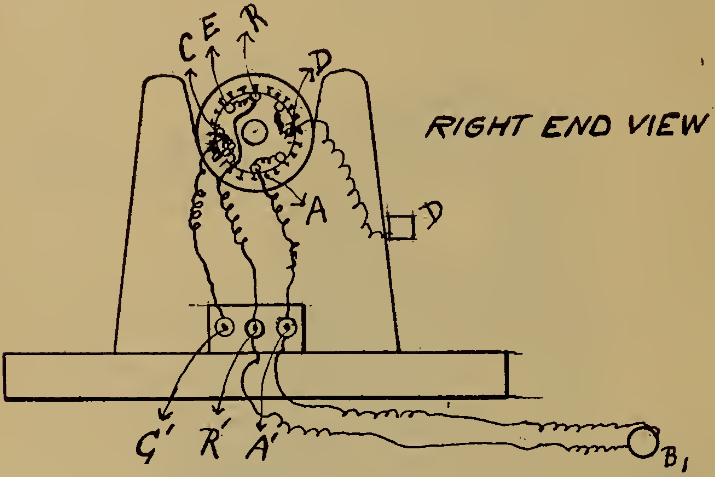
FIG. 5.



Small glass hooks fused to the edge of the disc support the wires. In fig. 6 it may be seen how one wire or arm is mounted. One end is permanently fastened to C and the wire stretched for six lengths from disc to disc and also permanently fastened to E. The loop between E and R is a continuation of the wire and is used for adjusting it equal to the one next to it. One arm, then, is included between C and R; another one between R and D, and so on. The other end of the tube is similar to this, with the exception of not having any leads, such as AA′, fig. 6, fused into the glass for heating the bridge EF. With the bridges EF and DC, fig. 3, mounted as shown in fig. 4, and the tube GH exhausted very nearly to a Crookes vacuum, radiation was the only controlling factor for the heat in EF and DC. A storage cell with a resistance in series was used to furnish the bridge current.

There was no relay at hand sensitive enough to put this apparatus into practical effect, and since a working theory was the main point aimed at, a galvanometer, as a detector, was considered sufficient. A curve, showing the relation between the current from B_1 and the time it took to move the galvanometer needle 7 divisions, was plotted. See fig. 7 for this curve, and Table II for the data. This shows a good inverse time element. With B_1 shunted off the line and a relay in the place of the galvanometer, we would have a working scheme. It was predicted that the time required to effect a certain throw in the galvanometer could be shortened by placing a reflector over the tube GH. For this purpose the tube was exhausted so as to get rid of convection currents. A nickel-plated sheet of copper in cylindrical form was used as a reflector. The reflector was mounted on a sliding frame OP, fig. 4. For an end view see fig. 5. With the same currents from B_1 and B_2 as were used for obtaining the curve, no difference in time required to effect a certain throw could be detected as the reflector was moved along the tube. This arrangement gave no "time element" adjustment and hence the reflector was abandoned.

Fig. 6.



The bridge current used was 0·065 amperes and the heating current ranged from this to about twice the amount. The heating current was furnished by a storage battery with a variable resistance in series.

In the frame OP, figure 4, in the place of the reflector there was placed a wire heater of cylindrical form. See figure 5 for an end view. The dots on the inner circumference represent

TABLE II (FOR FIG. 7).

Readings	Heating current in one arm in milliamperes	Time in sec. for 7 div. deflection
1	62·0	13·4
2	68·0	8·6
3	70·7	8·2
4	77·0	6·1
5	86·1	4·6
6	92·4	4·0
7	100·0	3·3
8	110·0	3·0
9	121·2	2·4
10	130·0	2·1
11	145·0	1·8

FIG. 7.

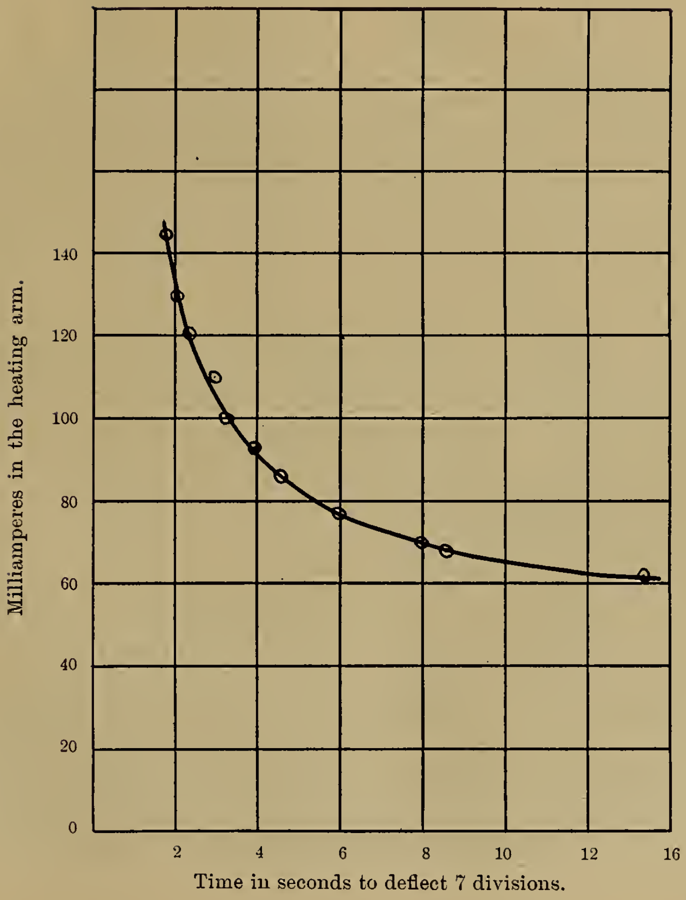


TABLE III (FOR CURVE IV, FIG. 8).

Readings	Heater setting in cm.	Time in sec. for 2 cm. defl.	Current in the heater in milliamperes
1	27·55	....	118·5
2	28·00	154·4	118·2
3	28·10	102·0	119·5
4	28·30	62·8	119·4
5	28·50	45·0	119·2
6	29·00	30·3	119·1
7	29·50	25·5	119·3
8	30·00	21·4	119·6
9	30·50	18·8	120·2
10	31·00	16·5	120·0
11	31·50	16·0	119·3
12	32·00	15·0	119·5
13	32·50	14·0	119·5
14	33·00	14·0	119·2
15	33·50	13·9	119·8

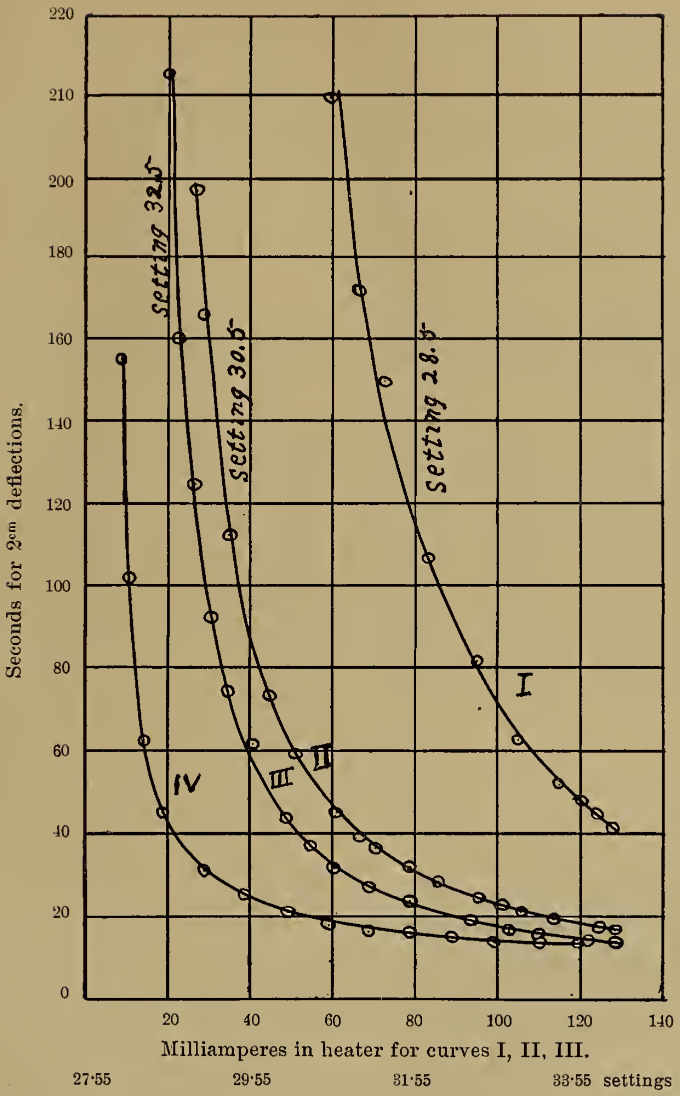
the wires, which are also shown by the full lines in figure 4. The battery B was now abandoned and the heater, joined in series with a variable resistance, connected across a 110-volt circuit. For different settings or positions of the heater over one arm of the bridge, curves were plotted connecting the current in the heater with the time for deflecting the galvanometer coil a certain number of divisions. See figure 8 for these curves and Tables III and IV for the data. For all these curves, the bridge current was very constant at 0·1 ampere. Curve IV connects the time with different settings of the heater along one arm of the bridge. The curve is parallel to the X-axis for the last three points or settings. These were positions when the heater was off one arm and only moving over the other. As seen in Table III, the heating current for this curve was nearly constant.

It was interesting to note that the electrical center for the heater, i. e., the position of symmetry, was only three millimeters away from the measured center.

It was noticed that there was a considerable time lag in the starting of the galvanometer coil after the heater switch was closed. In Table IV, for curve III, this lag is recorded.

This lag seems to indicate that the glass tube absorbed the radiation from the heater, thereby raising its temperature. This would lessen the radiation from the arm in the tube and hence raise its temperature. The change of resistance in the arm effected in this way gave rise to current in the galvanometer. This means that the current in the galvanometer is a function of the difference of temperature

FIG. 8.



between the arm and the tube. This also explains why the reflector showed no effect in time for small deflections as it was moved over the arm. The glass absorbed most of the radiation from the arm and hence the reflector had no appreciable function to perform. The apparatus was very sensitive and yet differential. Touching the tube with the hand was sufficient to unbalance the bridge to the extent of deflecting the galvanometer as high as 20^{cms}. It was also very reliable, for it was possible to reproduce any points on the curves at any time. If the plan of having the heater on the outside of the tube is pursued, the construction is very much simplified. The space inside the tube may be made much smaller. All that is needed in the resistance is that EF and DC as a whole shall be equal.

TABLE IV.

	For Curve I		For Curve II		For Curve III		
	Heater current in milli-amperes	Time in sec. for 2^{cm} defl.	Heater current in milli-amperes	Time in sec. for 2^{cm} defl.	Heater current in milli-amperes	Time in secs. for 2^{cm} defl.	Time lag.
1	60·0	220·0	27·0	196·6	20·0	226·7	6·0
2	66·9	172·4	29·1	166·6	23·0	160·5	?
3	73·1	150·0	35·8	112·4	26·5	124·8	5·8
4	83·4	107·0	45·0	73·7	31·0	92·7	5·6
5	95·4	82·0	51·0	59·5	35·0	74·8	5·0
6	105·1	63·0	61·0	45·0	41·0	61·8	5·5
7	114·8	52·4	67·0	39·2	49·2	44·1	3·9
8	120·5	48·5	70·5	36·6	55·0	37·0	3·8
9	124·5	45·0	79·0	32·0	60·5	31·6	4·0
10	127·9	41·5	85·5	28·2	69·8	27·0	3·6
11			95·3	24·8	79·0	23·5	3·2
12			101·4	23·0	94·0	19·1	3·2
13			106·0	21·3	102.6	16·8	3·4
14			113·6	19·7	110·0	15·7	3·0
15			124·5	17·8	122·0	14·4	3·2
16			128·5	17·0	128·5	13·8	3·0

Since the object of this paper was to study the time interval only from the experimental standpoint, there are no quantitative results given, which would be necessary for the construction of a practical relay.

I wish to thank Professor A. W. Goodspeed for the liberal allowances he made me in building the special apparatus required, and permitting me to draw freely from the resources of the laboratory.

I also acknowledge my indebtedness to Dr. R. H. Hough, who gave me many valuable suggestions, and was always ready for consultation even to the point of investigation.

Randal Morgan Laboratory of Physics,
University of Pennsylvania, May 2, 1910.

Art. XXXIII.—*On Some Herderite Crystals from Auburn, Maine*; by W. E. Ford.

Herderite is a rare fluo-phosphate of beryllium and calcium, $Ca[Be(F,OH)]PO_4$, in which the fluorine is replaced in varying amounts by the hydroxyl group. A variety, in which there was only a very little or no fluorine present, was described by Penfield, who suggested the name hydro-herderite for this type and the name hydro-fluor-herderite for the more usual occurrence in which both hydroxyl and fluorine occur.* The mineral was first described from the tin mines of Ehrenfriedersdorf, Saxony, on specimens that were obtained prior to 1825. It was later discovered at Stoneham, Maine, and has since been found at the neighboring localities of Auburn, Hebron, Paris and Greenwood. It has also recently been noted on specimens from Epprechtstein, Fichtelgebirge, Bavaria.†

The crystals from the original American locality, Stoneham, were described by E. S. Dana as belonging to the orthorhombic system.‡ Later Penfield found, on studying crystals from Paris, Maine, that they showed the symmetry of the monoclinic system with an axial inclination, however, of sensibly 90°.§ He proved that the Stoneham crystals were in reality penetration twins with the base, *c* (001), as twinning plane yielding pseudo-orthorhombic individuals. He further showed that the crystals from Paris, Maine, belonged to the hydro-herderite variety and gave slightly different crystal constants than the hydro-fluor-herderite from Stoneham.

The twin crystals so far observed, with only a few exceptions, have shown no external evidences of twinning, being in appearance strictly orthorhombic. Recently, however, the Brush Mineral Collection acquired from Mr. Lazard Cahn a suite of specimens from Mt. Apatite, Auburn, Maine, that included not only simple crystals of unmistakably monoclinic symmetry, but also twin crystals, which through prominent reëntrant angles and by unequal development of the two individuals showed clearly their twinned character.

These crystals varied somewhat in size but most of them averaged about one-half inch in their thickest part. They were colorless or white and were in part clear and transparent, and in part cloudy and translucent. The following forms were on them: *b* (010), *c* (001), *m* (110), *e* (302), *t* (032), *v* (031), *q* (332), *n* (331), n ($\bar{3}$31), r ($\bar{1}$21), *g* ($\bar{3}$43), *h* ($\bar{6}$34). These forms have all been observed before with the exceptions of *y* ($\bar{3}$43) and *h* ($\bar{6}$34). The form r ($\bar{1}$21) had only been described on crystals

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* This Journal, xlvii, 329, 1894.

† Centralbl. Min., 294, 1908.

‡ This Journal, xxvii, 229, 1884.

§ Loc. cit.

from Greenwood. Figure 1 is an idealized representation of the forms on a simple crystal, but shows them as nearly as possible in their characteristic development. The crystals were all elongated parallel to the clino-axis and, with one exception, showed only the faces at one end of this axis. The crystals were frequently broken and distorted in their development, as is shown by figures 2 and 3. Figure 3 is of a very small crystal, but one which was better adapted for measurement than the larger individuals and which was also unique in that it showed portions of the negative pyramid r $(\bar{1}21)$ at the negative end of the clino-axis.

FIG. 1.

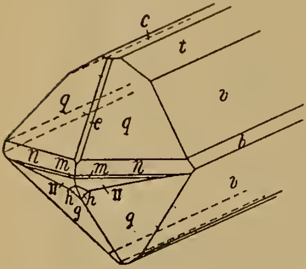


FIG. 2.

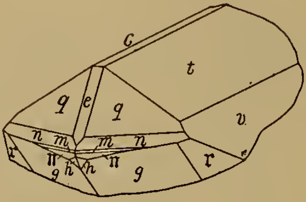
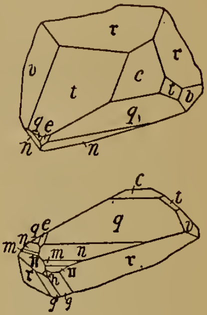


FIG. 3.



The most prominent faces on the crystals were the clino-

FIG. 4.

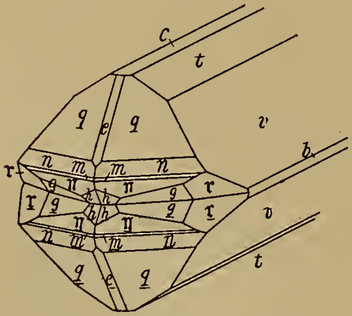
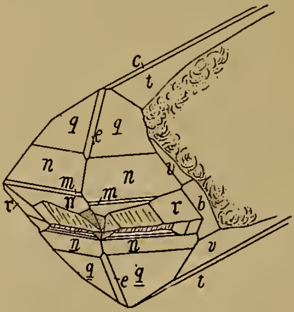


FIG. 5.



domes *t* (032) and *v* (031), the pyramids *q* (332) and *n* (331), and the negative pyramids *g* $(\bar{3}43)$ and r $(\bar{1}21)$. The base *c* (001) and the ortho-dome *e* (302) were always present, but only as small and narrow truncations. The prism *m* (110) was usually seen as an extremely narrow face. The pinacoid *b* (010) was observed on only one or two crystals. The negative pyramid n $(\bar{3}31)$ was commonly small but of good quality. The new negative pyramid *h* $(\bar{6}34)$ was ordinarily much etched and curved and in most cases quite minute in size. The other negative pyramids, *g* $(\bar{3}43)$ and r $(\bar{1}21)$, were of good size, but characteristically striated and curved.

Figures 4 and 5 show the twin crystals. Figure 4 shows the various forms in characteristic development, but it has been drawn with ideal symmetry. Figure 5 attempts to show one of the twin crystals according to its actual development. Most frequently, as is shown in figure 5, one of the twin individuals is larger and better developed than the other. The faces in the reëntrant angle are commonly etched and more or less curved. Oscillation from one pyramid to another is common.

The new forms were determined by a comparison of the following calculated and measured angles, the theoretical values having been derived from the constants given by Penfield. The measured angles given were derived from the measurement of the best crystal.

	Calculated.	Measured.
c (001) : *h* $(\bar{6}34)$ =	46° 58′	46° 38′
n $(\bar{3}31)$: *h* $(\bar{6}34)$ =	23° 44′	23° 51′
h $(\bar{6}34)$: *h′* $(\bar{6}\bar{3}4)$ =	25° 1′	24° 48′
g $(\bar{3}43)$: *g′* $(\bar{3}\bar{4}3)$ =	50° 0′	50° 29′

The agreement between calculated and measured angles is not as complete as could be desired, but considering the poor quality of the faces is reasonably close. In the case of *h* $(\bar{6}34)$ the evidence of the three different angles given leaves no doubt but that the correct symbol has been assigned to the form. In the case of *g* $(\bar{3}43)$ the one angle taken together with the fact that it clearly lies in the zone with *b* (010) and r $(\bar{1}21)$, was thought to establish its identity. The rare form, r $(\bar{1}21)$, was established by the following measurement:

	Calculated.	Measured.
r $(\bar{1}21)$: r′ $(\bar{1}\bar{2}1)$ =	69° 56′	69° 56′

The quality of the crystal faces was variable. In the case of certain forms and on particular crystals the character of the signals obtained on the reflection goniometer was excellent. With other forms, however, on account of their vicinal development and the striations upon them, the measured angles could only be considered approximate. When the more reliable angles were studied, however, it was found that in general they were intermediate between the theoretical values derived in one case from the crystal constants given by Dana and in the other from those given by Penfield. The variation between the measured and calculated angles was, however, commonly less when the Penfield angles were used. The following table giving the measured and calculated values of the more trustworthy angles will illustrate these points.

	Theory–Dana.	Measured.	Theory–Penfield.
c : *e*	45° 40′	45° 30′	45° 25′
b : *m*	58° 12′	57° 50′	57° 45½′
q : *q*	47° 52′	48° 13′	48° 22′
c : *n*	67° 27′	67° 18′	67° 20′
c : *t*	32° 25′	32° 38′	32° 40′

Penfield has suggested that the variation observed in the measured angles was due to the difference in composition, the crystals measured by Dana being hydro-fluor-herderites and containing several per cent of fluorine, while those measured by Penfield were hydro-herderites and contained no fluorine. If this idea is correct the present crystals, arguing from the close relationship of their angles to the hydro-herderite of Penfield, should be near at least the hydro-herderite in composition and contain only a small per cent of fluorine. This was an interesting point, and in order to determine it enough of one specimen was sacrificed to permit the making of an estimation of the percentages of fluorine and water present. The results gave, $F = 6{\cdot}04$, $H_2O = 3{\cdot}62$. These percentages did not agree with what had been expected. They showed that the present crystals were hydro-fluor-herderites and, as far as these two determinations can show, that they are closely related to the Stoneham material from which Dana derived his constants. These results would show that if the crystal angles vary at all with the variation in the percentages of the fluorine and hydroxyl, the change is much less than Penfield thought probable. It is likely that the angles obtained by him from the hydro-herderite of Paris, Maine, are very closely correct for all varieties of the mineral. The angles derived by Dana from measurement of the Stoneham crystals were not wholly to be relied upon, as he says in his original description:* "Considerable difficulty was found in obtaining satisfactory fundamental angles . . . . . because the planes seldom afforded sharp, well-defined reflections."

Mineralogical Laboratory of the Sheffield Scientific School
of Yale University,
New Haven, Conn., June, 1911.

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* Loc. cit.

Art. XXXIV.—*Mineral Notes from the Mineralogical Laboratory of the Sheffield Scientific School.*

I. Note on some Analyses of Stibiotantalite; by W. E. Ford.

In 1906 the late Prof. S. L. Penfield published with the present writer an article on stibiotantalite.* It was concerned chiefly with the description of crystals from Mesa Grande, San Diego County, California. In it, however, were included two analyses of the mineral. The two samples analyzed were distinguished from each other by marked differences in specific gravity. This variation in the specific gravity made it of interest to determine the relative amounts of the tantalum and niobium oxides in each sample. An attempt was therefore made to estimate the proper proportions of each oxide present. As no very satisfactory method had ever been devised for making a quantitative separation of these oxides, a new method was proposed and used in making the determinations. Briefly this method consisted in taking the specific gravity of the mixed oxides obtained in the analysis of the mineral and comparing this value with the specific gravities of the pure tantalic and niobic oxides. Time and material failed, however, to enable the proper systematic study of the method to be made. Sufficient work was done, however, to prove that the relationship existing between the specific gravities of the pure oxides and any given mixture could be at least approximately expressed diagrammatically as a straight line with the specific gravities of the pure oxides as its terminal points. It was on this assumption that the percentages of the two oxides were determined in the analyses given in the article referred to above. The statement was made, however, that as the method had not been thoroughly proven, the results could only be accepted as approximately correct.

Recently Foote and Langley have made a detailed study of this method.† They found that the relationship between the specific gravities of the pure oxides and that of the various mixtures of the two could not be represented by a straight line but rather by a somewhat irregular curve which, however, does not depart anywhere very far from the path of the straight line. The oxides apparently form a solid solution with each other and do not exist together simply as a mechanical mixture. The authors give, however, a table of the specific gravities for various mixtures, and from it, by proper interpolation, the relative proportions of the two oxides in any mixture can be very closely estimated.

In view of this recent work it seemed of interest to review and correct the analysis made by the writer, and also to add for

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* This Journal, xxii, 61, 1906.

† This Journal, xxx, 393, 1910.

comparison a new analysis given by Foote and Langley. The different analyses follow, the values in brackets being the original values given by Penfield and the writer. It will be noted that the correction has involved a change of about two per cent in each case. The ratios given are derived from the corrected values.

	I. (Penfield and Ford)		Ratios		II. (Penfield and Ford)		Ratios		(III. Foote and Langley)	Ratios	
Specific Gravity	5·98				6·72				6·80		
Ta_2O_5	13·00	(11·16)	·0291	·1682	33·86	(36·35)	·0759	·0759	41·92	·0939	·1543
				or				or			or
Nb_2O_5	37·30	(39·14)	·1391	1·00	21·47	(18·98)	·0801	1·00	16·19	·0604	1·00
Sb_2O_3	49·28		·1711	·1722	44·26		·1536	·1543	40·95	·1421	·1434
				or				or			or
Bi_2O_3	0·53		·0011	1·02	0·33		·0007	·989	0·60	·0013	0·92
	100·11				99·92				99·66		

II. On a Rhodonite (Fowlerite) Crystal from Franklin, N. J.; by W. E. Ford and R. D. Crawford.

The Brush Mineral Collection recently acquired through Mr. Lazard Cahn two specimens of crystallized rhodonite from Franklin, N. J. The crystals, while showing in general the characteristic habit of rhodonite from this locality, were uncommonly rich in planes and were of sufficiently good quality to admit of measurement on the reflection goniometer. One of the specimens, which was a detached crystal, was studied in detail. Since the results showed the presence of one new face and of another that has been listed as a doubtful form, it seemed worth while to publish a figure with a brief description of the crystal.

The crystal, represented as nearly as possible in its true proportions and development in fig. 1, measures about 2^{cm} in its greatest dimension parallel to the *b* crystal axis and about $1{\cdot}5^{cm}$ parallel to the *c* axis. The forms present are as follows: $a(100)$, $b(010)$, $c(001)$, $m(110)$, $M(1\bar{1}0)$, $\mu(401)$, $\rho(\bar{2}01)$, $q(221)$, m $(\bar{1}11)$, $k(\bar{2}21)$, $i(\bar{4}41)$, $r(\bar{1}\bar{1}1)$, $l(\bar{4}\bar{4}3)$, $n(\bar{2}\bar{2}1)$, and also $\kappa(2\bar{2}1)$ and $v(0\bar{4}1)$. The last form $v(0\bar{4}1)$ has never, so far as has been discovered, been previously recorded on rhodonite. It occurred as a small face, and because of its poor quality did not give a very sharp signal when measured on the goniometer. Its identity was however established by the fact that it lay clearly at the intersection of two well-defined zones on the crystal, namely, $b(0\bar{1}0)-c(001)-b(010)$, and $M(1\bar{1}0)-n((\bar{2}\bar{2}1)-M(\bar{1}10)$. The angle $c(001):v(0\bar{4}1)$ was measured as accurately as possible, giving 77° 35′; calculated, 77° 5½′.

Fig. 1.

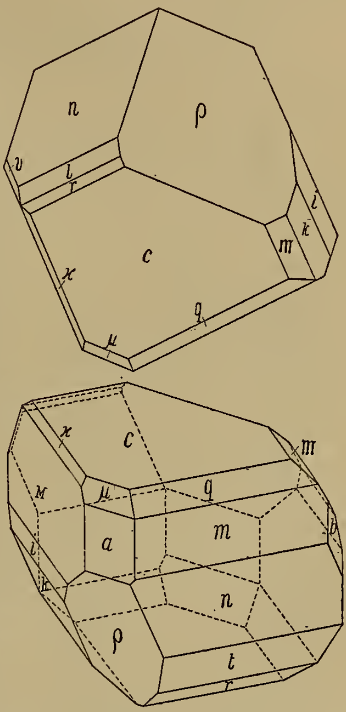

Fig. 1. Rhodonite, Franklin, N. J.

The pyramid κ $(2\bar{2}1)$ has been described by Hamberg as occurring on rhodonite from the Harstigen mine near Pajsberg, Sweden.* As, however, the measured angle of $c(001)$:

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* Geol. För. Förh., xiii, 565, 1891.

$\kappa(2\bar{2}1)$ varied by 1¾° from the calculated angle, the form has been listed as doubtful by Hintze.* The same form, however, undoubtedly occurs on this crystal from Franklin and should therefore be considered as definitely established. Its identification rests mainly on the fact that it was proven to lie at the intersection of the two zones: $a(100)-n(\bar{2}\bar{2}1)-a(\bar{1}00)$, and $M(1\bar{1}0)-c(001)-M(\bar{1}10)$. The following measurements, although not showing as close an agreement with the calculated values as could be desired, nevertheless serve to confirm the identity of the form.

$c\ (001) : \kappa\ (2\bar{2}1) = 57° 50'$ measured; $57° 0'$ calculated.
$a\ (100) : \kappa\ (2\bar{2}1) : 40° 50'$ measured; $41° 12'$ calculated.

III. On a Brookite Crystal from Companhia, Lençoes, Bahia, Brazil; by W. E. Ford and Freeman Ward.

A suite of brookite crystals from Companhia, Lençoes, Bahia, Brazil, was recently presented to the Brush Mineral Collection by Dr. H. S. Washington. One of the best developed of these crystals was studied, and as eleven different forms were identified upon it, it was thought, because of this complexity of development, to be worthy of a short note.

Fig. 2.

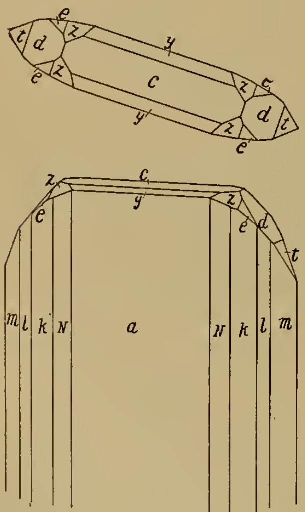

Fig. 2. Brookite, Brazil.

The crystal was thinly tabular parallel to the macropinacoid, measuring about 0·8^{cm} vertically and 0·5^{cm} in the horizontal direction. The macropinacoid faces were vertically striated, but the other faces in the prism zone and the faces of the terminal forms were sharply developed and possessed a brilliant luster. The following forms were identified: $a(100)$, $c(001)$, $N(710)$, $k(410)$, $l(210)$, $m(110)$, $y(104)$, $d(043)$, $t(021)$, $z(112)$, $e(122)$. Fig. 2 shows the crystal in ideal development but drawn so as to represent as nearly as possible the true proportions and relations of the different forms.

Mineralogical Laboratory of the Sheffield Scientific School
of Yale University, New Haven, Conn.,
June 1, 1911.

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* Handbuch der Mineralogie, ii, 1153.

ART. XXXV.—*The Twenty-Foot Terrace and Sea-Cliff of the Lower Saint Lawrence*;* by JAMES WALTER GOLDTHWAIT.

CONTENTS:

Introduction.

AMONG the raised beaches which border the Saint Lawrence estuary in southern Quebec, one is so conspicuous and so peculiar that it deserves especial attention. It is a strongly cut sea-cliff and terrace which stands hardly 20 feet above the present sea level. Although this is a much more maturely developed shoreline than the higher beaches which mark the work of the "Champlain" sea, on the one hand, or the faint beach which marks the modern high tide level, on the other, the twenty-foot terrace and cliff seem to have excited little interest. This is probably due in large measure to the fact that the few investigators of the Champlain deposits who have worked in this field have been so intent upon tracing the highest level of marine submergence that they have passed by the lower strand as a feature of comparatively little significance. The only recognition of the twenty-foot terrace which the present writer has found, in the literature on the surface geology of this region, appears in Sir William Logan's "Geology."† It is there stated, presumably on the authority of Sir William Dawson, who collaborated in the writing of the chapter on surface geology, that

> "At Rivière du Loup, the shells of *Mya* and *Tellina* are found imbedded in the sand and disintegrated shale of an ancient beach only a few feet above the present sea level. Similar beaches, which seldom attain more than fifteen feet above high-water mark,

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* Published by permission of the Director of the Geological Survey of Canada.

† Geology of Canada. Report of progress of the Geological Survey of Canada, from its commencement to 1863. Montreal, 1863, p. 921.

are met with in many localities along this southern shore, from Rivière du Loup to the Magdalen River. A low terrace, about five feet above the highest tides, and averaging about 100 yards in breadth, extends, with a few interruptions, from Rimouski to Whale Cape, a distance of seventy-five miles. It is composed of sand, gravel, and broken shells, and makes a good roadway, as well as a productive soil. The shells in this terrace are of the same species as now inhabit the adjacent waters. Besides these, bones of the whale and the morse have been found partially imbedded in this deposit, in several places between Bic and Matanne. At Ste. Anne des Monts, five or six terraces rise one above another to a height of about twenty-five feet above the sea. All of them abound in fragments of shells, belonging to the common littoral species."

This statement, half concealed by the detailed information on Champlain or "post-Tertiary" deposits, with which several pages are filled, escaped close attention from the present writer, when looking over the literature, before entering the field, in June, 1910. The more detailed reports of the late Dr. R. M. Chalmers,* although full of references to marine terraces at heights of from 200 to 800 feet, gave no hint of an important terrace at so low a level. The discovery of this conspicuous sea-cliff and bench, on the second day of field work, came therefore as a complete surprise.

The importance of the twenty-foot terrace rests mainly upon these facts: it is a mature shoreline, while the extinct shorelines above it and the modern one below it are comparatively infantile; it extends over a wide area, certainly more than 225 miles down the Saint Lawrence from Quebec, and presumably around a considerable part of the adjoining coast of the Gulf. The significance of the terrace, as will be shown in the following pages, consists in the possibility that it marks a long period of slow coastal subsidence, which followed the first great emergence from the Champlain sea, and which was itself followed

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*R. N. Chalmers: On the glaciation and Pleistocene subsidence of northern New Brunswick and southeastern Quebec. Transactions of the Royal Society of Canada, vol. iv, sec. iv, 1887, pp. 139–145.

Pleistocene marine shorelines on the south side of the Saint Lawrence Valley. This Journal (4), vol. 1, pp. 302–308, 1896.

Surface geology and auriferous deposits of southeastern Quebec. Geological Survey of Canada, Annual Report, vol. x, part J, No. 670, 1898.

Surface geology of the southern part of the province of Quebec. Geological Survey of Canada, Summary Report of the Director for 1903, pp. 140–143.

Surface geology of eastern Quebec. Ibid., Summary Report for 1904, pp. 250–263.

The geomorphic origin and development of the raised shorelines of the Saint Lawrence Valley and the Great Lakes. This Journal (4), vol. xviii, pp. 175–179, 1904.

Surface geology of the Saint Lawrence Valley. Geological Survey of Canada, Summary Report of the Director for 1907, pp. 69–71.

by a slow elevation of 20 feet. A brief description of the full series of Champlain beaches will first be given, in order to emphasize the unique character of the twenty-foot strand. Two working hypotheses to explain the peculiar strength of this terrace will then be presented; and a number of reasons will be given for the view that the post-glacial movements of the coast, in southern Quebec, have consisted in an uplift, a subsidence, and a second uplift.

THE RAISED BEACHES OF THE LOWER SAINT LAWRENCE.

The Higher Beaches.

The elevated shorelines along the south side of the Saint Lawrence, below the city of Quebec, are as a rule very weak in topographic expression. This weakness is especially noticeable near the upper limit of submergence. In most places the utmost care is required to select the critical horizontal line which marks the highest stand of the sea since the ice age. During the course of the field season of 1910, this upper limit of submergence was measured at fifteen localities on the south shore between Matane and Quebec. At many of these localities the highest beach is hardly more than an upper limit to stratified sands. Even where it possesses definite form, such as a low beach ridge or a hooked spit, this feature cannot be traced far before it disappears more or less completely against a hillside where the slope or the structure of the ground was originally unfavorable to the development of a distinct beach.

At not a single place, during the season of 1910, was the highest shoreline found to consist of a sea-cliff and wave-cut terrace. This was a source of surprise for two reasons: because of the long-standing use of the word "terrace" in the literature on the beaches of this region; and because there are strongly-cliffed shorelines around the borders of the extinct lakes Algonquin and Nipissing, where one might expect less vigorous wave action and less definite shore topography than along the borders of a great estuary like the Saint Lawrence.

The inference to be drawn from the weakness of the highest marine beach is either that the upwarping began almost immediately after the withdrawal of the ice and the opening of the estuary to the sea, or that it began while the ice still lingered in the region, and was already in progress when the estuary was opened.

Traces of wave work along the south coast of the Saint Lawrence were found at all altitudes below the upper limit of submergence. Contrary to expectation, again, there proved to be no shoreline below the highest one, with the exception of the twenty-foot strand, which possesses enough individuality of character, enough strength of expression, or enough continuity to indicate a long stand of the sea at any level. Distinct beach fragments were found at all altitudes, in such places as were peculiarly favorable in exposure to the open sea, or in supply of beach material. This is believed to indicate that the emergence of the Saint Lawrence valley from the Champlain sea was not accomplished by spasmodic uplifts, separated by intervals of repose, but was fairly steady and continuous. Observations on the marine beaches near the New York line, at Covey Hill, recently led Prof. H. L. Fairchild to the same conclusion as that here stated. On the other hand, Professor Daly, in his description of the raised beaches of Newfoundland and Labrador, is inclined to take the view that the general lack of harmony between measurements on the lower beaches is due to local conditions masking more or less perfectly the effects of spasmodic uplifts.*

While there are above the twenty-foot level no shorelines that are conspicuous, it is rather generally true that in comparing higher beaches with lower ones, in any locality, one finds greater distinctness and continuity of form at the lower levels. This is due partly, no doubt, to the fact that on an emerging coast, through the off-shore movement of beach material and the re-working of that material at lower and lower levels, lower shorelines inherit, to some degree, the straightness and strength of their predecessors. The prevalence of sandy beaches below and gravelly beaches above points likewise to a re-working of beach debris as the waters drew down the slope. It is possible, however, that this increase in topographic strength towards lower levels is due in part to a slower rate of emergence as elevation progressed and as conditions of stability were approached.

The Twenty-foot Terrace and Sea-cliff.

In marked contrast with the weak beaches at higher levels, the shoreline which stands 20 feet above the sea is strong and continuous. Although it was not practicable for my party to follow the shoreline continuously along the coast, it was found at so many places, so strongly developed, and with so nearly uniform an altitude that there could be no doubt of its virtual continuity from Quebec eastward at least as far as Matane,—a distance of 225 miles. At only three points of those we visited on the south shore, namely, Saint Simon, Riviere Ouelle, and Montmagny, was the twenty-foot terrace and sea-cliff absent. At each of these places our search was limited to a short

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* R. A. Daly, The Geology of the Northeast Coast of Labrador. Bull. Mus. of Comp. Zoöl., vol. xxxviii, 1902, pp. 205–273, and especially pp. 252–254.

stretch of coast, where the conditions were unfavorable for cliff and terrace development, because of ragged ledges of slate in the first two instances, and of delta deposits at the mouth of the Saint Thomas River in the third case. Everywhere else the low terrace and cliff were very prominent. Further evidence of the extent of the terrace was found, after returning from the field, in the Admiralty charts of the Lower Saint Lawrence, especially in the excellent charts which have recently been published.*

Fig. 1.

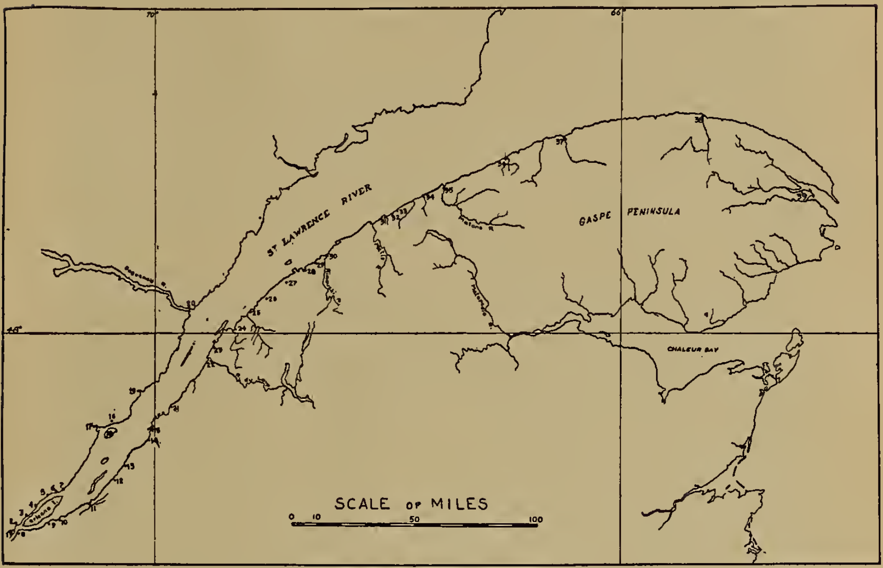

Fig. 1.—Index map of the Lower Saint Lawrence: 1 Quebec, 2 Beauport, 3 L'Ange Gardien, 4 Chateau Richer, 5 Sainte Anne de Beaupré, 6 Saint Joachim, 7 Cape Tourmente, 8 Levis, 9 Saint Michel, 10 Saint Valier, 11 Montmagny, 12 L'Islet, 13 Saint Jean Port Joli, 14 Sainte Anne de Lapocatiere, 15 River Ouelle, 16 Eboulements, 17 Bay Saint Paul, 18 Isle aux Coudres, 19 Murray Bay, 20 Tadoussac, 21 Kamouraska, 22 Fraserville, 23 Cacouna, 24 Isle Verte, 25 Trois Pistoles, 26 Saint Simon, 27 Saint Fabien, 28 Bic, 29 Sacre Cœur, 30 Rimouski, 31 Little Metis, 32 MacNider's, 33 Sandy Bay, 34 Rivière Blanche, 35 Matane, 36 Whale Cape, 37 Sainte Anne des Monts, 38 Cape Magdalen, 39 Gaspé.

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* Of the older charts, published in London, by the Admiralty, the most helpful are No. 307, which was published in 1901, and Nos. 313, 314, and 315, in 1890. Of the later charts, prepared by the Department of the Naval Service of Canada, at Ottawa, No. 202, of the coast from Razade Islands to White Island, published in 1910, and No. 201, of the coast from White Island to Orignaux Point, published in 1908, are very rich in detail. Other charts are now in preparation.

In the city of Quebec the twenty-foot terrace is occupied by a part of the "Lower Town," and is rather obscure. A few miles east of the city, however, both terrace and sea-cliff appear, near Beauport, and extend with little interruption past Chateau Richer, Sainte Anne de Beaupré, and Saint Joachim, and presumably to Cape Tourmente. For most of the distance between Beauport and Saint Joachim the sea-cliff is in full sight from the trolley line of the Quebec Light and Power Company. It is a precipitous bank, from 20 to 50 feet high, cut in glacial drift. While its course, instead of being straight, is gently curved, there are no marked irregularities, neither headland nor strong reëntrant. It is a typical mature coast. From the foot of the cliff the terrace slants gently outward for several hundred yards to the present high-tide mark, and continues, in the form of half-submerged mud flats, for an equal distance offshore. Its total width, from the foot of the cliff to the outer edge of the flats, ranges from half a mile to a mile and a half. Both cliff and terrace are plainly shown on chart number 315 of the Admiralty.

A view southward from Chateau Richer or Sainte Anne shows a corresponding terrace and cliff on Orleans Island. According to the Admiralty chart it is almost continuous around the island. On the north shore the only interruption is at a reëntrant near Point Argentenaye, where the wave-cut sea-cliff would be expected to pass into a bay-head beach. The straightness of the twenty-foot shoreline appears to be as marked on the island as it is on the Beauport–Saint Joachim shore; the terrace, however, is not so wide. On the south side of Orleans Island the chart shows a nearly continuous cliff, behind and above the modern beach, from one end of the island to the other; but it is more irregular in outline, and the terrace is much narrower.

Across the channel, on the south shore of the Saint Lawrence, scraps of sea-cliff appear on the chart a few miles east of Levis, behind Indian Cove, and in the vicinity of Saint Michel. A wide break occurs in the reëntrant at the mouth of River Boyer; but the cliff seems to appear again beyond Saint Valier. Although the Saint Thomas River, at Montmagny, has built a delta of considerable size at the present level, no well-defined twenty-foot delta level was found here. From here northeastward to L'Islet, the shore is protected by a long island known as Goose Island. The Admiralty chart (No. 315) shows a cliff on the north side of this island, near its east end, where exposure to wave action is most severe. On the main land a similar cliff appears a few miles down the estuary, near Anse à Pierre Jean (Chart No. 314). This cliff, which according to the chart lies not far behind the modern beach, yet distinctly above high tide mark, occurs interruptedly along the ten-mile stretch from Saint Jean Port Joli to Saint Roche Point. A few miles beyond the mouth of Rivière Ferrée, the cliff appears again, and extends on past Sainte Anne de la Pocatiere. At this place the twenty-foot terrace is a mile wide, sloping almost imperceptibly from the foot of the bluff near the College down to the water's edge, where a long dike shuts off the low marsh from the high tides. Beyond the dike, mud-flats extend out into Sainte Anne Bay as far as the eye can see. According to the chart (No. 314) the outgoing tide exposes two miles of flats, and beyond low-tide mark flats less than one fathom deep reach to a distance of five miles from shore. This extreme width of tidal flats is due largely, no doubt, to sediment brought down by Rivière Ouelle.

On the north side of the Saint Lawrence, the chart shows cliffing above and behind the modern beach at Bay Saint Paul, Eboulements Bay, Cape Martin, Goose Cape, and especially encircling the shore of the great Isle aux Coudres. Beyond Goose Cape no suggestion is to be found, on the chart, of a twenty-foot terrace on the north shore.

Beyond Point Saint Denis, on the south shore, the mud-flats have a width of fully three miles. Near Kamouraska two-thirds of this shallow coastal shelf is laid bare at low tide. As Kamouraska Island the entire terrace, three miles wide, is covered and bared, alternately, by the incoming and outgoing tides. Cliffs not far behind the modern beach, south of Kamouraska, seem from the chart to mark the inner border of the twenty-foot shelf. This is plainly the case near Fraserville, where a great tidal marsh occupies the reëntrant at the mouth of the River du Loup.

At Cacouna, the first point on the south shore visited by the writer in 1910, the terrace and sea-cliff are very distinct. The terrace here, at high tide, appears to be merely a narrow shelf behind the modern beach. At low tide, however, it can be seen extending out through shallow water for more than a mile, as far as Cacouna Island. The importance of so strong a shoreline, although suspected when it was first seen, was not appreciated until, on the following day, a similar display of cliff and terrace, at the twenty-foot mark, was found at Trois Pistoles, 25 miles east of Cacouna, and on the next day a still more striking occurrence of it at Bic, 35 miles east of Trois Pistoles. These observations, coming so rapidly at the beginning of the field season, quickly disposed of the suspicion that the beach at Cacouna might owe its extraordinary strength to local conditions.

A stretch of the twenty-foot terrace and cliff near Isle Verte is very well shown on the recently published chart No. 202.

FIG. 2.

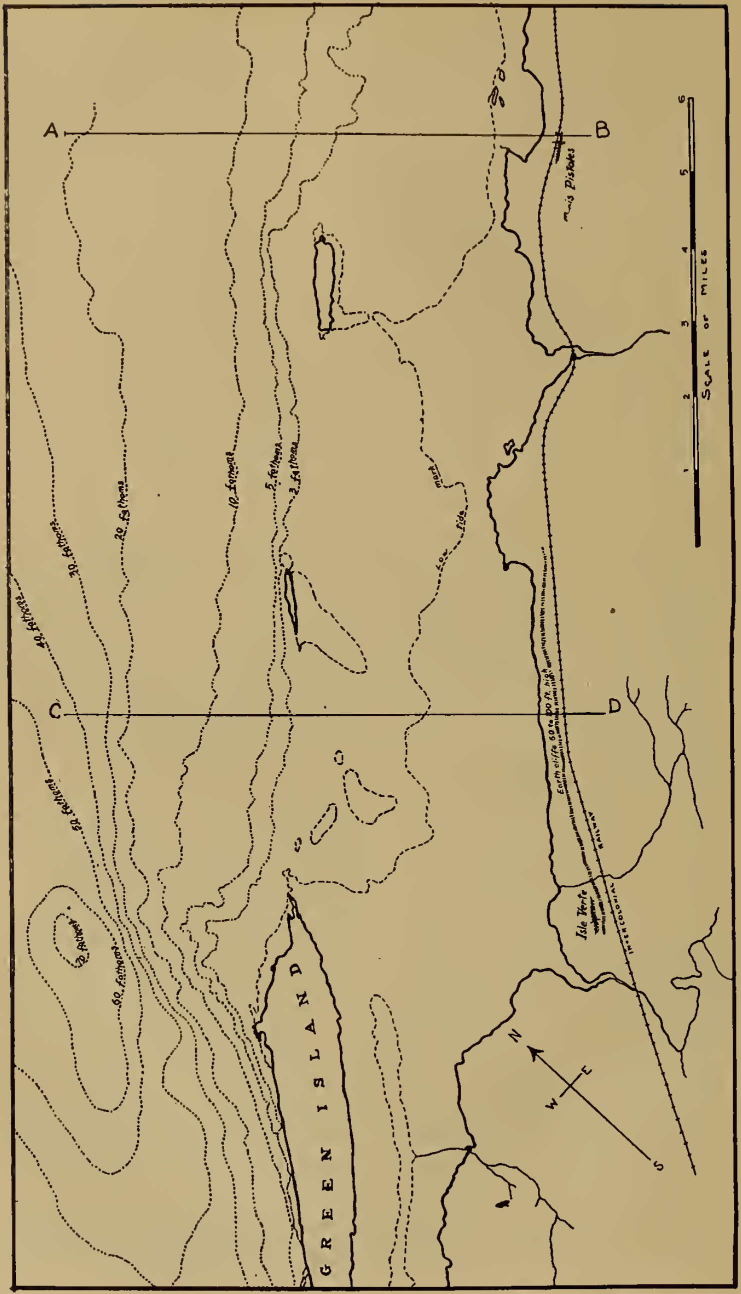

FIG. 2. Map of the coast near Isle Verte and Trois Pistoles (based upon Chart 202 of the Naval Service of Canada).

The long island, lying a mile and a half off-shore, is partly separated from the mainland at low tide by a narrow tongue of water; mud-flats occupy the rest of the interval. At the north end of the island, off the mouth of Rivière Verte, the delta of this river laps out across the channel, connecting the island to the south shore (see figure 2). From the village of Isle Verte northeastward for six miles to Point à la Loup, a straight line of "earth cliffs 50 to 100 feet high" is shown on the chart, lying from one-fourth to one mile inland from the modern beach. The Intercolonial Railway, here, approaches close to the brink of the bluff, and affords a plain view of the terrace which lies at the foot of it. A profile of the shelf, drawn to scale from chart No. 202, at this place, emphasizes the extreme flatness of this terrace, which runs out three and a half miles to reach a depth of five fathoms. The ebb tide lays bare nearly two miles of flats (see profile C–D in figure 3).

Fig. 3.

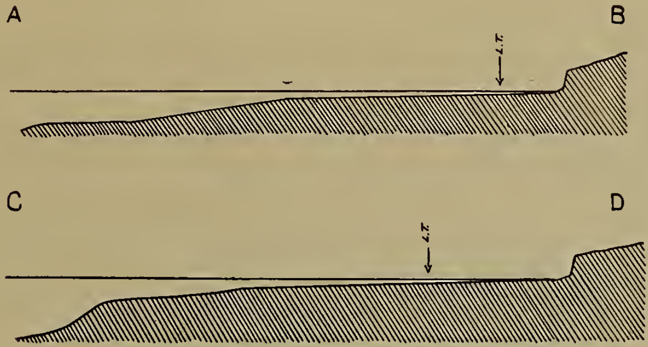

Fig. 3. Profiles of the twenty-foot terrace, constructed from Chart 202; A–B at Trois Pistoles; C–D near Isle Verte.

At Trois Pistoles the cliff and terrace lie along the north edge of the village. From the shore the old cliffs can be seen stretching eastward with gentle curvature for two miles or more. Not far beyond, near St. Simon, a long range of rocky ridges, rising to altitudes of 400 to 500 feet, forms a coast where instead of mature sea-cliffs the waves seem to have been able only to build pocket beaches among the ledges at the inner edge of the shelf. The coast from here past Saint Fabien is bold, and the shelf is narrow, until it approaches Bic.

Across the Saint Lawrence, at the mouth of the Saguenay, no distinct marks of wave work at the twenty-foot level were discovered, although there is a delta-like shoal of considerable size at the present level, overlooked by freshly cut cliffs which are over 200 feet high.

At Bic wide tidal flats find their shoreward extension in a terrace some 200 yards wide, which rises to the foot of a fine straight sea-cliff (see fig. 5). The contrast between the weak low bluff at the present high-tide mark and the great cliff at the twenty-foot level is very striking. A view of the terrace, taken from the top of the bluff shown in fig. 5, and looking in nearly the opposite direction, may be seen in Salisbury's High School Physiography.*

FIG. 4.

FIG. 4. The shore at Trois Pistoles. The ebb tide lays bare a wide expanse of mud-flats, over which large bowlders are plentifully scattered. They are probably ice-rafted. The weakness of wave action at the modern high-water mark is indicated by the thin shingle beach in the foreground, with salt marsh vegetation on its seaward margin.

About four miles beyond Bic, the Intercolonial Railway descends from the upland to the coastal shelf, and remains

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* R. D. Salisbury: Physiography for High Schools, Briefer Course, 1908, figure 276. The photograph is entitled "A coastal flat, village of Bic, Quebec," and is attributed to the U. S. Geological Survey.

there until it is within a short distance of Rimouski. Near Sacré Coeur station one gets a good view of the old shoreline. On one side is the precipitous sea-cliff over 40 feet high; on the other, a wide, half-submerged shelf, strewn with great bowlders. Just west of Sacré Coeur the cliff has been cut far back into the fissile slate which outcrops in this district, and here it attains its maximum height, about 120 feet. (See fig. 6.) At Rimouski the railway has again ascended to the higher ground, but lies not far from the top of the old sea-cliff. The old cathedral and mission buildings, on the main street of the village, stand close to the foot of the bluff, but well above the reach of high tides. Off-shore are broad mud-flats like those at Bic and Cacouna. The cliffs extend eastward from the village fully two miles, to the pier, in a long graceful curve. In order to reach deep water, even in a favorable situation, the pier runs out nearly half a mile. Although the old cliffs

Fig. 5.

Fig. 5. The twenty-foot terrace and sea-cliff at Bic. The village stands at the top of the old cliff. A schooner is being built on the twenty-foot terrace, in the middle distance. The contrast between the strong sea-cliff at the higher level and the indistinct, marshy beach at the modern high-tide mark is very striking.

are from 30 to 50 feet high, there is hardly a sign of wave work at the high-tide mark; the fresh-water marsh of the terrace passes gradually outward and downward into salt-marsh and mud-flats. The infantile condition of the modern shoreline is quite as striking as the full maturity of the higher one.

Opportunity was found, on the journey from Little Metis to Matane, to follow the old sea-cliff continuously for more than 25 miles. Although undeveloped at Mac Nider's, where ledges and obscure beaches occur at the twenty-foot mark, the cliff appears a few miles beyond, near Sandy Bay. From here on, the carriage road runs along the terrace, hugging rather closely to the present beach, at the outer edge of the terrace, but now and then drawing near the foot of the old sea-cliff, where an ancient headland forms a blunt projection

FIG. 6.

FIG. 6. The old sea-cliff about four miles east of Bic. The Intercolonial Railway lies on the twenty-foot terrace close to the foot of the cliff, which is here over 120 feet high.

between long crescentiform re-entrants in the cliff line. Looking seaward from the road, across the low beach that marks the upper reach of modern storm waves, one sees a wide expanse of mud-flats, through which appear here and there the truncated edges of upturned shale and sandstone layers,—as pretty an illustration of marine planation, interrupted by uplift, as one could wish. Bowlders are plentifully scattered over the shelf, from half-tide mark outward (see fig. 7), and seem to have reached their present positions by ice-rafting during the spring break-up. Even if observations on the twenty-foot terrace were wanting elsewhere, a day's drive along the foot of the ancient sea-cliffs from Little Metis to Matane would convince an observer of the importance of this, the lowest, of the elevated strands. According to Dawson,* this terrace continues as far as Whale Cape, and reappears, 40 miles beyond, at Sainte Anne des Monts. While nothing seems to be known about it on the east and south sides of the

FIG. 7.

FIG. 7. The old sea-cliff and twenty-foot terrace at Rivière Blanche, about ten miles west of Matane.

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*In Logan's Geology of Canada, 1863.

Gaspé Peninsula, it is quite probable that future exploration of that region, and of the adjoining coast of New Brunswick, will show that the extent of the strand southward is as great as its extent in the Saint Lawrence estuary; for in the Saint Lawrence it maintains an approximately uniform altitude for more than 200 miles, along a line which runs almost directly up the incline of the Champlain geoid surface. Although at Matane the altitude of the Champlain beach is 174 feet, and near Quebec, 632 feet, the altitude of this low terrace is practically the same at both places, and at all intermediate points where measurements have been made. This is shown in the table below.*

L'Ange Gardien	14–16 feet
Trois Pistoles	14–19 "
Saint Simon	beach at 17 feet
Bic	19–21 feet
Sacré Coeur	20–23 "
Rimouski	22 "
Little Metis	beach at 19 feet
Mac Nider's	20–22 feet
Rivière Blanche	15–17 "

A strongly marked terrace at about the height of this one has been reported at several distant places by other observers. In describing the elevated marine terraces of the island of Anticosti, Mr. W. H. Twenhofel states† that the lowest terrace, which stands from 8 to 15 feet above high tide mark, nearly surrounds the island. Its average width is about a quarter of a mile; and its maximum width, over two miles. Prof. R. A. Daly, in his description of the beaches of the Labrador coast, mentions an exceptionally strong shoreline not far above the sea, at West Bay, Hamilton Inlet. According to his account, "there was a comparatively long halt in the process of elevation when the sea level was about thirty-five feet above its present position; at that time there was developed a distinct bench."‡ Although Hamilton Inlet is about 600 miles northeast of Matane, the occurrence of a particularly strong shore terrace at this low level is rather suggestive

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*The measurement, unless otherwise indicated, is the altitude of a wave-cut terrace at the foot of a bluff. Where a beach was measured, the crest of it was taken. The datum plane is local high tide mark, as registered by the line of flotsam on the beach. This, at Sacré Coeur, was found to be four feet above mean tide, and three feet below the mark of storm waves at high tide. The high tide surface is of course somewhat irregular; and this may account for much of the discrepancy in the altitudes here given.

†W. H. Twenhofel: Geological bearing of the peat beds of Anticosti island. This Journal (4), vol. xxx, pp. 65–71. 1910.

‡R. A. Daly: Geology of the northeast coast of Labrador. Bull. Mus. of Comp. Zool., vol. xxxviii, pp. 205-273, especially p. 266. 1902.

of an extension of the twenty-foot terrace of the Lower Saint Lawrence, with increasing altitude in that direction.

Sir William Dawson, in the passage cited from Logan's "Geology of Canada," reports the discovery of the bones of the whale and the morse in the gravels of the twenty-foot terrace, at several points between Rimouski and Matane. Although the present writer was not fortunate enough to find fossils of that nature, small shells of common gastropod and lamellibranch species were found to be rather abundant. Care had to be used, however, to eliminate shells which might have been ploughed under, after the fields had been fertilized with seaweed.

In order to distinguish this, the strongest of the marine strands of the Lower Saint Lawrence, from the higher beaches, it seems desirable to find a name for it. The phrase "Twenty-foot terrace" is unsatisfactory for permanent use, since, obviously, this shoreline, when explored farther in the maritime provinces, will be found to depart from the twenty-foot altitude. Following Dr. J. W. Spencer's usage of Indian names for the strong shorelines of the extinct lakes "Algonquin" and "Iroquois," the name "Micmac shoreline" is here proposed for the great terrace and sea-cliff of the Lower Saint Lawrence, in honor of the great tribe of Indians who originally occupied southern Quebec and Acadia, and whose survivors to-day add to the picturesqueness of the more remote portions of the coast. The period of time during which the Micmac terrace and cliff were cut will be called the "Micmac stage."

THE SIGNIFICANCE OF THE MICMAC SHORELINE.

The Place of a Cliffed Coast in Shoreline Morphology.

The principles underlying the development of such a cliffed coast as this ancient one at the twenty-foot level are well known. It is a familiar principle, for instance, that if the relative level of land and sea remains unchanged, any shoreline, no matter how irregular it may be at first, will become straightened or simplified by the cutting back of headlands and the filling in or bridging of re-entrants ; and further, that it will ultimately come to have the form of a long line of cliffs, at the foot of which the waves, with ever diminishing force, encroach upon the land. Obviously, the time necessary for mature cliffs to be formed along a coast depends to a large extent upon the structure of the ground at which the waves are cutting. In the case of the mature shores of Lake Ontario and Lake Erie, the cliffs have been cut back in unconsolidated glacial drift, and their recession has consequently been rapid. On an indented and freshly glaciated coast, like the fjord coast of Maine, it is doubtful if a mature outline and profile could be reached before the relative level of land and sea would be changed by crustal deformation.

In seeking to interpret the significance of the Micmac terrace it is important to bear in mind its uniform altitude between Quebec and Matane. The approximate horizontality of the shoreline for 225 miles precludes the view that there has been a local change in high-tide level.* A change of twenty feet near the head of the estuary would be accompanied by a relatively small change of level out near the Gulf. Moreover, the configuration of the coast, near Gaspé, gives no suggestion of any barrier which could have lowered the high-tide mark twenty feet in recent times.

A factor in cliff development which is rather seldom emphasized is slow coastal subsidence. Its importance was recognized and clearly stated by Dr. Gilbert in 1883 †:

> "A slow and gradual submergence modifies the products of littoral action. The erosion of sea-cliffs is exceptionally rapid, because the gradually deepening water upon the wave-cut terraces relieves the waves from the task of carving the terraces, and enables them to spend their full force against the cliffs. The cliffs are thus beaten back before the advancing tide, and their precipitous character is maintained with constant change of position."

The truth of this statement, while sufficiently supported by Doctor Gilbert's masterful analysis of the physics of wave work, is also confirmed by observation. It is not unlikely that Doctor Gilbert had slow submergence in mind as one, at least, of the reasons for the marked cliff cutting at the high-water marks of the extinct Lake Bonneville. In the Great Lakes region the exceptional strength of the Nipissing shoreline and its peculiar cliff and terrace profile have been attributed, not simply to the greater duration of that stage, but to the fact that it was preceded by a prolonged submergence, due to the slow uplift of the Nipissing pass, which was then the outlet of the lakes. Certainly, if on the one hand slow submergence favors cliff cutting, while on the other hand slow emergence hinders it, and favors beach building, there is no lack of illustrative material among the extinct shorelines of the Great Lakes region, where beach ridges commonly mark halts during emergence, and extensive cliffs characterize the stages of climax during submergence.‡

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* See papers by J. W. Dawson, referred to in later notes, especially: On a modern submerged forest at Fort Lawrence, Nova Scotia. Quart. Journ. Geol. Soc., vol. xi, pp. 121–122, 1855.

† G. K. Gilbert: The Topographic Features of Lake Shores; Fifth Annual Report of the U. S. Geological Survey, 1883–1884, pp. 67–123, and especially pp. 110–111.

‡ J. W. Goldthwait: Physical Geography of the Evanston-Waukegan Region; Illinois State Geological Survey, Bull. No. 7, 1908, pp. 66–68, and figure 29.

It may confidently be said, therefore, that while a mature cliffed shore will result from prolonged wave action on any coast, the process will be greatly accelerated if that coast is sinking.

Hypothesis of an Interval of Stability between Two Uplifts.

With the foregoing principles of shoreline morphology in mind, we may frame a hypothesis for the development of the Micmac terrace and sea-cliff, which will be as follows: After the shores of the Saint Lawrence estuary had risen differentially, without interruption, a few hundred feet out of the Champlain sea, uplift ceased, and a long period of stability ensued. During this period, which we may call the Micmac stage, the irregular shoreline was straightened, its profile was corrected, and a line of cliffs were developed and cut back two or three miles towards the interior. At length, after this prodigious cliff recession had been accomplished, a second uplift occurred. This may have been a slow, epeirogenic movement, like the first one; or, perhaps, a sudden, seismic movement. If epeirogenic, it may still be in progress.

Examining the facts more closely, with this hypothesis in mind, we may test the working value of it.

The length of time required for the cutting back of the cliffs so far into the land is very great, in comparison with the time required to build any one of the weak upper beaches. One of these might have been constructed by a single storm during the period of emergence; the Micmac shoreline, however, with its wide off-shore terrace, plainly represents centuries of littoral marine planation. If we take the modern shore of Lake Michigan as similar in character to the Micmac shore, and assume an average rate of recession of the Micmac cliffs of 5 feet per year,* and a total recession, as at Isle Verte and Trois Pistoles (see figure 3, A and B), of 3 miles, the Micmac stage lasted somewhat more than 3000 years. This is a reasonably small fraction of post-glacial time, as inferred from the history of

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* The recession of the high clay cliffs on the west side of Lake Michigan between Milwaukee and Evanston, as computed in 1868 by Dr. Edmund Andrews, was about 5 feet per year. See his "North American Lakes considered as Chronometers of Post-glacial Time," Transactions of the Chicago Academy of Sciences, vol. ii, pp. 1–23, 1870 (quoted by Frank Leverett, in "The Illinoian Glacial Lobe," Monograph No. 38 of the U. S. Geological Survey, 1899, pp. 456–457). While the height of these modern lake cliffs is about the same as the height of the Micmac cliffs, and the structure of the glacial drift which composes them is essentially the same also, the terrace of the former has a width of barely two miles instead of three or four. It seems fair, therefore, to regard the greater width of the Micmac terrace as compensating for the greater vigor of the waves in the estuary, if, indeed, the wave action in the Saint Lawrence is any stronger.

Niagara Falls, and seems consistent with commonly accepted estimates.

The slope of the Micmac terrace, from the foot of the cliffs out to its submerged edge, and its depth there below the Micmac water-plane, are significant. Figure 3, plotted from the chart No. 202 (see fig. 2), shows the profile of the Micmac terrace at Isle Verte and Trois Pistoles. It will be seen that the outer edge of the terrace lies close to the 3-fathom line. Since the tidal range is about 16½ feet at Trois Pistoles, the outer edge of the terrace, at present, is covered by about 35 feet of water at high tide. When the Micmac cliffs were being cut back, and the water stood about 20 feet higher than now, the outer edge of the terrace was between 50 and 60 feet under water at high tide. Considering that this was 3 miles off-shore, 50 or 60 feet does not seem excessive for the position of the wave base; in other words, it might be expected that the waves would cut downward 50 or 60 feet on the shelf, while they cut forward 3 miles into the coast. The profile can consistently be regarded as a "profile of equilibrium," developed by erosion on a coast which was neither rising nor sinking.

There is perhaps some difficulty in explaining why, after this 225-mile stretch of coast had risen steadily, though differentially, a few hundred feet, it should remain stationary for a period of, say, 3000 years. One would rather expect to find other cliffed shorelines at higher levels, marking earlier intervals of stability. It is the more puzzling when we seek, further, to explain why, after so long a period of stability, there was a second uplift. Instability seems to have been the condition here during so large a part of post-glacial time, both before and after the Micmac stage, that one hesitates to adopt the view that for 3000 years or so there was a cessation of coastal movements.

It might possibly relieve this difficulty to conceive of the earlier, epeirogenic uplifts as having indeed satisfied such deep-seated stresses or temporary isostatic conditions (whatever their origin) as were resident beneath northeastern North America at the close of the glacial period; and to regard the rest of post-glacial time as a period of approximate stability, complicated only by local, seismic movements. There are, indeed, records of several severe earthquake shocks in the Saint Lawrence valley within historic times. In the most severe of these, which occurred Feb. 5, 1663, great rifts were formed in the ground, large landslides took place at the borders of river terraces, and much damage was done all along the north coast of the Lower Saint Lawrence as far east as Tadoussac. While the record of the shock along the south shore is very meagre, it is known that the quake was felt as far east as Gaspé, and as far south as New England.* While the Lower Saint Lawrence lies in a zone of seismic disturbances, as Laflamme has clearly shown,† it seems very doubtful whether any great seismic movement, or series of movements, along the Saint Lawrence fault line, would elevate 225 miles of coast so evenly. In the case of the earthquake of 1899, in Yakutat Bay, Alaska, recently described by Professors Tarr and Martin,‡ the changes of level along the coast were very irregular, varying from 45 feet uplift to several feet depression in distances of a very few miles. Granting that the fracture system along the Lower Saint Lawrence may be much simpler in character than that in Yakutat Bay, and that the seismic movements of the former region may consequently be more regular, it still seems exceedingly unlikely that the Micmac shoreline has reached its present uniform position by sudden earthquake movements. The only safe conclusion appears to be that it participated in a second great epeirogenic uplift. The difficulty therefore remains, of explaining a long interval of stability between two unstable periods.

Hypothesis of an Interval of Coastal Subsidence Between Two Uplifts.

With the principles of shoreline morphology again in mind, we may frame a second working hypothesis, and test its validity in the same manner as the first. According to this hypothesis, the sequence of events is, briefly, (a) a differential epeirogenic uplift, causing the emergence of the coast between Matane and Quebec of from 170 to 630 feet, respectively; (b) a reversal of the movement, involving a slow subsidence of the coast, of relatively small measure but perhaps of equal duration; (c) a second epeirogenic uplift, of unknown rate and duration, likewise of slight vertical measure,—20 feet. Leading toward the support of this hypothesis there are several lines of evidence.

Independent evidence of subsidence.—There are clear indications of a post-glacial subsidence of the coast of New England and the maritime provinces, which it may be possible to correlate with the Micmac shoreline. Submerged peat bogs

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* See the condensed account of this earthquake in Prof. W. H. Hobbs' "Earthquakes," New York, 1907, pp. 315–320. The chief source of information is the "Jesuit Relations," translated by Dr. Reuben Gold Thwaites.

† J. G. K. Laflamme : Les Tremblements de Terre de Quebec. Proc. Roy. Soc. Canada (3), vol. i, pp. 157–183, 1907.

‡ R. S. Tarr and L. Martin : Recent Changes of Level in the Yakutat Bay Region, Alaska. Bull. Geol. Soc. America, vol. xvii, pp. 29–64, 1906, especially plate 23.

and forest beds, containing stumps of trees in undisturbed positions of growth, have been found at many places, at depths of from 0 to 20 feet below modern high-tide mark. Among the numerous instances of such submerged forests may be mentioned cases at the head of the Bay of Fundy,[*] at several places near Boston, Mass.,[†] and on the island of Nantucket.[‡] This evidence coming from many different places on the coast, and reported by many observers, seems to leave no doubt that the seaboard of Acadia and New England has suffered a submergence, since the glacial period, of fully 20 feet. The position of these forest beds above glacial drift, yet much nearer the sea level than the beaches which mark the Champlain submergence, indicate that this coastal subsidence came after the extensive emergence of the coast from the Champlain sea.

There is difficulty, however, in correlating the Micmac terrace with these submerged forest beds, in the fact that the terrace has experienced a re-elevation of 20 feet, while the submerged forest beds are not known to have suffered a similar uplift. Indeed, it has recently been urged, that botanical evidence in the structure of the salt marshes overlying the forest beds proves that the subsidence of the coast, in those places, has been uninterrupted since the stumps were first submerged, and that the movement is still in progress.[§] Inasmuch as these and other alleged evidences of modern subsidence may to some extent be explained by appealing to other processes than crustal deformations,[‖] and at the same time are contradicted by alleged evidences of modern stability in Acadia and New England,[¶] and of modern elevation

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[*] Sir William Dawson: On a modern submerged forest at Fort Lawrence, Nova Scotia. Quart. Journ., Geol. Soc. London, vol. xi, 1855, pp. 119–122. (Abstract) this Journal, 2d series, vol. xxi, 1856. pp. 440–442. Also, in Acadian Geology, 2d edition, London, 1868, pp. 28–32.

[†] J. W. Sears: The physical geography, geology, mineralogy, and paleontology of Essex County, Massachusetts. Salem, Mass. Published by the Essex Institute, 1905, pp. 51–58, and fig. 27.

[‡] A. Gessner: On elevations and depressions of the earth in North America. Quart. Journ. Geol. Soc., vol. xvii, pp. 381–388, 1861, especially p. 382.

[§] C. A. Davis: Peat deposits of Maine. Bulletin No. 376, U. S. Geological Survey, 1909, pp. 19–21. Salt marsh formation near Boston, and its geological significance. Economic Geology, vol. v, p. 625.

Also, H. H. Bartlett: The Chamæcyparis bog at Woods Hole, Massachusetts, Rhodora, vol. xi, 1909, pp. 221–235.

[‖] D. W. Johnson: Personal communication regarding progress of the Shaler Memorial Investigation, 1911.

[¶] Robert Chalmers: Report on the surface geology of southern New Brunswick. Geological Survey of Canada, Annual Report, vol. iv, pp. 74–76 N, 1888–89.

Also, D. W. Johnson and W. G. Reed, Jr. The form of Nantasket-Beach. Journ. of Geology, vol. xviii, pp. 162–189, 1910, especially pp. 187–188.

in Newfoundland and Labrador,* it seems possible at present neither to affirm nor to deny the correlation of the Micmac shoreline with the submerged stumps described by Dawson and others. Here is a fruitful field for investigation, in which much may be learned from a botanical study of samples of salt marsh deposits, following the methods of Davis and Johnson.

It will be noticed that if the Micmac sea-cliff was cut back during a stage of slow coastal submergence, a record of this submergence might be left, in protected reëntrants, in the form of forest beds buried by the advancing gravels and sands of the beach, and subsequently raised, with the overlying material, above high-tide mark; in other words, stumps and fresh-water peat might be discovered beneath the marine sands on the Micmac terrace. Search for chance excavations or natural sections of the terrace which would show such stumps, during the season of 1910, was unrewarded. The negative evidence, however, is of little weight. It is desirable that a more thorough test of the underground structure of the Micmac terrace be made, by taking samples of the deposits with a soil auger, like the one used by Mr. Davis.

Post-glacial movements in Scandinavia.—The investigation of the raised beaches on the coast of Scandinavia, by De Geer, Broegger, and others, indicate that the post-glacial movements there have been essentially three in number,—two uplifts, separated by a slight subsidence. When the hypothesis of coastal subsidence as the cause of the great strength of the Micmac terrace suggested itself to the writer, in the field, the researches of the Scandinavian investigators were not at first thought of, as bearing upon a possible three-fold movement in southern Quebec. Very soon, however, the recollection of Broegger's statements concerning the complexity of the coastal movements in Norway and Sweden and Denmark came to mind, and their importance as affording a parallel case was realized.

The work done by the Scandinavian geologists on their raised beaches and the associated fossiliferous marine clays is much more comprehensive than has yet been done in northeastern North America. Not only have the altitudes of the beaches been measured at many points on the peninsula and in Denmark, and isobases drawn to show the amount and extent of the differential uplifts, but a great abundance of archeological material has been collected, and the position of the several distinct types of knives, axes, etc., with relation to the several distinct shorelines has been noted. Thus the relation of the

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* R. A. Daly: Geology of the northeast coast of Labrador. Bulletin Mus. of Comp. Zool., vol. xxxviii, pp. 205–273, 1902, especially pp. 261–262.

coastal movements to successive portions of the stone age, copper age, and bronze age has been worked out, and the approximate date of each shoreline has been estimated.* A brief outline of the conclusions reached by Broegger and others who have been investigating the post-glacial movements in Scandinavia will serve as an interesting commentary on the hypothesis of subsidence of the Canadian coast during the Micmac stage.

At the close of the last glacial epoch, the Scandinavian coast stood several hundred feet lower than it does now. This time of maximum submergence has been called the "Kristiania period" by Broegger. An open sound then extended across the peninsula, connecting the Skager Rack with the Gulf of Bothnia. The shoreline of this earliest marine stage now stands about 700 feet above the sea at Christiania. The *Yoldia* clay, characterized by boreal forms like those in the Champlain clays, mark the deposits of the Christiania period. Broegger has shown that the ice sheet had not entirely withdrawn from the estuaries at the time of the greatest submergence, for the Yoldia clays extend up the estuaries only as far as the great terminal moraine. Judging, therefore, from the absence of Yoldia clays behind this moraine, the emergence of the Scandinavian coast began before the heads of the estuaries were abandoned by the ice. In Canada, it will be remembered, a similar early emergence of the newly uncovered coast from the sea has been inferred from a different kind of evidence,—namely, the weak character of the highest beach. Above the *Yoldia* clays, other marine clays, known respectively as the *Arca*, the *Mytilus*, and the *Cardium* clays, show a gradual retreat of the Arctic fauna and the advent of more southern forms. The climax of this emergence of the coast was marked by the existence of a great fresh-water sea in the Baltic basin, with a fauna characterized by lacustrine species of such genera as *Planorbis*, *Limnœa*, and *Ancylus*. This *Ancylus* group of sands and clays is found at many places around the Baltic, up to altitudes of more than 100 feet above the sea. Broegger appears to regard this *Ancylus* sea as impounded not by an emergence of the straits to a higher level than the present, but rather to a blockading of the straits by an ice lobe. The time occupied by this first post-glacial emergence has been estimated by Broegger to be about 9000 years.†

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* W. C. Broegger: Strandliniens beliggenhed under Stenalderen i det sudoestlige Norge. Norwegian Geological Survey, No. 41, pp. 339, 1905. (Review by G. C. MacCurdy) Science, vol. xxiii, pp. 778–780, 1906.

† Gerard De Geer: On pleistocene changes of level in eastern North America. Proc. Boston Soc. Nat. Hist., vol. xxv, pp. 460–461. A. Geikie: Text book of geology, 4th edition, London, 1903, p. 1333. W. C. Broegger, op. cit., p. 283.

A slight subsidence of the southern part of Norway and Sweden next took place, and the barrier of the Ancylus sea was removed. The Ancylus sediments were buried by marine clays and sands, in which the predominant fossils are common salt-water species like *Littorina littorea* and *Mytilus edulis.* This stage is called by Broegger the Littorina subsidence; and has recently been shown to correspond to the first stone age of north Europe, or the age of "kitchen middens" in Denmark and Sweden. It was in this region a period of warmer climate than the present. According to Broegger, the subsidence lasted about 2000 years, but was of slight vertical extent as compared with the earlier and later uplifts, consisting in the Christiania region of a depression of only about 10 feet. Farther south the subsidence was greater; farther north, less.*

The long interval since the maximum *Littorina* submergence or kitchen midden epoch, estimated by archeological data† to be about 7000 years, is divided by Broegger into four parts: earlier, middle, and later *Tapes* periods; and the recent period. During the first three of these stages, the coast rose to its present position, bringing the *Littorina* shoreline at Christiania up to the 200-foot mark. This emergence, beginning, it is estimated, about 5000 years B. C., lasted approximately 4500 years, untill the end of the Bronze Age and the beginning of the Iron Age, about 500 B. C. It is of interest to note that this last emergence in Scandinavia was not simply a differential uplift, but was accompanied by a submergence of the more southern coasts of Jutland. In an isobase map, Broegger has recently shown how the amount of uplift of the *Littorina* shoreline decreases towards the southwest, reaching zero along a line that crosses the Laaland peninsula through Nissumfjord, Jutland, and Falster. This zero line ("nullinien") seems not to have been a hinge line, limiting the area of crustal deformation, but rather a pivot line, separating a region which suffered uplift from one which, concomitantly, suffered depression.‡ As Scandinavia slowly rose, southern Laaland slowly sank. The downward movement southwest of the pivot line was much less pronounced than the upward movement near Christiania, amounting to a tilt of about one-third of a foot a mile, as against one and a half feet per mile in the latter district.

The period of 2400 years since the close of the Bronze Age is regarded as a period of approximate stability. Broegger

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* Op. cit., pp. 98-99, 283, 305-306.

† Broegger takes, as the basis for his chronology, the estimates of Montelius: Les temps prehistoriques en Suede. Paris, 1895, and Die Chronologie der aeltesten Bronzezeit im Nord Deutschland und Skandinavien. Braunschweig, 1900, p. 223.

‡ Op. cit., plate 12. Cf. De Geer, op. cit., p, 461.

takes the view that the final uplift of about 33 feet at Christiania was completed soon after the beginning of the Christian era, and that since that time the coast has been stationary.*

While the data on coastal movements gathered in Scandinavia, and the conclusions drawn from them are not necessarily a reliable guide to the interpretation of the observations in Canada, the similarity between these two regions, both as regards their geologic structure and their glacial history, makes the comparison of more than passing interest. Noting first the points of likeness, we find :

(*a*) In both regions the emergence of the coast seems to have begun while the ice was withdrawing from the seaboard, if not, indeed, somewhat before that time. In Scandinavia this is shown by the absence of the *Yoldia* clays inside the terminal moraine; in Canada, by the faint expression of the highest beach.

(*b*) In both regions the first emergence seems at length to have been followed by a temporary subsidence; and this, in turn, by a re-elevation. While the elevated positions of the shorelines record the respective upward movements, in each case, the conclusions regarding the downward movement is based, in Scandinavia, chiefly upon the occurrence of fossiliferous marine clays overlying those which hold the *Ancylus* fauna; in Canada, while finding support in the submerged forest beds along the coast, it rests mainly upon the physiographic character of the Micmac shoreline. So far as the writer has been able to discover, the Scandinavians have not used abnormal strength in a wave-cut terrace and sea-cliff as an argument for slow coastal subsidence.

(*c*) In Canada, as in Scandinavia, the vertical amount of subsidence must have been small. As we have seen (p. 305), the outer edge of the Micmac shelf, three miles from shore, is only 50 or 60 feet lower than the inner edge at the foot of the bluffs. A part of this depth is doubtless due to downward erosion on the shelf. It is not probable that the entire depth is to be attributed to the downward movement of the coast at that time, for it is hardly likely that subsidence would keep pace with the littoral planation so closely as to allow the development of a slope of equilibrium without downward erosion on the shelf. If, however, we assume that the coast did sink just fast enough to prevent downward erosion on the shelf while the waves were trimming back the cliffs, this movement of the coast amounted to 50 or 60 feet. While the Micmac terrace admits the possibility of a subsidence as great as that, it is much more probable that the downward movement here, as in Scandinavia, was a slight one, of perhaps 10 or 20 feet.

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* Op. cit., pp. 123, 125, and table and figure on p. 283.

The points wherein the conclusions of investigators in Scandinavia differ from those here reached for Canada are chiefly the following:

(*a*) In Scandinavia the uplifts are said to have been intermittent, allowing time for the waves to cut distinct terraces at a number of levels. This view is rather generally held by English writers for the coastal movements of Scotland, and is accepted, with some reservation, by Professor Daly as the condition in Labrador.* In southern Quebec the uplifts, except for the one conspicuous interruption, seem to have been steady and continuous, although changing perhaps in rate, as already noted.† While as Professor Daly has pointed out,‡ local variability in strength of the shorelines, due to local conditions of exposure, slope, and other factors, may so mask the features which should harmonize so as to destroy the evidences of spasmodic uplift, the facts thus far observed indicate rather that the uplift of the Lower Saint Lawrence region was not seriously interrupted until the Micmac stage. The variety of altitudes in river terraces in New England, and the raised beaches of the New England coast, so far as they have yet been studied, point, likewise, to the conclusion that the first great uplift was steady, not spasmodic.

(*b*) In Scandinavia the stage of post-glacial submergence, or "*Littorina* stage," occurred when only about five-sevenths of the total uplift had been accomplished. The later elevation, at Christiania, amounted to 200 feet. In Canada, if we take Quebec, with over 600 feet total post-glacial uplift, as comparable to Christiania, we find that the later elevation amounted to only 20 feet; that is to say, the Micmac stage occurred after about twenty-nine thirtieths of the uplift had taken place. The nearly horizontal position of the Micmac terrace, between Quebec and Matane, so far beneath the differentially upwarped Champlain beach, indicates that the subsidence, if there was one, came after this part of the region had nearly reached its present condition of relative (if not absolute) stability, unless the second elevation consisted in a tilt in a very different direction from the first one.

The observations and conclusions of the Scandinavian investigators suggest other points of similarity or dissimilarity between the movements there and those here, which invite careful study in the field. A few of these may now be mentioned.

(*a*) Was the emergence of the Micmac terrace, in the Saint Lawrence valley, accompanied by a concomitant subsidence of coasts farther south, as has been pointed out for the region

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* Op. cit., pp. 252-254.

† Pp. 7-8.

‡ Loc. cit.

south of the pivot line in Laaland (p. 313)? The supposed recent subsidence in eastern Massachusetts, as recorded in salt-marsh structure, suggests such a possibility.* Further study might even indicate that the underlying forest beds along the coast from Massachusetts to the Bay of Fundy are to be correlated with an uplift of the Saint Lawrence valley, instead of with a subsidence. Until the Micmac terrace is traced around the Gaspé peninsula, and southward towards the Bay of Fundy, presumably down to sea level, as Broegger has traced the *Littorina* shoreline, no satisfactory correlation of the submerged stumps and the salt-marsh structure with the coastal movements in southern Quebec can be made.

(*b*) What, movement, if any, is now taking place along the coast? In Scandinavia, as we have seen, Broegger concludes that neither uplift nor subsidence has occurred during the last 2400 years. The best evidences bearing upon this question appear at present to be contradictory. On the one hand, the peculiar structure of the salt marsh on the New England coast has been accepted by some as proof of a continuous downward movement of the coast since the underlying forest beds were first submerged, extending to the present time.† On the other hand, the fact that West Beach at Nantasket, whose age is estimated as probably 2000 or 3000 years and certainly not less than 2000 years, has a crestline altitude which accords with that of the modern beach behind which it lies, seems to show that for the last thousand years, at least, there has been no change of level in eastern Massachusetts.‡ The solution of this problem is closely connected with that of the behavior of the coast during the Micmac stage, since the same movement may have aided the waves to cut back the Micmac cliffs as drowned the forests or aided in the upward growth of the salt marshes. Other alleged evidences of modern costal movements, such as human testimony and change in altitude of bench marks with reference to mean sea level,§ are either contradictory or open to a different interpretation.

It might seem that the weak character of the modern beach, along the south side of the Lower Saint Lawrence, would indicate that the present movement, if any, is an emergence; because if there was a subsidence, wave action would be more

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* See papers cited above, by C. A. Davis. His mention, on p. 21 of Bulletin No. 376, U. S. Geological Survey, of the occurrence in some localities of salt-water peat below fresh-water peat, "indicating a slight uplift of the coast previous to the subsidence which is still in progress," suggests a counteroscillation on the Maine coast during the Micmac stage.

† Papers by C. A. Davis and H. H. Baldwin, already cited.

‡ D. W. Johnson and W. G. Reed, Jr. Op. cit., pp. 187–188.

§ R. A. Daly: op. cit., pp. 261–262, and J. W. Dawson: Acadian Geology, p. 31, and J. R. Freeman: Submergence of land and harbor bottom. Report of Commissioners on the Charles River Dam, at Boston, Mass., 1902.

effective than it actually is at the present time. This, however, is not a valid argument, because the waves are now working on the outer, flatter portion of the Micmac shelf. Even if this shelf is now slowly sinking, wave action will be seriously hindered by the shallow water, until, with continued coastal subsidence, the sea again stands as high as the foot of the old cliffs.

Conclusion.

The elevation of the Lower Saint Lawrence Valley from the sea to its present position appears to be divisible into three stages. The first stage consisted in a differential upwarping of the region. Beginning no later than the withdrawal of the ice from the estuary, the uplift continued without interruption until the original Champlain beach stood from about 170 feet above the sea at Matane to about 630 feet above the sea at Quebec. Toward the close of this stage, the rate of uplift probably decreased, until it ceased altogether. The second stage, marked by the great Micmac terrace and sea-cliff, may have been an interval of stability, in which case it lasted some 3,000 years. More probably it was a stage of slow subsidence, of shorter duration, in which cliff cutting was accelerated, although the vertical amount of subsidence was not great. This Micmac stage is tentatively referred to that stage when forests were submerged, along the coast of Acadia and New England. Following the development of the Micmac terrace and cliff, the coast of the Lower Saint Lawrence rose, evenly, and slowly, to its present position. With existing data it is impossible to tell whether this movement is still in progress, or has ceased, or has been followed by minor oscillations.

While these conclusions rest primarily upon evidence in Canada, and especially upon newly collected data from the Lower Saint Lawrence, they are supported in part by a comparison with the conclusions of Professor Broegger, Baron De Geer, and others who have investigated the raised beaches of Scandinavia. Although it is expected that the post-glacial movements in these two regions on opposite sides of the Atlantic will prove to be alike in all respects, as more accurate and exhaustive studies are made in Canada and New England, the recognition of the Micmac shoreline as a record of one—and apparently the only—pronounced interruption in the emergence of the coast, in southern Quebec, points to a closer similarity of movements in Scandinavia and in Canada than has heretofore been supposed.

Dartmouth College, Hanover, N. H.,
July, 1911.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *A Chemically Active Form of Nitrogen Produced by the Electric Discharge.*—R. J. STRUTT has observed a very remarkable effect upon pure nitrogen when it is subjected to the action of an electric discharge from a Leyden jar in an exhausted tube. It is thus caused to glow for some time after the discharge has been discontinued. This glowing nitrogen has a characteristic band spectrum with green, yellow and red bands. It was found that the change which gives rise to the after-glow is retarded by heating and accelerated by cooling. When the gas was passed through an electric field with the object of removing gaseous ions, the glow was unaffected. When the glowing gas was passed over a small pellet of ordinary phosphorus, a violent reaction occurred, accompanied by the absorption of some of the gas and the formation of red phosphorus. This reaction was used to determine the percentage of active nitrogen in the gas. In one experiment the phosphorus increased in weight by $15{\cdot}5^{mg}$ after the passage of 2540^{cc}, corresponding to the absorption of $12{\cdot}2^{cc}$ or 1/210th part of the gas. On contact with iodine the yellow glow is replaced by a magnificent bright blue flame giving a brilliant banded spectrum. Sulphur and arsenic when heated give faint blue and green flames respectively; selenium, antimony and carbon are without action. Hydrogen merely acts as a diluent, but oxygen destroys the glow without any new luminous effect. Compound substances when volatilized in the gas give rise to the corresponding band spectra, and in this way spectra of compounds which are unstable at the temperature of the Bunsen flame may be readily obtained. The modified nitrogen reacts with organic halogen compounds, setting free the halogen, and combining with carbon to form cyanogen, of which a brilliant spectrum is obtained during the reaction. Cyanogen is formed also when the gas acts upon acetylene. With nitric oxide it yields nitrogen peroxide and a green flame is produced giving a continuous spectrum. It is suggested that this reaction may be represented as

$$2NO + N = NO_2 + N_2.$$

Water and carbon dioxide have no action upon the glowing nitrogen. Ammonia, cupric oxide, and manganese dioxide destroy the glow.—*Jour. Chem. Soc.*, c. II, 483. H. L. W.

2. *Gravimetric Determination of Fluorine.*—G. STARCK has devised a new method for making this determination. The solution containing the fluorine is neutralized and a large excess of cold saturated solution of lead chloride is added, which precipi-

tates the compound PbFCl. For 0·1^g of NaF in 50^{cc} of solution the author uses 200^{cc} of the lead chloride. The liquid is allowed to stand over night, filtered with a Gooch crucible, washed with a nearly saturated lead chloride solution, then 2 or 3 times with water, and the precipitate is dried for 2 hours at 140–150°. The author has determined the solubility of the precipitate in water and several other solutions, including lead chloride solution. It is very sparingly soluble in the latter, much more soluble in water, and still more soluble in hydrochloric and acetic acids. The errors in 17 determinations of NaF by the above method were from +0·46 to –0·30 per cent. Less accurate results were obtained by dissolving the precipitate and determining the chlorine.—*Zeitschr. anorgan Chem.*, lxx, 173. H. L. W.

3. *Uranium Hexafluoride.*—The preparation of this compound, UF_6, is of considerable interest in connection with the valency of uranium, since no hexahalide of this element has been previously prepared. RUFF and HEINZELMANN have prepared it in three ways: By the action of fluorine upon uranium pentachloride in the absence of moisture, when it is obtained mixed with the tetrafluoride from which it is easily separated by volatilization. By the action of anhydrous hydrofluoric acid upon uranium pentachloride the same products as before are obtained, but in this case the very volatile hexafluoride cannot be satisfactorily separated from hydrofluoric acid. The third method consists in treating metallic uranium or the carbide with fluorine mixed with a little chlorine, where the latter gas acts as a catalyzer and causes the complete conversion into hexafluoride, while fluorine alone produces practically pure tetrafluoride.

Uranium hexafluoride forms pale yellowish crystals boiling at 56° C. and melting under a pressure of two atmospheres at 69·5°. It forms the heaviest known gas with a specific gravity of about 12 compared with air. It fumes strongly in the air and is highly reactive.—*Zeitschr. anorg. Chem.*, lxxii, 63. H. L. W.

4. *Nitrification by Ultra-violet Rays.*—BERTHELOT and GAUDECHON show that a solution of ammonia after being exposed to ultra-violet rays for a few hours in the presence of oxygen gives all the reactions for nitrites, but no nitrates could be detected. Nitrites were formed from ammonium carbonate, chloride and sulphate under similar conditions, but much more slowly in the two latter cases where the extent of hydrolysis is small. Nitrates are changed to nitrites by the action of the rays. There are many points of resemblance between the action of these rays and that of certain microörganisms.—*Comptes Rendus*, clii, 522.

H. L. W.

5. *An Electric Furnace for Chemical Purposes.*—FISCHER and TIEDE have described a furnace in which substances may be heated to a very high temperature, approaching 3000° C., in a vacuum by making use of a tube of metallic tungsten heated by a powerful electric current. They were able by means of this apparatus to distil considerable quantities of metallic tin in a

short time. The method will be doubtless serviceable for other purposes. The original article must be referred to for the details of construction and manipulation.—*Berichte*, xliv, 1717.

H. L. W.

6. *Aqua Regia.*—PRIWOZNIK has shown, as the result of numerous experiments, that the solution of gold in aqua regia takes place according to the equation: $Au + HNO_3 + 4HCl = H_2O + NO + HAuCl_4$, and the proportions corresponding to this equation are recommended as being the most economical for employment. —*Jour. Chem. Soc.*, c. II, 484. H. L. W.

II. GEOLOGY AND MINERALOGY.

1. *Publications of the United States Geological Survey.* GEORGE OTIS SMITH, Director.—Recent publications of the U. S. Geological Survey are noted in the following list (continued from p. 69).

FOLIOS.—Foxburg-Clarion Folio, Pennsylvania; by E. W. SHAW and M. J. MUNN. Pp. 17, 2 charts, 4 colored maps.

Burgettstown-Carnegie Folio (No. 177), Pennsylvania; by E. W. SHAW and M. J. MUNN. Pp. 16, 10 figures, 4 colored maps.

PROFESSIONAL PAPER 70.—The Mount McKinley Region, Alaska; by ALFRED H. BROOKS, with descriptions of the Igneous Rocks and of the Bonnifield and Kantishna Districts, by L. M. PRINDLE. Pp. 234, 18 plates, 30 figures.

MINERAL RESOURCES, Calendar Year 1909.—Part I, Metals. Pp. 616, 1 plate, 4 figures. Part II, Nonmetals. Pp. 942, 4 figures.—These volumes bring together in complete and permanent form the numerous advance chapters which have earlier been given to the public. A considerable number of the chapters from the report for 1910 have also been already issued.

BULLETINS.—No. 448. Geology and Mineral Resources of the Nizina District, Alaska; by FRED H. MOFFIT and STEPHEN R. CAPPS. Pp. 111, 12 plates, 11 figures.

No. 449. A Geologic Reconnaissance in Southeastern Seward Peninsula and the Norton Bay-Nulato Region, Alaska; by PHILIP S. SMITH and H. M. EAKIN. Pp. 146, 13 plates, 15 figures.

No. 450. Mineral Resources of the Llano-Burnet Region, Texas, with an Account of the Pre-Cambrian Geology; by SIDNEY PAIGE. Pp. 103, 5 plates, 22 figures.

No. 452. The Lander and Salt Creek Oil Fields, Wyoming. The Lander Oil Field, Fremont County; by E. G. WOODRUFF. The Salt Creek Oil Field, Natrona County; by C. H. WEGEMANN. Pp. 87, 12 plates, 1 figure.

No. 454. Coal, Oil, and Gas of the Foxburg Quadrangle, Pennsylvania; by EUGENE W. SHAW and MALCOLM J. MUNN. Pp. 85, 10 plates, 15 figures.

No. 455. Copper Deposit of the Appalachian States; by WALTER HARVEY WEED. Pp. 166, 32 figures.

Nos. 457, 458, 459, 461, 462, 463, 464, 468, 469, 473, 476, 477, 481, 482. Results of Spirit Leveling, R. B. Marshall, Chief Geographer, work done in coöperation with the respective states. No. 457, State of Washington, 1896–1910 incl. ; pp. 108, 1 plate. No. 458, Arkansas, Louisiana and Mississippi, 1896–1909 ; pp. 79, 1 plate. No. 459, Missouri, 1896–1909; pp. 48, 1 plate. No. 461, Michigan and Wisconsin, 1897–1909 ; pp. 64, 1 plate. No. 462, Oregon, 1896–1910 ; pp. 82, 1 plate. No. 463, Arizona, 1899–1909; pp. 74, 1 plate. No. 464, New Mexico, 1902–1909, pp. 53, 1 plate. No. 468, Texas, 1896–1910 ; pp. 133, 1 plate. No. 469, Texas, 1896–1910 ; pp. 133, 1 plate. No. 469, North Dakota, 1897–1910 ; pp. 23, 1 plate. No. 473, Kansas and Nebraska, 1896–1909 ; pp. 42, 1 plate. No. 476, Ohio, 1909, 1910 ; pp. 79, 1 plate. No. 477, West Virginia, 1909, 1910; pp. 54, 1 plate. No. 481, California, 1907–1910 ; pp. 115, 1 plate. No. 482, Montana, 1896–1910 ; pp. 154, 1 plate.

No. 470, B. C. D. G. K. Advance Chapters from Contributions to Economic Geology (Short Papers and Preliminary Reports), 1910. Part I.—Metals and Nonmetals except Fuels. B, Gold and Silver, pp. 122, 3 plates, 15 figures. C, Copper, pp. 44, 1 plate, 12 figures. D, Lead and Zinc, pp. 28, 4 figures. G, Structural Materials, pp. 131, 4 plates, 9 figures. K, Miscellaneous Nonmetallic Products, pp. 43, 6 figures.

No. 475. The Difference of Crude Petroleum through Fuller's Earth, with notes on its Geologic Significance ; by J. Elliott Gilpin and Oscar E. Bransky. Pp. 50, 7 figures.

Water-Supply Papers.—No. 256. Geology and Underground Waters of Southern Minnesota ; by C. W. Hall, O. E. Meinzer, and M. L. Fuller. Pp. 406, 18 plates, 9 figures.

Nos. 265, 267, 268. Surface Water Supply of the United States, 1909 ; prepared under the Direction of M. O. Leighton. No. 265. Part V. Hudson Bay and Upper Mississippi Basins ; by Robert Follansbee, A. H. Horton, and R. H. Bolster. Pp. 231, 4 plates. No. 267. Part VII. Lower Mississippi Basin ; by W. B. Freeman and R. H. Bolster. Pp. 99, 2 plates, 1 figure. No. 268. Part VIII. Western Gulf of Mexico ; by W. B. Freeman and R. H. Bolster. Pp. 107, 6 plates.

No. 273. Quality of the Water Supplies of Kansas ; by Horatio Newton Parker. With a preliminary Report on Stream Pollution by Mine Waters in Southeastern Kansas, by E. H. S. Bailey. Prepared in coöperation with the Kansas State Board of Health. Pp. 375, 1 plate, 1 figure.

No. 274. Some Stream Waters of the Western United States, with chapters on Sediment carried by the Rio Grande and the Industrial Application of Water Analysis ; by Herman Stabler. Pp. 188.

No. 277. Ground Water in Juab, Miller, and Iron Counties, Utah ; by Oscar E. Meinzer. In coöperation with the State of Utah. Pp. 162, 5 plates, 13 figures.

2. *Cambrian Faunas of China;* by CHARLES D. WALCOTT. Smithsonian Miscel. Coll., 57, No. 4, pp. 69–108, pls. 14–17, 1911.—Further collections of Middle Cambrian fossils were made for the author in Manchuria by Professor Iddings, enabling him to add extensively to our knowledge of the Chinese Cambrian. Walcott here gives a corrected list of the formerly described forms and adds 29 new species of brachiopods and trilobites. The new genera or subgenera of trilobites are *Emmrichella*, *Inouyia*, *Lisania*, *Chuangia*, *Levisia* and *Coosia*. C. S.

3. *Middle Cambrian Holothurians and Medusæ;* by CHARLES D. WALCOTT. Smithsonian Miscel. Coll., 57, No. 3, pp. 41–68, pls. 8–13, 1911.—Here are described more of the wonderfully preserved fossils discovered by the author in the Burgess shale, near Mt. Stephen, British Columbia. The new genus of Scyphomedusæ, *Peytoia*, preserves only the lobate ventral side.

The particularly interesting fossils are the holothurians with representatives of both of the living orders of this class of Echinoderma. These are the only fossil sea-cucumbers preserving the general body form, but none show even a trace of the spicules if they ever had such. The order Paractinopoda is represented by a new genus described as *Mackenzia*, that clearly has relationship with the living Synaptula. It is a finger-shaped sack about 70^{mm} long and is now devoid of tentacles, but the cast of the calcareous ring indicates that there were at least 10 and possibly as many as 15 tentacles originally present.

The order Actinopoda is represented by poorly preserved fossils of the new genera *Laggania* and *Louisella*, forms referred to the living family Holothuriidæ. The most complex fossil and one very difficult to interpret is the new genus *Eldonia*, said to be a pelagic holothurian. More than 200 specimens are at hand. At first it was thought to be a Scyphomedusa with a large internal commensal worm, but the latter is now regarded as the digestive tract of this bell-shaped animal. C. S.

4. *The Crinoid Fauna of the Knobstone Formation;* by FRANK SPRINGER. Proc. U. S. Nat. Mus., vol. 41, pp. 175–208, 1911.—The stratigraphic position of the Knobstone formation has long remained uncertain, and to settle this matter the author began some years ago to assemble material properly collected in Indiana, Kentucky and Tennessee. These collections produced 45 species of crinoids, which were then compared with the well-known faunas found about Burlington and Keokuk, Iowa, resulting in the adjustment of the difficulty. The author states that "the main fossiliferous beds of the Knob [Indiana and Kentucky], and the lower limestone above the Black Slate at Whites Creek [Tenn.], must be placed stratigraphically as equivalent in part or closely related to the Lower Burlington." There is no Keokuk present as was long believed to be the case. The Knobstone is now known as the New Providence formation, and while Bassler is inclined to place it directly beneath the Lower Burlington, he states that it "is a provisional arrangement, since

the close relations to the Lower Burlington are appreciated, and the possibility of their partial equivalence is recognized." Bassler's paper resulting from Springer's desires to adjust some of the Mississippian crinoidal mixtures is reviewed below. C. S.

5. *The Waverlyan Period of Tennessee;* by RAY S. BASSLER. Proc. U. S. Nat. Mus., vol. 41, pp. 209–224, 1911.—This important paper describes the Subcarboniferous strata on either side of the Nashville dome and correlates them with those of Ohio and the Mississippi valley south of St. Louis. The period term Waverlyan is substituted for Mississippian on the ground of supposed priority, but the author also states that this term was not defined until 1869, the same year in which Alexander Winchell proposed Mississippi Group. It was Williams who in 1880 revived the latter term to cover all the American strata between the Devonian and the Pennsylvanian. As thus used the term is now thought to include two periods or disastrophic cycles, and accordingly Schuchert intended to preserve this well-known period name for the lower half, the strata with which Winchell was working.

The Waverlyan period is again divided into three series, two of which are named Osagian and Kinderhookian. The last named series is in Tennessee, represented by the Ridgetop formation (new), to which the term Hickman was apparently applied many years ago by Alexander Winchell. C. S.

6. *Die vulcanischen Erscheinungen der Erde;* von DR. KARL SCHNEIDER. Pp. viii, 272; with 50 figures. Berlin, 1911 (Gebrüder Borntraeger).—This volume gives an excellent summation of volcanic phenomena, its purpose being to enlarge on facts rather than theories and to treat superficial igneous activity to the exclusion of those of intrusive nature. The author notes in the introduction that the subject of volcanism has passed through a certain degree of stagnation during the past decade, as the center of interest in igneous activity has passed to the underground. This volume covers, therefore, a somewhat neglected field. Nine chapters are given to the subject, of which those of most timely interest are, perhaps, the nature of volcanism, the larger forms of the moon's surface, the development of the volcanic phenomena of the earth in different phases during the Cenozoic, the genetic system of volcanic construction, the geographic distribution of volcanoes of the present, and a catalogue of volcanoes which have erupted within historic times. The volume is thus seen to form a valuable reference book for the geologist whose interests may touch this field of knowledge. J. B.

7. *On some Mineral Constituents of a Dusty Atmosphere;* by W. N. HARTLEY.—The above subject is exhaustively treated by W. N. Hartley in a paper read before the Royal Society of London on May 11. By means of a small portable quartz spectrograph several series of spark spectra were photographed with graduated exposures of 1, 5, 10, 20, 40, and 60 seconds, all on the same plate. The electrodes in the first series were cadmium, iron,

nickel, and copper, a self-induction coil being interposed to eliminate the air spectrum and the short metallic lines. * * Of seven plates of spectra photographed in the months of April and May two were very carefully measured with the micrometer. Twenty-two lines were positively identified with those of elements known to be contained in atmospheric dust. The lines are principally the ultimate lines of the respective elements, viz. of calcium, lead, carbon, iron, manganese, nickel, copper, magnesium. The calcium lines were prominent and the presence of calcium carbonate in very minute particles of dust suspended in the air was definitely proven. Copper was also prominent and its prevalence in the dust was accounted for by the repeated flashes on the overhead cable, which is in the center of a wide street (St. Stephen's Green) at a distance of 54 feet from the window of the room in which the experiments were made. The condensation of the vapor of copper after each discharge would yield a dust of extreme tenuity such as could not arise from mechanical action.

The author adds that "Determinations of the weight of material necessary to give the lines of these spectra in the manner described, and with such short exposures, have been completed. From the loss of weight of the dry electrodes by the passage of the spark during successive intervals of 10 minutes, the weight of metallic calcium volatalized in one minute, and in one second, was calculated. The number of spark discharges per second was accurately determined, and likewise the number of discharges necessary to render the lines of calcium, as photographed from atmospheric dust, with an exposure 60 seconds. Similarly with copper, the number of discharges necessary to render the *ultimate* line and the two lines respectively, as measured on plates exposed to atmospheric dust for one second and for five seconds, was ascertained, and the weight of copper volatilized at each spark discharge was accurately determined. It was found that, in order to render the five principal lines in the spectrum of calcium, the weight of the metal passing between the electrodes in 60 seconds was from 0·0001 to 0·00014 mgrm., or, as calcium carbonate, from 0·00025 to 0·00035 mgrm. Similarly, the quantity of copper which passed between the electrodes in one second was from 0·0005 to 0·0007 mgrm., and in five seconds from 0·001 to 0·0014 mgrm. These quantities yield the spectra photographed, and the proportion of copper in the dust thus appears to be 10 times as great as that of the calcium.

"Both the calcium and copper reactions in the spark are more delicate than the sodium test by the yellow flame, or even by the photography of the *ultimate* lines of sodium in the oxyhydrogen flame and spark. Metallic sodium renders no lines with one spark when photographed, and with five sparks the lines λ 3301·1 and λ 3302·5 are both stronger than the yellow lines (mean λ 5893·2). These lines do not appear on any of the cadmium plates.

"The reactions of lead, manganese, and magnesium in the spark are much more sensitive than those of sodium, calcium, or copper.

For instance, 0·00003 mgrm. of manganese is volatilized by one spark discharge, and yields a spectrum with the following *ultimate group* of lines: 2940·3, 2939·4, and 2933·1.

As no atmosphere is free from dust, and that of cities is particularly dusty, these mineral constituents must be regarded as possible reagents in cases where there is evidence that very minute quantities of basic substances can initiate chemical reactions and isodynamic changes, such as have generally been considered as spontaneous, and in all cases where a solution in contact with air is liable to be affected."

8. *Crystallography and Practical Crystal Measurement;* by A. E. H. TUTTON. Pp. xiv, 946, with 720 figures, and 3 plates. London, 1911 (Macmillan & Co. Ltd.).—The student of crystallography, desirous of making himself familiar not only with the theoretical facts and principles but also with the practical methods of studying crystals, morphologically and physically, will find in the present volume a most satisfactory guide. It begins with a discussion of the preparation and collection of crystals, and then, before taking up the questions of symmetry and form, deals with the goniometer, so as to make the student acquainted at once with a method of handling and studying crystal forms. From this starting point practical examples are given under each system of the treatment of a typical case, carried out in all necessary fullness of detail. Under the triclinic system, for example, copper sulphate is taken, and the successive steps detailed from the measurement of the angles in the different zones to the calculation of the axial ratio and the description of the individual faces. The drawing of crystals is treated in the same clear, minute way.

The second part of the work is devoted to the physical side of the subject, and here also we have all necessary theoretical discussions coupled with full explanations as to the successive methods of experiment called for. The illustrations in the volume are particularly satisfactory, having been drawn by the author expressly for this work. The interference figures are represented in black and white in a series of plates made from excellent photographs, and throughout the mechanical execution of the work is up to the high standard of the subject matter.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Mendelism;* by R. C. PUNNETT. Third edition, entirely rewritten and much enlarged. Pp. xiv, 192, with colored plates and diagrams. New York, 1911 (The Macmillan Company).—The general recognition of the wide applicability of Mendel's discoveries has given a great impetus to the experimental breeding of plants and animals during the past decade. The wonderful results which have come from these experiments have so far changed the earlier conceptions of the nature of the hered-

itary processes, that the scientific breeder of to-day has come to look upon a given plant or animal as the result of a definite combination of heritable physiological factors. The visible characteristics of the body give little clue as to what these heritable factors may be. How these factors are determined, and how the offspring from two parents may appear perfectly similar and yet contain vastly different heritable factors, are clearly explained in this interesting little book.

The bearing of the Mendelian doctrine on the previously widely accepted theories of heredity, variation, and evolution, is fully discussed. The prevalent view that characters acquired by the body from its very beginning as a fertilized egg are in no case capable of transmission to offspring, is well supported by the very recent discoveries. The organism transmits only those characters which it has received from the germ cells from which it has originated, and each germ cell is capable of bearing only one of two contrasted characters, such as difference in color, stature, or other physical or physiological property.

The entire rewriting of the new edition was necessitated by the rapid growth of the new branch of science with which it deals. The usefulness of the earlier editions should assure a wide appreciation of the present volume. W. R. C.

2. *Plant-Animals: A study in Symbiosis*; by FREDERICK KEEBLE. Pp. 163, illustrated. Cambridge, 1910 (University Press).—This little volume, one of the Cambridge Manuals of Science and Literature, consists of a most interesting account, in popular language, of the natural history of the minute Turbellarian worms, belonging to the genus *Convoluta*. These worms are peculiar in that they can live only when infested with an alga which lives simbiotically within their cells. The structure of both symbionts is described, and the significance of the symbiotic relations explained. W. R. C.

3. *Allgemeine Vererbungslehre*; von VALENTIN HAECKER. Pp. x, 392, with 135 figures and 4 colored plates. Braunschweig, 1911 (Friedr. Vieweg & Sohn).—This book is based upon the university lectures of one of the foremost German authorities on the subject of heredity.

After a general discussion of the chemical and physical properties of the cell, and their relation to the phenomena of life, growth, cellular differentiation, sexual differentiation, and reproduction, the various theories of inheritance are reviewed in their relation to the cytological phenomena. The theories of variation, natural selection, and evolution are taken up historically, and examined critically in the light of the more recent discoveries.

The Mendelian doctrine is naturally given particular emphasis, and the close agreement is shown between the segregation of characters, the purity of the germ cells, and other Mendelian phenomena, and the visible processes which take place in the cell.

In the discussion of topics about which there is still a difference of opinion among scientists the author is careful to do justice to both sides of the question. The subject is presented fully and clearly, in a manner characteristic of the lectures at a German university. W. R. C.

4. *Publications of the Carnegie Institution of Washington.*—Recent publications of the Carnegie Institution are noted in the following list (continued from p. 81).

No. 74. The Vulgate Version of the Arthurian Romances, edited from manuscripts in the British Museum; by H. Oskar Sommer. Volume IV. Le Livre de Lancelot del Lac. Part II. Pp. 399.

No. 139. Guayule (*Parthenium Argentatum* Gray): A Rubber-Plant of the Chihuahuan Desert; by Francis E. Lloyd. Pp. viii, 313, 46 plates.

No. 148. Calendar of Papers in Washington Archives relating to the Territories of the United States (to 1873); by David W. Parker. Pp. 476.

No. 149. The Production of Elliptic Interferences in Relation to Interferometry; by Carl Barus. Pp. vi, 77.

No. 154. Beach-la Mar. The Jargon or Trade speech of the Western Pacific; by William Churchill. Pp. 54.

No. 156. Feeding Experiments with Isolated Food-Substances; by Thomas B. Osborne and Lafayette B. Mendel with the coöperation of Edna L. Ferry. Pp. 53.

5. *Publications of the Harvard College Observatory;* by Edward C. Pickering, Director.—Recent publications are noted in the following list (continued from vol xxxi, p. 581):

Annals.—Vol. LVI, No. 5. Classification of 1688 Southern Stars by means of their Spectra; by Annie J. Cannon. Pp. 115–164.

Vol. LXIV, No. 7. Observations with the Meridian Photometer during the years 1907 and 1908. Pp. 191–199.

Vol. LIX, No. 7. Photographic Observations of Occultations; by Edward S. King. Pp. 187–203, 2 plates.

Vol. LIX, No. 8. Transformation of Prismatic to Normal Spectra; by Edward S. King. Pp. 205–222, 2 figures.

Vol. LXVIII. Part II. Observations and Investigations made at the Blue Hill Meteorological Observatory, in the years 1906, 1907, and 1908, under the direction of A. Lawrence Rotch. Pp, 97–229.

Circulars.—No. 164. Nova Sagittarii, No. 4. Five New Variable Stars; by Edward C. Pickering. Pp. 3.

No. 165. Three New Variable Stars in Harvard Map, No. 22; by Edward C. Pickering. Pp. 4.

No. 166. Coöperation in Observing Variable Stars; by Edward C. Pickering. Pp. 7.

6. *United States Naval Observatory.*—The following volumes have been recently issued: Second Series. Volume VI, Contain-

ing Equatorial Observations, 1893–1907, pp. lxvii, 388. Also Appendix I. Miscellaneous Astronomical Papers; by Members of the Naval Observatory Staff; pp. 152. Appendix II. Miscellaneous Reports on the Transit of Mercury of November 10, 1894; pp. 43. Appendix III. List of Publications issued by the U. S. Naval Observatory, 1845–1908, by WM. D. HORIGAN, Librarian; pp. 36.

Volume VII. Pp. xlvii, 558. Catalogue of 23521 Stars between 13° 35′ and 45° 25 South declination for the Equinox 1850; from zone observations made at the U. S. Naval Observatory, 1846–1852. Compiled by W. S. Eichelberger and F. B. Littell.

7. *Publications of the Allegheny Observatory of the University of Pittsburgh.*—The following have recently been issued: Volume II. No. 11. On the Photographic Spectrum of β Lyræ; by R. H. CURTISS; pp. 73–120. No. 12. The Radial Velocities of Twenty-six Stars; by FRANK C. JORDAN; pp. 121–124. No. 13. On the Radial Velocity of R Lyræ; by ZACCHEUS DANIEL; pp. 125–26.

8. *British Association for the Advancement of Science.*—The annual meeting of the British Association was held at Portsmouth during the first week of September. Sir William Ramsay was President, and his address on the ancient and modern views regarding the chemical elements was full of interest. The meeting of 1912 will be held at Dundee, with Professor E. A. Schäfer as President, and that of 1913 at Birmingham.

9. *Annual Report of the Board of Scientific Advice for India for the Year 1909, 1910.* Pp. 210. Calcutta, 1911.—The Board of Scientific Advice for India includes, in addition to the President, Hon. E. D. Maclagan, Secretary to the Government, ten gentlemen who are the respective heads of the prominent scientific departments of the country, as the Superintendents of the Museum and of the Trigonometrical Surveys, the Inspector-Generals of Agriculture and of Forests, the Directors of the Geological and of the Botanical Surveys, etc. This volume gives an interesting account in very concise form of the results accomplished in the many lines of scientific work carried forward by the Indian Government during the year.

10. *Seismological Society of America.*—Number 2 of the Bulletin of the Seismological Society has been issued containing a series of papers, among which may be mentioned: Surface measurements of earthquake displacement, by Alexander McAdie; Measurements of earthquake monuments, by B. A. Baird; Relations of surface geology to intensity, by J. C. Branner; The earthquake of Southeastern Maine (March 21, 1904), by Harry Fielding Reid; The observation of earthquakes, by H. O. Wood; Shocks recorded at Ann Arbor during 1910, by W. J. Hussey; A boundary line deflection, by R. B. Symington.

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SCIENTIFIC INTELLIGENCE.

VOL. XXXII. NOVEMBER, 1911.

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FOURTH SERIES

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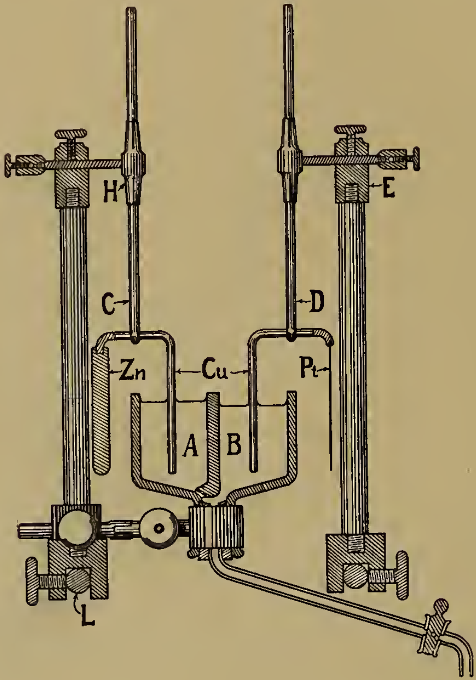
Art. XXXVI.—*Several Lecture Experiments in Elementary Physics;* by D. Albert Kreider.

Believing that it may prove of service to other teachers of the subject, the author has been persuaded to put into print the following description of some apparatus and experiments which have been yielding gratifying results for a number of years. It represents, in part, a development here which is the result of continuous effort to simplify and to expedite experimental demonstrations; to enable the student, as well as the demonstrator, to see distinctly all details of both the manipulation and the result of experiments; and primarily, wherever possible, to provide for the student's personal observation of all numerical readings.

1. A Projection Cell.—With the projection cell and its equipment, illustrated in figure 1, a few minutes suffice to demonstrate the essential construction, the chemical action and the voltage of several types of cells, and all of the methods of depolarization. The cell shown was originally cut from a commercial four-ounce bottle of rectangular section and has proved sufficiently satisfactory to be continued in service ever since. A bottle, when free from conspicuous defects, avoids the annoyance of leaky cells and, despite considerable irregularities in the thickness of the glass, affords projections which are perfectly distinct. The porous partition between the compartments A and B of the cell was cut from a chemist's unglazed porcelain drying dish; the flange on which the plate normally rested serving to close off half of the neck of the bottle. It was joined to the glass by a paraffin seal, with precautions against excessive clogging of the pores. A glass tube, provided with a stopcock and long enough to clear the side of the projection lantern, was attached to the neck of the bottle by a rubber stopper. The cell was held in proper position by means of a clamp attached to the neck of the bottle and to the side of the lantern.

A variety of readily changeable electrodes is provided by the construction shown at C and D. The anode, C, is formed of a No. 12 copper wire soldered to a rod of zinc; the combination being bent into the form of an inverted U and attached to the end of a brass rod about 3^{mm} in diameter. A similar construction characterizes the cathode D; in which a strip of platinum, 0·5 by 6^{cm}, and sufficiently stiff to be readily handled, takes the place of the zinc of the anode. The brass rods of these electrodes slide through the split brass bushings, H. The latter are attached to one end of a brass rod, the other end of which carries a binding post, and are supported by the lantern rods, L, by means of iron rods and the ebonite insulators, E.

Fig. 1.



It will be seen that by simply raising C or D sufficiently to clear the sides of the cell and then rotating them through 180°, a change of either electrode is promptly effected without any disturbance of the electrical connections.

Very satisfactory results may be obtained with any galvanometer whose indications can be read by the class. Originally we used one of the Max Kohl type, shunted with a variable but low resistance, by means of which adjustment could be made for a suitable range of deflections for the different cells, without reducing the current through the cell to a magnitude which would be unfavorable to the development of the phenomena of polarization. A voltmeter connected in parallel with the galvanometer circuit, while not essential to the experiment, makes it much more complete. For the past two years we have had the advantage of an admirable wall voltmeter, which has a large illuminated scale, neatly executed after our own design by the Weston Instrument Company. It is easily legible from all parts of the lecture room ; and distinctly shows the constant voltage of the Daniell and Grove types of cells by the instantaneous return to the original reading on open circuit, as well as a pronounced effect of mechanical depolarization in the simple cell.

With both of the compartments of the cell, A and B, filled with dilute sulphuric acid and using the two copper electrodes, the class observes that there is neither current nor difference of potential. Changing the anode from copper to the amalgamated zinc results in a pressure of about 0·8 of a volt, and on closing the galvanometer circuit a considerable current is indicated. The rapid decrease of the deflection, with the simultaneous accumulation of hydrogen on the cathode, both being visible to the class, clearly shows the cause and the effect of polarization. On opening the galvanometer circuit the voltage is found to be lower than the original. Flicking the cathode with one's finger sends the bubbles of gas scurrying through the liquid, which is accompanied by an increased deflection, illustrating a mechanical depolarization. The latter effect is the more noticeable on the voltmeter with the galvanometer circuit open.

After drawing off the contents of B, that compartment is refilled with concentrated copper sulphate solution, which is conveniently accomplished by the aid of a small flask with a long neck. The Daniell cell thus formed shows the unit voltage and the galvanometer indicates an appreciably greater and constant current. No gas appears ; but the class plainly sees a change in the vicinity of the cathode, made obvious by absorption and refraction effects, which is evidence of the action of which he has previously had an explanation.*

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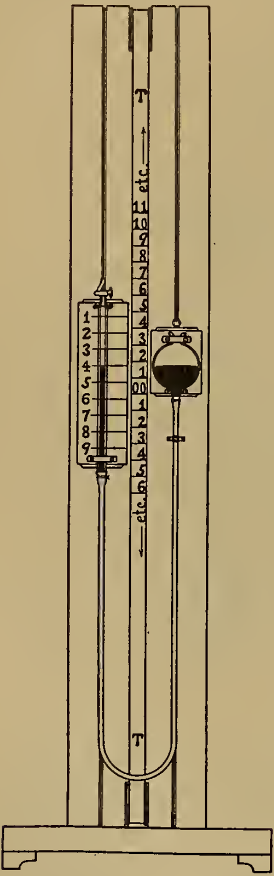
* Our general plan has been to have the discussions of principles, including blackboard sketches, etc., precede the experimental demonstrations which are distributed through all of the exercises of the week. The arrangement may appear wasteful of both time and energy ; on the other hand. it has the great advantage of presenting the experiment at the moment when it is most intelligible and significant.

To illustrate the Grove cell, as a type of the oxidizing depolarizers, the copper sulphate is withdrawn and washed out with a little water—all of which proves of interest to the observer. The platinum cathode is then inserted in place of the copper and some concentrated nitric acid is poured into B; whereupon the galvanometer deflection is still greater and again remains constant. It is interesting to show that both in the Daniell and in the Grove cell the voltmeter instantly returns to its original reading when the galvanometer circuit is opened. If the action goes on long enough in the Grove cell, bubbles again appear: but the difference from hydrogen is obvious both from the lack of the large back EMF and from chemical tests that may be applied.

A similar cell, without the porous partition, but with corresponding interchangeable electrodes, of which each has a platinum, a lead and a copper terminal, serves to illustrate a variety of electrolytic effects, including the principle of the storage cell. These electrodes may of course be made with four terminals each, instead of two, to answer for both purposes. But it is rather more satisfactory to have two sets of electrodes to fit the same holders, H.

Fig. 2.



2. *Boyle's Law Apparatus.*—For lecture room demonstrations the old shepherd's-crook apparatus is of little more value than a blackboard demonstration. Several features of the following piece of apparatus have made its use here most satisfactory. The manipulation is so simple and obvious and the results so direct as to enable each student, even those in the more remote parts of the room, to make his own readings and verifications of the law. So little time is required for the manipulation that the number of experiments may be multiplied and extended over different ranges, which affords the student a more satisfactory demonstration and simultaneously an excellent mental drill.

The volume tube is about 25^{cm} long, of uniform internal diameter—about 8^{mm}—and rather thick-walled for purposes of magnification. A stopcock is sealed to the upper end, which with good stopcock grease is easily made perfectly tight. The lower end is adapted to receive a heavy walled compression tube of rubber. The glass tube is mounted on a block of wood which is painted a good dead-white with horizontal dead-black lines about 2^{mm} wide and one inch on centers. These lines were numbered as shown. In attaching the volume tube to the block thus painted, allowance was of course made for the constriction at the stopcock, so that the graduations should represent equal volumes. The reservoir was laid into another block of wood which was also painted a dead-white. Both of these blocks were provided with tongues which matched vertical grooves in the standard, serving as guides. Endless cords, carrying iron counterpoises which hang back of the standard and are, therefore, not shown, supported both blocks with their mountings. This arrangement permits of easy and prompt adjustment of pressures greater or less than the atmosphere and, providing the cords run in smoothly rounded grooves at the top, rather than in pulleys as they do at the bottom, sufficient friction is obtained to hold the reservoir and tube in any desired relative position without the necessity of clamps. A pinchcock on the rubber connecting tube, so adjusted as to damp the oscillations of the mercury, facilitates the adjustments.

T is a white, endless tape, one inch wide, on which an inch scale was painted. It was found convenient to extend this scale in both directions from zero, as shown. The tape runs over wooden pulleys at the top and bottom of the standard, by which it is also held flush with the faces of the blocks on which the volume tube and reservoir are mounted.

One of the chief difficulties in this and similar apparatus is to secure scales sufficiently distinct to be read at a distance. The size of the figures, within obvious limits, is of relatively less importance than the provision of ample space between the figures and between parts of the figures. Where the figures are necessarily limited in size, a very satisfactory scale, legible to the normal eye at a distance of forty feet, can be made of figures about 2^{cm} in height and 3^{mm} width of stroke in dead-black on a dead-white surface; providing at least the same width, 3^{mm}, of white space is retained between all parts of the figures as well as between the separate figures.

To illustrate the convenience and the clearness of the demonstration by this apparatus, suppose the level of the mercury in both limbs to have been brought to 4 on the scale of the volume tube before closing the stopcock. The barometer then indicates the pressure under which this known volume of gas exists; and there is no mystery as to how the gas got there or how the equilibrium condition was ever practically attained, which were two unprofitable difficulties presented to the thoughtful student by the older apparatus. The class is then asked to calculate the position of the mercury surface in the reservoir when it is so moved as to reduce the volume of gas to (say) 3. They assume that $V \propto \frac{1}{P}$; and since $V_2 = \frac{3}{4} V_1$, $P_2 = \frac{4}{3} P_1 = \frac{1}{3}$ in excess of the barometer $= 10'' + \text{Bar}$. The adjustment is then made and the zero of the tape is moved into alignment with the nearest mercury surface, which is seen to be 10 inches from the other. After one such demonstration most of the class will promptly answer for the cases when $V_2 = 5, 2, 6$ or 8, in all of which the numerical work is so simple, when the barometer is 30 inches, as to be easily and promptly handled mentally. For the purposes of a lecture demonstration a barometer of 30 inches may be assumed without trouble in the experiment, except on the rare occasions when the atmospheric pressure departs greatly from the normal. It has the great advantage of simplifying the numerical work and, when followed by problems which are sufficiently varied, no harm is done. While the class is making its mental calculation the desired adjustments may be made, without prejudicing the results, providing the tape is meanwhile kept in motion or turned with its printed side back. The experiment can of course be varied by starting with any volume and pressure and with a fixed scale, as with any other apparatus.

Sloane Physical Laboratory,
Yale University,
Aug. 10, 1911.

ART. XXXVII.—*The Faunal Succession in the Port Clarence Limestone, Alaska*;* by EDWARD M. KINDLE.

Introduction.—The faunas under discussion in this paper represent the nearest geographic approach of American fossil faunas to those of Asia. The limestones holding them are typically developed in the western part of the Seward Peninsula, which extends westward to within 60 miles of eastern Asia. Reconnaissance surveys which were begun by Brooks and Shrader in 1899, and continued by various members of the Alaskan Division of the U. S. Geological Survey, furnished in 1908 a preliminary geological map of the major portion of the Seward Peninsula.† P. S. Smith‡ has recently published a summary of the geology of the Peninsula and a general map showing the geology of a considerable area to the eastward of that covered by the earlier map. The only beds which have yielded well-preserved fossils in the Seward Peninsula are included in a single cartographic unit called the Port Clarence limestone on the map published in 1908. A portion of this map is here reproduced. (See fig. 1.)

The writer's field work was confined almost entirely to the limestones which have been referred to the Port Clarence. Nearly all the other sedimentary beds in this region have undergone severe metamorphism. The collections which were made from these limestones in different parts of the Peninsula demonstrate the composite character of the beds which have been referred to this formation. The beds which have been mapped as Port Clarence limestone include horizons ranging in age from Cambrian to Devonian or Carboniferous. The determination of the thicknesses and relationships of the several terranes which have been included under the name of the Port Clarence limestone, must await the completion of much detailed work on the stratigraphy and faunas of the region. The present paper will attempt to give only the order of succession and correlation of the several faunas which are known in it, and preliminary lists of the species represented.

The material representing the various horizons varies considerably in quality and completeness. The younger of these faunas are very imperfectly known owing to the metamorph-

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* Published with the permission of the Director of the U. S. Geological Survey.

† Collier, Hess, Smith and Brooks, The gold placers of parts of the Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 328, pls. X-XI, pp. 61-110, 1908.

‡ Smith, P. S., Geology and mineral resources of the Solomon and Cassadapaga quadrangles, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 433, pp. 19–30, pl. II, 1910.

ism of the beds containing them. These later terranes have furnished sufficient material, however, to correlate the rocks of certain localities definitely with the Carboniferous and Silurian faunas in other parts of Alaska where the faunas are well pre-

FIG. 1.

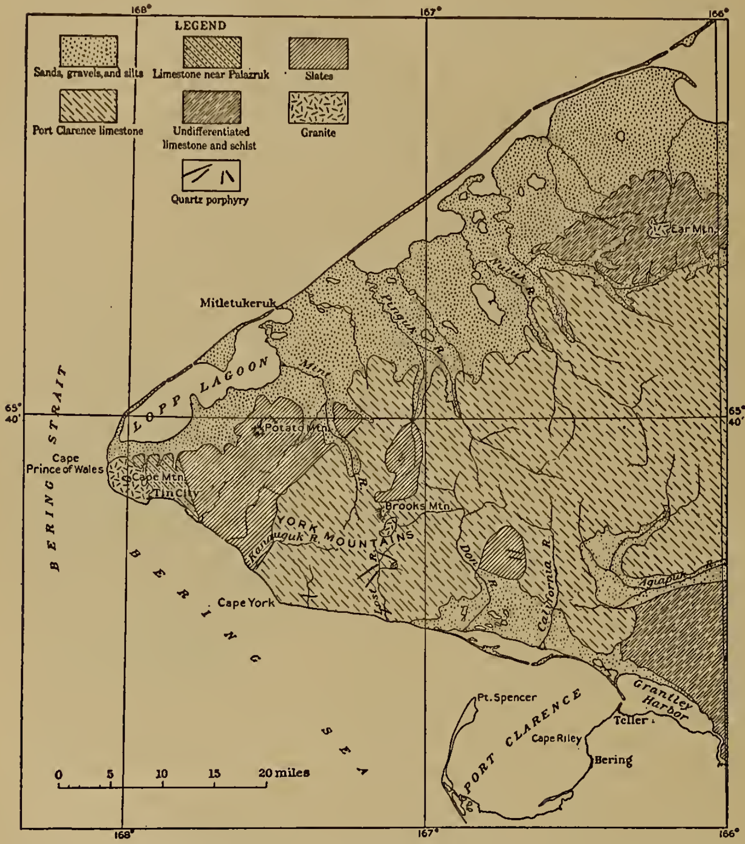

FIG. 1. Geologic sketch map of the western part of the Seward Peninsula showing the type region of the Port Clarence limestone. (After Brooks, Knopf, and others.)

served and well known. In the case of the Ordovician fauna the collections have afforded excellent material, representing not only better fossils but a much larger fauna than has been obtained elsewhere in Alaska from rocks of this age. The Cambrian fauna is also represented by well preserved shells. It includes, however, a rather small number of species which are represented by great numbers of individuals. Since the

Cambrian fauna has not previously been found in Alaska, its occurrence here is of unusual interest.

Areal distribution and general relations of the Port Clarence.—A limestone series of considerable thickness, known as the Port Clarence limestone, covers an extensive area in the western part of the Seward Peninsula. This formation includes the oldest rocks in the Peninsula whose age has been determined by paleontologic evidence. It appears that metamorphism has affected the area of the York Mountains in which these rocks occur less than any other part of the Seward Peninsula (see map fig. 1). As a result of the slight alterations which they have suffered we have a more complete knowledge of the faunas of these rocks than we have of any other portion of the geologic column in the Seward Peninsula. The type locality of the Port Clarence limestone is in the western part of the Peninsula, in the York Mountains north of Port Clarence harbor. Collier* applied the name to the limestones from which the York Mountains have been carved. According to Collier's original description,—

"This formation comprises a thickness of at least 2,000 feet of almost pure limestone. The basal beds are flaggy and slightly schistose, but the strata become more massive in ascending the series."† Collier's later provisional estimate which gives this limestone series a thickness of "at least 5,000 feet"‡ seems more likely to prove an underestimate than an overestimate of their thickness. These limestones are in general thin-bedded, as shown in figure 1, usually non-magnesian, and are prevailingly bluish or dark gray in color. They occupy an area of about 1,400 square miles in the York Mountain region. On the west the limestones terminate abruptly against a broad belt of argillites composed mainly of black slates but including greenstones, sandstones and limestones, whose relative abundance is in about the order named. (See fig. 1.) Widely divergent opinions have been held regarding the relationship of the limestones and the argillite series by geologists who have worked in this region. Brooks§ placed the slate or argillite series below the limestone series which were later called Port Clarence limestone. Hess‖ considered the black shale series to be probably younger than the Port Clarence. Collier¶ and Knopf** on the other hand agree that the slates are older

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* Prof. Paper U. S. Geol. Survey, No. 2, p. 18, 1902.

† Op. cit., p. 19.

‡ Bull. U. S. Geol. Survey, No. 328, p. 73, 1908.

§ Brooks and Shrader, Reconnaissance of the Cape Nome and Norton Bay regions, Alaska, in 1900; A special publication of the U. S. Geol. Survey, p. 30. 1901.

‖ Bull. U. S. Geol. Survey, No. 284, p. 14, 1906.

¶ Prof. Paper U. S. Geol. Survey, No. 2, p. 18, 1902.

** Bull. U. S. Geol. Survey, No. 358, pp. 12–13, 1908.

than the limestones but disagree as to the character of the contact between the two series. Collier* at first believed the two terranes to be unconformable but later found evidence of faulting at the contact, while Knopf† reports a transition zone into the slates at the base of the Port Clarence. An explanation of the relationship of the two terranes which seems to require more careful consideration than has been given it, is that of faulting. Conclusive evidence regarding the order of succession of these beds apparently must await the discovery of fossils in the black slates.

Fig. 2.

Fig. 2. Typical view of the Port Clarence limestone near Cape York.

On the eastward the limestone of the type region of the Port Clarence is limited areally by a series comprising slates, schists, greenstones and undifferentiated limestones. This series is supposed by the geologists,‡ who have mapped this area, to precede the Port Clarence limestone in this section. Two small areas of noncalcareous rocks, mostly slates, lie like islands in the midst of the Port Clarence limestone area. One

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* Prof. Paper U. S. Geol. Survey, No. 2, p. 18, 1902. Bull. U. S. Geol. Survey, No. 328, p. 72, 1908.

† Bull. U. S. Geol. Survey, No. 358, p. 13, 1908.

‡ Bull. U. S. Geol. Survey, No. 328, pp. 69–79, 1908.

of these lies between the Don and California Rivers, and the other extends northward from Brooks Mountain. (See fig. 1.) Both of these have been correlated, without,* however, any conclusive evidence of their identity, with the slate series lying west of the Port Clarence limestone. Knopf's contribution to the question of the order of succession of these slates and the Port Clarence limestone, is the statement that they are connected by a transition zone in which the "limestones of the Port Clarence formation merge imperceptibly into members of the slates,"† and that their present order of superposition in the vicinity of Brooks Mountain represents their original order. A small collection of fossils presented to the writer by Mr. Peter Esch of Nome, Alaska, is of interest in this connection. Mr. Esch states that these fossils were collected by him on the southeast slope of Brooks Mountain between 1,000 and 2,000 feet above sea level. Dr. T. W. Stanton has furnished the following report on this collection :

"The fossils (No. 5654) include the following species : *Daonella* sp. related to *D. lomelli* Wissmann, *Ceratites* (*Gymnotoceras*) sp.

These are characteristic Triassic fossils and probably came from the Middle Triassic. The collection is interesting from the fact that it affords the first evidence of the existence of Triassic rocks in that part of Alaska."‡

If these fossils were found at Brooks Mountain as the collector reports, the black slates in the vicinity of Brooks Mountain are, in part at least, of Triassic age and Triassic sediments are present in the Seward Peninsula as at Cape Thompson, 125 miles to the northward, where the writer has found a Triassic fauna following the Carboniferous limestones.§

From the type region of the Port Clarence in the York Mountains its correlation has been extended to various limestone masses elsewhere in the Seward Peninsula on the basis either of poorly preserved fossils or of stratigraphic methods. In most cases the limestone areas outside the York Mountain district are altered by metamorphism to such an extent as to afford no paleontologic evidence which will either confirm or disprove the correlation which has been made. In one of these metamorphosed areas in the southern part of the Peninsula, Mr. P. S. Smith‖ has begun the work of resolving

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* Bull. U. S. Geol. Survey, No. 328, 1908.

† Bull. U. S. Geol. Survey, No. 358, p. 13, 1908.

‡ Letter to the writer November 18, 1908.

§ Kindle, E. M., The section at Cape Thompson, Alaska, this Journal, vol. xxviii, pp. 527–528, 1909.

‖ Geology and mineral resources of the Solomon and Cassadapaga quadrangles, Seward Peninsula, Alaska : Bull. U. S. Geol. Survey No. 433, p. 54, 1910.

some of the limestones which have been correlated with the Port Clarence into more concise cartographic units. The most recent detailed work on the geology of this part of Alaska has been done by Smith and Eakin* on an area in the southeastern part of the Seward Peninsula. Three of the limestone areas without the York Mountain region which have been correlated with the Port Clarence have, however, furnished fossils which show that they are of distinctly later age than the faunas occurring in the typical Port Clarence. These outside limestone areas, which are known to be distinct from the Port Clarence and of later age, are known as Baldy Mountain, Devil Mountain, and White Mountain. Before considering the data relating to the age of these areas which have been mapped as Port Clarence beyond the York Mountains, the evidence showing the composite character of the faunas in the Port Clarence as found in the type region will be presented. The fossils collected by the writer in the York Mountain region were obtained at somewhat widely distributed stations. These were selected with the intention of determining the thickness of the beds to be ascribed to the different faunas in the limestone series, but the amount of time allotted to the work, together with the uncertainty regarding some of the structural features involved in the present orientation of the limestones, made it impracticable to carry out the original intention. Hence the more salient facts concerning the fauna are presented without such stratigraphic detail.

Faunas of the Port Clarence.—The oldest fauna which was found in the Port Clarence limestone occurs in the limestones exposed about the head of Tin Creek and to the southeast of Cassiterite Creek. Two fossiliferous zones were found in this vicinity separated by several hundred feet of apparently barren limestones. In one of these, station No. 8 at the head of the north fork of Tin Creek, fossils occur in abundance in a single thin band of limestone which seems to lie in the midst of barren beds at an elevation of about 2,000 feet A. T. This fauna was referred to Mr. E. O. Ulrich, whose determination of the species is as follows:

> "*Eoorthis* sp. or var. nov. Closely allied to *E. wichitensis* and *E. remnicha texana* of Walcott. These and all similar species of this genus known to me occur in the upper part of Cambrian and in the basal part of beds immediately following it. *Huenella texana* Walcott? Associated with *Eoorthis remnicha texana* in the Upper Cambrian in Central Texas." †

To the northward of the zone holding this fauna the blue-gray limestones which are supposed to lie below it stratigraphically

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* Bull. U. S. Geol. Survey No. 449.

† Letter to the writer, Mar. 10, 1909.

are supplanted in the section by 300 feet, more or less, of light gray limestones which are mostly magnesian, and are exposed along the crest of the mountain east of Cassiterite Creek. These light-colored limestones are terminated abruptly by a black slate and thin-bedded limestone series. The only fossils seen in these light grey limestones were a few stromatoporoid corals.

Station No. 7 is located near the head of the south branch of Tin Creek at its junction with a ravine from the east. The brachiopod fauna of station 7 occurs in a hard blue-gray limestone stratum a few inches in thickness which lies just above beds with numerous fucoid-like impressions. Brachiopods belonging to a single species are present in abundance in this band of limestone, but they are extremely scarce or absent for many hundred feet above and below it. Several hundred feet of limestones separate this zone from station No. 8. These are chiefly of the dark bluish-gray, fine textured type. A 60-foot band of nearly black limestone is the only conspicuous interruption of the blue limestone series. An igneous intrusion on Tin Creek somewhat interrupts the continuity of the limestone beds between stations 7 and 8.

The fossils collected at station 7 have been determined by Mr. E. O. Ulrich to be *Finkelnburgia* sp. nov. indistinguishable from a species occurring in the Roubidoux formation of the Cambrian in Missouri. Concerning the age of these two faunas Ulrich states* that,—

> "I feel no hesitancy in saying that Nos. 7 and 8 are older than Beekmantown (basal formation of the Ordovician) and younger than middle Cambrian."

In other words, they are of Upper Cambrian age. While each of these faunules is of Upper Cambrian age, it is not equally clear from the faunal evidence, in the opinion of Mr. Walcott, which is the older of the two. The assumption that 7 is the older would involve less complicated structural relations, and appears, from the writer's knowledge of the section, the more probable as well as the simplest interpretation of the succession.

Two other stations from which the writer collected fossils in the Port Clarence limestone lie near the coast. These lots were determined as Ordovician. They appear to belong in the same general zone which is represented by previous collections which were also determined as Ordovician, made by Washburne† at Merrill Mountain, and Collier‡ at Locality 26, Seward Peninsula.

The collection made by the writer at Cape York (station No. 9) is represented by a single species which is present in abundance

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* Letter to the writer, Mar. 10, 1909.

† Bull. U. S. Geol. Survey No. 328, p. 78, 1908.

‡ Op. cit., p. 75.

in one bed of limestone. This is identified by E. O. Ulrich as *Eoorthis? wimani* Walcott. Mr. Ulrich's remarks on this lot of fossils are as follows:

> "Concerning No. 9, the stage of evolution attained by the abundant orthoid brachiopod (*Eoorthis? wimani* Walcott) which comprises the entire known fauna of the bed, is that known to me only in post-Cambrian. Although Mr. Walcott has described the species as a Cambrian fossil, I may say that the Swedish geologists, in whose country the typical *E. wimani* was found, do not agree with this assignment, but place it in the Ordovician. In this country I have a similar—possibly identical—species in the Beekmantown."

Another faunule which is also of Ordovician age, but somewhat younger than No. 9 in the opinion of Mr. Ulrich, was collected at the mouth of Lost River. The beds which furnished this fauna include 15 feet of dark gray, thin-bedded limestone near the top of the cliffs, 450 yards southeast of the mouth of Lost River. This is essentially a trilobite fauna and is listed as follows by Ulrich:

Lot No. 6.

Maclurea cf. *emmonsi* Billings.
Ceratopyge? sp. undet. Pygidium only.
Encrinurus? sp. undet. Pydigium only.
Bathyurus? sp. undet. Glabella only.
Bathyurus? sp. undet.

Doctor C. D. Walcott made a preliminary examination of this lot of fossils and communicated the following remarks concerning it to the writer:

> "There are several species of trilobites in the collection indicated by fragments. All of these indicate the Ceratopyge horizon of the Swedish section. This horizon has been placed both in the Upper Cambrian and the Lower Ordovician. The fauna may also be compared with that of the upper portion of the Hamburgh shale of the Eureka District horizon. (See Monographs 8 and 20, U. S. Geol. Survey.)"*

At the writer's request these faunas were examined also by Dr. C. D. Walcott and Mr. L. D. Burling. Dr. Walcott has kindly furnished the following statement of his views concerning the relative age of these faunules: †

> "Locality 8 is approximately the equivalent of the Upper Cambrian in Oklahoma and Texas and older than Locality 6, which can be correlated with the Ceratopyge fauna of Scandinavia. The latter fauna I have placed in the passage beds between the Cambrian and the Ordovician.

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* Letter Jan. 9, 1909.

† Letter of Jan. 18, 1911.

"There is little evidence upon which to base the opinion that Locality 7 is younger than Locality 8, and the best possible explanation of the sequence appears to be the presence of a fault somewhere between 6 and 7."

It will be noted that Dr. Walcott and Mr. Ulrich fully agree on the important points that the faunule of station 8 is of Upper Cambrian age, and that it is older than the faunule at station 6. Whether the latter faunule should be placed in the passage beds between the Cambrian and Ordovician, as suggested by Dr. Walcott, or entirely in the Lower Ordivician, as held by Mr. Ulrich, is not a matter of great moment in this connection. The order of succession of the two faunules on which they agree, however, necessitates the postulation of structural features between the mouth of Lost River and Brooks Mountain which were not previously suspected. In view of the extremely complicated structure which Smith* has shown to exist in a portion of the Seward Peninsula, it is perhaps not profitable to attempt in the light of our present knowledge of the structure of the York Mountain region to state just what these structural features are.

Fucoid-like impressions are abundant between the beds of station 6 and the coast, apparently 200 feet or more above them stratigraphically. Similar impressions were observed by Collier and Washburne, and are mentioned by Ulrich,† who had some doubt as to their organic nature, in his report on their collection. In addition to the "fucoids" the Washburne collection contained fossils which Ulrich‡ compared with the following species:

Stromatocerium rugosum
Hormotoma bellicincta
Trochonema sp.
Cyrtoceras ?
Endoceras ?

These fossils were collected near the mouth of Lost River and appear to belong to the same general horizon as the fauna from station 6. They represent with it an early Ordovician horizon. Knopf§ also obtained some fragmentary gasteropods in the Lost River valley which appeared to represent an Ordovician horizon.

The next fauna in the order of age which is known in the Port Clarence limestone occurs in limestones on the Don River, about 9 miles from the coast. The first collection from this

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*Smith, P. S., Geology and Mineral Resources of the Solomon and Cassadepaga quadrangles: Bull. U. S. Geol. Survey, No. 433, pp. 1–234, 1910.

† Bull. U. S. Geol. Survey, No. 328, p. 78, 1908.

‡ Bull. U. S. Geol. Survey, No. 328, p. 78, 1908.

§ Bull. U. S. Geol. Survey, No. 358.

locality was made by Collier. Professor Schuchert's report on this fauna is as follows:

> "Loc. 45. Don River, 4 miles north of Tozier Creek. *Maclurina*, probably *M. manitobensis* Whiteaves; *Columnaria* with small corallites; *Halysites catenularia* Linne; *Syringopora* sp. undet.; *Streptelasma*?; and an undetermined *Lophospira*."*

This fauna was referred by Schuchert to the Ordovician although he was somewhat perplexed by the unusual association of *Halysites*, *Syringopora*, and *Maclurina* in the same fauna. The writer's collections have yielded a fauna of about 40 species from this locality, most of which are in an excellent state of preservation. This comparatively large fauna gives a much more adequate conception of the fauna than the original collection and confirms the earlier determination of its Ordovician age.

The fauna obtained by the writer from Don River was collected from two sets of adjacent and closely similar beds numbered 13a and 13b. Station 13a represents the beds exposed in the sides of a short ravine heading on the slopes of a mountain marked 1,242 feet on the map† and joining Don River nine miles from the coast. The fauna, unlike the earlier faunules which have been described, is distributed through a thickness of 300 feet or more of beds and includes a considerable variety of fossils. Mr. E. O. Ulrich‡ has furnished the following list of fossils from the limestone near the mouth of this ravine:

"CORALS:

Halysites gracilis var. 1, (? var. *harti* Etheridge).
" " " 2, with closer meshes.
" " " 3, " very thick leaves.
" " " 4, " clusters of 3-8 corallites at intersections.
Calapœcia canadensis var. Same in 13b and in upper Richmond of Mississippi Valley.

BRACHIOPODA:

Strophomena trilobata (Owen) W. & S.
" cf. *scofieldi* W. & S.
Rafinesquina sp. undet. (small spines, possibly a Leptæna).
Leptæna n. sp. (Closely allied to one in beds of lower Mohawkian age in Minnesota).
Dinorthis cf. *meedsi* W. & S.
Hebertella borealis Billings?
Rhynchotrema increbescens Hall. (Small, new variety.)
" cf. *sanctipauli* Sardeson.

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*Bull. U. S. Geol. Survey, No. 328, p. 75, 1908.
† Bull. U. S. Geol. Survey, No. 328. 1908.
‡ Letter to the writer, March 20, 1909.

Rhynchonella ? n. sp.
Triplesia extans Hall.

PELECYPODA :
Modiolopsis cf. *faba* Hall.
" sp. undet.

GASTROPODA :
Patelloid shell suggesting *Stenotheca unguiformis* Ulrich.
Maclurea bigsbyi Hall.
Lophospira sp. undet.
Hormotoma cf. *gracilis* Hall.
" cf. *bellicincta* Hall.
Eotomaria ? sp. undet.
Trochonema sp. undet.

TRILOBITA :
Bumastus sp. undesc. (near one in beds of lower Mohawkian age in Minnesota).

Judging from the general aspect of this fauna of 26 species, it seems unquestionably Ordovician in age. The forms of *Halysites* also are of the type found in the lower part of rocks of Trenton and Black River age in Minnesota and Wisconsin, and later of the Mississippi Valley and elsewhere."

Station 13b includes about 100 feet of limestones immediately north of the mouth of the ravine mentioned above, and lying stratigraphically probably 200 feet higher. This limestone is exposed in the low bench just south of a small draw and contains a great profusion of corals in which *Halysites* is conspicuous. Brachiopods are not uncommon, but less abundant. The following is a list of the fauna found there as determined by Mr. Ulrich:

" CORALS :
Columnaria alveolata Goldfuss.
" ? cf. *goldfussi* Billings. (Can not be distinguished from basal Trenton form except by closer arrangement of its tabulæ.)
Calopœcia canadensis Billings.
Halysites gracilis Hall.
" " var. with small corallites and very small meshes. (Very much like a form in the Silurian at Wisby, Gotland, received from Lindstrom.)
Stromatocerium ? sp. undet.

BRYOZOA :
Nicholsonella ? sp. undet.

BRACHIOPODA :
Leptæna tenuistriata Hall.
Hebertella ? sp. undet.
Rhynchotrema capax ? Conrad.

PELECYPODA:
- *Ctenodonta* cf. *levata* Hall.
- *Cyrtodonta* sp. undesc.

GASTROPODA:
- *Liospira* sp. undet.
- *Lophospira quadrisulcata* ? U & S.
- " sp. undet.
- *Trochonema* cf. *umbilicatum* Hall.

Other beds holding the same fauna as 13b follow it in the section. These, together with the limestones included in beds 13a and 13b, appear to give the limestones holding the fauna listed from 13a and 13b a thickness of about 500 feet. A considerable thickness of limestones follows these fossiliferous beds along the Don River in which no organic remains were found. These may represent the Silurian limestones. The series of limestones holding the fauna of stations 13a and 13b are somewhat darker in color than the Cambrian and Lower Ordovician limestones. Bands of very dark limestones and of magnesium limestone interpolated in the gray limestones are more common in this than in the lower series. No stratigraphic break has been observed anywhere in the Port Clarence limestone, but it is probable that one or more such breaks are present.

Although recognizing the strong affinities between the faunules from stations 13a and 13b, Mr. Ulrich is inclined to consider the former to be the equivalent of the Black River fauna, and the latter (13b) to represent the Richmond fauna. The completely exposed section between the two faunas, however, appears to afford no evidence of any stratigraphic break which the definite correlation with these two Ordovician horizons would suggest.

The facts which do not appear to be open to question or discussion regarding the faunas from stations 13a and b are that (1) they are distinctly younger than the trilobite fauna from station 6 at the mouth of Lost River, and (2) they are of Middle or Upper Ordovician age. The older of these faunas, 13a, appear to represent about the same general horizon of the Ordovician as the fauna of this age discovered by the writer in the Porcupine River in northeastern Alaska.* Still another and later fauna than any of those already noticed was found by Collier in or near the typical region of the Port Clarence limestone in beds ascribed to that formation. This locality was not revisited by the writer, hence the list of species determined by Schuchert from Collier's collection will be quoted.

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*Kindle, E. M., Geologic Reconnaissance of the Porcupine Valley, Alaska; Bull. Geol. Soc. America, vol. xix, p. 323, 1908.

"Loc. 3AC146 (near the forks of Rock Creek, a northern tributary of Agiapuk River) has

- *Stromatopora* sp.
- *Favosites favosus* Goldfuss.
- *Favosites* cfr. *niagarensis* Hall or *F. gothlandicus* Fought.
- *Columnaria*? apparently closely related to *Favistella reticulata* Salter of the Arctic Silurian.
- *Halysites catenularia feildeni* Etheridge.
- *Halysites catenularia harti* Etheridge.
- *Diphyphyllum* cfr. *multicaulis* (Hall).
- *Alveolites* sp.
- *Gasteropods*, one a *Lophospira*, another a *Hormotoma*.
- *Orthoceras* sp. undeterminable."

This fauna as determined by Prof. Schuchert appears pretty clearly to represent the middle Silurian. Larger collections of it will probably show that it is the equivalent of the middle Silurian* fauna on the Porcupine River in northern Alaska.

A late Silurian fauna, comparable with the Guelph, occurs in a limestone which has been correlated with the Port Clarence fauna, but which is unknown in the type region of the Port Clarence. It was originally discovered by Mendenhall at White Mountain on the Fish River. When this fauna was first discovered the rich and excellently preserved fauna from Glacier Bay in southeastern Alaska was unknown and unavailable for comparison with it, and the few cross-sections of large lamellibranchs representing the first collection were provisionally referred to the Mesozoic or Tertiary.† Since the southeastern Alaska fauna has become available for comparison there ceases to be any question as to the error of the earlier opinion. Through identity with the Glacier Bay and Freshwater Bay fauna‡ it is well established that the White Mountain fauna is of late Silurian age. Several hundred feet of white to light gray magnesian limestone forms an eminence known as White Mountain which rises 300 feet or more above the broad alluvial plain of the Fish River. The limestone is much broken by joints and shows very indistinct bedding plains. Freshly broken specimens emit a strong fetid odor. The thickness can only be conjectured. The limestone at White Mountain contains in certain strata numerous specimens of a large, thick-shelled pelecypod which is identical with a species occurring in southeastern Alaska—abundantly at Glacier and Freshwater Bays in association with other late Silurian

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* Op. cit., p. 325.

† Mendenhall, W. C., A reconnaissance in the Norton Bay region, Alaska, in 1900, p. 204, in Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900; U. S. Geol. Survey, 1900.

‡ Brooks, A. H., Prof. Paper, U. S. Geol. Survey, No. 1, p. 19, 1902. Kindle, E. M., Jour. Geology, vol. xv, p. 323, 1907.

species. It belongs to an undescribed species and has been referred to *Megalodon* sp. A *Murchisonia* of undetermined species also identical with a species from Glacier Bay occurs with the *Megalodon*. The presence of this large lamellibranch here leaves no doubt of the equivalence of the limestone at White Mountain to the limestone at Glacier Bay.

On the north coast of the Seward Peninsula the writer has found at Cape Deceit a fauna which appears to be the same as the fauna at White Mountain. It is represented by a coral which is probably a species of *Amplexus* and a lamellibranch apparently identical with the *Megalodon* occurring at White Mountain. The limestone at Cape Deceit has the highly magnesian composition characterizing the limestone at White Mountain. Since both the rocks containing this later fauna and the fauna itself are here shown to be distinctly unlike the Port Clarence limestone of the type region and any of its faunas, there remain no reasons for continuing to correlate the two* as distinct formations.

The correlation of two other small limestone areas which have been referred to the Port Clarence, appear to require revision in this connection. One of them is the limestone eminence known as Black Mountain, located a few miles above White Mountain on the Fish River. The other is Baldy Mountain and the closely related Harris Creek locality near the center of the Peninsula. Concerning the first Schuchert stated that it "may also be Silurian."† From the Harris Creek locality Prof. Schuchert recorded three generically determined corals ‡ which he considered to indicate a middle Silurian age. An important fact in this connection is that the collection comprising the Harris Creek and Devil Mountain faunas does not show a single species common to it and the large collection from the typical region of the Port Clarence, Three fossils were cited by Schuchert as evidence of the Silurian age of the fauna, namely, *Cladopora* sp. resembles *C. seriata* Hall of the New York Silurian; *Striatopora* sp.; *Alveolites* sp., a branching form.

The *Cladopora* of this list, which was compared with *C. seriata*, a Silurian species, appears to the writer to resemble *C. labiosa*, a Devonian species, rather more than *C. seriata*. The additional evidence afforded by the writer's collection is meager and, as in the case of the earlier collection, rests on corals alone. It includes, however, a *Favosites* much like *F. radiciformis* and a *Diphyphyllum* resembling *D. archiacai*. The latter appears to be identical with a *Diphyphyl-*

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* Bull. U. S. Geol. Survey No. 328, map, 1908.
† Bull. U. S. Geol. Survey No. 328, p. 77, 1908.
‡ Op. cit., p. 76.

lum from Cape Lisburne fauna which is known to be of Carboniferous age. The former species is common to the Devil Mountain and Harris Creek localities. The most abundant fossil in the Harris Creek and Baldy Mountain localities is an undetermined species of *Striatopora.* Thus the three localities appear to represent a single horizon. This horizon is either of Devonian or Carboniferous age, in the writer's opinion. It certainly has much closer affinities with the Carboniferous fauna at Cape Lisburne* than it has with any fauna known in the Port Clarence limestone. The limestone at Baldy and Devil Mountains should, it is believed, be correlated with the limestone at Cape Mountain which has been referred to the Carboniferous on satisfactory evidence.†

Summary.—It has been shown in the preceding pages that the rocks which have been mapped as Port Clarence limestone range from Upper Cambrian to Devonian or Carboniferous. The older of these Paleozoic rocks, including the Cambrian and Ordovician beds, occur in the type region of the Port Clarence, in a limestone series which is not known to have any stratigraphic break. The middle Paleozoic faunas which have been included in this limestone as it has been mapped are known only from occurrences outside the type region. One of these, a fauna of late Silurian age, is found in a limestone of very different lithologic type from any known in the type region of the Port Clarence, which clearly represents a formation distinct from either that holding the Ordovician on the one hand, or the Devonian or Carboniferous faunas on the other.

It appears probable from the data which has been presented that in the more detailed work of the future the term Port Clarence limestone will have to be restricted to beds characterized by one or more of the pre-Silurian faunas noted in this paper. There is however not sufficient information available concerning the range of these faunas and the stratigraphic relations of the beds holding them to justify a redefinition of the formation at present.

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* Bull. U. S. Geol. Survey No. 278, pp. 22–28, 1906.

† Bull. U. S. Geol. Survey No. 328, pp. 81-82, 1908.

ART. XXXVIII.—*Some Factors Influencing the Percentages of Mineral Plant Foods Contained in Soils*;* by O. D. VON ENGELN.

THE writer has attempted a correlation of selected soil analyses with soil history in order to ascertain if any correspondence exists between the present chemical composition of soils and the formative processes involved in their production. The comparisons presented are based on averages of analyses chosen as typical; and such tentative deductions as are made are founded primarily on the results obtained from bulk analyses of soils. The numerical insufficiency and incompleteness in publication of such analyses, available for comparison, proved to be the greatest difficulty in making the study. As it was not intended to take account of the variations in chemical composition of soils induced by climatic variation, the comparisons are confined to soils from the humid, temperate, eastern portion of the United States, in order that this factor should be, as near as possible, negligible.

A reiterated contention of the Bureau of Soils, United States Department of Agriculture, is variously expressed in such terms as: "Investigations have shown that there are sufficient quantities of the mineral plant food constituents in the soil moisture to produce good crops, and that the supply is maintained from the continuous solution of the minerals of all ordinary soils throughout the growth of the crop;"† and: "The chemical composition of soils varies so greatly without any obvious law of general relationship to crop production that averages mean little or nothing, and figures are given without any attempt at averaging."‡ These statements imply that no direct relationship exists between either the origin or fertility of soils and their chemical composition.

The latter of the two statements quoted above prefaces a compilation of "acid digestion" analyses of soils of the United States, published in the same bulletin. An examination of the sources from which the analyses were obtained made it apparent that the data afforded no safe basis for so broad a generalization. Aside from the fact that incomplete, i. e., acid digestion, analyses are untrustworthy for purposes of comparison, it was also found that many of the analyses included in the compilation were of extremely doubtful value from other reasons. The exact origin and method of sampling is in many

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* The writer desires to express his obligation to Professor T. L. Lyon and Dr. J. A. Bizzell of Cornell University for criticisms and suggestions in connection with this paper.

† Bull. 55, Bureau of Soils, U. S. Dept. of Agri., 1909, p. 63.

‡ Bull. 57, Bureau of Soils, U. S. Dept. of Agri., 1909, p. 61.

instances obscure. Again, a large number of the analyses are of samples sent in by farmers to the various State experiment stations in the hope that a chemical analysis would shed a light on some peculiarity of a, perhaps, isolated and untypical, small area of soil. In either case such samples must be considered as being individually unrepresentative of the region of their origin.

The analyses given by Merrill* show that, in humid regions, rock weathering results in a greater proportional loss of the relatively soluble constituents of rock than of the less soluble substances, that is, primarily of silica. In other words, residual soil contains a lesser percentage of calcium and phosphorus than the rock material from which it was derived. An extreme case is that of limestone residual soils which are often almost totally deficient in lime.

The facts exhibited by Merrill's analyses of specific rock types and the residual material derived from them can be more generally shown by a consideration of the averaged bulk analyses of representative series of soils, contrasted with the average chemical composition of the rock material composing the lithosphere. Such analyses are available in publications by Clarke,† Veitch,‡ and Mooers.§ Clarke has calculated the average composition of the outer ten-mile shell of the lithosphere. Veitch presents a comprehensive series of bulk analyses of Maryland soils, comprising residuals from many rock types, both igneous and sedimentary, and of greatly varying geological age. The samples he analyzed were from the subsoil immediately below the top soil; and each analysis represents the average of several determinations from different localities. Considering the wide range of the original rock formations represented, the averaged values of the analyses, and the nature of the material selected for analysis, it is fair to assume that an average of these averages will, in an indicative way, express the mean composition of the soil material residual from weathering and erosion processes in a temperate, humid region. Mooers' results may be considered as confirmative of the averaged figures from Veitch. They are less representative than the Maryland series, especially in that eight of the ten soils analyzed, and here averaged, were derived from limestones and dolomites. Below are tabulated, in percentages, the averaged amounts present of three important mineral plant food constituents, as obtained from these investigations:

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* Merrill, G. P., Rocks, Rock Weathering, and Soils, Macmillan Co., 1906.

† Clarke, F. W., Data of Geochemistry, Bull. 330, U. S. Geol. Survey, 1908, p. 31.

‡ Veitch, F. P., The Chemical Composition of Maryland Soils, Bull. 70, The Md. Agri. Expt. Station, 1901.

§ Mooers, C. A., The Soils of Tennessee, Bull. 78, Agri. Expt. Station of the University of Tenn., 1906, p. 74.

	$\%P_2O_5$	$\%CaO$	$\%K_2O$
Average composition ten mile shell of the lithosphere	·25	4·82	2·96
Average composition of representative residual soils of Maryland	·125	·50	1·73
Average composition of 10 Tennessee soils	·147	·244	1·022

It will be noted that of P_2O_5 and K_2O only about one-half the amount was present as compared to the percentage computed for the average rock of the lithosphere. In the case of the CaO the difference is still greater. In any event, the differences shown are sufficiently great to indicate that residual soils are notably deficient in such plant food elements as compared to the parent rock.

Glacial soils may be regarded as composed of a thorough mixture of mechanically derived material from many rock types; especially when they comprise a portion of the drift sheet resulting from continental glaciation. Such soils, having been subject to solvent denudation only since their deposition by the glacier, should, according to the above deductions, under favorable conditions, show a higher concentration of the mineral plant food elements than do residual soils.

In the state of Illinois are found soils from several glacial advances, the earliest of which probably antedates the youngest by a long time interval. Hopkins and Pettit* have published partial results of a large number of complete analyses of soils from this state and have, moreover, correlated their soil types with the various glacial advances, and with the topographic features of the soil's occurrence. Tables are given "showing the average results of analyses of many representative samples of each soil type." These data afford an excellent opportunity for some interesting comparisons. Soil from the youngest glaciation, the Late Wisconsin, brown stilt loams occurring on undulating prairie lands show percentages of P_2O_5 and K_2O at various depths as given below. Calcium is unfortunately not given.

ILLINOIS SOILS—LATE WISCONSIN GLACIATION.

Brown Silt Loams on Undulating Prairie Lands.

Depth	$\%P_2O_5$	$\%K_2O$
0–7″	·162	2·71
7–20″	·112	2.90
20–40″	·100	3·21

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*Hopkins, C. G. and Pettit, J. H., The Fertility in Illinois Soils, Bull. 123, University of Illinois, Agri. Expt. Station, 1908, pp. 196–200–201.

It will be noted that the phosphorus percentage in this glacial soil is of very nearly the same value as that shown by the averaged Maryland residuals; while the potassium ranges about the figure computed for the average rock of the lithosphere. It would seem from this that the phosphorus in the glacial material was either originally present in lesser amounts (the rocks from which the Illinois glacial soils are derived were largely shales and sandstones), or else the phosphorus was leached much more rapidly than the potassium. A comparison of the Maryland residual soil averages and those of the youngest Illinoian glaciation, on the basis that the former represents average rock material chemically decomposed, while the latter typifies such material derived mechanically, fails of exactness in that some of the Maryland residuals are very probably derived from rock crumbling on steep slopes, i. e., mechanical weathering and erosion, without complete decomposition; and in that the glacial soils were laid down unconsolidated, and were, therefore, very permeable from the first to water, and susceptible to rapid leaching. For these reasons a comparison of the youngest glacial soil in Illinois with that from the oldest glaciation will express much more exactly the effect of continued leaching on soils, for in this case the original material can be considered identical. In all probability the direction of the glacial advance in the several glaciations cited was uniformly from the Labrador center of dispersion. It may be assumed, therefore, that the glacially transported material of the several glaciations was derived from essentially the same bed rock. It has been found, also, that in the peripheral deposits of the continental glaciations, a large percentage (87 per cent in one case) of the whole are of local origin, that is, composed of material derived from bed rock underlying and near-adjacent to the area surveyed.* Probably the finer particles of sand and rock flour have a more distant source, and therefore represent a greater commingling of material from widely different rock types. As to original constituents these soils should, accordingly, be essentially similar both in the derivation of their coarse and fine particles. The figures given below, bulk analyses of soils from undulating prairie lands, consisting of "gray silt loam on tight clay" deposited by the earliest glaciation, the Lower Illinoian, may, therefore, with confidence as to the essential similarity of original constituents, be compared with the figures given above for the brown silt loams of the Late Wisconsin glaciation.

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* Alden W. C., The Delavan Lobe of the Lake Michigan Glacier of the Wisconsin Stage of Glaciation and Associated Phenomena. Prof. Paper 34, U. S. Geological Survey, 1904, pp. 86-67.

ILLINOIS SOILS—LOWER ILLINOIAN GLACIATION.

Gray Silt Loams on Tight Clay, Undulating Prairie Lands.

Depth	% P_2O_5	% K_2O
0–7″	·096	1·49
7–20″	·085	1·61
20″–40″	·091	1·68

An appreciably and consistently lower percentage of these constituents is shown by these averaged analyses to exist in the older than in the younger material, and at all depths. This difference in the percentage of the mineral plant foods present, and in the physical conditions, i. e., brown and gray color, can only be ascribed to changes due to natural processes, operative since the glacial age. In other words, as a result of the development of drainage, leaching and weathering in general, under a natural vegetation cover, the soils of the earlier glaciation are notably poorer in phosphorus and potassium.

The important point to be noted here is that the concentration of the soluble plant-food constituents in soils seems to be a characteristic of the age of the soil, or better, of the stage in an erosion cycle in which the soil occurs. Soil of the youngest glaciation has higher percentages than the oldest, while the percentage average for the Maryland soils lies between the two, but approaches the condition indicated for the oldest glaciation. According to this, glacial soil, young and old, occurring on dissected uplands, where the runoff is rapid, and leaching correspondingly active, should show a much closer agreement in plant-food constituents for young and old glaciations than is shown by glacial soils from areas of prairie topography. Such an assumption finds confirmation in the figures given by Hopkins and Pettit (loc. cit.) for the yellow silt loam type of soil, which occurs on "sloping hillsides and on the broken lands adjoining water courses in all parts of the state": thus on the divide areas of the main glacial deposits of various ages, as well as in the unglaciated section. An exception is the youngest, or Late Wisconsin glacial deposit, where a yellow-*gray* silt loam occurs on "undulating timber uplands."

In this table the percentage values for the phosphorus are strikingly consistent; such discrepancies as are shown in the case of this element, and the larger variations for potassium, are within the limits of error introduced by the number and character of samples from the individual areas. Glacialists, moreover, are not agreed as to the verity and succession of all the advances here differentiated.

Illinois Soils—Hilly Uplands—Surface Soil, 0–7″—
Yellow Silt Loam.

Soil Area or Glaciation	% P_2O_5	% K_2O
Unglaciated	·109	1·894
Lower Illinoian	·109	1·918
Middle "	·094	2·016
Upper "	·096	2·099
Pre-Iowan	·095	2·239
Iowan	·104	2·155
Early Wisconsin	·101	1·958
Yellow-gray Silt Loam—Undulating Upland.		
Late Wisconsin	·093	2·867

On the other hand, positions in an erosion cycle, held by the deposits of the various glaciations, serve glacialists as criteria for distinguishing between the glaciations. The existence of sluggish and obstructed drainage, a topography marked by the presence of many small lakes, kettle holes, and wide areas of swamp lands, are, in glacial regions, the earmarks of a very recent advance. In localities where the glaciation is so recent the drift sheet is practically continuous over the area. The drainage has not yet had time to establish itself. It is a region of youth in the development of an erosion cycle. Leverett* compares the erosion and weathering of areas, with similar original topography, in the Wisconsin and Illinoian glacial deposits as follows: "In the Illinoian glacial drifts of western Illinois approximately one-half the surface has been reduced below the original level as a result of post-Illinoian glaciation, drainage development; while in the Wisconsin drift, post-Wisconsin drainage has scarcely sufficed to reduce one-tenth its original surface. In the Illinoian drift calcareous constituents, pebbles as well as fine material, are nearly completely removed to a depth of four to six feet by leaching, while weathering often extends to two or three times these depths. In the Wisconsin drift limestone pebbles are present at the top of the bowlder clay, and leaching of fine calcareous material seldom extends to more than a meter. The weathering is very slight as compared to the Illinoian drift." These facts indicate a real difference in the composition of the materials; one that should be reflected in the chemistry of their soils.

Indeed, a very real difference exists in the actual productivity of the soils of the early and late glaciations, whether or not it depends on the percentages of the mineral plant foods

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*Leverett, F., Weathering and Erosion as Time Measures, this Journal, xxvii, pp. 356–7, 1909.

Idem., Comparison of North American and European Glacial Deposits, Zeitschr. f. Gletcherkunde, iv, p. 332, 1909–10.

present in them. Hubbard* shows this very strikingly by contrasting the agricultural conditions in the north-and-south-adjacent Coles and Cumberland counties of Illinois; the former of which lies almost wholly in the Early Wisconsin glaciation, while the latter has a Lower Illinoian glaciation soil-cover over the greater part of its area. In Coles County tile drainage is practised, rich swamp lands are thus reclaimed,—in Cumberland such drainage is useless; primarily because tributaries to main natural drainage streams are developed in so much greater numbers as to 'make the map of Cumberland County appear darker.' Land values in Coles County at the time the article was written ranged between $75 and $125 per acre, with the average above $75; while in Cumberland County the prices were from $15 to $40, with the average near $30. The value of crops per acre of improved land was from $10 to $15 for Coles County, and from $6 to $10 for Cumberland County. It has been stated by Chamberlin† and others that soil particles are at once wasted and mixed by wind and wash, and that the mixing is so complete, even in humid regions, that nearly all soils acquire the essential plant food constituents. If such processes were effectively operative to insure the presence of sufficient amounts of these elements for the largest crop production, then the adjacent soils of the early and late glaciations in Illinois should show greater similarities in crop productivity and chemical composition. According to the data here presented, one may as reasonably conclude that different positions in an erosion cycle make for differences in the percentages of soluble salts present in a soil, and for differences in fertility, as applied to farm crops.

It was originally planned to base such comparisons and correlations as are cited above from bulk analyses, on the far greater number of published "acid digestion" analyses of soils. Especially in mind was a comparison of the averaged HCl soluble analyses of alluvial soils, i. e., bottom lands subject to overflow, from the residual regions; with averaged analyses of similar soils from the glacial regions of the humid, eastern portion of the United States. By choosing alluvial soils the assumption could be made that these are naturally greatly commingled samples, representative of the contributive geological formations of the various drainage basins; and also that the average of even a small number of such analyses would be typical of wide areas. Unfortunately analyses are not available for such a comparison. The references given by Whitney‡ in

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* Hubbard, Geo. D., A Case of Geographic Influence Upon Human Affairs, Bull. Am. Geog. Soc., vol. xxxvi, pp. 145–157, 1904.

† Chamberlin, T. C., Soil Productivity, Science, Feb. 10, 1911.

‡ Whitney, Milton, A Study of Crop Yields and Soil Composition in Relation to Soil Productivity, Bull. 57, 1909; Bureau of Soils, U. S. Dept. of Agri., pp. 65–90.

his compilation of published HCl analyses of soils of the United States were consulted in the sources for the states of Alabama, Florida, Kentucky, Maryland, West Virginia, Tennessee, and North Carolina for residual, alluvial soils; and for Indiana, Maine, Michigan, Minnesota, North Dakota, New York, New Hampshire, Ohio, Rhode Island, and Wisconsin for glacial, alluvial soils, with the result that while for certain sections, e. g., Tennessee, a representative number of such analyses were found available, in other states there are none, or the analyses are of samples individually unrepresentative, their exact origin and manner of sampling being obscure, and their total number inconsiderable. The only HCl analyses data at all permissible of comparison on this basis are some fourteen alluvial soil analyses from Tennessee, and an average of some 72 surface soils, not all alluvial, from Minnesota. As the samples from the latter state are from the different parts of its area, it may, however, be assumed that their average represents a commingling comparable with that in the Tennessee alluvial soils. Analyses showing extreme percentages were omitted in both cases.

HCl Analyses	$\%P_2O_5$	$\%CaO$	$\%K_2O$
* Tennessee Residual, Alluvial	·108	·376	·376
† Minnesota Glacial, General	·20	1·29	·43

The reputed worth of partial HCl digestion analyses is in the vaguely probable relation their figures bear to the amount of 'available' plant food in the soils analyzed. If the percentage of acid soluble, mineral plant food constituents has any such relation to the proportions of these materials available to crops, then the ratio of acid soluble substance to total amount present is an index as to the relative fertility of the lands, provided other fertility factors are equal. Data are available in the bulletins cited above for an application of this idea to the Illinois glacial soils and the Maryland residual soils. In the Illinois glacial soils the total content and the acid soluble figures for the element of potassium vary so widely for different samples from the same glaciation that the ratio of their averages would have little or no significance. The acid soluble percentage of the element phosphorus, however, shows a much greater constancy for different samples from the same glaciation. A comparison of averages shows the following: The acid soluble portion of the phosphorus content of the gray silt loam subsoil, 20–40″ deep, on undulating prairie lands, of the oldest or Lower Illinoian glaciation comprises 81·2 per cent of the total amount

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* Mooers, Charles A., The Soils of Tennessee. Bull. 78, Agri. Expt. Station of the University of Tenn., 1906, pp. 74 and 83.

† Snyder, H., Soil Investigations, Bull. 65, University of Minnesota Agri. Expt. Station, 1899, p. 69.

present, an average from 15 samples. An average of nine samples of brown silt loam subsoil of similar depth and location, but from the youngest, or Late Wisconsin glaciation, shows 87·6 per cent of the phosphorus content to be acid soluble. The difference in solubility of the phosphorus in these subsoils is therefore 6·4 per cent. In the surface portions, 0–7″, of these same soils a more marked difference is apparent. Of the Lower Illinoian surface soil 80 per cent. of the phosphorus is acid soluble, in the Late Wisconsin 89·7 per cent, a difference of almost 10 per cent. This greater difference in solubility is probably influenced by the fact that the Late Wisconsin soil has its higher, total phosphorus content in the surface layer; the concentration of this constituent being much more nearly of the same magnitude in the subsoils of the two glaciations. The average acid solubility of the total phosphorus in the widely different soils of Maryland is 56·5 per cent; and only three soil series (?) of the sixteen given show a percentage solubility of over 80 per cent. This is in marked contrast to the comparative uniformity shown by the extreme types of the glacial soils.

If these tentative comparisons and conclusions serve to point out the paucity of reliable data on the chemical composition of soils in the United States and the need of further systematic investigation along such lines, before broad generalizations are made regarding the effects of varying amounts of mineral plant foods on soil fertility, their purpose has been, in the main, achieved. They further indicate a relationship between chemical composition and the geologic-physiographic conditions of soil origin and state. On this basis soil classification should follow physiographic principles, and soil sampling should be done in the field by investigators trained in geology and physiography. The names of soil series might well correlate with recognized physiographic and geologic formations in the United States. A large scale map of the United States and Southern Canada showing the areal distribution of acidic and basic igneous rocks, sandstones, shales, and limestones, irrespective of position in the geologic time scale, would give a basis for the correlation of soil surveys having regard for such a classification. On the same map, or on different ones, should be shown the areas of glaciation, generalized drainage features (topography), and the climatic regions of the United States, to serve as a further basis for such classification. There is no attempt to argue here that soil fertility will closely correlate with provinces so marked out. Soil texture, bacteriological considerations, etc., may be the fertility determining factors, without rendering invalid the rationality of such a classification of soils.

Cornell University, June, 1911.

ART. XXXIX.—*The Alunite-Beudantite Group*; by WALDEMAR T. SCHALLER.

Introduction.

THE analysis of the new mineral hinsdalite, described in an earlier paper (this Journal, October, 1911), led me to review carefully the various minerals forming the alunite-beudantite group. This review has brought out several points in regard to the relationships of some of these minerals, about which it is very desirable to obtain more definite and accurate information. Some of the suggestions offered in this paper must remain unsettled until such new work can be performed. Prior* has brought together the various minerals belonging to this group and clearly shown their similarity in composition and in crystal form. Before this comparison is again repeated here, some short discussion bearing on members or possible members of this group will be given.

The probable identity of hamlinite with goyazite.

Goyazite was described by Damour† in 1884 as a hydrous phosphate of alumina and lime, the rather improbable formula being given as $3CaO.5Al_2O_3.P_2O_5.9H_2O$. Hussak‡ has recently tested the original specimen of Damour and found that strontium was present in greater amount than lime, so that goyazite is, in reality, a hydrous phosphate of alumina and strontia. Hartley, in analyzing plumbogummite,§ has suggested that the accuracy of Damour's separation of P_2O_5 from Al_2O_3 was open to serious question, due to the method used. If we assume that a similar inaccuracy is true for his analysis of goyazite, then an interesting conclusion becomes at once evident, namely, that the mineral described and analyzed by Penfield and named hamlinite is identical with goyazite. The probable identity of goyazite and hamlinite can be best shown by a comparison of their properties.

The hamlinite from Maine contains a little barium and fluorine, but their amount, in comparison to that of strontium and water (hydroxyl) respectively, is small and moreover the absence of barium and fluorine in goyazite has not been established.

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* Prior, G. T., Note on a connection between the molecular volume and chemical composition of some crystallographically similar minerals. Mineral. Mag., vol. xiii, p. 217, 1903.

† Bull. soc. min. franc., vol. vii, p. 214, 1884.

‡ Hussak, E., Uber die sogenannten "Phosphat-Favas" der diamantführenden Sande Brasiliens. Min. petrog. Mitt., vol. xxv, p. 335, 1906.

§ Hartley, E. G. J., On the constitution of the natural arsenates and phosphates. Mineral. Mag., vol. xii, pp. 223, 225, 1900.

Goyazite	Hamlinite
Yellowish, white	Colorless, yellowish
semi-transparent	transparent
uniaxial, positive	uniaxial, positive
tetragonal or hexagonal	hexagonal (rhombohedral)
cleavage, basal	cleavage, basal
$H = 5$	$H = 4·5$
$G = 3·26$	$G = 3·228$, $3·159–3·283$
per cent $Al_2O_3 + P_2O_5 = 65·53$	per cent $Al_2O_3 + P_2O_5 = 62·87$
fuses with difficulty	fuses about 4

Utahite and related minerals.

On the basis of our present knowledge, utahite, cyprusite, raimondite, pastreite, carphosiderite, and apatelite form a group of minerals which are very closely related. They are all hydrous sulphates of ferric iron with very similar quantitative composition and all occur in hexagonal or rhombohedral scales. The only one of these minerals which has been found in measurable crystals is utahite, for which two values for the *c* axis have been given, namely 1·1389 and 1·0576. If one remembers that the quality of the material analyzed was of doubtful purity in many cases and that perhaps the analytical methods used were not always of the best quality, the differences in the analytical figures become of minor weight, and one seems almost justified in regarding them as all identical. They may be placed chemically into three divisions, the formulas of each of these being as follows:

I.	Utahite	$3Fe_2O_3.3SO_3.6H_2O$
II.	Carphosiderite	$3Fe_2O_3.4SO_3.10H_2O$
	Apatelite	$3(Fe,Al)_2O_3.3SO_3.9H_2O$
III.	Raimondite	$2Fe_2O_3.3SO_3.7H_2O$
	Pastreite	like raimondite
	Cyprusite	$4(Fe,Al)_2O_3.5SO_3.7H_2O$

These different formulas are all very close and, taking into consideration that as far as the published descriptions go, the crystalline form is the same, it seems reasonable to regard them all as identical. It may be noticed that the above formulas are all close to

$$3Fe_2O_3.4SO_3.7H_2O$$

though to none of them has this formula been ascribed. This formula corresponds to that of a jarosite in which the K_2O is replaced by H_2O.

Jarosite $= K_2O.3Fe_2O_3.4SO_3.6H_2O$

New formula $= H_2O.3Fe_2O_3.4SO_3.6H_2O$

The formula of carphosiderite and apatelite* may be expressed in similar form, the only difference being the slightly higher water:

$$\text{Carphosiderite} = H_2O.3Fe_2O_3.4SO_3.6H_2O + 3H_2O$$

I would therefore propose that, until proven to be otherwise by careful work, carphosiderite, apatelite, raimondite, pastreite, cyprusite, and utahite be regarded as the same mineral with the formula $H_2O.3Fe_2O_3.4SO_3.6H_2O$, to which the name carphosiderite be applied by right of priority.

The compilation of analyses of these minerals, given in the table below, shows their close chemical relationship and also their general agreement with the formula

$$H_2O.3Fe_2O_3.4SO_3.6H_2O.$$

Analyses of Carphosiderite.

	Calculated	Utahite		Cyprusite	Pastreite		Raimondite	Carphosiderite		Apatelite
		1	2[b]		1	2		1	2	
H_2O	13·5	9·35	[12·41]	11·06	16·04	13·95	17·40	18·30	18·48	19·2
SO_3	34·7	28·45	26·83	35·34	30·47	30·55	36·08	31·82	30·18	29·7
Fe_2O_3	51·8	58·82	58·51	49·68	46·50	52·80	46·52	49·88	48·52	40·0
Al_2O_3	---	---	---	3·89	---	---	---	---	---	11·0
X	---	3·19[a]	2·19[c]	---	6·40[d]	2·68[e]	---	---	2·72[f]	---
	100·0	99·81	100·00	99·97	99·41	99·98	100·00	100·00	99·90	99·9
Density				1·7–1·8!			3·19–3·22	2·49	2·73	3·2

[a] As_2O_5.
[b] Arzruni and Thaddeeff. Zeitschr. Kryst., vol. xxxi, p. 244.
[c] Insoluble.
[d] SiO_2, 2·40; As_2O_5, 1·86; PbO, 1·25; (Al_2O_3, MnO, CaO), 0·89.
[e] As_2O_5, 2·05; (Al_2O_3, CaO, sand), 0·63.
[f] P_2O_5.

Miscellaneous Notes.

Though the members of the group are uniaxial rhombohedral, optical anomalies indicating biaxiality have been noted for several of the species: for a sulphate (jarosite), a phosphate (hamlinite) and a compound sulphate-sulphate (hinsdalite). Jarosite has been described as showing optical anomaly

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* Apatelite is only an aluminous carphosiderite.

by Slavik,[*] who described jarosite from Schlaggenwald which, in basal section, showed a division into six parts, each part being biaxial, with the trace of the axial plane normal to the prism edge. The negative, biaxial interference figure varied in size in different crystals, up to 32°. Some basal plates were pleochroic and decidedly doubly refracting.

Hamlinite[†] from Switzerland, at first thought to be a new species and called bowmanite, shows[‡] optical anomalies. The larger crystals show a division into six sections, each showing a positive, biaxial figure, 2E varying from 0° to 50°. Hinsdalite likewise shows a pseudohexagonal character,[§] the crystals being built up of six sectors, each normal to an acute bisectrix, 2E varying from 0° to 40°. These optical anomalies are very suggestive of dimorphism in the series.

The isomorphous relation of sulphate and phosphate is still further confirmed by the presence of 2·72 per cent P_2O_5 in an analysis of carphosiderite from France and also by the presence of nearly one per cent P_2O_5 in a sample of alunite from Utah, tested by the writer.

The formula of beudantite and corkite have been taken as suggested by Lacroix,[‖] namely the arsenate called beudantite and the phosphate corkite. The composition of miriquidite, munkforssite, and munkrudite are too little known to definitely include them in this group, although their qualitative composition is such as to suggest their belonging here.

Pharmacosiderite has been shown[¶] to contain considerable potash and Hartley's formula $2FeAsO_4.Fe[O(H,K)]_3.5H_2O$ can be written analogous to that of hamlinite, as $2(H,K)_2O.3Fe_2O_3.2As_2O_5.7H_2O+4H_2O$, in which the $4H_2O$ does not really belong to the mineral. Though pharmacosiderite is considered isometric, the form is very close to the rhombohedral crystals of this group and it would be highly desirable to test the mineral optically to see if it could be referred to a uniaxial mineral, as it commonly shows weak double refraction.

The composition of plumbogummite still needs careful study and it is entirely possible that more than one species is included under that name. The analyses of Hartley have established the presence in quantity of CO_2 in some varieties, while the analyses of Brazilian plumbogummite, given by Hussak, are

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[*] Slavik, Franz, Mineralogische Notizen. Zeitschr. Kryst., vol. xxxix, p. 297, 1904.

[†] The name hamlinite is retained until its identity with or distinction from goyazite is definitely determined.

[‡] Bowman, H. L., On hamlinite from Binnenthal, Switzerland. Mineral. Mag., vol. xiv, p. 389, 1907.

[§] See paper on Hinsdalite, this Journal, page 251, Oct., 1911.

[‖] Lacroix, A., Mineralogie de la France, vol. iv, p. 592, 1910.

[¶] Hartley, E. G. J., On the constitution of the natural arsenates and phosphates. Mineral. Mag., vol. xii, page 152, 1899.

free from CO_2, although these latter contain more water than is usual. Perhaps the fine grinding of the samples has a very marked effect on the water content of these minerals, as Hartley has suggested for pharmacosiderite.

The mineral harttite is an isomorphous mixture of about two parts of hamlinite and one part of a strontium alunite. More accurately the ratio is 1·97 to 1 instead of exactly 2 to 1. Its formula may therefore be written $2[2SrO.3Al_2O_3.2P_2O_5.7H_2O]$ $+1[SrO.3Al_2O_3.4SO_3.6H_2O]$, which can be simplified to $5SrO.9Al_2O_3.4P_2O_5.4SO_3.20H_2O$. This is very close to the formula deduced by Hussak, whose formula, quadrupled, gives: $4SrO.8Al_2O_3.4P_2O_5.4SO_3.20H_2O$. In fact, the ratios deduced by Hussak from the analysis of harttite are in better agreement with the formula here proposed than his own.

Ratios of Harttite.

	Ratios of analysis		Required by Hussak's formula	Required by Schaller's formula
SrO	1664	4·57	4·00	5·00
Al_2O_3	3355	9·22	8·00	9·00
P_2O_5	1528	4·20	4·00	4·00
SO_3	1475	4·05	4·00	4·00
H_2O	1733	19·60	20·00	20·00

The Minerals of the group.

The minerals forming the alunite-beudantite group may be divided into three smaller groups,—the sulphates, the phosphates, and the sulphate-phosphates. Taking alunite as the type of the sulphates, hamlinite of the phosphates, and corkite as that of the sulphate-phosphates, we have:

Alunite	$K_2O.$	$3Al_2O_3.$	$4SO_3.$	$6H_2O.$
Hamlinite	$2SrO.$	$3Al_2O_3.$	$2P_2O_5.$	$7H_2O.$
Corkite	$2PbO.$	$3Fe_2O_3.$	$2SO_3.P_2O_5.$	$6H_2O.$

The analogous composition is not clearly seen in the three formulas just given, but it is possible, by rewriting them in a slightly different form, to show very clearly the analogy between them:

Alunite	$K_2O.$	$3Al_2O_3.$	$6H_2O.$	$2SO_3.$	$2SO_3.$
Hamlinite	$SrO.$	$3Al_2O_3.$	$6H_2O.$	$2HPO_3.$	$Sr(PO_3)_2.$
Corkite	$PbO.$	$3Fe_2O_3.$	$6H_2O.$	$2SO_3.$	$Pb(PO_3)_2.$

By assuming the isomorphous replacement of SO_3 by HPO_3, the relationship becomes very clear. The formulas can, however, be better written by regarding $=[SO_4]$ and $=[HPO_4]$ as the isomorphous groups which are replaceable. The formulas for these minerals then become:

Alunite	$[Al(OH)_2]_6.$	$K_2.$	$[SO_4]_2.$	$[SO_4]_2.$
Hamlinite	$[Al(OH)_2]_6.$	Sr.	$[HPO_4]_2.$	$[Sr(PO_4)_2].$
Corkite	$[Fe(OH)_2]_6.$	Pb.	$[SO_4]_2.$	$[Pb(PO_4)_2].$

The general formula is written:

$$[R'''(OH)_2]_6.R''.[M]_2.[M_2].$$

where $R''' = Al, Fe'''$.

$R'' = K_2, Na_2, H_2, Pb, Sr, Ba.$
$M = SO_4, HPO_4, HAsO_4, Pb_{\frac{1}{2}}PO_4, Sr_{\frac{1}{2}}PO_4.$

The entire group then consists of the following minerals:

Sulphates.—Type formula $[R'''(OH)_2]_6.R'_2$ or $R''.[SO_4]_2.[SO_4]_2.$

Alunite	$[Al(OH)_2]_6.$	$K_2.$	$[SO_4]_2.$	$[SO_4]_2.$
Natroalunite	$[Al(OH)_2]_6.$	$Na_2.$	$[SO_4]_2.$	$[SO_4]_2.$
Jarosite	$[Fe(OH)_2]_6.$	$K_2.$	$[SO_4]_2.$	$[SO_4]_2.$
Natrojarosite	$[Fe(OH)_2]_6.$	$Na_2.$	$[SO_4]_2.$	$[SO_4]_2.$
Plumbojarosite	$[Fe(OH)_2]_6.$	Pb.	$[SO_4]_2.$	$[SO_4]_2.$
Carphosiderite	$[Fe(OH)_2]_6.$	$H_2.$	$[SO_4]_2.$	$[SO_4]_2.$

Phosphates.—Type formula $[R'''(OH)_2]_6.R''.[R'PO_4]_2.[R''(PO_4)_2].$

Hamlinite	$[Al(OH)_2]_6.$	Sr.	$[HPO_4]_2.$	$[Sr(PO_4)_2].$
Plumbojarosite	$[Al(OH)_2]_6.$	Pb.	$[HPO_4]_2.$	$[Pb(PO_4)_2].$
Gorceixite	$[Al(OH)_2]_6.$	Ba.	$[HPO_4]_2.$	$[Ba(PO_4)_2].$
Florencite	$[Al(OH)_2]_6.$	$Ce_{\frac{2}{3}}.$	$[Ce_{\frac{1}{3}}PO_4]_2.$	$[Ce_{\frac{2}{3}}(PO_4)_2].$

Sulphate-Phosphates.—Type formula $[R'''(OH)_2]_6. R''. [SO_4]_2. [R''(PO_4)_2].$

Beudantite	$[Fe(OH)_2]_6.$	Pb.	$[SO_4]_2.$	$[Pb(AsO_4)_2].$
Corkite	$[Fe(OH)_2]_6.$	Pb.	$[SO_4]_2.$	$[Pb(PO_4)_2].$
Svanbergite	$[Al(OH)_2]_6.$	Sr.	$[SO_4]_2.$	$[Sr(PO_4)_2].$
Hinsdalite	$[Al(OH)_2]_6.$	Pb.	$[SO_4]_2.$	$[Pb(PO_4)_2].$
Harttite	$\{[Al(OH)_2]_6.$	Sr.	$[SO_4]_2.$	$[SO_4]_2.$
	$2\{[Al(OH)_2]_6.$	Sr.	$[HPO_4]_2.$	$[Sr(PO_4)_2]\}.$

NOTE.—Pastreite has been determined as jarosite (Bull. soc. franc. Mineral., vol. xxxiii, 1910, p. 130), the earlier analysis being wrong.

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ART. XL.—*The Electrolysis of Sodium Chloride with the Mercury Cathode;* by CHARLES A. PETERS.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxxvi.]

CONTENTS:

WOLCOTT GIBBS* was the first to suggest the use of mercury as a cathode in analysis. The extension and development of this idea has been carried on by Vortmann,† Speketer,‡ and others,§ notably by E. F. Smith‖ and his co-workers.

The present paper is concerned with the study of the electrolysis of sodium chloride using a silver or silver plated anode to hold the chlorine and a mercury cathode to fix the sodium. In general, to sum up the work briefly, it may be said, that, within the writer's experience, silver is invariably carried from the anode to cathode, though under certain conditions the amount is analytically negligible; that the fixation of conditions necessary for accurate analysis is dependent upon many factors, such as amount of salt electrolyzed, time of electrolysis, etc.; and further, that the ammeter does not show by any sudden drop the correct end-point of the process.

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* Paper read before National Academy of Sciences, 1883.

† Monatshefte f. Chemie, xv, 280, 1894; xvi, 674, 1895.

‡ Zeitschr. f. Electrochem., iv, 539.

§ See references in Gooch and Read, this Journal, xxviii, 544, 1909.

‖ Electro-Analysis, 1907.

APPARATUS.

Cell.—The cell used was the one described by Hildebrand[*] consisting of a bottomless beaker 6·3$^{\text{cm}}$ in diameter and 6·3$^{\text{cm}}$ tall set into a crystallizing dish 11·3$^{\text{cm}}$ in diameter and 5·7$^{\text{cm}}$ high. Midway between the cells, above the mercury, was a coil of 6 turns of nickel wire 1$^{\text{mm}}$ in diameter. At three places on the nickel wire a single wire ran down forming legs, in the feet of which rested the ends of a Y. This Y, made of glass rod 3$^{\text{mm}}$ in diameter, formed the support for the inner cell and also held the nickel wire in position when the whole apparatus was inverted in emptying. Three rubber stoppers placed radially held the inner cell in position. The apparatus is pictured by Hildebrand[†] and also in Smith's Electro-Analysis. Less than 2 kg. of mercury sealed the two compartments. The contact with the cathode was made through an S-shaped tube filled with mercury which hung on its side on the edge of the outer cell. The S-shaped tube had a platinum wire sealed in one end dipping under the cathode mercury.

Plated Anode.—The anode was the platinum one previously used in this laboratory,[‡] consisting of two circular discs of platinum gauze, 300 meshes to the sq. cm., attached 1$^{\text{cm}}$ apart to the end of a heavy platinum wire. The weight was about 16·5 grms. When plated the weight was increased to 21 or 22 grms. A loop of platinum wire was easily welded on the stem (best extending above the top) by means of which the anode was suspended in the balance or in the heating apparatus.

Silver Anode.—Described later when used, p. 382.

Electrical Apparatus.—The rotating apparatus was one with which this laboratory is equipped, and operated by the 110 volt direct current circuit. The ammeter was of American Instrument Company's make graduated to ·01 of an ampere. Storage batteries furnished the energy for electrolysis.

Air Bath.—Some of the time the anode was dried in an air bath. This consisted of two sheet iron cylinders each about 20 inches high set one inside the other, the inner one about 4 inches in diameter and single; the outer one about 7 inches, double, and filled with asbestos. The lower end of the inner cylinder was fitted with two iron covers packed with asbestos to prevent the entrance of the gases from the Bunsen burner. A tinned copper or iron cover placed over the inner cylinder, through which passed a nickel wire holding the anode, and a nasbestos cover over all, greatly increased the heat. A thermometer through both covers gave the temperature, which could be regulated approximately anywhere up to 600°.

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[*] Jour. Amer. Chem. Soc., xxix, 451.

[†] L. c.

[‡] Gooch and Read, this Journal, xxviii, 544, 1909.

The use of this apparatus, however, was of short duration, as in one experiment after the silver chloride coated anode had been heated 11 hours, in intervals, at temperatures ranging from 300°–565°, the weight changed suddenly, showing a complete reduction of the silver chloride to silver. The inner chamber was considered permeable to the gases of the flame and the bath thereafter discarded.

Heating Crucible.—A simple but yet very satisfactory device for heating the anode was made by setting a porcelain crucible, 8^{cm} wide and 4·8 deep, into a heavy piece of asbestos 6^{mm} thick and about 30^{cm} square so that only 3^{mm} of the crucible projected above the asbestos board. A loose cover of mica, with a slit to the middle—the width of the stem of the anode—and a second piece of mica to cover the slit, allowed the anode to be easily introduced and adjusted to any height. The anode hung from a nickel hook. When hydrogen, or a thermometer, was introduced into the crucible, holes were cut in the mica cover. In the early work an iron cover with two or three holes of appropriate size was used.

The temperature of the crucible was determined by use of a nitrogen thermometer. When this was placed $2{\cdot}5^{cm}$ from the bottom of the crucible and the gas slightly lowered it registered 390° (corrected). With the full heat of the Bunsen burner the temperature was 530° (corrected). When the thermometer was lowered to $1{\cdot}3^{cm}$ of the bottom of the crucible the temperature, at full heat of the burner, was beyond the reach of the thermometer and was considered to be something over 600°. The temperatures were constant and could easily be duplicated by use of the same burner. It was much hotter near the sides and bottom of the crucible, as shown by the fact that the anode could be placed so that silver chloride on the lower gauze disc would melt while that on the upper disc would not melt. This, however, was no serious objection to the use of the crucible.

Electric Furnace.—A more satisfactory apparatus for heating the anode was made somewhat similar to that described by Goldbaum,* as follows: Six brass rods wound with asbestos cord soaked in water glass were set with screws into a 15^{cm} square top and bottom of transite asbestos wood 6^{mm} thick. The diameter of the circle of brass rods was about 10^{cm}. Water glass wet asbestos cord was wound around the insulated brass rods in screw-like fashion about 40 times, leaving 7 or 8^{mm} between the threads. Two strands of 3^{mm} nicrome ribbon were next wound flat into the space between the dried threads with another water glass wet asbestos cords between the nicrome ribbons, thus completely insulating each ribbon.

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* Jour. Amer. Chem. Soc., xxxiii, 37.

At one end the wires were joined and went through a porcelain tube to a binding post (*c*) on top. At the other end each wire went separately to posts (*a*) and (*b*) on top. This furnished three heats with the 110 volt direct current. Connection *a* to *b* gave a temperature of 285°, *a* to *c*, or *b* to *c*, 400°, and *a* and *b*, together, to *c* 580°. The insulation on the sides was bright metal, aluminum or tin, in three layers each packed loosely with powdered magnesia or loose asbestos between and the whole surrounded by wood. The top and bottom was composed of three layers of the asbestos-soapstone board packed with less than a centimeter of magnesia between each. A sliding door on the bottom allowed a draft when desired. The same mica cover that was described under the Heating Crucible closed the top.

Mercury Still.—The apparatus described by Hulett and Minchin* was used.

Thermometers.—Nitrogen thermometers were used to determine temperatures over 350°. In determining the temperature of the electric furnace two thermometers—one certified—gave the same results.

CHEMICALS.

Sodium Chloride.—The salt was the pure article of German origin further purified by one precipitation with hydrochloric gas. It was fused in platinum and bottled. Two liters of solution, made up at once after the fusion, contained 11·6920 grms. of salt.

Hydrochloric Acid.—The pure acid was diluted and standardized. Two 100^{cm^3} portions precipitated at considerable dilution gave, including the residue after evaporation of the filtrates mostly in platinum, 1·4768 and 1·4770 grms. of fused silver chloride respectively.

Mercury.—The ordinary redistilled mercury of commerce was used. After use in some preliminary experiments and before using in the experiments quoted it was subjected to triple distillation. No residue was found after the first distillation.

PROCEDURE.

Plating Anode.—The platinum gauze anode was plated from an ammoniacal solution of silver nitrate to which ammonium oxalate had been added.† To insure an even deposit of silver

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* Physical Review, xxi, 395, 1905.

† It was found convenient to add crystalline ammonium oxalate after solution of the silver nitrate by ammonia had been effected. The oxalate dissolved as the anode was rotated during the plating.

the position of the platinum cathode was changed twice during the plating. First the prong of a right angle bent piece was inserted between the rotating gauze discs nearly to the central stem of the anode and about one-third the silver, say two grams, deposited; then the cathode was pointed at a 45° angle between the stem and the upper disc and a little more silver deposited. The point where the stem passes through this disc seems to be the most difficult place to cover. Finally the cathode was removed to a position below the anode and the electrolysis continued until the electrolyte was silver free. The weight of the anode was generally increased about 5 grms. as a result of the plating. Only once was unplated platinum, presumably the same as noticed by Goldbaum,* seen by the writer, and then as black specks appearing on the center stem between the disc, and these were easily covered by plating on a few tenths of a gram more silver with the cathode between the discs.

Electrolysis.—For an electrolysis about 2 kg. of mercury was placed in the apparatus, the amount of sodium chloride—generally 50^{cm^3} of the ·1N solution—was introduced into the inner cell and about $70–90^{cm^3}$ of water into the outer cell with 1^{cm^3} of saturated salt solution. The plated anode was introduced, rotated at a speed of 200–300 r.p.m. and the current applied. After the first few experiments no particular attention was paid to the speed of the rotation of the anode. When the electrolysis was considered sufficient and the current discontinued the anode was withdrawn, washed, and dried by appropriate means. The contents of the inner cell were pipetted out—when separate titration was necessary—the remainder of the solution washed into a separatory funnel and separated from the mercury by three washings. The contents of the outer cell were titrated by hydrochloric acid, using methyl orange, generally at a dilution of 250^{cm^3}. When other dilution was used correction for that volume was made at the time. The inner cell was titrated by approximately ·1N sulphuric acid. The end-point in all titrations was obtained by using a sodium hydroxide solution, about ·06N, to discharge the pink color of the indicator.

In some cases, as in obtaining the results given in Table VI, where it was unnecessary to separate the contents of the inner and the outer cells, hydrochloric acid was added directly to the liquid above the mercury to about the neutral point to methyl orange, then the whole was shaken in a separatory funnel to decompose the last of the amalgam and the titration finished in an Erlenmeyer beaker in the absence of more than a few tenths of a gram of the mercury at a volume of 250^{cm^3}. This procedure was shorter and to be preferred to the complete sepa-

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* Jour. Amer. Chem. Soc., xxxiii, 42.

ration of the mercury before titration. Of course in such cases the rubber stoppers were first taken out, one at a time, and the inner breaker washed as it was removed from the apparatus.

Determination of Silver in Mercury.—In the first attempts to estimate the residual silver in the flask after distillation the mercury was driven out completely by cutting off the neck of the distillation flask and heating it—after most of the mercury had been driven out—opening down. The heavy vapor gradually settled out and left the silver adhering to the flask. Solution and precipitation followed. The long time necessary to get the mercury completely out of the flask and the solubility of the silver chloride in acid upon precipitation suggested the following procedure, which was used in all the work here quoted. The mercury was distilled until only a small globule the size of a pea remained. Then after the apparatus had cooled and the distillate had been emptied from the receiver, the globule remaining in the distilling flask, together with some of the mercury that had collected about the neck of the flask, was poured into a small tared crucible and heated gradually in the crucible until all the mercury had left and then the silver was weighed. In case the globule of mercury was quite rich in silver and some of it stayed behind on the flask, gentle jarring caused more mercury to fall to the bottom, and this was used to wash out the last trace of amalgam. A preliminary experiment showed that a few milligrams of silver were completely freed from added mercury by five minutes heating over the Bunsen burner.

DEPTH OF MERCURY IN CELL.

Smith,[*] Hildebrand,[†] Goldbaum and Smith[‡] recommended the use of the mercury 3^{mm} above the bottom of the inner cell. Goldbaum[§] later used about 6^{mm}. The writer's experience confirms the use of at least 6^{mm} of mercury to seal the two compartments. In several experiments when less than 6^{mm} of mercury were used liquid passed from the inner to the outer cell, the speed of the anode being 250–300 revolutions per minute. Faster rotation, 470 revolutions, forced water to the outer cell on some occasions even with 6^{mm} of mercury above the lower edge of the inner cell.

EXPERIENCE WITH ANODE.

Drying and Heating.—In a number of experiments after the electrolysis of generally 50^{cm^3} of ·1N sodium chloride solution the anode was dried over night in a sulphuric acid desiccator, then heated to a constant weight in a steam oven at

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[*] Electro-Analysis (1907), 304.

[†] L. c. 451.

[‡] L. c. 1470.

[§] L. c. 36.

105°. This was followed by heating in the air bath or porcelain crucible to about 300°, and finally the silver chloride was fused over the tip of a low flame of a Bunsen burner. The results are given in Table I.

Table I.

Chlorine taken as NaCl	Increase in Weight of Anode				
	After drying in sulphuric acid desiccator	After drying in steam oven at 105°	After heating in air bath	After heating in crucible	After fusion over tip of flame
grms.	grms.	grms.	grms.	grms.	grms.
·1773	·1809	·1803	·1751	----	·1745
·1773	·1868	·1801	·1770	----	·1768
·1775	·1881	·1873	----	·1784	----
·1516	·1663	·1612	----	----	·1495

It is noticed that the constant weights obtained after heating in the steam oven are less than those obtained after the anode had stood over sulphuric acid. Apparently some water was not taken out by the sulphuric acid trying.

On heating in the air bath or porcelain crucible it is seen that the weights decreased 30 to 90 mgrms. more. On fusion over the free flame further reductions in weight of a few tenths of a milligram were obtained.

It is noticed, in general, that the increase in weights are nearer the theory after the heating at the higher temperature of the air bath or heating crucible than after the heating at 105° in the steam oven. This corresponds to the experience of Vortmann,* the later work of Goldbaum and Smith,† Goldbaum,‡ and not with the earlier statements of Smith.§

Increase in Weight upon Heating.—It was noticed that when the anode with its silver chloride deposit was kept at high temperature for long periods the weight gradually increased. In one typical experiment the anode with the silver chloride from 25^{cm^3} of ·1N sodium chloride (equivalent to ·0877 grms. of chlorine) was heated in the air bath at 320° for about five minutes and weighed. The heating was continued for 11 hours in the air bath for periods from one-half to four hours each, the temperature varying from 400° to 565°, most of the time being about 520°. The anode gradually got heavier, and increased in all ·0085 grms. over the first weighing.

In the porcelain crucible the same effect was noticed to a less degree. For example, the anode covered with chloride equiv-

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* L. c.

† Jour. Am. Chem. Soc., xxxii, 1469, Nov. 1910.

‡ Jour. Am. Chem. Soc., xxxiii, 42, Jan. 1911.

§ Electro-Analysis, 305, 1907.

alent to ·0887 grms. of chlorine was heated for 1¼ hours at about 390° and nearly 14 hours at about 530°, gained in all ·0011 grms. The same anode, after being relieved of most of its silver chloride by solution in ammonia, was heated a total of 25½ hours at about 390° (8 separate heatings) and gained ·0055 grms. At 530° one heating of four hours caused an increase of 1 mgrm.

In the electric oven three heatings of an hour each at about 435° (varying from 390–480°) caused an increase of ·0008 grms. on an anode holding the chlorine from 50$^{cm^3}$ of ·1 N sodium chloride solution.

The increase in weight, then, of a silver-plated platinum electrode is apparent upon long heating at temperatures of from 400° to 500°, but it is so small during short periods, say 15 minutes, that it may be neglected.

The only explanation offered is the statement of Graham's* that silver heated to redness will absorb the surrounding gases. If this is the explanation for the phenomena observed, it is evident that the absorptive power of silver is considerable below red heat.

Decrease in Weight upon Heating.—H. Rose† says silver oxide begins to decompose at 250°. One might expect, therefore, that exposure of an anode to a temperature of 300° would quickly decompose all the oxide on it. The action of an anode, then, coated with silver chloride and silver oxide at temperatures of 300° and over will be interesting.

To observe such action a solution of 50$^{cm^3}$ of ·1N sodium chloride (·1773 of chlorine) was electrolyzed and the anode heated 15 minutes in the electric oven at 305° and weighed. It showed a gain of ·1793 grams. The heating was continued for 6 periods of about an hour each at temperatures of 300–500° as shown in Table II.

TABLE II.

Increase in weight of anode grms.	Successive loss in weight of anode grms.	Time of heating min.	App. av. temp. C°.	Range of temperature C°.
·1793	----	16	305	280–320
·1789	·0004	60	"	230–335
·1784	·0005	65	"	275–325
·1782	·0002	60	"	280–325
·1770	·0012	100	"	305–370
·1767	·0003	65	410	400–465
·1767	·0000	60	450	415–480

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* Phil. Mag. (4), xxxii, 503.

† Ann. Phys. [I], lxxxv, 317 (Pogg.).

It is evident that the weight of the anode decreases until the temperature reaches 400–500°. If we assume that this loss in weight is due to the decomposition of silver oxide it is evident that heating to 300° for a short time cannot always be depended upon to break up all the silver oxide. Goldbaum and Smith* used a temperatnre of 300° and Goldbaum† later exposed his anode to a temperature of 330–400°. The necessity for heating at the higher temperature will seem more reasonable if the point of view is taken that the anode after electrolysis does not consist of successive distinct layers of platinum, silver, silver chloride and silver oxide, but rather, on some occasions, of the chloride and oxide intermixed, these being deposited simultaneously. One would expect silver oxide covered with silver chloride, particularly fused silver chloride, to decompose with more difficulty than silver oxide by itself.

Richards and Wells‡ state that the hardened silver chloride must be fused to rid it of the last traces of water and further that the vapor pressure of the silver chloride at 500° is analytically inappreciable.§ These statements furnish an added argument for the use of a high temperature, over 487°, in preparing the silver coated anode for weighing and tend to show that there would be no loss by volatilization by so doing.

In two instances heating in the crucible at the highest temperature—over 600°—caused a slow but decided loss in weight of the silver chloride coated anode. This was evidently due to the volatilization of the silver chloride, as the glaze of the crucible in the immediate vicinity of the anode was attacked and turned yellow. This fact would set 550° as a limit to the temperature to which the anode safely may be heated.

Weighing Silver Chloride.—In view of the facts stated in the last seven paragraphs: the danger of increase of weight upon long heating; the danger of insufficient heating at about 300°, the following method was adopted for treatment of the anode covered with silver chloride and oxide before weighing. The anode was introduced into the heating device at a temperature below the fusion point of silver chloride, 400–450°, and the temperature of the oven increased until the silver chloride fused. When the silver chloride had assumed the "yellow hot" condition or had acquired the still hotter "brown red" color the heating was considered sufficient. The process required from 5 to 15 minutes, varying with the manipulation of the oven.

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* Jour. Am. Chem. Soc., xxxii, 1469.

† Jour. Am. Chem. Soc., xxxiii, 42.

‡ Jour. Am. Chem. Soc., xxvii, 496.

§ Jour. Am. Chem. Soc., xxvii, 518.

Change of Color and Fusion of Silver Chloride.—It was noticed that as the anode containing silver chloride darkened by light was exposed to the higher temperatures of the various ovens used, it became gradually lighter in color and finally colorless. The change was most rapid as the melting point, 487°,* was approached.

Silver chloride that had been rendered colorless by fusion and weighed, turned dark on exposure to light without change in weight and became again colorless upon refusion with no detectable change in weight.

Goldbaum† and other writers speak of distinguishing by color the silver chloride darkened by light from the silver oxide also deposited on the anode. This is not always the writer's experience. There were times in the course of this work when he could distinguish between them. At other times only reference to the treatment the anode had undergone could decide whether it was coated with oxide or chloride or both, and the color gave no correct indication of what might be on the anode. These points are noted in progress of the work, which, however, have no direct bearing upon it.

Cleaning with Potassium Cyanide.—Gooch and Read‡ have shown that the gauze electrode plated from potassium cyanide is contaminated by the cyanide. Consequently even for the solution of the silver chloride from the anode the use of this reagent, for the most part, was avoided.

The two exceptions where it was used gave the following experience. In one the anode covered with the fused chloride, from the electrolysis of salt equivalent to ·1773 grms. of chlorine, was rotated in 5 per cent potassium cyanide for 1¼ hours, then rinsed in running water under the tap and rotated again in fresh water in a beaker for 2 hours. The water in this second beaker gave a white precipitate when silver nitrate was added, showing that potassium cyanide had diffused into it.

In the second experiment the anode, also covered with fused silver chloride from salt equivalent to ·1773 grams of chlorine, was allowed to stand in 5 per cent cyanide solution all night and part of a day, then washed under the tap and placed in a fresh beaker of water, where it stood during the remainder of the day and all night. The following day it was rinsed again and allowed to stand four hours in a second fresh beaker of water. The water in the first beaker of water gave a precipitate with silver nitrate solution and the second none, not even upon evaporation to 5^{cm^3} on the steam bath. These experi-

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* Kohlrausch, P. A. (2), xvii, 642 (Dammer).

† L. c.

‡ This Journal, xxviii, 550, Dec. 1909.

ments show that potassium cyanide used for solution of the silver chloride cannot be washed out in a few seconds under the tap but does practically all diffuse out upon long standing in water.

After the experiment last recorded in the previous paragraph was performed, the silver (5·7 grams) on the anode used was dissolved in half strength nitric acid. Some platinum, finely divided, appeared in the beaker. The mixture was evaporated on the steam bath and water added. A white precipitate was apparent. The addition of more nitric acid caused the disappearance of the white precipitate. The liquid upon evaporation was now noticed to have the reddish yellow color of platinum chloride and did contain platinum in solution. The writer would say that the solution of the platinum black was due to the action of nitric acid and hydrochloric acid, which latter could only have come from some silver chloride left unattacked by the cyanide, and, consequently, that potassium cyanide may not completely dissolve fused silver chloride from the gauze anode. This experiment verified a previous observation to the same effect.

Cleaning with Ammonia.—It was attempted many times to remove the fused silver chloride from the anode by solution in ammonia. This was only partially successful, as a few selected experiments will show. In one the anode covered with ·72 grms. of fused silver chloride lost ·52 grms. upon ten minutes rotation in strong ammonia.

In a second experiment the anode was rotated in one-half strength ammonia four hours. Then, after heating to redness again, rotated for 15 minutes in fresh ammonia and the solution evaporated. The residue showed silver chloride. The anode after heating again to dull redness and still showing silver chloride, was fused and rotated 17½ hours in ammonia of half-strength and the liquid was evaporated. Silver chloride was found in the residue. The anode, upon being weighed, showed a loss of ·0110 grms. in weight. Reduction in hydrogen reduced the weight ·0020 grms. more.

It was evident from these and other experiments that complete solution of the fused silver chloride in ammonia was tedious if not impossible.

Reduction in Hydrogen.—The reduction of the silver chloride on the anode by hydrogen was more satisfactory than the cleaning with either cyanide or ammonia. The process as it was carried out was briefly as follows: The anode after weighing, covered with fused chloride, was suspended in the porcelain heating crucible previously described, the cover of iron or mica snugly but lightly adjusted, hydrogen dried by sulphuric acid introduced briskly, Rose fashion, through the cover and the

Bunsen burner under the crucible lighted. The temperature in the crucible was 500–600°.

After the reduction was over, the flame was lowered and withdrawn and the anode cooled for a minute in the current of hydrogen. Occasionally when the cover was loose the air got in and caused the mixture to explode, or the hydrogen escaping burned at the edges of the crucible. This did no harm, but a cover fastened tightly to the crucible should not be used.

In Part 1 of Table III, which follows, are recorded in the order in which they were obtained the results of reducing the anode containing, each time, the chorine from 50^{cm^3} of ·1N sodium chloride solution (equivalent to ·1773 grms. chlorine). The same plated anode was used throughout the series, being reduced each time after fusion and weighing, and then used in electrolysis to hold more chlorine.

Table III.

	Chlorine added by electrolysis grms.	Sum of amounts of chlorine added grms.	Chlorine lost by reduction grms.	Sum of amounts of chlorine lost by reduction grms.	Chlorine unreduced remaining on anode grms.	Time of heating min.
			Part 1.			
1	·1775	----	·1387	----	·0388	5
2	·1771	·3546	·2111	·3498	·0048	10
3	·1770	·5316	·1791	·5289	·0027	25
4	·1781	·7097	·1767	·7056	·0041	20
5	·1775	·8872	·1266	·8322	·0550	9
6	·1743	1·0615	·1234	·9556	·1059	15
7	·1780	1·2395	·1782	1·1338	·1057	19
			Part 2.			
8	·1770	----	·1768	----	·0002	20
9	·1768	·3538	·1768	·3536	·0002	13

In column 5 are recorded the differences between the sum of the amounts of chlorine added to the anode by electrolysis and the sum of the amounts lost by reduction; in other words, the amount of chlorine still remaining on the anode.

It is seen that five or ten minutes heating in hydrogen is not sufficient to reduce all the silver chloride to silver, and that if the anode is used in electrolysis with some silver chloride still unreduced on it, the complete reduction of all silver chloride thereafter is hardly possible.

In Part 2 are recorded two experiments, made in succession with a freshly plated anode. It is seen that when the first reduction (exp. 8) is made sufficiently long to reduce all the silver chloride, there seems to be no difficulty in a subsequent complete reduction.

The most satisfactory method, then, for the removal of the silver chloride on the anode is reduction by hydrogen in the porcelain crucible at a temperature of 500–600°, and the time required is about 20 minutes. This method has the added advantage of allowing the same silver-covered anode to be used over and over again without repeating.

LIQUID OF THE INNER CELL.

Alkalinity.—Hildebrand* states that the inner cell after electrolysis contains nothing but pure water. Smith,† apparently quoting Hildebrand, makes a statement to the same effect. Goldbaum‡ speaks of the possibility of decomposition of the sodium amalgam in the inner cell, giving rise to sodium hydroxide. In the writer's experience the liquid of the inner cell, after electrolysis had begun, was alkaline to indicators whenever tested. In one experiment a drop of phenolphthalein was added to the inner cell liquid. Upon passing the current the liquid turned pink and remained alkaline throughout the electrolysis. In a second experiment the inner cell liquid, colored pink by the same indicator shortly after the electrolysis had begun, stayed pink during the remainder of the operation.

In a number of experiments the alkalinity of the inner cell was determined by titration with ·08996N sulphuric acid using methyl orange. The amounts of acids used together with the initial and final current conditions are given in Table IV as follows:

TABLE IV.

No.	Sulphuric acid ·08996N cm³	Time of electrolysis min	Amp. initial & final	Voltage initial & final	Remarks
1	13·69	140	·24–·035	4 cells	
2	8·66	70	·28–·063	4–3	Changed during expt.
3	2·39	14	1·4 –0·1	7·2–8	
4	2·38	18	1·4 –0·1	7·2–8	
5	2·15	19	1·3 –0·09	7·2–8	
6	2·09	18	1·17–0·1	7·4–8	
7	1·31	42	·77– ·03	4 cells	
8	1·01	38	·6 1·0 –·03	6–8	·6 Raised to 1·0 near the start
9	·92	13	·63 –·03	7·4–8	
10	·62	31	1·3 –·03	7–8	

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* L. c. 452 and 453.

† L. c. 305.

‡ L. c. 41.

Looking at the table and omitting expts. 3–6 and observing the remainder in which the current was interrupted when the ammeter read about ·03, it is seen that the alkalinity of the inner cell is less when the initial current is greater. Looking at expts. 1, 2, 7, 8, and 9, in which a lower current, ·24–·77 amp., was used, it is seen that the alkalinity increases with the time of electrolysis. In experiments 3–6, where initial current was larger and the time short, the alkalinity is small.

Now with these experiments comes the very natural conclusion that an electrolysis conducted for a longer time with a low current produces more sodium hydroxide in the inner cell than one run the shorter time with a stronger current.

Silver Oxide.—The presence of sodium hydroxide in the inner cell suggests the presence of dissolved silver oxide in the inner cell liquid. Accordingly a few drops of ·1N sodium chloride solution were added to the acidic liquids of inner cells described in expts. 7 and 8 of Table IV. In No. 8 an opalescence appeared at once and in No. 7 a slight precipitate appeared after standing a few days, indicating in both experiments the presence of soluble silver compound, the oxide, in the inner cells. The amounts of silver chloride precipitated from these inner cell liquids by sodium chloride was not determined but was judged to be only one or two tenths of a milligram.

When the electrolyses recorded in expts. 3–6 of Table IV were made, in which the current was stopped at 0·1 ampere, no soluble silver oxide was found in the inner cell by the addition of ·1N sodium chloride solution to the liquid acidic with sulphuric acid.

Silver, then, may be lost by solution, as silver oxide, when the electrolysis, under the conditions given in expts. 7 and 8, proceeds from 30 to 45 minutes; but is not dissolved—expts. 3–6—if the current is strong enough to complete the operation in 14–19 minutes.

Turbidity.—The opalescence of the inner cell liquid during electrolysis has attracted the attention of many workers. Goldbaum and Smith[*] suggested that the distance of the anode from the mercury was a factor in its production; and that electrolyses made with the anode 1^{cm} above the mercury were free from turbidity. Later, Goldbaum[†] stated that platinum exposed to the electrolyte during electrolysis is responsible for the opalescent phenomenon.

The writer is unable to draw any conclusions from his work regarding the matter. The opalescence was encountered in some instances and in others, apparently identical, it was

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[*] L. c.

[†] L. c. 43.

absent. Certain it is that in the electrolysis with an anode of pure silver alone—no platinum about the apparatus—in the experiments recorded in Part 2 of Table V the turbidity was present; showing that platinum exposed to the electrolyte is not, as supposed by Goldbaum, the controlling factor.

In general when an electrolysis of 50^{cm^3} of ·1N salt solution was conducted with a low initial amperage, ·24–77, opalescence made its appearance when the current fell to ·02–06 amp.; the time, 28–140 minutes, varying inversely with the strength of the current used.

The liquid of the inner cells in some of these experiments on settling spontaneously some weeks gave precipitates which weighed ·5–·8 mgrms.

In some cases where the electrolyses were conducted for long periods the opalescence came and disappeared. It is assumed here that the silver chloride, the substance giving rise to the opalescence, reacted with the sodium hydroxide and that the products were electrolyzed; the chlorine going to the anode and the silver into the mercury.

Even in the experiments recorded in Part 4 of Table V, the conditions being the most ideal for quantitative work that the writer was able to obtain, the liquid of the inner cell showed a trace of opalescence when viewed alone in a small beaker.

Reactions.—Some remarks, mostly theoretical, may not be out of place at this point. If we assume the simultaneous deposition of chlorine and oxygen on the anode, the chlorine being deposited most freely at the beginning of the process and the oxygen at the end, it would seem natural that the process should go smoothly until the silver anode surface is covered with these products. One of the natural results of crowding on more oxygen and chlorine would be to cause the formation of compounds of silver, oxygen and chlorine. Allowing the formation of soluble silver oxygen compounds, say the hypochlorite, either or both of the following reactions might take place, according to the amounts of sodium hydroxide or chloride present in the inner cell:

$$\mathrm{AgOCl + NaOH = AgOH + NaOCl}, \text{ or}$$
$$\mathrm{AgOCl + NaCl = AgCl + NaOCl}.$$

The writer has found soluble silver oxide in the inner cell; Goldbaum,* under some conditions, also found a deposit of silver oxide. The opalescent substance occurring during electrolysis one would expect to be silver chloride. Gooch and Read† found hypochlorite in the inner cell using

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* Loc. cit. 42.

† Loc. cit.

no mercury cathode. Goldbaum and Smith* verify this observation. The writer was unable to find hypochlorites at any time when the mercury cathode was used. What the function of the mercury is in decomposing or preventing the formation of the hypochlorites has not been explained, although it is well known that metallic mercury and sodium hypochlorite react to form mercury oxide and sodium chloride, both of which products one would expect to be decomposed in the electrolytic cell.

TRANSFER OF SILVER TO MERCURY CATHODE.

Using the Silver Plated Anode.—Gooch and Read† in one experiment had a loss unaccounted for of ·0012 grms. which pointed towards the transfer of silver from the anode to the mercury. Goldbaum,‡ however, after performing 50 electrolyses found, by the use of the nephelometer, only ·0003 grms. of silver in the residue from the cathode mercury after distillation. In the present work the writer found silver in the cathode mercury whenever an electrolysis with silver on the anode was made, though, under some conditions, the amount was small enough to be quantitatively negligible.

On the supposition that the transfer of silver to the cathode takes place to a greater degree toward the end of the electrolysis the effort was made to reproduce repeatedly in one experiment such conditions as exist at the end of an electrolysis, expecting by this means to get the maximum transfer of silver. Accordingly two experiments were made in which about 48$^{cm^3}$ of ·1N sodium chloride, added in approximately 2$^{cm^3}$ portions, were electrolyzed. Twice during the operation, once after the ninth addition of salt solution and once after the fifteenth, the anode was removed, heated to free it from silver oxide, and the contents of the inner cell siphoned out. In greater detail: The apparatus was set up as usual, 50$^{cm^3}$ of water added to the inner cell (the lower disc of the anode being now about 4–5^{mm} above the surface of the mercury) and the approximately 2$^{cm^3}$ portion of the salt solution added. The current, ·06–·09 amp., decreased generally in 8–10 minutes to ·03 amp. when a fresh portion of salt solution was added.

After about 48$^{cm^3}$ of the salt solution had been electrolyzed in 24 portions, consuming 5 hours, the mercury was separated and distilled. The residue from the two distillations contained, on the average, 8 mgrms. of silver. These details are found in Part I of Table V and show plainly the transfer of silver under these conditions.

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* Loc. cit. † L. c. p. 549. ‡ L. c.

TABLE V.

Total NaCl sol. ·1N, added cm³.	No. of additions	No. of times anode was heated during process to free from oxide	Total time of electrolysis min.	Initial and final current conditions amp.	volts	Amount of silver recovered by distillation grms.
Part 1. (*Silver plated anode.*)						
47·98	24	3	305	·06 } –·03	8	·0075
48·12	24	3	232	·09		·0083
Part 2. (*Silver anode.*)						
17 ±	12	4	1077			·0162
Part 3. (*Silver plated anode.*)						
50·00	1	0	38	·6–03	7·4–8	·0006
50·00	1	0	31	1·0–03	"	·0005
Part 4. (*Silver plated anode.*)						
Experiments 3–6 in Table IV.						
50·02	1	0	14	1·4–0·1	7·2–8	·0005
50·00	1	0	18	1·4–0·1	7·2–8	
50·00	1	0	19	1·3–0·09	7·2–8	
50·00	1	0	18	1·17–0·1	7·4–8	
Part 5. (*Silver plated anode.*)						
50	1	0	14	1·2–0·2	7·4–8	·0001
50	1	0	16	1·2–0·2	"	
50	1	0	13	1·5–0·19	"	
50	1	0	11	1·2–0·19	"	

Next, two experiments with the platinum anode, silver covered, were made separately, the current being interrupted, as before, when it fell to ·03 ampere. From the data in Part 3 of Table V it is seen that a quantity of silver, half of a milligram, analytically appreciable, was recovered from the mercury in each experiment. Previous to these experiments the anode was freshly plated and after each the anode was treated with hydrogen at a high temperature to reduce the silver chloride. Other data from these same experiments was given previously in Part 2 of Table III.

Again four electrolyses were made, reducing the silver chloride on the anode more or less completely between each electrolysis and stopping the current at ·01 ampere. [Examination of the liquid of the inner cell (expts. 3–6 Table IV) showed the decomposition of the sodium chloride complete under these conditions.] The amount of silver transferred to the mercury in the four experiments, recovered by distillation, was ·0005 grms., an amount analytically negligible. These experiments are written in Part 4 of Table V.

In another group of eight experiments made, as always, with freshly distilled mercury—those recorded in Table VI—done under practically the same conditions as those mentioned in the previous paragraph, part of the mercury yielded ·0009 grms. of silver. Part of the globule of mercury containing all the silver was spilled just before the final heating but not more than one-quarter was lost. Allowing for this loss and calling the actual amount of silver ·0011 grms., the amount of silver transferred to the cathode is proportionately the same as in the four experiments of the previous paragraph—·0001 for each electrolysis—and also small enough to be neglected.

Further, as shown in Part 5 of Table V, four electrolyses were made similarly, except that the current was interrupted when the ammeter read 0·2. The mercury upon distillation yielded ·0001 grms., an amount of silver easily visible in a porcelain crucible and which was precipitated as the chloride with sodium chloride after solution, evaporation to dryness and re-solution. The decomposition of the sodium chloride in the inner cell was not complete under these conditions, as amounts varying from 8 to 30 mgrms. were found by titration of the inner cell liquid.

These facts show the transfer of silver from the plated anode to the mercury to be a regular feature of the electrolysis, under the conditions described in this paper, and that the amount of silver so transferred is considerably increased if the electrolysis is continued beyond the point where the sodium chloride is all decomposed; but if the electrolysis is interrupted as soon as the salt is all decomposed very little silver is transferred to the mercury.

Using a Silver Anode.—Next the silver plated platinum anode was substituted by one of pure silver with the same general result, although the size and shape of the silver anode were decidedly different from the plated platinum one previously used.

This silver anode was made by wrapping a piece of gauze* 10×6^{cm} around a 20^{mm} test tube shortened in length to $5·5^{cm}$. A couple of sharp glass points on the outside of the test tube held the gauze in position and a silver wire wrapped around the top of the tube secured the gauze firmly as well as furnished connection with the metal rod above, onto which the rubber stopper and, in turn, the test tube, fitted. The amount of gauze dipping into the electrolyte during the experiment was about $1·5 \times 10^{cm}$, making the surface of anode metal exposed much less than in the two previous experiments with the silver

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* A German article copper free.

plated anode, and consequently the conditions of electrolyses not comparable.

After two additions of approximately 2^{cm^3} portions of salt solution the current would not decrease to as little at ·03 amp. even when the electrolysis of the third 2^{cm^3} was continued from 2 to 4¼ hours. Upon the failure of the current to fall to ·03 ampere the inner cell liquid was siphoned out, the anode heated to free it from oxide and the electrolysis continued with a fresh 2^{cm^3} portion of the salt solution.

As seen from the data of the experiment in Part 2 of Table V the electrolysis ran, in all, nearly 18 hours and ·0162 grms. of silver were recovered from the mercury by distillation. Comparing this experiment with those recorded in Part I it would seem to make little difference as to whether the anode was pure silver or silver plated if the transfer to silver to the cathode is alone considered.

No experiments were made to determine the best analytical conditions for the use of this pure silver anode, those having been satisfactorily worked with the more efficiently sized and shaped silver plated platinum electrode.

CONDITIONS FOR ANALYSIS.

The matter in the foregoing pages may now be used to determine the best conditions for the electrolysis of 50^{cm^3} of ·1N sodium chloride solution using the apparatus at hand and 4 storage cells. What the proper conditions would be with a sodium chloride solution of different strength with an apparatus of slightly different dimensions or under different current conditions, the author feels, would have to be determined by preliminary experimentation.

The ammeter cannot be relied upon, without previous experimentation, to determine the end of the electrolysis, as the current, during the operation, falls gradually from the start to an indefinite end. There is no rapid decrease in the ammeter reading at any point to indicate the complete decomposition of the sodium chloride, the accumulation of the alkali in the inner cell being sufficient to carry considerable current meanwhile.

Procedure.—The procedure, then, for the quantitative electrolysis of ·2923 grms. of sodium chloride in 50^{cm^3} of water would be as follows: Introduce about 2 kg. of mercury into the apparatus or sufficient mercury to rise $6\text{–}8^{mm}$ above the bottom of the inner cell. Cover the nickel wire with water ($70\text{–}80^{cm^3}$) and add to it 1^{cm^3} of saturated salt solution. Introduce the 50^{cm^3} of salt solution (·2923 grams NaCl) into the inner cell and electrolyze with the bottom of the anode $6\text{–}10^{mm}$ above the surface of the mercury. The current should be

1·2–1·5 amp. at the start, and stop at 0·1 ampere. Take out the anode, hold it over the inner cell and wash with the jet of the wash bottle. Introduce into the heating apparatus—the electric furnace or the heating crucible—heat at 400–450°, and raise the temperature during 5–10 minutes until the silver chloride is fused, avoiding temperatures over 550°. Cool and weigh. Titrate the liquid over the mercury to near the end-point, using methyl orange with ·1N hydrochloric acid, then transfer to a separatory funnel and shake well to decompose the remaining sodium amalgam. Draw off the mercury and finish the titration, using sodium hydroxide to determine the end-point. In case violent shaking introduces suspended mercury into the liquid, making the end-point difficult to determine, the mercury may be allowed to settle out, or the mixture may be filtered, or more methyl orange may be added.

Results.—Following these directions, a few experiments were made using 50^{cm^3} of ·1N sodium chloride solution (·2923 grms. NaCl) to determine the accuracy of the process in the hands of the present investigator. One hour was the time required to make a single determination. The results given, in the order in which they were obtained, follow in Table VI.

TABLE VI.

No.	Chlorine found grms.	Sodium found grms.	Time of electrolysis min.	Time of heating anode min.	Temp. of heating anode C°.	Error. Chlorine grms.	Error. Sodium grms.
1	·1755	·1152	19	10	390 455	—·0018	+·0002
2	·1771	·1159	21	23	410 460	—·0002	+·0009
3	·1770	·1158	18	14	550 458	—·0003	+·0008
4	·1781	·1166	18	13	400 470	+·0008	+·0016
5	·1775	·1157	20	19	400 450	+·0002	+·0007
6	·1743	·1132	20	72	450 480	—·0030	—·0018
7	·1780	·1161	19	7	405 440	+·0007	+·0011
8	·1767	·1155	19	6	405 440	—·0006	+·0005
Aver.	·1768	·1155	19			—·0005	+·0005

The fifth column shows the temperature of the electric oven at the beginning and end of the heating.

Under the most favorable conditions, determined empirically for one definite amount of sodium chloride, results show fair analytical accuracy. The chlorine tends to be low, averaging −·0005 grms. between the extremes of +·0008 grms. and −·0030 grms.; and the sodium high, averaging +·0005 grms. between the extremes of +·0016 grms. and −·0018 grms. The direction of the errors is just what would be expected from the preceding work of this paper.

SUMMARY

This work shows then, that in the electrolysis of sodium chloride, under the conditions described, with the anode of silver, or silver plated, and the mercury cathode, silver is always transferred from the anode to the cathode mercury; although, under conditions determined by experiment to be most favorable for a given amount of chloride, the amount of silver transferred may, for analytical purposes, be neglected.

The favorable conditions used in this work for the electrolysis of 50^{cm^3} of ·1N sodium chloride solution, containing ·2923 grams of salt, with the apparatus described, were obtained by using a current 1·2–1·5 amps. and allowing it to fall to 0·1 amp. This required 18–20 minutes.

It is recommended that the anode covered with silver chloride be first heated below the fusing point of the chloride to decompose all of the silver oxide and that then the heat be increased so as to fuse the chloride, five or ten minutes at a temperature 400–500° being sufficient.

Sodium hydroxide is always present in the inner cell after the beginning of the electrolysis.

The best method of treating the anode covered with fused silver chloride to prepare it to be used in a subsequent electrolysis is by heating about 20 minutes at about 500° or a little over in a current of hydrogen.

Art. XLI.—*The Reactions in a System of Nickel or Platinum, Mercury, and Sodium Chloride*; by Charles A. Peters.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxxvii.]

During the progress of work upon the electrolysis of sodium chloride with the mercury cathode,* it was noticed that when the outer cell containing sodium hydroxide, sodium chloride in solution over mercury, and nickel wire in contact with both liquids was allowed to stand several days a scum formed on the surface of the mercury. Upon shaking the liquids in the separatory funnel and drawing off the mercury the remaining liquid appeared turbid. Under the microscope transparent colorless crystals were easily seen mixed with air bubbles.

To study the conditions under which these crystals might be formed and to determine their identity, such systems as compose the outer cell of the electrolytic apparatus were made and allowed to stand. These consisted of Erlenmeyer beakers containing 300 grms. of mercury, sodium chloride solutions of different strengths and an inverted V-shaped piece of nickel wire.

In a day a scum was visible on the surface of the mercury which accumulated as the systems stood, seemingly more dense in the immediate vicinity of the wire, and, after several weeks showed, increasing in distinctness as the time increased, the familiar "apple-green" color. The nickel was corroded. The amount of the green precipitate increased faster when a greater surface of nickel was exposed in the salt solution.

This precipitate, crystalline under the microscope, when collected on the filter and well washed with water, gave tests for nickel but none for mercury, chlorine, or sodium. It turned black upon ignition. By these characteristics the crystalline substance was identified as nickelous hydroxide.

Tupputi† has formed crystalline nickel hydroxide from nickel carbonate dissolved in ammonia. Crystals made by the hasty evaporation of such a solution appeared similar to those obtained from the mercury-nickel-salt systems.

The solution over the mercury showed a tendency to develop alkalinity very slowly. In one case a beaker with the mercury, water, nickel wire, and a piece of red litmus paper—without sodium chloride—stood 24 hours. The litmus paper was still reddish and showed no trace of blue or purple, but upon adding a cubic centimeter of saturated salt solution the litmus was decidedly bluish when observed two hours later.

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* This Journal, preceding article.

† Gmelin—Kraut, 1910, Bd. V, Abt. 1, p. 44.

Two days later another piece of red litmus was added, and this, in three minutes, was blue on the edges. After standing several months a piece of red litmus turned blue instantly upon introduction into the liquid over the mercury. It is evident that the amount of sodium hydroxide produced in a few days is extremely small and inappreciable in analysis.

In other experiments platinum wires were substituted for nickel. A scum formed slowly as before and under the microscope was found to be composed of coarse white crystals with numerous small globules of mercury between them. The crystals contained mercury and chlorine, and were very insoluble in water. Small amounts crystallized from boiling water had the characteristic "silky" appearance of calomel. The crystals consequently were identified as mercurous chloride. The platinum showed no erosion.

The liquid over the mercury showed the same tendency, in about the same degree as when the nickel was present, to develop alkalinity. A few cubic centimeters from one of the platinum-mercury-salt systems which had been standing several days developed only the faintest pink coloration with phenolphthalein.

Summary.

From the work described in this paper it is seen that when a solution of sodium chloride is allowed to stand over mercury with a nickel wire connecting both liquids, crystalline nickelous hydroxide is formed very slowly, sodium hydroxide being produced at the same time. When platinum is substituted for nickel, mercurous chloride is formed, sodium hydroxide being likewise produced.

Art. XLII.—*Remarks on the Paper by L. A. Bauer: "On Gravity Determinations at Sea"*;* by O. Hecker.

In the above mentioned paper, L. A. Bauer is chiefly occupied in criticising my gravity determinations at sea. The stress of work connected with entering upon my new office as director of the Kaiserliche Hauptstation für Erdbebenforschung at Strassburg in E. has prevented me from sooner taking notice of L. A. Bauer's criticism, which, as will be seen in the course of the present discussion, can only be considered as carelessly made and mistaken in every way.

The opening pages of the paper I need not discuss, as they contain things which are generally known. I will only mention that, as regards the experiments made on the "Carnegie" with the boiling thermometer, an inferior way of reading the thermometer is used, the thermometers being read with a hand-lens, and not with a telescope, as done by me. There is no doubt that in using a hand-lens parallactic errors can easily arise in the reading. Moreover, I wish to remark that the barometer was read by eye. In a heavy sea the pumping of the barometer was not less than 5^{mm}. Bauer says then: "several settings were made, and both the low and high readings were recorded". How this is possible, I cannot understand. On the ocean, the period of the pumping of the barometers is about 6–7 seconds; hence, within 3 seconds the barometer must be set and the vernier read; for the positions which follow each other must be recorded. For me it was quite impossible, even when the pumping was very small, to do this with sufficient accuracy.

I now come to Bauer's formula (5). He writes: "Hecker's final observation equation is of the following form:

$$\beta + k_n + \frac{a\,dB}{dt} + bp + cr + ds + e(t - t_0) + k_2 = 0"$$

He gives the explanation of the meaning of the different terms and of k_2 he says: "k_2 = constant which enters into the equation only for deep-sea observations, say for depths beginning with about 2000 meters."

I am sorry to say, that Bauer must have gone through my work in a very superficial way, or he would not have stated that my observations were adjusted according to that formula. In the first place, during the two cruises on the Atlantic, the terms cr and ds were not used. Secondly, on the Indian Ocean, k_2 has quite a different meaning from that on the Atlantic: it is the

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* This Journal, vol. xxxi, pp. 1–18, January, 1911.

difference between gravity observed on board, and gravity determined from pendulum observations at land stations, where the vessel passed, reduced to the geographic position of the ship. In my second work, page 109, those places are especially mentioned. Thirdly, during the two cruises on the Pacific, the term k_2 does not enter at all into the equations, any more than does the term $e(t—t_0)$; here the changes proportional to the time are determined by the observations made in the ports. Bauer seems not to have noticed that. As to the three last-named cruises, a term $f\Delta$ is introduced, which takes into account the difference of the period of the upward and downward movements of the vessel. That also seems to have been overlooked by him.

Moreover, Bauer claims that, according to the adjustment of the observations on one cruise, I must admit that the local anomalies have the character of accidental errors, and consequently that the mean anomaly of gravity on a cruise must theoretically be equal to zero. Evidently this is with him the chief basis for estimating the value of my observations. But it is incomprehensible how he can make such a statement, which does not at all agree with the method of my adjustment. As one reason for its inaccuracy, it may be stated that account has been taken of the difference of gravity on the deep sea and on the shallow sea, relatively to land stations, when observations of both kinds enter into the equations.

But there is still another reason why his statement is erroneous. Every one who reads Bauer's remark must infer that *all* the observations enter into the equation. But, as is stated quite clearly on page 194 of my second work, all the observations made on the deep sea have *not* been taken into account for the adjustment, but only those made at places where the bottom of the sea was of uniform depth, as shown by the hydrographic charts, that is, where there were no marked elevations and depressions, in consequence of which no important anomalies of gravity were to be expected.

Of the 62 observations on the cruise from Bremerhafen to Melbourne, for instance, 16 deep-sea observations only enter into the equations; of the 44 observations on the cruise from Sydney to San Francisco, 20 only; and for the cruise from San Francisco to Yokohama, 21 out of 44 have been taken into account for the adjustment.

The influence of the movement of the ship has been derived from these observations, and the influence thus determined was taken into account for all the other observations. Bauer's assertion, therefore, is entirely wrong.

He seems surprised that I have not reduced together the observations made on shore in Rio de Janeiro and Lisbon, and believes that the reduction of the observations made at these two places is on the whole without value. He ought, however, to have noticed the comparison of the corrections k_n for the four series of observations, proving that a combination of the observations made on shore with those made on board was impossible, because the photographic barometers were greatly altered, having been dismounted for the transport from ship to land, and vice versa. I have, moreover, expressly drawn attention to this fact. Hence the observations made in Rio de Janeiro and in Lisbon could not be reduced together. Regarding the two visual barometers, the mean value of the readings was taken ; (in consequence of their greater want of precision),—this also cannot be taken into consideration, for, on my second cruise, I could not make any observations with them. In this place, he also says, that the terms with b, c, d, of his formula (5) as well as k_2 were omitted in the adjustment of the observations made on land, and that they were only taken into account for the adjustment of those made at sea. I repeat, that this is not so ; on these two cruises c and d do not enter into the equations of the observations made at sea.

As to the differences resulting for the observations made on board ship, when the ship was anchored in the harbor, engines at rest, and when the ship was in motion, her body being put into regular vibrations through the working of the engine, I regard it as proved that these differences are a consequence of the above-mentioned different conditions under which the whole apparatus works, and which are typical for each ship, depending upon her construction. (Comp. p. 159 of "Best. d. Schwerkraft auf dem Schwarzen Meere.")

Further on Bauer states that the observations made on the vessels at rest agree badly. This, of course, cannot be otherwise, for, as is well-known, highly damped barometers, when perfectly at rest, do not have very accurate readings.

I considered it quite a matter of course, that all the influences coming into consideration on one cruise were to be derived independently from the observations made on the particular cruise ; as already stated, I had continually to change ship, and, therefore, the instruments had to be dismounted and packed for transport. Sometimes they remained packed for a long time before being put together again for use. Considering these circumstances, it cannot be supposed that the corrections of the barometers would remain constant.

Further on Bauer asserts (in italics): "The corrections for Hecker's thermometers were never redetermined after they had once been furnished by the German Physikalische Reichsanstalt." This places the matter in a wrong light.

The corrections for the calibration of the boiling thermometers were determined by the Physikalisch-Technische Reichsanstalt for three thermometers only; for the other three thermometers I determined the corrections myself. With the help of these corrections, the corrections depending on the height of the thermometer were determined, combining therewith the total corrections given by the Institute for several points. After I had returned from my cruise on the Indian and the Pacific Oceans, Mr. Meissner undertook an entirely new and most careful determination of the errors of calibration :—small depressions of the zero point are of no consequence, as they give only a constant difference. (See page 83 of the before mentioned publication.) He obtained practically the same results as obtained from the previous investigations. That also shows the great precision of the two determinations. All this is given in my work.

Bauer says then (also in italics): "The corrections for the various barometers on a standard barometer for various barometric heights were never determined."

This shows clearly that he did not at all understand the method of procedure adopted by me, and which was the only right one. This is also shown by the following remark: "Another very important point introducing a source of error not considered by Hecker is with regard to the possible errors in the vapor-tension tables used to convert boiling-point temperatures into corresponding atmospheric pressure." He did not notice that I have referred the corrections for the capacity of the barometers, by a special series of observations, to the boiling thermometers. This is the reason why the above mentioned errors disappear, and the vapor-tension table of Wiebe plays only the rôle of an interpolation-formula. All this seems to show clearly, that he has not a clear idea of the difficulties of the determination of absolute barometric heights.

We now come to where Bauer speaks of the results of my observations. As a rule in estimating the precision of observations, one compares them, if possible, with observations made with instruments affording greater precision. That is quite self-evident.

As to the Pacific Ocean, which he treats especially, the result is, that the agreement, between the determinations of gravity made on board and those by the pendulum, can be considered to be satisfactory within the mean errors. That is the case for Auckland, as it was twice the case for Honolulu. Two observations made near San Francisco as well as the observations near Yokohama show also in the mean the satisfactory agreement with the value of gravity deduced from the pendulum stations. Besides, for six places on the Pacific, at which determinations of gravity were made on each of the two cruises, there is also an agreement comparable to the mean error of the observations.

But what does Bauer now do? He adds to my determinations the topographic and isostatic corrections calculated by Hayford, and in comparing the anomalies with those observed in America or elsewhere, he finds, that to him they are too large I need not waste words on such an unscientific method of procedure. A valuation of the magnitude of the anomalies of gravity, as one must expect them on gigantic Gräben, such for instance as the Tongadeep, where I observed a depth of over 8500 meters, is something which even geodesists have not hitherto been able to arrive at. The topographic and isostatic corrections can certainly be calculated, but not the anomaly. I should, however, like to draw attention to a work of E. Kohlschütter,* well worth reading, and in which he speaks of the determinations of gravity that I made in the Pacific. Based on a study of the determinations that I made, Kohlschütter arrives at quite a different conclusion about the precision of my observations, from that of Bauer.

Bauer then speaks about the "Method to be tried on the Carnegie," as if this method were quite a new one. This method seems to be the same as the one I made use of, except that he introduces the freezing-point observations; but, although he has no experience in the matter, he thinks that by means of an instrumental arrangement it may be possible to render a series of corrections unnecessary. He writes: "It is believed that equally good, if not indeed superior results can be obtained with less equipment than used by Hecker." He is welcome to his belief, although I am astonished at this dictum. It would certainly have been better, if he had first proved the reality of his opinion by results, instead of giving only his opinions; for, as far as I know, he has made no determinations of gravity at sea until now.

The reason why I made no freezing-point observations is that they would have introduced new errors into the observations; for freezing-point observations are also subject to errors.

Bauer intends to make such observations every week, or as often as necessary, in order that he may immediately reduce; he forgets, however, the fact that even if he could deduce the changes of the thermometers therefrom, he gains nothing for estimating the constancy of the barometers, which play an equal part with the boiling thermometer. At the end of his paper he seems, however, to feel this.

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*Ueber den Bau der Erdkruste in Deutsch-Ostafrika, Vorläufige Mitteilung, Nachrichten der k. Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse, 1911.

To my surprise he introduces the expression $e(t-t_0)$, for the change of the instruments depending on time, into the equations for the adjustment; he even thinks that later on perhaps it will be necessary to introduce a quadratic term. He thus tries to find a correction for the relation between freezing-point determination and barometric correction. This of course influences his determination of the freezing-point. I will not enter further into Bauer's plans. I leave them to the future.

The above explanations should prove sufficiently, that I was justified in characterizing the criticism, as I did at the beginning of these pages, as carelessly made and in every way mistaken.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Volumetric Determination of Iron and Vanadium.*—Müller and Dieffenthäler have found that vanadic acid is readily reduced to V_2O_4 by the action of hydrochloric acid and alcohol, while this reaction is difficult to complete by the action of hydrochloric acid alone. For the analysis of ferro-vanadium they dissolve 1 g. of the substance in not too much concentrated nitric acid, evaporate off the excess of acid and decompose the nitrates with a little concentrated hydrochloric acid. Then they add 50^{cc} of alcohol and 20^{cc} of concentrated hydrochloric acid and evaporate, first over the wire-gauze, with gentle boiling, then on the steam-bath to about 5^{cc}. The residue is transferred with water to a graduated flask, and an aliquot is taken for the determination of iron, most conveniently by the iodometric method as presented by Treadwell in his text-book, while the remainder of the liquid is titrated for vanadium with 1/10 normal permanganate, after an addition of manganese sulphate, at ordinary temperature. The authors state that the results are exact for vanadium by this method, but that while the vanadic acid may be reduced by alcohol and sulphuric acid, organic matter acting upon permanganate is left in the solution by this means of reduction.—*Zeitschr. Anorg. Chem.*, lxxi, 243. H. L. W.

2. *The Passive State of Metals.*—The fact that a group of metals, especially iron, nickel and chromium, are capable of assuming a passive state in which they are not attacked by certain acids, is very well known, and it has been the subject of much speculation and investigation since the time when Faraday advanced the theory that the passive state is due to the formation of a protective film of the oxide of the metal. Several other

theories have been put forward more recently to explain the phenomenon. ERNST GRAVE has now made a very elaborate study of the subject, and comes to the conclusion that pure iron and nickel are passive, and only become active from the presence of hydrogen ions, which act as a catalytic agent.—*Zeitschr. Physikal. Chem.*, lxxvii, 513. H. L. W.

3. *Combinations of Metallic Chlorides.*—G. HERRMANN has studied the results of fusing together a large number of pairs of metallic chlorides, as well as several pairs of bromides and iodides, according to the methods used in the study of metallic alloys. The salts used were $PbCl_2$,Cu_2Cl_2,$CdCl_2$,$FeCl_3$,$SnCl_2$,$BiCl_3$ and MCl_2, as well as $PbBr_2$,$BiBr_3$,Cu_2Br_2,Cu_2I_2 and CdI_2. As a result he has found no parallelism between the combinations of the metals and their salts. Very few compounds of the salts were found, for among 17 binary mixtures of chlorides there were 14 that formed no compound. The three compounds formed were one of $PbCl_2$ and $BiCl_3$, the formula of which was not determined, the compound $Cu_2Cl_2.(FeCl_3)_2$ and also $(Cu_2Cl_2)_2CdCl_2$.—*Zeitschr. Anorgan. Chem.*, lxxi, 257. H. L. W.

4. *New Method for the Separation of Cerium from other Earths.*—C. JAMES and L A PRATT have found that potassium bromate effects this separation in faintly acid or neutral solutions upon boiling. To attain the proper neutralization of the small quantity of free nitric acid present in the solution, they put in a smooth lump of marble containing no crevices. Care is required not to boil too long, but with proper precautions, and by repeating the separation, the authors obtained satisfactory analytical results, and found the method serviceable for the preparation of pure cerium material.—*Chem. News*, civ, 61. H. L. W.

5. *The Composition of the Atmosphere after the Passage of Halley's Comet.*—G. CLAUDE has found that the inert incondensible gases of the atmosphere show an unchanged specific gravity of 0·55 since the passage of Halley's comet, thus indicating an unchanged proportion of neon and helium since that event.—*Ann. Ch. Phys.*, xx, 573. H. L. W.

6. *Modern Science Reader, with Special Reference to Chemistry*, edited by ROBERT MONTGOMERY BIRD. 12mo, pp. 323. New York, 1911 (The Macmillan Company).—This is a collection of popular essays and addresses gathered from various magazines, journals, and encyclopedias. There are 27 of these articles, most of them written by eminent authors on important and interesting subjects. Some of the topics are The Diamond, Waste Products, Explosives, Artificial Silk, Steel, Commercial Oxygen, Plant-growth and Decay, Coal, Coal-tar Dyes, Artificial Perfumes, Glass, Electro-chemistry, Yeast, Old and New Alchemy, Radioactivity, Electronic Theory of Matter and Ether of Space.

The book is well suited for giving the general reader an idea of the recent views and achievements in chemistry, and it is a very suitable work to place in the hands of the chemical student for the purpose of arousing his interest and enthusiasm. H. L. W.

7. *Volumetric Analysis*, by FRANCIS SUTTON. Tenth edition. 8vo, pp. 621. Philadelphia, 1911 (P. Blakiston's Son & Co.).—This work, being one of the best-known and most valued handbooks of analytical chemistry, requires no comments except in regard to the appearance of a new edition. The author states that at the age of fourscore he has found himself less and less equal to the task of revision, but is looking forward already to the appearance of a Jubilee edition, when 50 years shall have elapsed since the first appearance of his work in 1863. The preparation of the present edition has been placed in the hands of the author's son, W. Lincoln Sutton, and of Alfred E. Johnson. The revision appears to have been very thoroughly and well done. A good deal of obsolete matter has been deleted, the subject matter has been well brought up to date, and many other improvements have been made in the book. H. L. W.

8. *Principles of Physics;* by W. F. MAGIE. Pp. ix, 570; 281 figures. New York, 1911 (The Century Co.).—The novelty of this book consists chiefly in the exposition of the subject according to its historical development. In his preface, the author says:—"The use of the historical outline accounts for what is nowadays the unusual order followed in the presentation of some of the subjects." "It leads to a much fuller discussion of statics than is generally given, and to other peculiar features of the treatment, such as the use of the statical measure of force, the belated introduction of the relations of heat to energy, the use of the method of rays in geometrical optics, and to other minor divergences from common practice."

The principles discussed are clearly illustrated by examples which are completely solved and which are collected in groups at appropriate intervals. When the formal demonstration of a theorem is of much less importance to the student than the theorem itself, the proof is given in fine print. The figures are clear, line diagrams. The calculus is not used, but a thorough knowledge of plane trigonometry is presupposed. The work is up to date and relatively complete, as may be inferred from the fact that such subjects as Brownian movements, pressure of light, discharge of electricity through gases, radioactivity, etc., are presented. The text proper is followed by a list of 254 examples with their numerical answers and also by tables of physical constants.

Since this book differs so markedly from the majority of recent texts of the same degree of advancement, it is a matter of importance pedagogically to observe what success the text meets with in the hands of teachers other than the author. Also, the volume should be of much assistance to many instructors themselves because the point of view of the author is especially conducive to acquiring a good perspective of the entire field.

H. S. U.

9. *Direct and Alternating Current Manual, Second Edition*, with Directions for Testing and a Discussion of the Theory of

Electrical Apparatus; by FREDERICK BEDELL, assisted by C. A. PIERCE. Pp. xiii, 360. New York, 1911 (D. Van Nostrand Co.).—The first edition of the present work (see this Journal, vol. xxix, page 83) was issued under the title "*Direct and Alternating Current Testing.*" The second edition avoids certain omissions made in the first and includes discussions of induction motors and generators, synchronous motors and converters, and wave analysis. Chapter XI, on wave analysis, is very concise and ends with two appendices dealing with the origin, proof and use of Runge's method of analysis. "In a restricted sense the book is now complete." H. S. U.

10. *Applied Electrochemistry;* by M. DE KAY THOMPSON. Pp. xii, 329; 137 figures. New York, 1911 (The Macmillan Co.). —This is the first English text-book in which an attempt has been made to cover the whole field of electro-chemistry. Consequently it seems desirable to quote the headings of the chapters in order to give an idea of the scope of the work in as concise a manner as possible. The titles are:—" I, Coulometers or Voltameters; II, Electrochemical Analysis; III, Electroplating, Electrotyping, and the Production of Metallic Objects; IV, Electrolytic Winning and Refining of Metals in Aqueous Solutions; V, Electrolytic Reduction and Oxidation; VI, Electrolysis of Alkali Chlorides; VII, The Electrolysis of Water; VIII, Primary Cells; IX, The Lead Storage Battery; X, The Edison Storage Battery; XI, The Electric Furnace; XII, Products of the Resistance and Arc Furnace; XIII, The Electrometallurgy of Iron and Steel; XIV, The Fixation of Atmospheric Nitrogen; XV, The Production of Ozone."

The plan adopted in this book has been to discuss each subject from the theoretical and from the technical point of view separately. In the former part a knowledge of theoretical chemistry is assumed. Numerous references to English, French, and German scientific journals are given so that the volume should be useful as a reference book as well as a text. A pleasing feature of the work is afforded by the full-page reproductions of photographs of the interiors of manufacturing plants, of electric furnaces, etc. In addition to the tables of electrochemical data, the appendix also contains full details of the legal electrical units. H. S. U.

11. *Der electrische Lichtbogen;* by HERMANN TH. SIMON. Pp. 52, 31 figures, 1 plate. Leipzig, 1911 (S. Hirzel).—This little book is a formal account of an experimental lecture delivered in January, 1911, before the Scientific Society of Berlin. The material is presented in a very interesting and semi-popular manner. Twenty-two demonstration experiments are explained in fine print. The colored plate, representing the appearance of an arc between carbon electrodes, is the best picture of the subject which the writer of this notice has seen. H. S. U.

II. GEOLOGY AND MINERALOGY.

1. *Notes on the Geology of the Gulf of St. Lawrence;* by J. M. CLARKE. Bull. 149, N. Y. State Museum, pp. 121–133, 1911.—The author during his annual summer vacations along the southwestern shores of the Gulf of St. Lawrence continues to interest himself in the local geology. In this paper he discusses: (1) the relations of the Paleozoic terranes in the vicinity of Percé; (2) eruptive contacts in the marine Devonian Dalhousie beds at Dalhousie, New Brunswick, concluding that they are contemporaneous lavas, tuffs, and ash beds, a determination which therefore fixes the time of these widely spread ejections as of the age of the Lower Devonian; (3) the stratigraphy of the Devonian fish beds of Scaumenac, Quebec; and (4) history of the lead mines of Gaspé basin. The author states: "It is a singular illustration of the undying persistence of legend in the face of well-established fact that a forlorn hope early dismantled should have revived and been persistently pursued for well nigh 250 years." C. S.

2. *Observations on the Magdalen Islands,* by J. M. CLARKE; and *The Carbonic Fauna of the Magdalen Islands,* by J. W. BEEDE. Bull. 149, N. Y. State Museum, pp. 1–50, 1911.—In this work are described the history, topography, geology, and paleontology of the Magdalen Islands. The lowest rocks are of the Windsor series, regarded by Beede as of Kinderhook age. These rocks are overlain by a series of red shales and sandstones devoid of marine fossils and are probably of continental origin. They are correlated with the red beds of Prince Edward Island, which have yielded bones of a pelycosaurian reptile and are sometimes regarded as of Permian age.

The paper is well illustrated and is written in Doctor Clarke's interesting style. The Windsor series here has yielded a fauna of 65 species, of which at least 17 forms also occur in Nova Scotia. C. S.

3. *Some New American Fossil Crinoids;* by FRANK SPRINGER. Mem. Mus. Comp. Zool., 25, pp. 117–161, pls. 1–6, 1911.—The author here revises the families Gasterocomidæ and Poteriocrinidæ and as well their genera, of which there are 26, one, *Schultzicrinus,* being new. Dimerocrinus is redefined, and a new American species of Marsupites is described. Of species described there are 12.

Much study has been given to the mode of articulation of the arms, that is, the nature of the radial facets. Among crinoids there are at least four kinds of articular surfaces typified by (1) Poteriocrinidæ, (2) Forbesiocrinus, (3) Cyathocrinidæ, and (4) Camerate crinoids. C. S.

4. *Middle Cambrian Annelids;* by CHARLES D. WALCOTT. Smithsonian Misc. Col., 57, No. 5, pp. 109–144, pls. 18–23, 1911. —The Burgess shale of British Columbia yields remarkably perfect fossils and in this paper Doctor Walcott describes one new

order, seven new families, twelve new genera and twenty new species of annelids, the fossils revealing more or less of the entire form of the animals. This is a most remarkable preservation, the like of which is unknown in any other deposit. The animals vary in length from 3/8 inch (10^{mm}) up to more than 10 inches (26^{cm}). The class Chætognatha is represented by *Amiskwia* (1 species); the Polychæta by *Miskoia* (1), *Aysheaia* (1), *Canadia* (5), *Selkirkia* (3), *Wiwaxia* (1), *Pollingeria* (1), and *Worthenella* (1); the Gephyrea by *Ottoia* (3), *Banffia* (1), *Pikaia* (1), and *Oesia* (1). There is also an illustration of Hyolithes with parts of the animal that suggest pteropod fins.

This discovery "opens up a new point of view on the development of the Annulata. The fact that from one very limited locality there have been collected eleven genera belonging to widely separated families points clearly to the conclusion that the fundamental characters of all the classes had been developed prior to Middle Cambrian time. No examples of the Class Hirudinea have been recognized, but the segmentation of the Chætopoda is present in *Ottoia* and *Banffia*, annelids which otherwise are true Gephyreans. To a certain extent these two genera serve to link the Chætopoda and Hirudinea.

"I should not be at all surprised to find representatives of the Archi-Annelida in the Burgess shale." C. S.

5. *The extent of the Anderdon beds of Essex county, Ontario, and their place in the geologic column;* by Rev. Thomas Nattress. Thirteenth Rept. of the Michigan Academy of Science, pp. 87–96, 1911.—This paper presents conclusive evidence that the Anderdon and Amherstburg limestones are not Silurian in age and cannot be included in the Monroe series, but "are of Devonian age." The Anderdon limestone lies in a trough of Monroe strata, and is to be grouped with the Onondaga formation of Middle Devonian time. C. S.

6. *Connecticut Geological and Natural History Survey. Volume III, Bulletins 13–15.*—This third volume of the Connecticut State Survey contains Bulletins 13, 14, and 15, all issued previously in separate form and noticed in earlier numbers of this Journal. Bulletin 13 is on the Lithology of Connecticut; Bulletin 14 gives a Catalogue of the Flowering Plants and Ferns of Connecticut; Bulletin 15 is a second report on the Hymeniales of Connecticut.

Bulletin 16, now published, is a Guide to the Insects of Connecticut, prepared under the direction of W. E. Britton. Pp. 169, 66 figures, 8 plates. Part I by Dr. Britton is given to a general Introduction, and Part II by B. H. Walden gives a list of the Euplexoptera and Orthoptera of Connecticut.

7. *The Production of Gems and Precious Stones in 1910;* Douglas B. Sterrett.—This advance chapter from the Mineral Resources of the United States in 1910 has recently been issued. A summary of the chief points of interest is contained in the fol-

lowing paragraphs from the introduction : "There was a decrease in the production of precious stones in the United States during 1910, though the output of such matrix gems as turquoise and variscite was still large. Nearly 8½ tons of rough turquoise were produced in 1910, as compared with more than 17 tons in 1909, and more than 2½ tons of rough variscite, as compared with 3½ tons in the preceding year. New deposits of both these minerals were found in Nevada and a very promising deposit of variscite was developed near Lucin, Utah. New deposits of californite were discovered in California, and a white garnet scarcely to be distinguished from the white vesuvianite variety of californite was found in quantity in Siskiyou County, Cal. This mineral is with difficulty distinguished from white jade, for which it could well be substituted.

The output of tourmaline was considerably less in 1910 than in 1909, but a new deposit of fine gems and specimens of tourmaline was opened in Maine. The aquamarine deposit on Mount Antero, Colo., yielded a quantity of good gem material along with crystals of associated minerals, as phenacite, colorless and smoky quartz, etc. The development of the new emerald prospect in North Carolina was limited and met with only partial success. More recent work during 1911 has resulted in finds of better promise. The presence of valuable gem material has been proved, but the quantity of gems to be expected from the vein is still a matter of doubt. Further prospecting and dredge mining for the variegated sapphires of Montana were carried on, but the principal value of the sapphire production came, as usual, from the deposits of blue sapphire in Fergus County."

8. *The Crystalline Symmetry of the Diamond.*—The true symmetry of the diamond has often been questioned, and some authors have been inclined to refer it to a class of low symmetry, that of the tetrahedrite type. A monograph on this subject has recently been published by A. L. W. E. VAN DER VEEN as an inaugural dissertation at the University of Delft. The author has investigated the subject from the physical as well as crystallographic side, basing his observations particularly on the Molengraaff collection. His conclusion is stated with much confidence that the species really belongs to the holosymmetric class, the hexoctahedral class of Groth.

9. *Rock Minerals: Their Chemical and Physical Characters and their Determination in Thin Sections;* by J. P. IDDINGS. Second Edition, revised and enlarged. Pp. 617. New York, 1911 (John Wiley & Sons).—The first edition of this valuable book was published in 1906 and numbered 548 pages. The present edition has been enlarged to 617 pages, chiefly through the addition of the descriptions of more than sixty rarer species which were not included in the earlier edition. The optical tables at the end of the book have been somewhat enlarged and a birefringence diagram added. W. E. F.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Langley Memoir of Mechanical Flight.* Part I, 1887 to 1896; by SAMUEL PIERPONT LANGLEY, edited by CHARLES M. MANLY. Part II, 1897 to 1903; by CHARLES M. MANLY. (Publication 1948.) Pp. x, 320, with 101 plates. Washington, 1911. Smithsonian Contributions to Knowledge, volume 27, number 3.—Now that practical aviation has been developed so far and a degree of success attained which even the most sanguine could not have predicted ten or fifteen years ago, it is very interesting to look back and follow the series of carefully conducted scientific investigations, whose results were essential in the recent development of the practical side of the subject. The experiments by Professor Langley in mechanical flight are well known, but as they stopped just short of the full success which would probably have come to them had the author lived to carry them further, especially with the aid of the perfected gasolene motor, it may not be generally appreciated how thorough and exhaustive his work was. Earlier publications on "Experiments in Aërodynamics" and "The Internal Work of the Wind" were printed in 1891 and 1893, as parts of volume 27 of the Smithsonian Contributions. The present memoir was in course of preparation at the time of the author's death in 1906. At that time, part I (pp. 1–122, plates 1–31) had been practically completed by him. This part describes experiments made between 1887 and 1896, and discusses the various forms of available motors, and the history of the construction and use of various aërodromes, as the flying machine was named by him in 1893. In the final preparation of the manuscript for the press, Mr. Charles M. Manly, assistant in charge of experiments, has acted as editor.

The second part of the volume describes experiments made betwen 1897 and 1903, and has been prepared by Mr. Manly. It describes the later experiments with the original models as well as with new models, and also the construction of the larger machine. Although this last did not have full success, and the experiments closed in December, 1903, it is to be noted that a machine of essentially the same type was employed for a flight of nearly 500 feet by a French aviator in August, 1907. It is stated that the third part of the present memoir will be published later, giving technical data and tests of various types of curved surfaces, propellers, and other apparatus. The editor of this volume closes his prefaces with the following paragraphs, which should be read by all desirous of forming a correct estimate as to the importance of Professor Langley's long-continued experiments:

"To such men as Mr. Langley an unsuccessful experiment is not a failure but a means of instruction, a necessary and often an invaluable stepping-stone to the desired end. The trials of the large aërodrome in the autumn of 1903, to which the curiosity of the public and the sensationalism of the newspapers gave a character of finality never desired by Mr. Langley, were to him merely members of a long series of experiments, as much so as any trial of one of the small aërodromes or even of one of the earliest rubber-driven models. Had his health and strength been spared, he would have gone on with his experiments undiscouraged by these accidents in launching and undeterred by criticism and misunderstanding.

"Moreover, it is to be borne in mind that Mr. Langley's contribution to the solution of the problem is not to be measured solely by what he himself accomplished, important as that is. He began his investigations at a time when not only the general public but even the most progressive men of science thought of mechanical flight only as a subject for ridicule, and both by his epoch-making investigations in aërodynamics and by his own devotion to the subject of flight itself he helped to transform into a field of scientific inquiry what had before been almost entirely in the possession of visionaries."

2. *A Treatise on Hydraulics;* by Hector J. Hughes, Assistant Professor of Civil Engineering, Harvard University, and Arthur T. Safford, Consulting Hydraulic Engineer. Pp. xiv, 505 with 177 figures and 5 plates. New York, 1911 (The Macmillan Company).—This treatise is a refreshing contrast to some engineering books which have found publishers in this country in recent years. There is no novelty in the contents, for the portion of the field covered is that usually found in elementary treatises. But in its clear style, logical treatment, orderly arrangement, and full presentation of the latest and best researches in hydraulics, the book is in many ways a model one. Chapters I–IV treat of hydrostatics, covering the usual topics of fluid pressure and equilibrium of floating bodies. Chapter V is a useful summary of the principles of hydromechanics. Chapters VI, VII, VIII treat of the measurement of flow of water by various forms of meters. The space given to applications of the Pitot tube is an indication of its growing importance. The chapters on orifices, nozzles and weirs follow in the order named. The chapter on flow in pipes is marked by fullness of reference to original data. This is a difficult subject, and if confusing to the student, it is so because of the unsatisfactory state of the experimental data. The chapters on hydraulic motors form a good introduction to that subject.

A feature of the book is a collection of problems at the end of each chapter. There are tables, including logarithms, squares, square roots, cubes, cube roots, areas and circumferences of circles, also logarithmic diagrams for several hydraulic formulas. The tables will be useful in solving the problems in the book. In view of the convenience of the slide for hydraulic calculations the omission of reference to it is surprising. E. H. Lockwood.

3. *Pure Foods—Their Adulteration, Nutritive Value and Cost;* by John C. Olsen, A.M., Ph.D. Pp. 210. Boston, 1911 (Ginn and Company).—This is a useful little book adapted to

meet the demand for accurate information in these days of active agitation and reform, when the real distinctions between the pure and wholesome, adulterated and injurious products are by no means apparent. It is intended for individuals such as teachers and the thinking public, rather than for the technical chemist. Many will be surprised to learn that "a food is pure if it has been in common use for a long time" (p. 19). In addition to a review of the general composition and characteristic of food materials, the book deals with the sources, manufacture, and uses of some of the more common foods, together with current practices in the way of preservation and sophistication. Directions for selected illustrative experiments are appended. L. B. M.

4. *Physikalische Chemie der Zelle und der Gewebe;* von Professor Dr. Rudolf Höber, Privatdozent der Physiologie an der Universität Kiel. Dritte, neubearbeitete Auflage, mit 55 Textfiguren. Pp. 671. Leipzig, 1911 (Wilhelm Engelmann).—The expansion of this standard reference work from a volume of 460 pages in the edition of 1906 to its present size in 1911, indicates the great strides which have characterized the recent applications of physico-chemical methods and points of view to the elucidation of biological problems. The text has been enriched by extensive additions on the subject of colloids and absorption phenomena, the study of which has been so vigorously prosecuted of late. The rôle of lipoids, especially in relation to the permeability of cells, is extensively and critically reviewed. To the physiologist the newer interpretations of secretory phenomena are of special interest. As in earlier editions, several chapters are devoted to the more familiar facts and deductions of physical chemistry, such as osmotic pressures, the theory of solutions, and equilibrium reactions. L. B. M.

5. *Guide to the Exhibition in the British Museum of Natural History of Animals, Plants, and Minerals mentioned in the Bible.* Pp. 74, with 7 figures. London, 1911. (British Museum of Natural History. Special Guide, No. 5.)—The task of identifying the various natural history objects and minerals mentioned in the Bible is difficult and yet one of very general interest. The pamphlet here issued by Dr. Fletcher of the British Museum takes up this subject and deals with the various topics with care and thoroughness; it is based upon a collection now placed on exhibition in the Museum. The animals have been selected and arranged by Mr. R. Lydekker, the minerals by Dr. G. F. Herbert Smith, and the plants by Dr. A. B. Rendle. Many people will be interested in the facts here presented, and not the least in those relating to the somewhat vaguely characterized minerals referred to in the Book of Revelations.

OBITUARY.

The Rev. F. J. Jervis-Smith, F.R.S., died on August 23 at the age of sixty-three years. He did much important work in designing and constructing instruments of delicacy and precision.

M. Pierre Emile Levassent, the French geographer, died recently at the age of eighty-two years.

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URAL MOUNTAINS.

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[FOURTH SERIES.]

Art. XLIII.—*On the Emission of Electrons by Metals under the Influence of Alpha Rays*; by H. A. Bumstead.

It was observed by Bragg and Kleeman* that when a thin sheet of a metal, such as gold, was interposed in the path of a pencil of α-rays, the diminution in range produced was less when the metal sheet was far from the source of rays than when it was near; in other words, the rays seemed to be "stopped" less by the metal when they were going slowly than when they were moving with greater speed. T. S. Taylor† made a careful study of the phenomenon and found that this differential effect increased regularly with the atomic weight of the metal. Substances whose atomic weight was much greater than that of air showed the effect very markedly; substances, such as paper, whose average atomic weight was nearly equal to that of air did not show the effect at all; and when a layer of hydrogen was used instead of a solid obstacle, the effect was reversed. By plotting the ionization curves of the α-rays in air and in hydrogen, Taylor showed that there was exactly the same relation between the ionization in the two gases at different parts of the range as between their relative stopping powers. Where the ionization in hydrogen was greater than in air, the hydrogen was more effective in retarding the rays, and vice versa; and the numerical ratios for the two effects were equal. These results led naturally to the hypothesis that the energy lost by the α-particles in their progress through a gas was mainly, if not wholly, consumed in the production of ions, and that where the ionization was great (as at the "knee" of the Bragg curve), the α-particles lost energy

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* Phil. Mag., x, 318 (1905).

† This Journal, xxviii, 357 (1909). Phil. Mag., xviii, 604, 1909.

more rapidly than where the ionization was less. As the knee is more conspicuous in hydrogen than in air, the relative stopping effects of these two gases are easily accounted for on this hypothesis.

Shortly afterward Geiger* published the results of a repetition of Rutherford's measurements of the velocities of the α-particle at different points in its range. The measurements were made under more favorable conditions than were possible at the time of Rutherford's original experiments, and Geiger was able to show that the loss of energy by the particles in passing through a layer of air was at least approximately proportional to the ionization produced in that layer, and was not the same for equal paths in air at different parts of the range as Rutherford had supposed. The large value of the ionization as the α-particle approaches the end of its range, involves a correspondingly rapid diminution of its energy, and this rapid expenditure of energy in all probability brings the α-particle to rest at the end of its range instead of leaving it with a residual velocity after it ceases to ionize, as Rutherford at first supposed.

The continuity of the effects observed by Taylor with hydrogen, air, and various metals of increasing atomic weight made it probable that, in solids as well as gases, the α-particles expend their energy in a process analogous to gaseous ionization, and that this process follows a curve similar to the ionization curve in gases. Just as the curve for air has a less conspicuous knee than the hydrogen curve, so, from the stopping effects, we should expect the "ionization curve" for gold, for example, to show less projection than the air curve. According to this view all atoms are less effective in retarding swift rays than slow ones; but heavy atoms are relatively more effective in stopping the swift rays than the light atoms, while they are on more nearly equal terms in their effect upon the slower rays. This view accounts satisfactorily for the results obtained by Taylor.

The following experiments were undertaken to obtain, if possible, some direct evidence of the existence of an ionization process in metals subjected to α-rays, and to see whether it varied with the speed of the rays in a manner analogous to the ionization which the rays produce in gases. It has been known for some years that a source of α-rays, or any solid struck by them, emits slowly-moving electrons (called δ-rays by Sir J. J. Thomson, who discovered them).

If the atoms of solids are ionized by the rays one would expect that some of the electrons set free in the process from the atoms near the surface would escape from the metal, and

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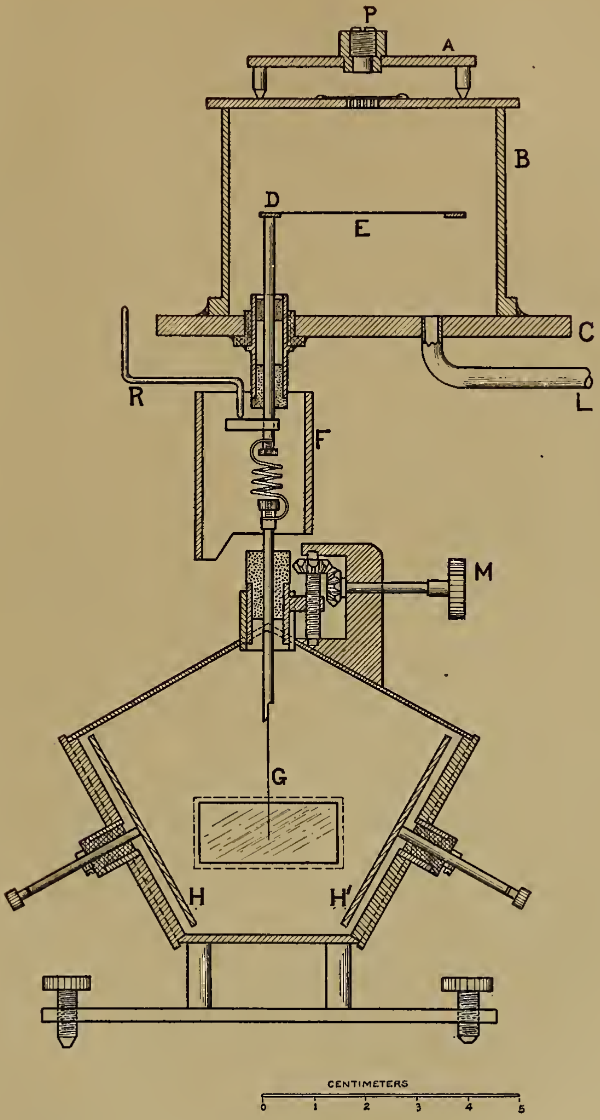
* Proc. Roy. Soc., lxxxiii, 505 (1910).

Fig. 1.



that the number escaping would be more or less nearly proportional to the number of atoms ionized. Accordingly measurements were made of the number of electrons escaping from a thin metal foil when struck by a-rays at different points in the range.

In order to avoid possible complications from the effects of β- and γ-rays, polonium was used as the source of α-rays. Professor Boltwood kindly separated the polonium from a solution of radio-lead and it was deposited on the end of a copper plug, 4^{mm} in diameter. The first preparation was not very strong and it was necessary to use a system of small capacity in making the electrical measurements. The following form of apparatus was used. A piece of thin aluminium leaf, E, fig. 1, $\cdot 064 \times 10^{-4\,cm}$ thick is stretched over the flat brass ring, D, which has a clear opening of $3\cdot 2^{cm}$. The brass rod which supports the ring passes through the base plate, C, and is insulated from it by amber, ebonite, and an earthed guard tube; the joints are made air-tight with sealing wax. A cylindrical cover, B, rests on the base plate, the two surfaces in contact being ground to each other and made tight with rubber stop-cock grease. The interior is connected by means of the tube, L, with pump, gauge, and charcoal bulb. The copper plug, P, which has the polonium on its lower end, is supported by a little tripod, and there are punch marks in the top of the cover into which the feet of the tripod fit so that it can be removed and replaced in the same position. The distance from the polonium to the top of the cover is 6^{mm}. In the cover just below the polonium are nine holes, 1^{mm} in diameter, to permit the passage of the α-rays; these holes are covered by aluminium foil, $8\cdot 65 \times 10^{-4\,cm}$ thick. This foil was some that was supplied with tubes intended to demonstrate Lenard rays; it was the thinnest I could find which was not full of holes and its effect on the range of α-particles was equivalent to that of $1\cdot 47^{cm}$ of air. It was fastened down to the top with a ring of low melting sealing wax, which was then covered with stop-cock grease.

The rod which supports the ring and aluminium foil was connected to the gold leaf of an electroscope which had been made some time before in this laboratory. It may be regarded as developed from a Wilson tilted electroscope in the same manner that a twinned crystal is developed from an ordinary one. The two plates, H and H′, are charged to equal and opposite potentials (usually 200 volts), as in Hankel's electroscope. The gold leaf is kept in the middle by means of the leveling screws, and the sensitiveness (and stability) are easily altered by raising or lowering the leaf by means of the milled head, M. The latter adjustment is the chief convenience of this electroscope. The sensitiveness of such an electroscope is a very indefinite thing; it depends upon the degree of instability of zero point and deflection that one can permit, and this, in turn, depends on the greater or less protection of the case from rapid changes of temperature, currents of air, etc. This double electroscope appears to have some slight advantage over Wilson's form; when the two were mounted side by side under the same conditions, the double electroscope had a sensitiveness about three times that of the tilted form, for equal stability. As used in the present experiments the capacity of the leaf and its connections was about 5^{cm}, and the sensitiveness was so adjusted as to give about 25 or 30 divisions on the scale in the microscope for 0·1 volt. The key, R, which was connected to a potentiometer arrangement, allowed the leaf to be insulated, grounded, or charged to any desired potential, and the volt sensitiveness was taken immediately after each reading.

The case containing the aluminium foil electrode was exhausted while the charcoal bulb was heated to a pressure of a few thousandths of a millimeter, after which the bulb was cooled with liquid air. The bulb was between the case and the pump and thus formed a trap for the mercury vapor; two liters of liquid air were used, which lasted for about ten days. For that length of time the air pressure could be kept continuously below $·0001^{mm}$. The pressure of the mercury vapor in the case must have been very small under these conditions. What vapor there was from the rubber stop-cock grease used to cover the joint between the base plate and cover, must have been constantly distilling over from the case into the bulb; that its amount was small is shown by the fact that no visible traces of the grease could be seen in the charcoal bulb after a week or more of this distillation, although in the same time drops of mercury of considerable size had distilled over from the pump.

When the a-rays from the polonium were admitted into the case through the aluminium-covered holes in the top, both the insulated electrode and the case emitted electrons under their action. In order to separate the two effects it was necessary to charge the case; when it was charged positively the electrons which were set free from the case were prevented from reaching the electrode, and the latter received a positive charge due to the loss of electrons from its two surfaces; when the case was charged negatively, the electrode received electrons from the case and emitted none itself. With +25 volts on the case the current of electrons from the aluminium foil was fully saturated, and it was not increased by the application of +200 volts. With +6 volts the lack of saturation was about 7 per cent. On the other hand, with a negative potential on the case, it was distinctly more difficult to reach the saturation value; with −25 volts the current was 20 per cent less than with −200 volts. The probable cause for this difference will be discussed in the next paragraph.

When the case was charged negatively, the current was approximately twice as great as when the case was charged positively. Thus, apparently, twice as many electrons were emitted by the case under the influence of the α-rays as from the two sides of the aluminium foil electrode through which the rays passed. This difference persisted when the case itself was lined with aluminium foil, so it was not due to a specific difference between aluminium and brass. It is probable that the explanation of this difference, as well as the difficulty in obtaining negative saturation mentioned in the last paragraph, is to be found in the construction of the cover and the apertures through which the rays enter the exhausted chamber. Many of the rays, passing in a divergent pencil through the aluminium foil which covers the holes, strike the sides of the holes and do not reach the electrode. They thus liberate a number of electrons from the case and no corresponding ones from the electrode; and to draw all of these superfluous electrons from the small apertures in the top of the cover requires a considerably greater potential-difference than when they come from the electrode.

In order to find out whether the observed currents really had their source in the metals and were not due to residual gas or vapor, the foil was removed from the ring electrode. (The apertures in the top of the cover were so placed that the geometrical beam of rays fell entirely within the ring.) Under these conditions the current with the case charged positively fell to 4 per cent of its former value, while with a negative potential on the case the current was 90 per cent of what it had been before. This slight falling off in the negative current was doubtless due to the fact that the ring-electrode was less efficient in catching electrons from the case than when it was covered with foil. Of the small positive current, part at least was due to the rays which struck the brass rod which supported the ring (see fig. 1), so that we may be quite sure that the gas effect contributes not more than 2 or 3 per cent to the currents observed with this apparatus. The absence of positive particles justifies the further conclusion that the effect produced by the rays on a metal consists in the direct expulsion of electrons, and not of neutral pairs which afterward break up. As will be seen later, there is a very close relationship between this metal effect and the ordinary ionization of gases by α rays; and the result just given renders it at least unlikely that neutral pairs are emitted when gases are ionized by α-rays as has been sometimes assumed in the case of other ionizing agents.

A further test of the relative importance of the metal and gas effects was made by measuring the current at different gas pressures up to $0{\cdot}2^{\text{mm}}$. The result may be expressed by the linear formula

$$i = A + Bp$$

where i is the current, p, the pressure and A and B are constants. In the apparatus described, Bp was equal to A when $p = {\cdot}068^{\text{mm}}$, so that even with a pressure of several thousandths of a millimeter, the gas effect was small in comparison with the metal effect.

The above measurements (which were incidental and somewhat rough) permit an estimate of the number of electrons emitted when one α-particle passes through the aluminium foil electrode. The α-rays were at a point in their range corresponding to a distance in air from the polonium of $2{\cdot}07^{\text{cm}}$. At this point in the range Geiger's* results show that an α-particle produces about 4000 ions per mm. of its path in air at standard pressure. In the present case, the depth of the ionization chamber was 40^{mm}; most of the rays passed through somewhat obliquely, and the average distance traversed was about 45^{mm}. At a pressure of ${\cdot}068^{\text{mm}}$ the ions per α-particle would be

$$4000 \frac{45 \times {\cdot}068}{760} = 16.$$

Half of these (the positives) reached the electrode, and gave an effect equal to that of the electrons which left it. The number of electrons leaving both sides of the foil for each α-particle passing through it is thus approximately eight.†

The foregoing preliminary experiments having shown that the effects observed in the electroscope were due to the emission of electrons from the surfaces of the metal, the speed of the α-particles was varied by interposing sheets of aluminium foil between the polonium and the cover of the exhausted chamber. Foils of two different thicknesses were used; the thinner was $0{\cdot}64 \times 10^{-4\ \text{cm}}$ in thickness and its approximate air-equivalent, according to Taylor's results, was $0{\cdot}116^{\text{cm}}$; the other was $3{\cdot}2 \times 10^{-4\ \text{cm}}$ thick, and was equivalent to $0{\cdot}58^{\text{cm}}$ of air; it happened to be just five times as thick as the first foil.

With the case charged to +40 volts, the current of electrons from the electrode was measured as successive layers of foil were interposed. The current increased until five or six of the thin foils had been added, after which it rapidly decreased. Curve I, fig. 2, shows the result of a series of such measurements made on Jan. 12, 1911. In the figure, the currents in volts per minute are plotted as abscissæ, and the number of layers of foil as ordinates; in order to facilitate comparison with the ionization curve of polonium, however, the scale of ordinates indicates the air-equivalents of the foils. Each plot-

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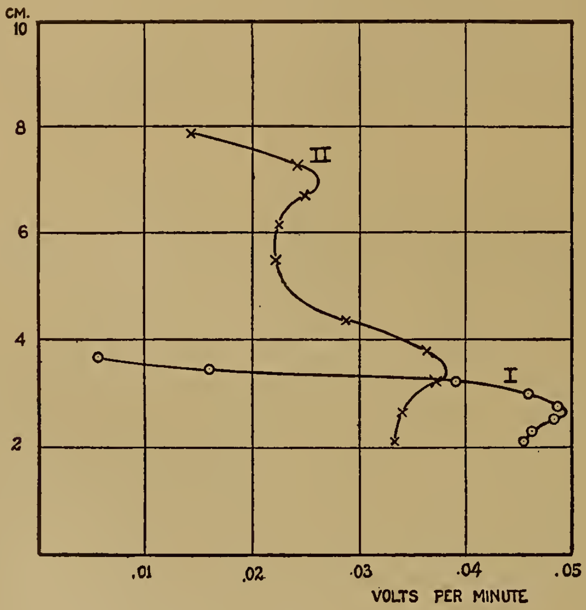
* Proc. R. S., lxxxii, 486, 1909.

† Hauser, Phys. Zeits., xii, 466, 1911, whose paper appeared after the completion of these experiments, finds that about 20 electrons are emitted from one side (the emergence side) of an aluminium foil for each α-particle.

ted point is the mean of from three to six separate observations, taken in various orders and with frequent returns to the measurement of the current with no foils, to check the constancy of the electroscope readings. Several repetitions of these measurements gave entirely similar results.

Before entering the case the a-rays passed through $0{\cdot}6^{cm}$ of air and through the thick aluminium foil which covered the holes in the top and whose air-equivalent was $1{\cdot}47^{cm}$, so that, with this apparatus, only the upper part of the polonium curve can be obtained. To obtain a-rays of greater range, I used the active deposit from the thorium emanation, which emits a-rays of two different speeds; the rays from thorium B have a range in air of $5{\cdot}0^{cm}$, and those from thorium C, of $8{\cdot}6^{cm}$. An additional advantage is the slow rate of decay of the thorium active deposit, which falls to half-value in 10·6 hours.

Fig. 2.



. Curve I, Polonium ; Curve II, Thorium Active Deposit.

A small quantity ("activity of $2{\cdot}4^{mg}$ Ra.Br$_2$") of Professor Hahn's mesothorium, obtained from Knöfler & Co. of Berlin, was available. This was placed in a small cylindrical cup of platinum with a hemispherical bottom, and was slightly moistened to increase its emanating power. The top of the cup was closed with a rather thick stopper of ebonite, in the center of which was a hole through which passed a copper plug of the same dimensions as that on which the polonium had been deposited (4$^{\text{mm}}$ in diameter). The lower end of this plug was flush with the bottom of the ebonite stopper, which was about half way between the top and bottom of the cup. By this arrangement, when the cup was charged to +80 volts with respect to the copper plug, most of the lines of force which passed through the emanation fell upon the end of the plug, and the greater part of the active deposit was collected there. After an exposure of 24 hours the accumulated deposit was sufficient to give very good readings in the apparatus described above, though somewhat less than had been obtained with the polonium. As there is an appreciable amount of radium with the mesothorium, it is necessary to wait about two or three hours before beginning measurements, in order to allow the radium-active deposit to decay to a small value.

Series of observations were made in the same manner as with the polonium except that the thicker aluminium foil alone was used. On account of the decay of the active deposit it was necessary to complete a series within a reasonable number of hours, and it was desirable to repeat each measurement several times to guard against possible vagaries of the electroscope. Each reading was corrected in the usual manner for the decay of the active deposit. Curve II, fig. 2, shows the result of the series of March 9, 1911, which is typical of other similar series. The two "knees" are distinctly shown, and their position is in excellent agreement with the ionization curve in air given by Hahn.*

It appears from these experiments that (as was anticipated) the secondary δ-radiation from aluminium varies with the speed of the α-rays producing it in a manner entirely analogous to the variation in the gaseous ionization under like conditions. But the possibility of an error in this conclusion here suggests itself. When the α-particle is not near the end of its range it passes through the thin aluminium electrode and the latter receives its positive charge solely on account of the electrons emitted by it. Near the end of the range, however, some of the α-particles (those entering most obliquely) will stop in the foil, and it is possible that the observed increase in the positive charge acquired by the electrode is due to the positive charges on these α-particles and not to any true increase in the δ-radiation. It is easy to test this by charging the case negatively, and measuring the negative charge received by the electrode from the electrons emitted by the case, for under these circumstances the stoppage of α-particles by the electrode would

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* Phys. Zeitsch., vii, p. 415, 1906.

decrease, instead of increasing, the effect. Unfortunately when this was tried a decisive result was not obtained. The current observed in the electroscope remained nearly constant while several foils were interposed and then fell off more gradually than with the positive charge on the case. As will be shown in the following pages, however, this was not due to the cause suggested above, but was in all probability the result of the construction of the chamber. As has been pointed out, many of the α-rays must have struck the sides of the holes in the top at various angles up to grazing incidence. Thus the electrons emitted from the case were not all produced by particles moving with approximately the same speed, but by particles whose velocities varied considerably. Hence the effect was somewhat analogous to ionization curves obtained when the pencil of rays is not limited to a small angle by a "Bragg screen."

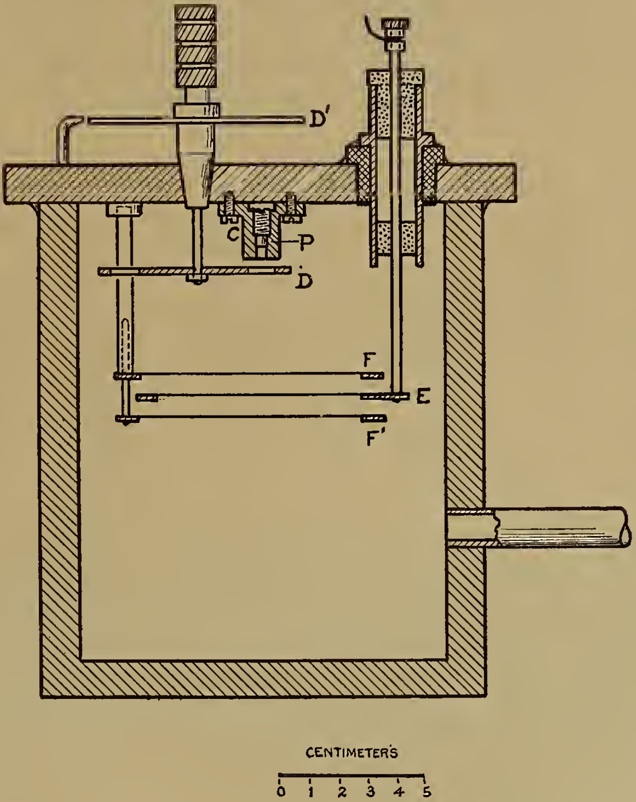
However, it was necessary to investigate the matter further. As a more intense source of radiation was desirable, Professor Boltwood was good enough to attempt the preparation of a much stronger deposit of polonium. By a special method he succeeded in depositing upon a 4^{mm} plug as much polonium as would be in equilibrium with about $0{\cdot}6^{mg}$ of radium, and yet having so little foreign material with it that it appeared as a mere discoloration upon the copper. With this preparation, the difficulties of the experiment were greatly lessened; an electrometer could be used instead of the electroscope, and much larger and steadier readings could be obtained.

In order to avoid the difficulties mentioned above, which prevented satisfactory readings when a negative potential was put on the case, the experimental arrangements were altered.

The polonium-coated plug, P (fig. 3), is placed within the evacuated chamber; it is surrounded by a brass cylinder, C, whose opening limits the cone of rays so that they fall within the ring, E, which supports the aluminium-leaf electrode. Two other rings, F and F′, above and below the electrode at a distance of 7^{mm}, are also covered with the aluminium leaf; they are in metallic connection with each other and with the case. The brass disc, D, is divided into six equal sectors; one of these is left blank so that the rays may be stopped, while the five others have holes through them $1{\cdot}3^{cm}$ in diameter. These five holes are covered respectively with 2, 3, 4, 5, and 6 layers of the thicker aluminium foil whose air equivalent is $0{\cdot}58^{cm}$. The disc can be rotated about its axis, which passes through the cover plate with a cone bearing, made tight by rubber stop-cock grease. A dial, D′, enables one to set the disc so that the different layers of foil are interposed, or the rays stopped altogether by the blank sector. The electrode is insulated from the case by amber, guard tube, and ebonite, and the joints made tight by sealing wax; it was connected with a Dolezalek electrometer, which, with 80 volts on the needle, had a sensitiveness of about 650^{mm} divisions per volt. It was necessary to reduce somewhat the current-sensitiveness of the instrument; for this purpose a small mica condenser of about 150^{cm} capacity was put in parallel with the electrometer.

With a positive potential on the case, the saturation current was reached with 40 volts; and when the brass sector was interposed in the path of the rays the current fell to a negligible value. On the other hand, it was impossible to approach saturation with a negative potential on the case, even at −320 volts; the negative current when the rays were stopped by the disc was always large (20–40 per cent of the total), and increased with the negative potential on the case. This part of the cur-

Fig. 3.



rent was due to the electrons set free between the polonium and the disc; by subtracting this from the currents obtained with the foils interposed it was possible to eliminate this disturbing portion of the negative current. What was left consisted of the electrons from the two foils on the rings F, F′, and from the surfaces of the disc-foils farthest from the polonium.

With this apparatus, practically identical results were obtained whether the case was charged positively or negatively; that is to say, whether the electrode emitted electrons or received those given off by the other aluminium foils. In the following table the results of various series of measurements are given. In order to facilitate comparison, the currents are reduced to the same scale, that obtained with 2 foils (the smallest number used) being taken as 100 in each case.

TABLE I.

Date	Volts on Case	Number of Foils				
		2	3	4	5	6
May 23	+160	100	107·2	118·5	107·	39·
" "	−160	100	104·	118·2	107·	54·
May 27	+ 80	100	104·5	116·3	106·8	38·7
" "	− 80	100	104·6	119·	108·6	55·5
June 9	+ 80	100	106·	118·	109·	39·5
" "	− 80	100	104 5	119·	110·	51·8

These results leave no doubt, I think, that the increase in the secondary δ-radiation is real, and is not due to the charge on the α-particles themselves. The discrepancy between the positive and negative currents when six foils are interposed is easily explained. With a negative charge many of the electrons come from the foil on the disc, D; with a positive charge, they all come from the electrode, E, and to reach this the α-rays must penetrate the foil, F (air equivalent = 0·116$^{\text{cm}}$). With 6 foils interposed we are in the nearly horizontal "top" of the curve, and a small difference in the range makes a considerable difference in the effect.*

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* An effect, probably due to this increased emission of electrons with diminishing speed of the particles, was observed by Aschkinass (Ann. d. Phys., xxvii, p. 377, 1908). He was measuring the charge of the α-particles after passing through various thicknesses of aluminium, and had a transverse magnetic field to curl up the δ rays. The α-rays passed through an aluminium window into a separate chamber and fell upon a copper plate. Even without a magnetic field the plate acquired a positive charge; when

In order to test the effect with another metal, three gold leaves were put upon the rings, E, F and F′, instead of aluminium. These leaves were $\cdot 09 \times 10^{-4\,\mathrm{cm}}$ thick and had an air equivalent of approximately $0\cdot 05^{\mathrm{cm}}$ (about half of that of the aluminium leaf). The emission from the gold electrode was about 13 per cent less than from the aluminium but the variation with the speed of the α-rays was very nearly the same. In the following table are given the averages for all the experiments with both metals (with positive potential on the case); the currents with two foils are called 100 as before. Included in the table are two series of ionization measurements. These were made by removing the foil from the electrode, E, admitting a small quantity of air (pressure $\cdot 032^{\mathrm{mm}}$), and charging the case positively. The first of the two ionization experiments is with the aluminium-leaf on F and F′, the second with the gold-leaf.

TABLE II.

No. Foils	2	3	4	5	6
Al	100	105·2	117·6	107·3	39·1
Gold	100	105·6	118·2	115·6	72·2
Air (1)	100	110·5	134·	143·	57·3
Air (2)	100	110·	130·	143·	96·5

As will be seen, the course of the series with the two metals is nearly identical; the differences in the last column are to be attributed to the greater stopping power of the aluminium leaf; it appears also in the two ionization experi-

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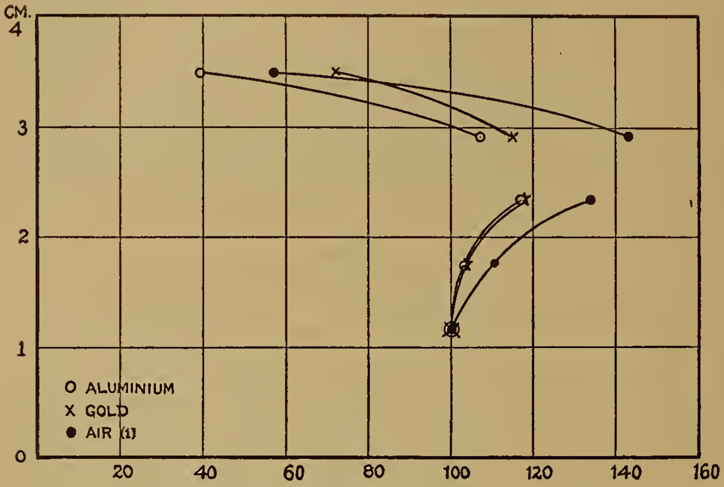
a small thickness of aluminium was in the path of the rays, the magnetic field increased this positive charge, but only slightly; (evidently the number of electrons emitted by the window and falling upon the plate was in excess of the number emitted by the plate itself, but this excess was not enough to neutralize the charge carried by the α-rays.) When the α-rays had to pass through a thicker layer of aluminium, the application of the magnetic field *diminished* the positive charge acquired by the plate; (in this case, the electrons emitted by the plate appear to be in excess of those received from the window.) The author draws the conclusion that "with diminishing speed of the primary α-particles, it appears that the intensity of the secondary radiation increases, at first slowly, and finally considerably." It does not appear that the conclusion is altogether justified by the experiment; the δ-radiation from the window seems to have been left out of consideration; the most that can be concluded is that there is a differential effect as between copper and aluminium

Another effect which is doubtless due to the same cause was observed by Duane (C. R., cxlvi, 1088, 1908). He found that the secondary radiation ceases a little less abruptly at the end of the range than the charge on the α-particles. As he used an unlimited beam of rays, this result may well have been due to the increased emission of electrons near the end of the range.

ments with the two metals on the ring, F. Fig. 4 gives a graphical representation of these results; it is to be remembered, however, that the ordinates of the different curves are not exactly adjusted to each other, on account of the differences just mentioned. It is indeed impossible to make satisfactory correction for these differences without knowing the relative values of the "incidence" and "emergence" δ-radiation; for, between the generation of the two, the α-rays pass through the leaf on the electrode—in the one case aluminium, in the other case, gold. It is plain, however, that this correction (if it could be made) would bring closer together the two curves in their decreasing portions, while it would not much affect their increasing portions where they are already in close agreement.

Fig. 4.



The results of Taylor, mentioned at the beginning of this paper, would lead us to expect that the metal curves would lie to the left of the air-curve and have a less pronounced knee, as appears to be the case. But they give equal grounds for anticipating that the gold curve should be to the left of that obtained with aluminium, and this is not confirmed by the experiments. Quite apart from these somewhat hypothetical considerations, it does not appear probable that two metals which differ so much in atomic weight and in other properties should give effects so nearly identical; the ionization curves in different gases are markedly different even when the gases differ much less from each other than gold and aluminium.

The close similarity observed with the two metals gives rise to the suspicion that the electrons we have been measuring are emitted not from the metals themselves, but, perhaps, from a layer of adsorbed gas which is the same in both cases. I have not yet had an opportunity to test this possibility, or to obtain the "ionization curves" of other metals, but I hope to do so shortly. The observation of Aschkinass (p. 414, foot note) seems to indicate that copper and aluminium would not give identical results.

Conclusions.

1. The emission of electrons by aluminium and gold foils under the influence of α-rays (secondary δ-rays) varies with the speed of the α-rays in a manner entirely analogous to the variation in the gaseous ionization produced by α-rays. The emission at first increases and then rapidly decreases as the α-rays near the end of their range, and the curves obtained show all the characteristics of the ionization curves in gases first obtained by Bragg.
2. The curves lie within (to the left of) the corresponding curves for gases and have a less conspicuous "knee." So far, they are in agreement with the known results on the retardation of α-rays by metals, and with the hypothesis that the loss of energy by the α-particles is due to an ionization of the metallic molecules. But the close similarity in the behavior of gold and aluminium is not in accordance with this view.
3. In view of the dissimilarity in the ionization curves of different gases, the agreement in the curves obtained for aluminium and gold is unexpected, and leads to the suspicion that the observed effects may not be due to the metals themselves, but, perhaps, to a layer of adsorbed gas in both cases. A further investigation of this will be undertaken shortly.

Sloane Laboratory, Yale University, August, 1911.

Art. XLIV.—*Some Minerals from Beaver County, Utah*;*

by B. S. Butler and W. T. Schaller.

Introduction.

While making an examination of some of the mines in Beaver County, Utah, in the summers of 1909 and 1910, one of the writers, B. S. Butler, collected several minerals that on examination proved to be of unusual interest. One of these is a species not hitherto known, a second has never before been reported from this continent, and a third, although previously reported from but two localities, was found to be relatively abundant in this district.

Beaverite, a New Mineral.

From the Horn Silver mine near the town of Frisco was collected a mineral that on examination in the laboratories of the United States Geological Survey proved to be a new species. For this mineral, which is a hydrous sulphate of copper, lead and ferric iron, the name *beaverite* is proposed, after the name of the county from which it was first described.

Occurrence.—The mineralization in the Horn Silver mine occurs along a fault plane that has thrown Tertiary lavas down against Cambro-Ordovician limestone, the ore deposits being mainly a replacement of the volcanic rocks.

The principal primary minerals of the deposit are: Galena, sphalerite, wurtzite, pyrite, chalcopyrite, a sulph-antimonite of lead possibly jamesonite, pyrargyrite, argentite, quartz, barite, muscovite, and small amounts of other minerals.

The mine has been developed to a depth of 1600 feet. For about 600 feet the primary minerals have been almost entirely altered by descending solutions, and this alteration has taken place in a lesser degree to a much greater depth. The characteristic alteration in the deposit is to sulphates with some carbonates, chlorides and sulphides.

The following secondary minerals have been recognized: Anglesite, cerussite, plumbojarosite, jarosite, beaverite, linarite, bindheimite?, smithsonite, calamine, goslarite, covellite, chalcocite, brochantite, malachite, azurite, chrysocolla, chalcanthite, cerargyrite, sulphur, chalcedony, kaolinite, gypsum, alunite, and hydrous oxides of iron and manganese.

The beaverite occurs with other secondary minerals in the upper part of the deposit. Only a small portion of the upper levels was accessible at the time of the visit and the mineral

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

was not seen in place, but the frequency with which it was met in the old dump leads to the belief that it must have been a rather common mineral in some parts of the deposit.

Physical Properties.—The mineral is a canary-yellow earthy looking material commonly mixed with other secondary lead and copper minerals, but occasionally in small masses that appear to be composed of a single mineral. Such masses are easily crushed in the fingers. Under the high power of the microscope the material is seen to be crystallized in distinct hexagonal plates. These are too small for accurate measurement of the crystal angles or determination of the optical character. The refractive index of the light ray vibrating perpendicular to the plates is considerably higher than that of solutions available in the laboratory for the immersion method of determining indices, namely 1·74.

Almost every crystal contains a minute inclusion whose character has not been determined. The material analyzed appeared under the microscope to be very pure except for these inclusions, and it is possible that the silica that appears in the analysis is due to them.

Chemical Composition.—The mineral is soluble in boiling hydrochloric acid, leaving the insoluble matter, chiefly silica, behind. On cooling, lead chloride separates out in considerable amount. The lead reaction can also readily be obtained with sodium carbonate on charcoal. On adding ammonia in excess to the hydrochloric acid solution, the ferric iron is thrown down as a voluminous brown precipitate, and the solution has the deep blue color indicative of copper. By the quantitative determination, the presence of a small amount of alumina was established. The insoluble matter consists mostly of silica, only a slight residue remaining after treatment with hydrofluoric acid.

The average of the results of the chemical analyses is shown in the table below. The ratios obtained therefrom are also given.

Analysis and ratios of beaverite (*W. T. S.*).

Insol.	10·05			
CuO	9·70	·121		·92 or 1
PbO	29·44	·132		1·00 " 1
Fe_2O_3	17·28	·108	·144	1·07 " 1
Al_2O_3	3·64	·036		
SO_3	21·32	·266		2·01 " 2
H_2O	9·02	·501		3·80 " 4 (=4×·95).
	100·45			

The ratios agree well with the formula $CuO.PbO.Fe_2O_3.2SO_3.4H_2O$, in which the copper and lead are assumed to be present in equal molecular amounts, and in which a little ferric iron is replaced by alumina. As the ratio of Fe_2O_3 to Al_2O_3 is as 3:1, the formula can be written more exactly as $4CuO.4PbO.3Fe_2O_3.Al_2O_3.8SO_3.16H_2O$. A comparison of the analysis with the insoluble matter deducted and reduced to 100 per cent, with the values calculated for the formula last given, is shown below.

Comparison of analysis with calculated values.

	Analysis	Calculated
CuO	10·74	11·70
PbO	32·50	32·80
Fe_2O_3	19·13	17·61
Al_2O_3	4·03	3·75
SO_3	23·60	23·54
H_2O	10·00	10·60
	100·00	100·00

The water is all constitutional, as none was driven off below 250°. The actual results obtained are as follows:

Loss of weight of beaverite on heating.

Tempt.	Total loss
110°	0·04%
170°	0·10
250°	0·14
390°*	3·72
590°*	10·45

* Heated in an electric furnace.

The loss at 590°, as given, is higher than the true value, as a little of the material was lost by the thermal couple accidentally reaching into the crucible when some of the powder adhered to the wires.

No known mineral could be found with which beaverite seems related, so that at present it must stand as an isolated member of the sulphate group.

Wurtzite.

The hexagonal zinc sulphide, wurtzite, is present in considerable abundance in the primary ores of the Horn Silver mine. The principal primary minerals of this deposit have been noted above. The richer zinc ore in the hand specimen has the general appearance of light honey-yellow sphalerite, but under the microscope a portion is seen to be rather strongly birefringent and some of this has the outline of pyramidal crystals.

A closer examination of the specimen revealed pyramidal crystals that could be separated from the surrounding material. Several of these crystals were removed from the matrix and measured. They showed a steep hexagonal pyramid, which was strongly striated horizontally. Accurate measurements were not possible, as the striations caused the crystals to become rounded with consequent absence of plane faces. The crystals were measured on the two-circle goniometer and ρ angle determined for the pyramid faces. This angle corresponds to that between the basal plane (absent on these crystals) and the pyramidal faces. The values obtained are shown below, the pyramid being the form $o\{20\bar{2}1\}$

Fig. 1.

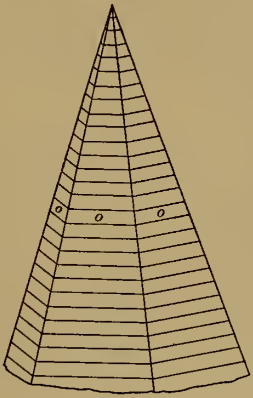

Fig. 1. Wurtzite, $o\{20\bar{2}1\}$.

Measurement of $o\{20\bar{2}1\}$ *wurtzite.*

Crystal No.	1	2	3	4	
Average measurement	61°	62°	60°	61°	Calc. 62° 06′

The general habit of these crystals is shown in figure 1, where the marked horizontal striæ are also shown.

The crystals of wurtzite dissolve readily in HCl, evolving H_2S. The solution contained abundant zinc and no other metal was present in appreciable quantity.

It may be noted that the zinc sulphides in this mine have the property of tribo-luminescence or of giving off light when scratched. This is so marked that sulphides of zinc can be readily detected in the mine by drawing the point of the pick or mine candlestick across the ore. If zinc sulphides are present the point of the metal is followed by a line of sparks.

Plumbojarosite.

Plumbojarosite has previously been described from two localities, first from Cook's Peak, N. M.[*] and second from American Fork, Utah.[†]

Since this mineral has been so rarely noted, it was a matter of some surprise to find it in no less than six mines and prospects in Beaver County, in some cases in such abundance that a considerable quantity could be picked from the ore bins and dumps. The writer was told by one superintendent that several tons of the mineral had been thrown on the dump and later on being found to contain metal values had been shipped to the smelter.

Plumbojarosite has been determined from the following mines and propects in Beaver County: Horn Silver, Hub, Moscow, Red Warrior, Harrington-Hickory, and an unnamed prospect pit, and probably is present in still others.

Occurrence.—The mineral is secondary, resulting from the alteration of ore composed mainly of sulphides of iron, lead, copper, and zinc. The secondary minerals for the most part are the oxides, sulphates, carbonates and silicates of these metals, and with these are plumbojarosite, frequently jarosite, and other minerals in varying amounts. It is of interest to note that from the Horn Silver mine three members of the jarosite group were determined, namely, jarosite, plumbojarosite, and alunite.

Physical properties.—As seen in the hand specimen, the material is dark brown in color and distinctly micaceous in appearance with a silky luster. Where the crystals are very fine the micaceous character is less pronounced and the mineral, if not examined with some care, might be mistaken for limonite or some iron-stained material. Although the mineral is frequently in rather large pieces as it comes from the mine, it is readily crushed in the fingers and has an oily look and feel, similar to fine graphite. Under the microscope the crystals are seen to be thin hexagonal plates of a light golden-yellow color. The crystals vary greatly in size but rarely exceed 0·25^{mm} in width. Measurement of the crystals has not been made but they are undoubtedly hexagonal and so far as their properties have been determined they correspond to the material examined by Wright from the American Fork locality. The

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[*] Hillebrand, W. F., and Penfield, S. L., this Journal, vol. xiv, p. 213, 1902.

[†] Hillebrand, W. F., and Wright, Fred E., this Journal, vol. xxx, p. 191, 1910.

crystals are uniaxial, optically negative with strong birefringence. It may be noted that jarosite from the same mines is so similar to the plumbojarosite in physical properties that a distinction can be made only by chemical tests.

Chemical composition.—The analysis (by W. T. S.) of the plumbojarosite is shown in the table below, where, for comparison, are also given the two analyses, by Hillebrand, of the mineral from New Mexico and American Fork, Utah. The values calculated from the formula $PbO.3Fe_2O_3.4SO_3.6H_2O$ are also given in the last column for comparison.

Analyses of plumbojarosite.

	Beaver Co., Utah	Cook's Peak, N. M.	American Fork, Utah	Calculated
Fe_2O_3	42·11	42·37	42·87	42·38
PbO	18·32	19·84	18·46	19·74
K_2O	0·13	0·17	0·15	....
Na_2O		0·21	0·52	....
SO_3	27·59	27·06	27·67	28·33
H_2O	9·16	9·56	10·14	9·55
CuO	....	0·27	0·10	....
CaO	0·00	0·05	0·06	....
Insol.	2·64	0·51	0·40	....
ZnO	0·30	....	....	....
	100·25	100·15	100·37	100·00
Density	3·60	3·665		

The three analyses show a close agreement among themselves as well as with the calculated values.

Corkite.

A light yellowish-green mineral that has the properties of corkite, a hydrous phosphate and sulphate of lead and iron, was collected from the Harrington-Hickory and the Wild Bull mines. So far as is known to the writers, these are the only localities on this continent from which this mineral has been reported.

In both of the mines mentioned the original ores were a replacement of limestone near the intrusive rock and there was considerable apatite and contact silicates formed with the metallic sulphides, mainly pyrite, galena, sphalerite, and chalcopyrite. The corkite is a secondary mineral resulting from the alteration of these ores, the phosphate doubtless being derived from the apatite and the metallic content from the sulphides.

In physical properties the mineral corresponds with that previously described. In the hand specimen it is a light green earthy looking material which when crushed in the fingers has a gritty feel like fine sand. Under the microscope it is seen to be well crystallized, the larger crystals being 0·15^{mm} in diameter. The crystals are golden yellow in color and have the general appearance of being a combination of the cube and octahedron. They are rather strongly birefringent, however, and are probably hexagonal rhombohedral. The index of refraction is higher than 1·74.

Corkite is readily soluble in boiling hydrochloric acid from which solution lead chloride separates out in quantity on cooling. The solution contains, besides lead, abundant ferric iron and the sulphate and phosphate radicals. Qualitative tests failed to show the presence of any arsenic, and only a mere trace of copper is present in the American corkite. Heated in a closed tube, the mineral darkens and gives off water.

ART. XLV.—*A Method of Determining the Density of Minerals by means of Rohrbach's Solution having a Standard Refractive Index;* by H. E. MERWIN.

Two methods of finding the density of minerals or glasses which are in granular form, or which require to be granulated in order to be made homogeneous, are in general use—the pycnometer method and the suspension method.[1] Fine powders (grains less than about ·1 or ·2^{mm} in diameter) cannot be used successfully with the suspension method on account of the disturbing effects of convection currents and viscosity in the suspending liquid, and of flocculation of the solid particles. The pycnometer method is a universal method if sufficient material (a few grams) is available. The method is laborious, and requires much skill and standardized apparatus. The suspension method, with the same skill and care as to the adjustment of the instrument used, should yield equally accurate results for much less labor, provided the material may be obtained in sufficiently large homogeneous grains.

The difficulty of convection currents in the liquid can be largely overcome by preventing evaporation and by surrounding the cylinder in which the liquid is held with a closed vessel of air or water. The proper adjustment and standardization of the specific gravity balance by means of which the density of the liquid is obtained are, of course, essential. Some of the more sensitive balances cannot be adjusted and tested without the use of special devices not furnished with the balances. If properly adjusted, the best of these balances are sensitive to ·0003, but errors in the graduation of the beam often amount to ·001. The density of a liquid may be correctly determined within ±·001 with such a balance. If the grains of material suspended in the liquid are not moved about by convection currents, then the density of the grains may be matched by the liquid much closer than ±·001. A disadvantage of the specific gravity balance is that the column of liquid must be deep enough to receive the sinker; this depth increases the possibility of convection currents.

An alternative method of finding the density of the liquid in which the grains are suspended, which depends upon the relation of refractive index to density, has been found to be expeditious and accurate. The liquid is contained in the small glass cell accompanying the standard refractometers, and its

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[1] Recently J. L. Andreae has described a method of finding the density of suitable solids correctly within ± ·0001 by suspending a fragment of the solid in a heavy solution in a dilatometer. Zeitschr. phys. Chem., lxxvi, 491-496, 1911.

refractive index is determined while the grains are suspended in it.

A liquid having as great a range of refractive index as possible for a given difference of density is most advantageous for accuracy. The liquid should have also a wide range of density. Further requirements are convenience in attaining a standard condition, and permanency. Rohrbach's solution of barium-mercuric iodide meets these requirements.

Rohrbach's solution as ordinarily prepared[2] and as sold by the dealers has a maximum density of about 3·5. To standardize the liquid it is diluted, at a temperature of 19° to 21°, with water, to the density of clear crystals of sulphur (about 2·07), or until the refractive index for sodium light is 1·510 to 1·520. The solution is cleared of the precipitated mercuric iodide, a part is left dilute and the remainder concentrated by evaporation. But if crystals are present in the cold concentrated solution, enough water should be added to dissolve them, for they differ in composition from the liquid above them. Mixtures of these solutions thus prepared have a fixed density (correct to ±·001) for a given index of refraction. If desired, the concentrated solution may be diluted with water if it is stirred rapidly to prevent precipitation of mercuric iodide; it is to be noted, however, that a very slight precipitate on the bottom of the cell of the refractometer greatly obscures the signal.

The prepared Rohrbach's solution or the materials for making it may be obtained from the dealers sufficiently pure[3] for the preparation of the standard solution. As a check the purity of the solution should be tested by bringing it to the density of clear quartz, 2·6495, and determining its index of refraction ω for sodium light at 20°. This index should be 1·6208.

The relation of density to refractive index of this solution at 20° was found by means of a standard refractometer giving results correct to ±·00015, and indicators of standard density, correct to ±·0015.

The results are contained in Table I.

These results may be plotted on coördinate paper and connected by a curve; or their relations may be stated in a simple

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[2] By rapidly mixing 100 g. BaI_2 and 130 g. HgI_2, adding 20^{cc} of water, then placing immediately in an oil bath at 150° to 160°, and agitating till boiling and solution take place. The solution may be prepared equally well by rubbing the constituents together in an evaporating disk over a hot water-bath.

[3] Barium iodide may be strongly colored by iodine. Washing with benzene, xylol or ether will remove the iodine.

If the heavy liquid becomes discolored it may be cleared by shaking with mercury. Restandardizing is not necessary unless the solution was deeply colored.

empirical formula which gives the density,[4] *d*, between 2·25 and 3·40 at 20° with a maximum probable error of ±·002.

$$d = 5{\cdot}39(n-1{\cdot}5467)+2{\cdot}25$$

which in a simpler form is $d = 5{\cdot}39n-6{\cdot}0865$. For accurate work, if the temperature is more than 3° from 20° a correction for *d* of $-{\cdot}001$ for each 2° below 20° and of $+{\cdot}001$ for each 2° above 20° should be made.

TABLE I.

Density at 20° C.	Refractive index.
3·449	1·7686
3·396	1·7590
3·246	1·7312
3·180	1·7195
3·046	1·6944
2·980	1·6823
2·748	1·6391
2·649	1·6207
2·648	1·6205
2·367	1·5685
2·163	1·5320
2·067	1·5148

V. Goldschmidt[5] constructed a similar table for a solution of potassium-mercuric iodide. The standard solution is difficult to prepare and maintain.

At given densities the observed refractive index varied with the temperature as follows:

Density.	Refractive index.	Temperature.
2·067	1·5147	23
	1·5150	20
2·367	1·5695	14
	1·5685	20
2·748	1·6398	13
	1·6391	20
*c*3·449	1·7690	16
	1·7686	20

In using the cell with the refractometer it is more convenient to use only one part of the vertical circle scale. If accuracy within ±·002 is desired, it is then necessary that the

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[4] The formula between 2·0 and 2·25 is $d=5{\cdot}7n-6{\cdot}567$, and between 3·4 and 3·5 is $d=5{\cdot}52n-6{\cdot}313$.

[5] N. Jahrb. f. Min., Beil.-Bd., i, 234, 1881.

accuracy of the refractometer be tested, for errors in the adjustment of the cross-hairs and of the vernier are not compensated as they are when both parts of the circle are used. The testing may be done by observing the error of the instrument for ωNa of quartz, 1·54425. A drop of the concentrated solution may be used between the cell and the hemisphere. The trouble from diffraction bands may be largely avoided by placing a triangle of thread between the cell and the hemisphere.

Before finding the density of grains of a material the grains should be examined under the microscope in a watch glass of xylol or alcohol to make sure of freedom from foreign matter. So little attention has been given to such an examination that many of the recorded densities of minerals which have been carefully analyzed are in error ·5 per cent or more. Greater error is apt to come from lack of care in selecting material than from other causes.

If only the approximate density of a substance is desired, it may be found quickly by matching its density approximately with that of the heavy solution, placing a drop of the solution on the refractometer, covering with a glass slip (to prevent evaporation) and determining the index of refraction.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C., Oct. 2, 1911.

ART. XLVI.—*Quartz and Fluorite as Standards of Density and Refractive Index;* by H. E. MERWIN.

FOR checking the accuracy and adjustment of instruments easily available standards are desirable. Such standards should be as nearly as possible independent of other standards. Standards of density correct to ±·001, and of refractive index correct to ±·0001 are particularly useful to the mineralogist.

Pure water is a most important standard, although its properties vary with temperature beyond these limits under ordinary laboratory conditions. The density of water at 15° is ·999; at 20° is ·998; at 25° is ·997. Its refractive indices according to H. Dufet's[1] tables are as follows:

	15°	20°	25°
Li	1·3312	1·3308	1·3303
Na	1·3334	1·3330	1·3325+
Tl	1·3353	1·3349	1·3344

The effects of dissolved air and of ordinary impurities may be neglected.

There are very few natural solids of wide distribution that are uniform enough in composition to serve as standards of the above specified accuracy. Quartz and fluorite approach such conditions.

The relative density of twelve fragments of clearest quartz about 1^{cm} in diameter, from different localities, was investigated by suspending the fragments in Thoulet's solution. The solution was brought to the density of Brazilian pebble quartz, then the other fragments were put in. Only two fragments differed sensibly in density: one was quartz from Herkimer Co., New York, which slowly settled; the other, of unknown locality, came slowly to the top. The experiment was repeated with other fragments from the same localities with the same result. A balance of the Westphal type sensitive to ·0003 barely detected the difference of density of the solutions matching the densities of the two fragments.

The density of the Herkimer Co. quartz was determined by means of a Rueprecht balance with a Reiman's plummet, which by test was found to displace 5 grams of water at 18°. The riders were weighed and found to be in error less than

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[1] Recueil de Données Numériques, Optique, p. 87, 1900.

·0015 g. each, an error which affects the density determinations less than ·0003. The beam was found to be inaccurate by as much as ±·0007. After adjusting the balance to read unity for water at 18°, it read 2·653 for the quartz at 20°. Reducing this reading to true density at 20°, we obtain 2·6495. A second determination with a different combination of riders gave 2·649. Standardizing the balance by means of several fragments of glasses, the densities of which had been determined by E. S. Larsen in the Geophysical Laboratory, a value of 2·650 was obtained. The density of any one of the twelve quartzes investigated is thus accurately expressed by the figures 2·6495 ±·0010. This value may be taken as the density at 20° of clear quartz from any locality. As a check upon the suspension method, L. H. Adams and R. B. Sosman of the Geophysical Laboratory determined the density of two of the fragments of quartz, using the Principle of Archimedes. The fragments weighed about 30 g. The values found were 2·6495 and 2·6496. By the pycnometer, the Earl of Berkeley[2] obtained, for powdered and ignited quartz, the mean value 2·6486.

According to Fizeau and others[3] the decrease in the density of quartz between 10° and 30° amounts to about ·001 for 10 degrees rise of temperature. At ordinary laboratory temperatures the density of any clear colorless quartz is therefore 2·6495 ± ·0010.

Fragments of nearly colorless fluorite from nine different localities[4] in Europe and America, furnished to the writer by the United States National Museum, were suspended in Rohrback's solution.[5] A maximum difference of density of ·001 was observed. The mean density as found by the Westphal balance was 3·180, with a probable error of ±·001.

The density of three pale-colored fluorites from different localities was found by Dudenhausen,[6] using the Principle of Archimedes. The values twice determined at 14° to 16° all came within the limits 3·181 ± ·001. At 20° this density, calculated from the coefficient of expansion of fluorite as given by Kopp,[7] is 3·180 ± ·001. This is the value found by the writer. Further evidence of the approximate identity of density of various fluorites is found in the uniformity of their indices of refraction.

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[2] Jour. Chem. Soc., Trans., xci, 60, 1907.

[3] Smithsonian Physical Tables, 215–216, 1904.

[4] Durham, Weardale and Cumberland in England; Freiberg, Saxony; Rosiclare, Ill. (from three different occurrences); Macomb and Muscalonge Lake, N. Y.; Pike's Peak, Col.; Shenandoah, Va.

[5] The temperature of the solution was kept constant within ·3° by placing the cylinder containing the solution in a covered vessel of water at the air temperature.

[6] N. Jahrb. f. Min., i, 8–29, 1904.

[7] Pogg. Ann., lxxxvi, 156, 1852.

It is of course essential that fluorite or quartz to be used as standards of density should be clear. The specimens should be carefully examined in alcohol or water under the microscope in order to detect minute cracks or inclusions.

By means of water, and solutions standardized by quartz and fluorite, the Westphal type of balance of standard make can easily be adjusted to an accuracy of ±·0015 for all readings.

Substances of standard index of refraction are useful chiefly for adjusting, or determining the errors of the total refractometer. If the indices of refraction of the glass hemisphere for certain wave lengths are not known, they may be calculated from the value of the observed angle of total reflection of these wave lengths from the surface of the standard of known index of refraction. If N is the index of refraction of the hemisphere, n that of the standard, and α the observed angle, then $\frac{n}{\sin\alpha} = N$.

The refractive index of quartz has been the subject of repeated investigations. Most of the careful and experienced observers have obtained values that are accordant within ±·0001. The extreme values given in Dufet's tables (pp. 427–432) for the ordinary ray and the sodium lines are 1·5446 and 1·54412. Reference to the original papers shows that few of the observers have stated the locality from which their quartz was obtained. For this reason it cannot well be determined whether the index of refraction varies to this extent or whether the values obtained are in error. Esselbach,[8] who obtained the highest value, considered the possibilities of error and concluded that the high values he obtained throughout the entire spectrum were probably due to the quartz. Danker[9] obtained 1·5444 for quartz from Middleville, Herkimer Co., New York, by total reflection. A comparative study by the writer of the index of refraction for sodium light of five quartzes, one from Herkimer Co., New York, and one of Brazilian pebble, gave, by the Abbe-Pulfrich total refractometer, an extreme difference[10] of ·00015. Each value obtained represents the average of 32 readings (16 for each of two polished faces) on both parts of the graduated circle. The highest index was obtained from the Herkimer Co. quartz, and the lowest from the lightest quartz used in the tests for density. The accuracy of the adjustment of the refractometer and the errors of its vernier and circle were determined by observing the angle of total reflection from air, water at known temperatures, crown glass, flint glass, and a calcium-magnesium silicate

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[8] Pogg. Ann., xcviii, 541–546, 1856.

[9] N. Jahrb. f. Min., Beil.-Bd. iv, 266, 1886.

[10] Dufet (Bull. Min. Soc. de Fr., xiii, 274, 1890) found about this difference among twenty quartzes—some deeply colored.

glass.[11] The indices of refraction of the glasses had been carefully determined on a standardized spectrometer, with a probable error of less than ± ·00005. The index of refraction of air was taken as unity, and of water at 20°, 1·3330.

The five quartzes gave the following indices of refraction for sodium light: Herkimer Co. and Brazilian pebble 1·5443–, three others 1·5442. By the spectrometer the value found for the Herkimer Co. quartz was 1·54428 ±·00004.

Gifford[12] has made most precise measurements of the indices of refraction of quartz. His values for ω are very close to the values obtained by most observers. The indices of refraction of various quartzes, with rare exceptions, do not depart more than ± ·0001 from his values, which are given here (*Li* and *Tl* are interpolated by the writer). *Li*=1·5415; C=1·5419+; D=1·54425–; *Tl*=1·5465; E=1·5472–; F=1·5497–. According to Gifford and others a rise in temperature of 17° to 20° lowers the refractive index ·0001.

The refractive index of fluorite is an exceedingly constant quantity; even the colored varieties[13] differ from the clear varieties scarcely more than ±·0002. From the data in Dufet's tables (pp. 436–439) and in later papers[14] the following values have been compiled as representing the index of refraction of fluorite at 20°. The probable error in applying these values to any clear fluorite is less than ±·0001.

B	1·4320	*Tl*	1·4353
Li	1·4322	E	1·4355
C	1·4325	F	1·4370
D	1·43385		

8° to 10° rise in temperature causes a decrease of ·0001 in the refractive index.[12]

Plates of fluorite from Rosiclare, Ill., Macomb, N. Y., and Muscalonge Lake, N. Y., polished first on block tin then on felt with rouge, gave the following extreme values with sodium light, each the mean of sixteen readings of the refractometer: 1·4338+ and 1·4338–.

Geophysical Laboratory, Carnegie Institution of Washington,
Washington, D. C., Oct. 2, 1911.

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[11] The refractive index of the glass hemisphere for sodium light calculated from the reflection angles observed from these standard substances was: from air 1·9062, water 1·9062, crown glass 1·9064, flint glass 1·9065, calcium-magnesium silicate glass 1·9065. Water was most satisfactorily used by placing a large drop on the hemisphere and covering it with a glass slip to prevent cooling by evaporation. One edge of the glass slip was slightly elevated to avoid diffraction bands by placing a bit of soft paper between the glass and the hemisphere. A standard thermometer near the hemisphere gave the temperature of the water. It was necessary to screen the hemisphere from the direct radiation of the flame by a double glass screen, or to place the instrument at a distance from the flame and take the light from a large condensing lens.

[12] Proc. Roy. Soc., (A) lxx, 329, 1902.

[13] See ref. 8.

[14] F. F. Martens, Ann. d. Phys. (4F), viii, 459–465, 1902. See also refs. 6 and 12.

Art. XLVII.—*On the Williamsonian Tribe;* by G. R. Wieland.

(A preparatory study published by permission of the Carnegie Institution of Washington.)

To show how the investigation of the Cycadophyta in both field and laboratory, following the elaboration of the flowers of *Cycadeoidea* a dozen years ago, has established the long problematic genus *Williamsonia* as the type of a great and dominant Mesozoic group, to further bring together, perhaps for the first time, the data indicating the general alignment of this group, and to give in plain form the story of its discovery, with its principal structural features and something of their bearing on plant evolution, is the object of the present preparatory study. Obviously in so dealing with an alliance in the initial stages of discovery, it is convenient to speak of it as a tribe for the very reason that as used in science this term is an elastic one; though as here employed the larger sense as an aggregate of diverse families, rather than of genera or subfamilies, is the one inferred. Also the silicified cycads as named the Cycadenoideæ by Robert Brown in 1828 are arbitrarily separated from the family Williamsoniæ, Carruthers 1870(5),* although no very distinct line of demarcation appears. And, too, in singling out the genus *Williamsonia* as the group type, regard is had only for the order of discovery; it being important to point out that this genus is by no means the most interesting form,—that distinction unquestionably belonging to *Wielandiella* of the Rhät of Skone, as so ably and skilfully studied by Professor Nathorst (21, 25), by means of the collodion film method brought into practice by him and destined to play an important rôle in all future study of fossil plants.

It is but a few years since it was accepted with little thought of question that the common types of Mesozoic cycadophytean leaves must all pertain to plants belonging to true cone and carpellary-leaf bearing Cycads near to existing types, or at least to ancestral forms of strictly Cycadalean aspect. True enough, Williamson (4), from long study of the specimens collected by himself and his father along the Hawsker and Runswick cliffs of the Yorkshire coast early in the last century, had reached, about 1870, an excellent restoration of his "riddle" *Zamia gigas*,—renamed *Williamsonia gigas* by Carruthers (5). But, as Carruthers had meanwhile found, the Isle of Wight silicified trunk *Bennettites Gibsonianus* had an ovulate fructification so different from other gymnosperms that its characters sug-

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* See list of authors cited given at the end of this article.

gested no relationship to the imperfectly known *Williamsonia*, in fact could scarcely have been fairly interpreted short of the broader knowledge of the past ten years. And precisely because of this very new type of ovulate cone it was not seriously suspected that the great majority of fossil cycad trunks bore fruits like it or could be other than ordinary cone-bearing forms. While Saporta (10) with all the weight of authority, and having in his hands the splendid James Yates collection of Williamsonias brought to the Paris Museum by Brongniart in 1843—a collection the equal if not the superior of any that remained on English soil—rejected the idea of any organic connection between the Williamsonian "pyriform axes" and "carpellary disks," and the "*Zamia gigas*" fronds. In which he was followed by most continental botanists, with various suggestions as to the possible affinities of the Yorkshire coast specimens, ranging from the Cordaites-like *Yuccites* to *Orobanche* (9).

Thus it was that the idea that complexity of structure might lie hidden behind the great array of Mesozoic cycad stems and leaves, failed of development and study, and came to receive but scant mention in paleontologic texts. And so rested the subject until the structure of the *Cycadeoidea* flowers was at last elaborated from the American specimens, and the true position of *Williamsonia* as the representative of a slender-stemmed family closely related to the Cycadeoideæ, made apparent (12). While at the present time collateral evidence has so accumulated that nothing in Paleobotany is more clearly established than that a great complex of *Williamsonia*-like plants, including other families yet to be determined, spread over the earth in the Mesozoic. As Scott has said, the application of comparative criteria may lead one to the conclusion that thirty to forty thousand of these species existed in Mesozoic times. Moreover, every year that goes by strengthens the view that of all post-Paleozoic gymnosperms the type represented by *Williamsonia* is the one most generalized, plastic, and capable of floral variation.

For as is now so clearly discerned, the silicified trunks of the near family Cycadeoideæ are simply the bizarre relatives capable of fossilization as entire plants with their flowers conserved in that exquisite perfection which has so advanced our knowledge of cycad structure and growth. They are the structural key to their race, failing which it would not have been possible to decipher even by the more refined methods of fossil imprint and cast study developed in the past few years, either the true floral structure of *Williamsonia* or the full extent of its cycadofilicalean relationship. But this great service once rendered, the silicified series wholly fails of the extended interest of the allied casts and imprints, amongst which lies our great hope of future discovery not only of critical anatomic features, but eventually of the ecology and larger history of the Cycadophyta. In short the narrow structural range of the silicified trunks, well nigh expressable in the terms of a single genus, is only what might be hypothesized from the features of a single species like *Cycadeoidea dacotensis*, were it the only known form. These are but the stereotyped terminal forms of a side branch from a great plastic and dominant precursor race unquestionably including the vast bulk of Cycadophytean vegetation from the earliest Triassic to mid-Cretaceous times. We thus see in the Williamsoniæ the representatives of a vast Mesozoic plexus derived from a Paleozoic quasifern ancestry in which pro-angiospermous characters are ever surely and obviously engrafting themselves. And we conceive this plexus to contain many discoverable forms of great variety in size, foliage, branching, and floral types dis-

Fig. 1.

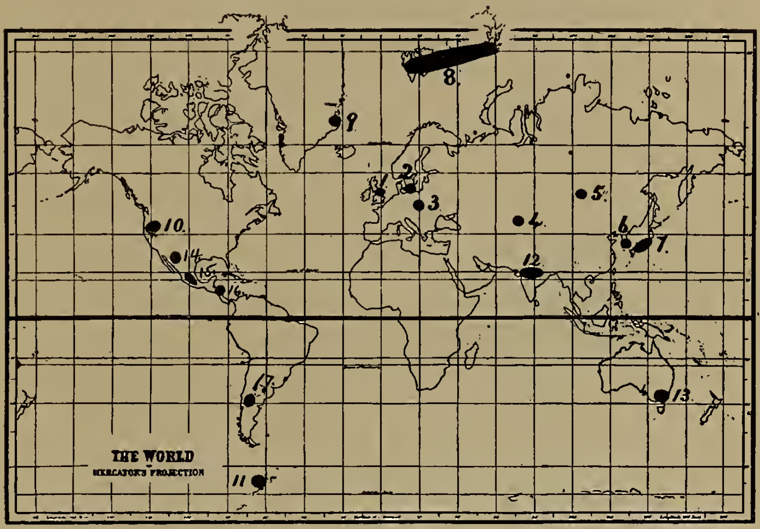

Fig. 1. Map of the globe showing the principal Rhät-Liassic localities yielding Williamsonian foliage and fructifications. Various scattered Liassic and other mid-Mesozoic areas in Europe, America, Madagascar, and elsewhere, are not indicated; though some of these, as for instance the Liassic of Italy (Zigno), yield important fossil floras.

This map as modified from Seward (26) shows the notable chain of localities on the Pacific coast of the Americas with the newly discovered Oaxacan region in the same latitude as, and on the exact opposite side of the globe from its nearest analogue, in the Rajmahal Hills and Gondwanas of India.

[References: Localities 1–13 in Seward (26); 14 cf. (3), 15 cf. (22) and (27), 16 cf. (11), 17 cf. (13).]

playing every phase of monœcism, diœcism, and bisexuality, coupled with a continuous series of sporophyll reductions, sterilizations, and increasing flower output.

The stems and leaves of this great series considered merely as typical and cosmopolitan cycad vegetation (cf. Map, fig. 1), of course held scant interest for the biologist; though now that to initial knowledge of the sporophylls has been added a complementary knowledge of the cycadofilicaleans, no one may set boundaries to the harvest of new fact certain to be yielded by the Cycadophyta year by year.

But while enumerating these new fields for exploration and reciting recent *Williamsonia* discoveries, it is of more than merely retrospective interest to further show how truly rich some of the earlier *Williamsonia* collections from the Yorkshire coast really were. And this we may readily do by illustrating in their order a series of ovulate specimens originally forming a portion of the celebrated James Yates collection, but now transferred to the Yale Museum collections by the Curators of the Paris Museum. This interesting illustrative series, of historic as well as structural interest, forms a nearly indispensable complement to the Yale collection of Cycadeoideans which it had become a special aim to secure; and as a just equivalent there was turned over to the collections of the *Jardin des Plantes* a unique quadruply branched trunk of *Cycadeoidea Marshiana* of large size,—probably the only distinctly branched specimen of its kind in any European museum. In addition, I am enabled through the unfailing courtesy of the French curators to present figures of several other characteristic specimens of the Yates collection of much interest as being the forms with Yuccites-like features (figures 2 and 11*A*) which reasonably explain the earlier variant views of the *Williamsonia* habitus. But before turning to these interesting specimens, we may briefly consider the stems and then the foliage of Williamsonian types, progress in the study of the group now fairly permitting this normal order.

Trunks of Williamsoniæ. (Figures 2–4.)

So far as critical details go knowledge of Williamsonian wood types has not kept pace with that of either the foliage or flowers, despite the fact that more or less imperfect casts and imprints of various kinds of stems are of constant occurrence in the cycad-yielding terranes. Williamson early noted slender stems of cycadaceous character accompanying the *Zamites gigas* fronds and fruits of the Yorkshire coast so persistently as to justly lead him to the conclusion that these remains, though seldom or almost never seen in organic connection, must represent one and the same plant (4); while Feistmantel (7) found other yet slenderer stems with short nodes of smaller scars regularly distributed along the stem, always closely associated with the fine Williamsonian buds and foliage of the Gondwanas of India, as had Oldham and Morris at an earlier day (8*b*). And later Nathorst satisfactorily established the unity of the slender, much-branched, *Anomozamites*-like

Fig. 2.

Fig. 2. *Williamsonia* (?). About half natural size.
Stem fragment enveloped in linear leaves of Cordaites-like aspect rather than that of either scale leaves or bracts. Doubtless a member of the Williamsoniæ of Yucca-like aspect, the generic attribution of which remains uncertain. (Paris Museum specimen. Collection Yates from the Yorkshire Coast Oölite, Cliffs of Hawkser and Runswick; obtained by Brongniart, 1843.)

fronds, and fruits of Williamsonian affinity, recovered from the Rhät of Skone. First restored as a *Williamsonia* (14), this interesting plant as it since transpires from renewed study by the collodion method (21), has a staminate form quite as much reduced as, or even comparable to that of *Tumboa*, necessitating the new genus *Wielandiella*.

More recently still, the validity of these determinations of leaf and stem unity based mainly on data of association, has been strongly confirmed by the writer's discovery of the recurrence in the Rhät-Liassic of the so-called "Mixteca Alta" of Oaxaca in southern Mexico, of precisely the same association of stems, leaves and *Williamsonia* buds as in the Gondwanas (22, 27). In fact the general features of the Indian specimens are so nearly repeated that Feistmantel's figures would well nigh answer for their Oaxacan counterparts as shown in fig. 4 *C*. Similarity even extends to the stem nodes of vertically compressed scars, a most interesting feature completely establishing relationship with *Wielandiella*, in which such nodes are also present and must be due, since we know both the ovulate and staminate fructification, to scars left by old leafy crowns or to bract whorls enveloping the terminal branch and fruit buds following stages of vegetative growth.*

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* The argument for the Williamsonian nature of these stems rests on their notably close and persistent association with *Williamsonia* foliage in India and Mexico, and the presence of the nodes of closer set horizontally elongated scars as in *Wielandiella*. These nodes were noted by both Oldham and Morris and Feistmantel (8*b*), both of whom give figures clearly showing the characters of these stems. Oldham and Morris in particular seem never to have doubted their cycadaceous [and therefore Williamsonian!] nature, since always found with *Ptilophyllum* and *Dictyozamites* (Dictyopteris) foliage. But Feistmantel, though likewise supposing such stems to be cycadaceous and Williamsonian, has in one instance (ref. 8, plate xiii, figs. 6 and 7) figured slender forms as *Brachyphyllum*, from which there is a real difficulty of separation, it not being wholly certain that the nodes seen to be characteristic of forms like those shown in figure 4 (*n*, *n*) are either present in most Williamsoniæ, or absent in all Brachyphylloideæ.

Indeed because of certain Cordaites-like characters common to both these groups such difficulty of separation may even be expected to increase with the finding of new and more varied forms. Though setting anatomic characters aside it would tax belief to now regard the node-bearing group of stems as mainly Brachyphylloid instead of Williamsonian, in which case leaves and fruits only of the latter type would uniformly accompany stems only of the former in such widely separated localities as the Yorkshire coast, India, and Mexico. Such anomalies of conservation and association may be possible, but appear improbable.

Regarding the nodes of laterally broadened and smaller scars alternant with the long internodes of large vertically elongate and keeled rhombic scars several explanations may be offered. But it appears from Nathorst's study of *Wielandiella* (14) and the Paris Museum stem with leaves attached figured by Wieland (20), that the long internodal spaces were occupied by scale-leaves, the old bases of which thus really form quite three-fourths of the thin armor. The general habitus is near to that of Cycas, which fully explains why such stems have been hitherto regarded as Cycadacean.

In addition the Oaxacan localities yield three other stem types presumably all generically distinct, one being nearly like the *Williamsonia* forms of the Yorkshire coast, one a heavy columnar type, and the third slender branching forms presumably more like *Wielandiella*, accompanied by small *Otozamites* leaves in an association leaving slight doubt that an entire plant is represented.

FIG. 3.

FIG. 3. *Williamsonia* sp. × 1/3 nearly.

A branching, scale-leaf covered stem, or possibly stem and peduncle, on a slab bearing fragmentary cycad and other foliage. (Cliffs of Hawkser and Runswick, 1843 or earlier. James Yates Coll.).

To this general evidence there can be added but two recorded instances of organic union of stem and leaves,—the Gondwana stem with heavy concentric wood rings, noted by Seward as having *Ptilophyllum cutchense* leaves attached, and the famous stem of the Paris Museum Yates collection with *Zamites gigas* fronds attached, as figured by the writer several years ago (20). But save these general facts gleaned from evidence of association as borne out by rare instances of organic connection, and not once clearly extending to structure, all direct knowledge of Williamsonian stems suddenly stops and stubbornly awaits the discovery of silicified forms, or at least the elaboration of some better carbonized parts than have so far been seen. Such in the hands of some shrewd worker using the Nathorst collodion-method, or the Hollick and Jeffrey staining and imbedding method, may perhaps suffice.

Aside from these meager results in the field, which, except for the proof of the occurrence of the small, much branched and quite certainly plastic types like *Wielandiella*, really go no further than to show the presence of just the surface details one would expect to find, one step further can, however, be made. It is now possible to add a most important inference as to the possible nature and variety of Williamsonian stem structure. It will be recalled that the Gondwana stem just mentioned as having *Ptilophyllum cutchense* leaves attached has, as figured by Seward,* a decidedly heavy wood zone marked by a certain appearance or simulation of seasonal wood, and also that the writer in his American Fossil Cycads (Pl. XIV) gave a photographic representation of a Black Hills *Cycade-*

FIG. 4.

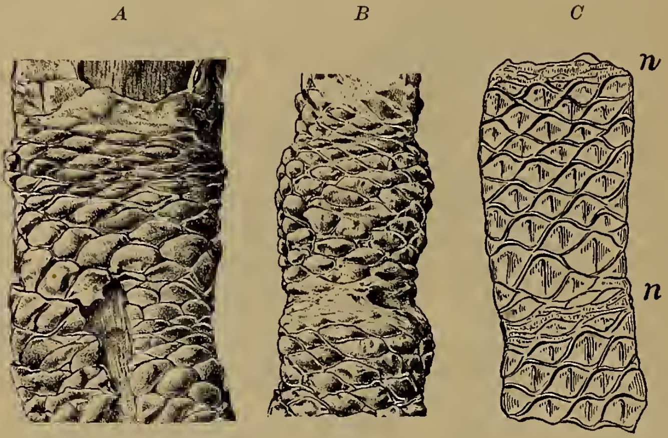

FIG. 4. Williamsonian stem types of the characteristic form always found most closely associated with the *Williamsonia* fruits of the Yorkshire and Scottish coasts, India, and Mexico, and hitherto supposed to indicate more *Cycas*-like forms, with carpellary leaves.

n, *n*, the *Wielandiella*-like nodes of leaf-base scars, the vertically elongate intervening scars supposedly being those of scale-leaves. Cf. fig. 1, which appears to be of different type rather than a huge peduncle or fruit-bearing stem.

(*A*) *Bucklandia Milleriana* Carr. × 3/10. Brora, Sutherlandshire, Scotland. From Carruthers (5).

(*B*) *Bucklandia* (Yatesia) *Joassiana* (Carr.). × 3/10. Brora, Sutherlandshire, Scotland. From Carruthers (5).

(*C*) *Williamsonia* sp. × 3/5. Typical stem from the Rio Consuelo, Oaxaca, Mexico.

[All of these stems have been observed to branch dichotomously like *Wielandiella*. They differ distinctly from *Fittonia*, which is a *Cycadeoidea*.

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*Seward, A. C., Catalogue of Mesozoic Plants in the British Museum, Part I, the Jurassic Flora of the Yorkshire Coast. Page 194, fig. 30. [Oldham and Morris also mention such Indian stems as silicified.]

oidea stem with a similar though far heavier wood zone, and a very narrow cortex. But in both cases the structure, though apparently a sharp departure from the ordinary type of collateral woody wedge cylinder almost universal in the cycads hitherto observed, was left in doubt. Now, however, it has been found from the simultaneous examination of thin sections of the Black Hills trunk figured, and of the "*coal-ball*" Cordaitean trunk *Mesoxylon* (24, 28) that the wood of these forms is strikingly alike. Thus those who have seen *Mesoxylon* will recall that though a solid stem, it also has a decided simulation of growth rings which largely disappears under the microscope and is there found to be due to some areal variation in resin content, or to staining during mineralization; and precisely the same condition is present in the *Cycadeoidea* stem.

That is to say, the wood of the Cycadeoidean [and Williamsonian] stems was at times, even in the more robust types, not only as heavy as that of *Cordaites*, but exhibited the same compact structure; thus permitting the open habitus of plants with small freely branching stems, thin cortex, and finally, excision or non-retention of old leaf bases, as in the conifers. And from this notable approximation of *Cycadeoidea* to *Cordaites*, taken with the known occurrence of small stemmed forms and the even more significant complementary fact that following the seed fern stem types of the Paleozoic there is that long series of Medullosan stems, it may be deemed virtually proven that the Williamsonian stem had, as a rule, a fairly compact wood zone and that it was normally slender and branching, and in the smaller thin-barked armorless forms could very readily be mistaken for coniferous types. At least it may be expected that when the discovery of a more extended series of Williamsonian stems does finally come, solid types of wood, even those with annual rings, will prove abundant, rather than the lax lattice of collateral bundles as developed in the Cycadaceæ, and most *Cycadeoideæ*. It is becoming evident enough that instead of being representative of the Cycad vegetation of the past, these robust stems with thin wood, an immense medulla, and heavy persistent armor, are exceptional to the point of abnormality. They do not represent the characteristic type of cycad vegetation in the past, which is reason enough for their relatively rare occurrence in ancient rocks.

Foliage. (Figure 5.)

Admittedly the greatest bar to progress in the study of Williamsonian forms arises from the extreme difficulty of homologizing the abundant isolated cycadophytean foliage and fruits, as usually associated not only with other fragmentary and distantly related plants, but with conifers, the last of the seed ferns, persistent Cordaitaleans, and yet other little known relatives of these gymnospermous types. As every collector knows, the utmost circumspection barely suffices in drawing inferences from association of isolated organs of fossil plants; when behind a thickness of a few centimeters in a sedimentary plant-bearing rock, or a mere joint or separation plane, may lie the hidden change of a river bed and cutting away of a bank in a different plant community, or perchance a year of time with its change of winds and uprooting storms. Indeed with such factors added to the infrequency of joined stems just noted, absolute proof of leaf, stem and fruit unity is so difficult to establish that the claim for a great extent of the Williamsonian alliance might even excite the derision of one who has not seen the field and studied the recurrence of species, in widely separated localities. Not to forget how but recently all true Paleozoic ferns threatened to vanish before an onslaught of Cycadofilicaleans.

Yet the recent field work, especially on the Yorkshire coast (21, 25)—and in the newly discovered Mixteca Alta localities (22, 27)—has minimized these difficulties more than might have been anticipated, and will still further do so. The argument for a heavily preponderant Williamsonian element in the cycadophytean foliage of the Mesozoic, with a lesser Cycadeoidean series and a nearly negligible cycadacean representation, is chiefly one of analogy and association. The two main points are:

Firstly: The only known Mesozoic cycad stems with leaves attached are cycadeoidean and Williamsonian; and now that it is seen that the nodes of lesser scars in forms like *Wielandiella* as well as *Yatesia*, and *Bucklandia* (fig. 4) do not necessarily indicate a succession of scales and carpellary leaves, scarcely a single Mesozoic cycad stem is left free from the suspicion of belonging to the Williamsoniæ. Just as all the silicified trunks finally proved to belong to the Cycadeoideæ, so now either that family or the Williamsonian tribe threatens to absorb the entire series of stem imprints and casts. In fact Mesozoic stems indisputably belonging to the Cycadaceæ are most difficult to cite, it being on the contrary the generalized and far more varied Williamsonian types along with the earlier Medullosan forms that appear to be ubiquitous.

Secondly: The recurrence and association of strobili and fronds is strikingly the same on the Yorkshire coast, in India and in Mexico. And while in each of these great Williamsonian fruit-yielding regions, the fossil plant series is a most varied one, carpellary leaves and cones of Cycadaceæ are exceedingly rare or absent. Nor are they ever abundant in the other cycadophytean frond-yielding localities of the globe (cf. Map, fig. 1) in most of which it is rather to be expected that the Williamsonian fruits remain to be collected. Whence the evidence from the side of the fruits precisely bears out that from the stems.

And that the inference just reached is valid, is further attested by some of the lesser results of the field work of the past ten years. Thus Nathorst and Halle on the Yorkshire coast, and the writer in the Mixteca Alta, have added perhaps a dozen species to the *Williamsonia* ovulate cone series, and shown the immense fossil wealth of the new quarries located in both regions; though as we see true Cycadaceæ remain quite as scarce as before. In fact it lends no little emphasis to observe that amongst all the *Williamsonia* collections made in Oaxaca, there occurs just one single group of carpellary leaves, poorly conserved, but with the medium sized seeds plainly indicating

Fig. 5.

Fig. 5. Foliage types of Williamsoniæ.

A. *Williamsonia gigas.* × 1/5. Superior surface of frond showing oblique insertion of pinnules with upper and basal angles free. Also portion of frond of the pygmic species *W. pecten* (Phillips).

B. *Pterophyllum* sp. Trias of Guilford, Conn. Frond type with linear insertion of pinnules near midline. Slightly reduced.

a species of *Cycas*, while no cycadacean cones whatever were recovered.

But precisely because there is mixed alignment, we must not go beyond the data of inference accurately enough applying to cycad vegetation in bulk, and arbitrarily declare a given genus with all its species to be Williamsonian. Moreover, it must be equally obvious that in strong contrast to the non-determinative or non-taxonomic results of the past fifty or more years, the generic and family groupings are destined to soon undergo much and even rapid change. Indeed the Greenland form *Cycas Steenstrupi*, so long familiarly cited as a true boreal *Cycas*, has already been found by Nathorst to represent a hitherto unsuspected new genus *Pseudocycas* of uncertain family reference; while Zamia-like leaves have been found closely associated with carpophylls (American Fossil Cycads, reference 104).

If we call to mind, however, the comparative paucity of cycads of any kind in the Tertiary, and the certainty that very few Williamsonias passed beyond the Cretaceous, it does seem a fair inference that these latter not only made up the great bulk of Mesozoic cycadophytean vegetation, but that contrary to all previous views, true Cycadaceæ have never been markedly more abundant in species at any time in the past than they are to-day.

Briefly told there are, omitting aberrant little-known forms like the bipinnate *Ctenis*, and the older *Cordaites*-like forms, about a dozen more or less indefinitely separable genera of representative Cycadophytean leaves with either direct or analogic evidence of Williamsonian affinity. Their general foliar relations, culmination and extinction, may be simply set forth as in the two subjoined tables:

I. *The Williamsonian Alliance.*

Pterophyllum Series: (Pinnule base entire)	*Zamites* Series: (Pinnule base contracted)	
Pterophyllum	*Podozamites*	*Sphenozamites*
Dioonites (?)	*Ptilophyllum*	*Glossozamites*
Nilssonia (?)	*Zamites*	*Sewardia*
Wielandiella	*Otozamites*	*Dictyozamites*

II. *Williamsonian Culmination and Extinction.*

	Trias	Rhaet	Jura			Cretaceous		
			L.	M.	U.	L.	M.	U.
Pterophyllum	←	-----	-----	-----	-----	-----	→	
Zamites	X	-----	-----	-----	-----	-----	-----	→
Podozamites	-----	X	-----	-----	-----	-----	→	
Dioonites	-----	X	-----	-----	-----	-----	→	
Wielandiella	-----	X	-----	-----	-----	→		
Nilssonia	-----	X	-----	-----	-----	-----	(?)	(?)
Glossozamites	-----	-----	-----	-----	-----	→		
Sewardia	-----	-----	-----	-----	X	→		
Otozamites	-----	X	-----	-----	→			
Sphenozamites	-----	-----	-----	→				
Ptilophyllum	-----	-----	X	→				
Dictyozamites	-----	-----	X	→				

As far as fossil preservation goes, *Pterophyllum* and *Zamites* are the representative ancient lines, with *Sphenozamites* as a relative merely characterized by oddity of leaf form. And these old lines pass on to add their quota to the great Williamsonian group of the Rhætic, the period of most rapid evolution. Culmination occurs in the lower Jura; while extinction begins in the middle Jura and progresses steadily to the upper Cretaceous, where the Cycadeoideas also find their final repesentation in both Europe and America.

Were tabulation extended to the one hundred or more species referred to the twelve listed genera, the origin and extinction curve might likely remain quite the same as when the genera alone are considered; though any such fuller elaboration of the data of species must remain in abeyance until considerable comparative work with better collected and prepared specimens in hand has given generic, to say nothing of specific determination the needed accuracy.* That such extended and accurate study of the species must finally reveal further relationships as well as ecologic factors of deep interest, can hardly be doubted.

Naturally enough, aside from the question of precise specific determination, field work has not reached that advanced stage when much emphasis can be placed on the last reputed occurrence of even the better known genera. So that it would be

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* For instance, the genus *Glossozamites* is by no means so isolated as might usually be inferred. Since the superb fronds from the copper mines near Abiquiu, Rio Arriba County, New Mexico, called by Newberry (3) *Otozamites Macombii*, are very near to *Glossozamites zitteli* Schenk, being indeed a transitional form between the latter species and *Otozamites*.

singular indeed, if persistent forms were not reported from time to time, forms bearing the same simple longevous relation to an ancient and cosmopolitan race, as, for instance, the New Zealand "Tuatara" bears to the Triassic Rhyncocephalia. *Accordingly, even after granting full validity of determination, no more than a casual interest can attach to the reported occurrences of Triassic and mid-Mesozoic forms like Nilssonia in the Eocene, least of all in far northern regions long a favored hypothetic home of early dicotyls.*

But, on the other hand, the fossil plant record is, we contend, sufficiently well known to draw the main conclusions as to culmination and extinction in the case of a large and cosmopolitan group like these cycads. Nor is there anything in all the paleontologic record more impressive than the manner in which, following the steady disappearance of seed fern and Medullosan types, the Williamsonian alliance quickly spread over the earth and then "disappeared" before the invasion of the Angiosperms.

With a few further remarks on what is conceived to be the older type of Cycadophytean leaf and its possible variation in the direction of net-veined leaves, we shall be ready to show the range of fructification so far determined in the Williamsonias.

There is excellent reason for saying that the most ancient type of Cycadophytean leaf was of more or less Marattiaceous aspect. At least Cycadofilicalean foliage is of this general appearance; though ultimate relationship to other gymnosperms, especially the Cordaitales, and eventually even to Angiosperms, must also have found clear expression in the foliage of the later Paleozoic. However, a possible transition from these earlier members of the ancestral line in the direction of *Pterophyllum* and *Wielandiella* is suggested by old bladed types like *Oleandra*, *Oleandridium*, and perhaps early Nilssonias—that is, if outward and general form only are had in mind. For while on the one hand the Tæniopterid series approaches very near to *Nilssonia*, the latter may on the other include quite diverse elements.

But while as we see the Cycad leaf type was fully differentiated even in the Permian and earlier, and reached variety within its somewhat stereotyped limits in the Trias, the relation of leaf genera to chronology has not been worked out with sufficient exactness to serve in Mesozoic stratigraphy, save in the most general manner. In fact, we have confronting us a great plexus of leaves exhibiting every gradation from laminar to pinnate and bipinnate forms, with venation varying from parallel through the commoner dichotomous to long and finally anastomosely netted forms, a series which so far baffles resolution with respect to time. Though surely a transition from the old Cycadofilicalean alliance with tri- and even quadripinnate fronds to the Cycadaceæ and also to net-veined leaves, must be somewhere involved in the origins of the types already known. It is plainly the more stereotyped cycad and coniferous genera that now survive; in both groups the sameness of foliage is but the expression of stability, and wholly deceptive when we try to picture the certainly more varied foliage in earlier and plastic stages or lesser plastic groups of these gymnosperm lines. But even so, in a species of *Zamia* found growing near the Pacific coast in Southern Oaxaca, the writer has noted a strongly dichotomous venation give rise to a sparse false netting. And the gap between such a form and the long mesh net-veined cycad *Dictyozamites* is not so great, nor yet that between the latter form and a true type of mesh netting, such as we see in presumably archaic dicotyledonous forms like *Cissites* and *Vitiphyllum*, and in *Liriodendropsis;* or again in *Gnetum gnemon*. Nor is it unreasonable to infer a transition from a frond with few pinnules, as in the *Oaxacan* Zamia just cited, to a single blade, whether in the case of parallel or net-veined types. While it may prove fully significant that not once amongst the great Permian series of *Ginkgo* leaf types does a transition from dichotomous to netted venation occur, but exactly amongst the cycads as characterized by yet other definitely proangiospermous features.

Ovulate Cones and Buds. (Figures 6–15.)

The discovery of the Williamsonian tribe began, as already recalled, early in the last century with the collection of the sightly buds, ovulate fruits, disks and leaves of *Williamsonia gigas*, found intermingled with an abundance of fossil plants along the eroded cliffs of the Yorkshire coast. Here Williamson and his father, as well as other local collectors, diligently sought out the handsome series of Cycadophytean fruits, which mostly found their way into the Williamson collections, those of the Jermyn Street Museum, of Cambridge, and the James Yates collection already specially alluded to in the introductory paragraphs.* But it appears that the partly indiscrimi-

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* Williamson says that his father first drew attention in 1832 to some fine specimens he had just discovered at Hawkser, both visiting the locality in 1833 (4). But in this connection it should be remarked that the first Cycadeoidean or Williamsonian fruit ever figured appears to have been Buckland's *Podocarya* of 1836 (1a) from the "lower region of the inferior oölite" on the E. of Charmouth, Dorset, which is on the coast near Lyme Regis.

This fossil may also have been collected earlier than 1833, and the failure of the locality to yield other recorded specimens is only less to be lamented than the loss of the original; for a close study of the figures of Buckland as

FIG. 6.

FIG. 6. *Williamsonia gigas.* × 1/2 nearly. Typical fruit bud attached to its bract-enveloped peduncle. Partly retouched photograph, furnished through kindness of the officials of the Paris Museum. (One of the specimens of the James Yates collection of Williamsonias from the Hawkser and Runswick Cliffs of Yorkshire, secured for the Paris Museum by Brongniart in 1843.)

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redrawn by Saporta in the form reproduced in excellent style in my American Fossil Cycads indicates beautiful conservation. As any one who has studied such fossils can easily see, all the figures have excellence stamped upon them. In particular the form of the seed and position and size of the embryo are clearly disclosed. The seed, about the size of a small grain of rice, is more angular than in the Cycadeoideas, showing a distinctly pentagonal to hexagonal form with a rather clearly marked shoulder surmounted by five to six ribs of the blow-off layer, so that with the aid of my figure 15c a most perfect model of the outer form can be constructed. While the "two lunate bodies" of the upper middle transverse section are, of course, none other than the two cotyledons of a notably smaller embryo than is found in any *Cycadeoidea*. Evidently the seed had a well developed albumen surnate search for "*Pracht-Stücke*" had mostly ended by 1835 or 40 without the careful establishment of quarries, and without attention having been directed to the abundant and important smaller fruits and disks of other species of *Williamsonia*, which the visits of Nathorst first in 1879, and then in 1907, followed by that of his associate Halle, have brought to light. So that for quite thirty years previous to the study of *Cycadeoidea*, which again so pointedly directed attention to the Yorkshire coast fossils, the original and more or less scattered collections of Williamsonian fruits failed of addition, and came to be regarded as mere assemblages of rare fossils of uncertain affinity and even minor interest. The more especially so after Saporta's decision that the ovulate cones were Pandanus-like, just as Buckland originally surmised in the Bridgewater Trea-

FIG. 7.

FIG. 7. *Williamsonia gigas.* × 1/2. Bract-enclosed strobilar casts further illustrating the sharp outlines characteristic of these fossils and their abundance. (Yale—James Yates Collection.)

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rounding the embryo, an interesting point which leads me to suspect it to be some Williamsonian form. Just once in his plate legends Buckland refers to the seeds as calcified with the lunate bodies dark; but from the remarkable conservation of the isolated specimen, it is likely to have been silicified, such fossils often having a whitish exterior, that without further test could deceive even a practiced eye.

tises. Indeed, the later discovery of similar cones in close association with the *Ptilophyllum* leaves of the Gondwanas, and Nathorst's observation of related fruits with Anomozamites leaves would almost seem to have confirmed any ideas of isolation and rarity of such fruits, or even to have diverted attention from the urgent need of renewed study in nearer fields. And it still remains difficult to understand why most of the

FIG. 8.

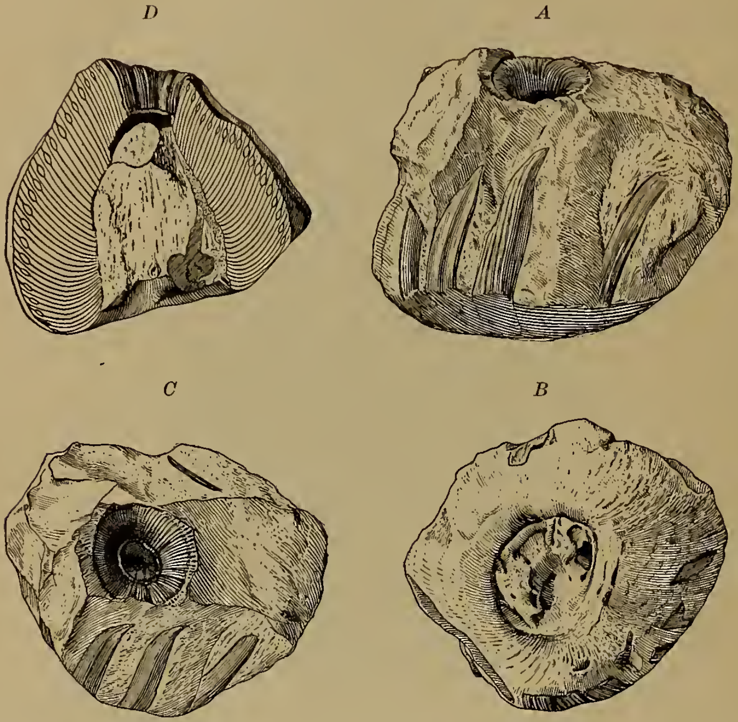

FIG. 8. *Williamsonia gigas.* ×1/2. Ovulate strobilus of the Yale-James Yates collection from the cliffs of Hawkser and Runswick (1843 or before).

A. Lateral views showing, together with portions of ensheathing husk of bracts, apical cavity due to failure of conservation resulting in "pyriform" surfaces.

B. Basal view showing large insertion scar, and somewhat worn surface of strobilus, with bracts split off or worn away.

C. Apical view, nearly the same as at A.

D. Partial restoration of cone effected by sawing in two, and drawing in natural form and position the seed stem and seed zone which failed of conservation, though the axis is fairly conserved. (Hence restored view = median long. section.)—*The strobilus probably ended as a loosely compacted and flowing more or less silky mass of sterile filaments, just as in Cycadeoidea dacotensis.*

localities of Mesozoic fossil cycads indicated on the map, fig. 1, have so far failed to yield other than scattered fruits. In truth it has required not only the renewed field work on the Yorkshire coast, but the *richesse* of Williamsonian fruits in the newly discovered Mexican horizons to fully and finally dispel this mistaken idea of the rarity of casts, imprints and fruits, and especially of difficulty in learning the import of the main facts of association. These fossils doubtless occur in most of the localities yielding fronds; their fragile nature, with occurrence in clays and shales barren of economic products save occasional scant seams of coal, are amongst the obvious reasons for infrequency of observation or collection. Though it is of interest to observe in this connection that aside from silicified fruits, casts of singular beauty are confined neither to the Williamsoniæ nor to the Mesozoic. When I was in Paris a few years since, Professor Zeiller showed me the original type of his *Lepidostrobus Laurenti* (18), a cast broken out of certain Dinantien phosphatic nodules from the flanks of the Pyrenees. Uncrushed, and without any adherent matrix, the original form and larger features, including the sporangial outlines, all appear so much as in life that both illustration and description fail to visualize the singular beauty of this fossil.

Fig. 9.

Fig. 9. *Williamsonia gigas.* × 1/3. Slab containing foliage and two fructifications weathered out in nearly full relief. That to the right is an ovulate fruit of the largest size. (Yale—James Yates Collection.)

The lack of earlier attention to the fuller possibilities of the Yorkshire coast is now, however, not alone compensated for by the field work of Nathorst, which has added so much to our knowledge of *Williamsonia*, but by the recent organization of a society for the consecutive study of the region and especially of its fossil plant wealth (26). All the more interesting, then,

FIG. 10.

FIG. 10. *Williamsonia gigas.* × 1/2. Two views of a partly conserved bract-enclosed ovulate strobilus partly broken out of matrix traversed by many fronds of "*Zamitas gigas.*" Now adjudged to be fruit and foliage of one and the same plant. (Yale—James Yates Collection.)

becomes the series of fructifications of the Yorkshire coast, shown in figs. 2–12, from both the historical viewpoint and the study of modes of occurrence and conservation which may direct attention to other regions and localities equally rich in fossil remains. That a freer illustration of the Yorkshire coast fossils would soon have brought out the peculiarities of cast conservation, and would long since have disclosed the chief structural features of the ovulate cones, can scarcely be doubted.

Ovulate Cone and Cast Characters.—Nothing is more baffling in the study of these cones than the capricious manner in which conservation begins and ends, often in the midst of a tissue zone. Thus in the English Williamsonias, save the lost type of Buckland's "*Pandanus*," figured in the Bridgewater Treatises, the seeds uniformly fail of preservation. Yet in an isolated cone of Cycadeoidean form from the Argonne the large seeds are distinct and even the embryos are at times outlined. But while the seeds so often fail to outline themselves, the conserved sterile interseminal scales are very apt to clearly demark the fruit base and the summit, a caprice of cast and imprint formation also much in evidence in the Oaxacan region.

The ovulate fruits of the Yorkshire coast as collected in the early days when the naturally weathered-out specimens were to be found in some abundance, are the large forms five to eight centimeters in diameter, and often but not always flattened. Such are shown in the painstaking drawings of Mr. Weber, reproduced in the figs. 7–13, all the result of joint study of details by both writer and artist.

The striking association of fronds with an abundance of strobili in some of the weathered specimens seemingly broken up at random, appears especially in figs. 9–11. But further considering fruit outlines, a most instructive strobilus is fully illustrated in complete projection by fig. 8 showing the lateral and end views with a median longitudinal section partly restored. As clearly appears from the figure, the bracts enclosed a strikingly handsome fruit; though as partly due to weathering and partly to the lack of uniformity in preservation already spoken of, no surface details actually appear, and one is left to wonder at the weathering-out so nearly on the original outer surface. But contrariwise, certain interior features are unexpectedly clear; the form of the conical-shaped receptacular axis is sharply outlined, some of the soft tissue even retaining structure, while at the apex conservation again begins in the outcurving mass of interseminal scales, and as sharply ends to form a pyriform cavity more or less filled with the white clayey material "scarbroite." In fact we can easily see that the entire space occupied by the cavity was in life filled out by the continuation of the zone of slender sterile organs as a closely packed mass, silky or wavy and slightly spreading at the summit. And this is an interesting feature, in its turn aiding us to better understand the outer apical features of some of the silicified strobili. It shows, especially, how in the bisporangiate strobilus of *Cycadeoidea-dacotensis* the prolongation of the apical region of the young ovulate cone must have filled out the inverted conical space formed by the incurving of the microsporophylls beneath the enveloping bracts, so as to form a solid bud. [Etching experiments with hydrofluoric acid or alkalies producing erosion effects in *Williamsonia* fruits yet remain to be tried.]

Fig. 11.

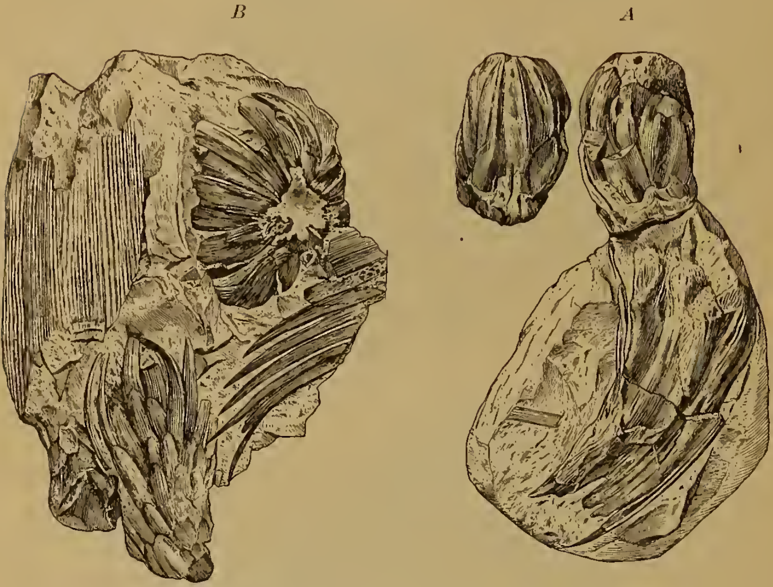

Fig. 11. *Williamsonia* fructifications of the James Yates collections from Cliffs of Hawkser and Runswick (1843 or before). × 1/3.

(*A*) *Williamsonia* (species). Probably not *W. gigas*, the bracts being very large. This specimen is in the collections of the Jardin des Plantes, Paris. It is figured by Saporta in Plantes Jurassiques. The present figure results from developing the specimen slightly. Two views of the terminal bud are given. Might pertain to the stem shown in fig. 3.

(*B*) *Williamsonia gigas* fruits and foliage accompanied by large and broad leaf of *Yuccites* (= Cordaites ?). Compare the young fruit below with (A) illustrating distinct variation in bract husk. (Yale—James Yates Collection.)

Throughout the entire fruit, therefore, the manner of preservation is found most instructive in its bearing on both fossilization and features, it being altogether clear how preservation of the sterile apical region with either dehiscence of the lateral mass of seed stems and interseminal scales, or its nonpreservation, would at once result in the formation of the "pyriform axes" figured by Williamson and so puzzling in his day. In addition to the suggested early dehiscence of the seed-stem zone, its preservation as a weak zone easily split off during erosion may also account for some of the axes figured by Saporta.

However this may be, in the present case the finely outlined form suggested that the strobilus was a complete one at the time of fossilization, and it was hoped that a longitudinal section might reveal inner features. But on sawing through the fruit longitudinally, and smoothing the surface of the saw cuts, all directly visible traces of the internal structure outside the conical receptacle were found curiously absent.

FIG. 12.

FIG. 12. *Williamsonia gigas.* ×1/2. Bract whorl (left), and ovulate strobilus to the right, showing interseminal scales near base with the strobilar axis or receptacle on which is seated the seed-stem series. The original is a most instructive specimen. (Yale—James Yates Collection.)

So too in the case of the huge bud shown in fig. 9 a saw cut only disclosed some lesser apical detail. In both instances it seems that aside from the condition of the fruit at the time of fossilization, the indication of tissue zones has been partly determined by the course of erosion and weathering from the matrix. Curiously enough, the parenchyma ground tissue of the receptacle is well enough conserved to plainly show the gum canals. Whence the seed zone may be restored with all confidence as has been done in outline in fig. 8*D;* and it would be likewise exact to represent the apical region as a long and finally spreading top of sterile scales. In fact it is marvelous to find first one and then another feature conserved until, not forgetting the supposed Pandanus of Buckland, it is clear that had all the evidence been rigidly put together, a fair reconstruction of the entire fruit and form of fructification could have been made long before the later discovery of the silicified specimens.

That even the embryos can be outlined in the casts without actual silicification or calcification is proven by the presence of dicotyledonous embryos in the Cycadeoidean strobilar cast *Amphibennettites Renaulti* (Fliche, 1896).

Newly Discovered Strobili.—For nearly a century the Williamsonian casts clearly showing seeds have been limited to the oft-mentioned specimen thought by Buckland to be an ancient *Pandanus*, and so clearly figured in the Bridgewater Treatise that despite the fact that the original has seemingly disappeared from view, it is clear that little improvement in illustration could be made except with respect to contained embryos. But as related in the Botanical Gazette (22), the Buckland fruit has now been complemented by a *mould* of a closely related species found by the writer in Oaxaca, from which clay casts were readily made showing the fruit in nearly full lateral relief. The presence of a low conical-shaped apex formed by sterile organs, quite in agreement with other *Williamsonias*, appears to be the only difference from the Buckland strobilus, which so far as one may judge from the figure had the apical region all fertile. Whence it appears that both in the *Williamsonia* and *Cycadeoidea* series both kinds of apex are present, the prolonged form obviously being the more primitive.

Fig. 13.

Fig. 13. *Williamsonia gigas.* × 1/2. Base of an ovulate strobilus with large peduncle scar. Conservation ends at the beginning of the ovulate region except in one small area where three fully outlined seeds of about the same size and form as in the larger species of *Cycadeoidea* may be seen. This is one of the very few instances in which such seeds appear and fully confirm the nature of these fruits. (Yale – James Yates Collection.)

Yet other species or genera occur in abundance in the Oaxacan country, and through the courtesy of Señor Aguiléra, the director of the Mexican Geological Survey, I am enabled to give figures 14, 15 *A* and *B*, and 17 *C*, showing characteristic features, in advance of the publication of my memoir on the Fossil Plants of the Mixteca Alta now in course of completion.

FIG. 14.

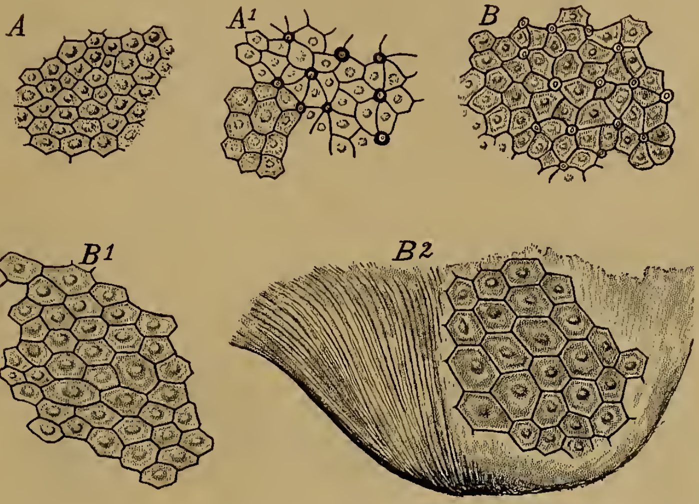

FIG. 14. Surface details of various ovulate strobili of *Williamsonia* discovered by the writer on the Rio Consuelo of Oaxaca, Mexico. × 7/4 nearly. *A*, sterile, A^1, *B*, partly sterile and partly fertile areas. B^1, B^2, an apparently different species from the preceding with large sterile scales occupying all the lower half of the fruit axis. In B^2 the outer nail-head like ends of the scales have in breaking the matrix so split away as to reveal the stem mass beneath. The drawing shows all of the fruit conserved.

As will be noted from the figures, the surface characters are often very clear; though it is only occasionally that a fairly complete crushed cone was found.

Easily the most curious fructification is that shown in figure 15*A* with exactly the outlines of a short leafy seed resembling *Gnetum gnemon*. At first these forms as found closely associated with a slender poorly conserved branching stem, and nowhere else, were thought to be bract-surrounded ovulate strobili of the usual Williamsonian type, though small.

But they have the apical depression seen in *Gnetum* seeds, and the leafy appendages cannot be made out to have the overlap of bracts. In view of certain resemblances of the *Cycadeoidea* seeds to those of *Gnetum*, the possibility of further relationship here indicated is highly suggestive.

It should be emphasized that the fossil fruit-yielding region of Oaxaca is large, extending into the State of Puebla, and probably Guerrero, and the opportunities for opening quarries almost without limit. This is easily the most promising region for the collection of Williamsonian types in North America, and as already stated, ranks with the Yorkshire coast and the Gondwanas of India, which it more nearly resembles, as the third great region of the globe yielding an extensive Williamsonian fruit series. In a first season of collecting following discovery by the writer, he secured along with a beautiful *Williamsonia* series, *Podozamites*, *Ptilophyllum*, *Otozamites* (or *Pterozamites*), *Cycadolepis*, *Wielandiella* (?) *Araucarioxylon* (silicified), *Nœggerathiopsis*, *Yuccites*, *Trigonocarpon*, *Sphenopteris*, *Pecopteris*, *Cladophlebis* (?), *Taeniopteris*, *Glossopteris*, or *Sagenopterids*, *Coniopteris* (?) and *Equisetum*. Whence it is safe to say the Mixteca Alta region must fully vie with, if not finally exceed both the Yorkshire coast and the Gondwanas in the abundance of its Rhät-Liassic plant life. The flora is most like that of the Rajmahal Hills, and its occurrence on the exact opposite side of the globe in precisely the same latitude is, therefore, geographically impressive.

Fig. 15.

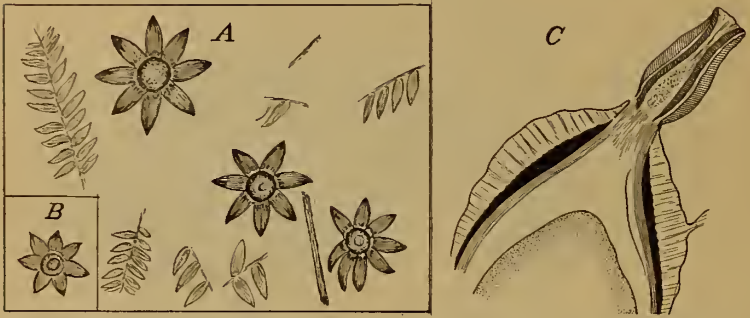

Fig. 15. Gnetales-like seeds of the *Williamsonia*-bearing horizon of Oaxaca (*A*) compared with the seed of *Gnetum gnemon* (*B*), and Cycadeoidea. *A* and *B* × 1/2. *C* × 30 ±.

(*A*) Portion of large slab from the Rio Mixtepec, Oaxaca, bearing three leafy seeds with numerous small cycadaceous fronds and stem fragments all thought to belong to one and the same plant.

(*B*) *Gnetum gnemon* seed in superior view showing lateral leafy appendages or capsule like the preceding.

(*C*) *Cycadeoidea turrita* seed in longitudinal section showing upper (radical) end of embryo, and structure of the apical region nearly paralleling that of the similarly ribbed seed of *Gnetum gnemon*. The section traverses two opposite wings of the outer or "blow-off" layer.

Almost at the same time this far southern Williamsonian flora was discovered, Nathorst and Halle had been at work on the Yorkshire coast, and there too, fully demonstrated that all ideas of a paucity of Williamsonian ovulate fruits in either number or variety of species have been due to almost unaccountable failure of botanists and paleobotanists to engage in adequate field work. Nathorst had indeed found at Cloughton Wyke the first type of his *Williamsonia Leckenbyi* thirty years ago (9); but it is only this later work that has demonstrated the presence of variety of species.

In some cases it appears that the strobili had an outer form much like a *Nelumbium* fruit (25, p. 25), but the writer, while finding in the Mixteca Alta forms he at first explained in the same way, wonders if splitting away of an outer surface as the only part conserved, after the manner shown in figure $14B^2$, may not throw some light on the Nathorst fruit.

In summation then, it may be said that at the present time it is likely that to the score or so of species of ovulate cones of the Cycadeoideæ may be added about an equal number of species of Williamsonian strobili, mainly from the Yorkshire coast, India and Oaxaca. But while much variation in size has been noted, hypothetic or reduced few-seeded forms, or types of lax structure, have not yet been determined; so that the range of ovulate structure approaches but does not so far equal that seen in the Coniferales. The reverse is true when staminate structures are also brought into such a merely general comparison.

Staminate Fructification. (Figures 16–18.)

It has been justly doubted by Professor Nathorst, to whom we owe the demonstration of the type-series of staminate *Williamsonia* fruits from the Yorkshire coast, if the nature of these pollen-bearing structures could ever have been satisfactorily deciphered before the elaboration of the silicified bisporangiate strobili of *Cycadeoidea*. For not only are the essential structures of the imprints of staminate organs difficult of observation, but the exigencies of preservation are greater by far than in the case of the ovulate cones. Indeed, because of the compact and durable form of the latter, with a requirement of several years for reaching maturity and shedding of the seeds, it might well be expected that many examples must be found to one of the fragile staminate fruits of quicker growth, probably as a rule dehiscent only after the wilting down of their little resistant tissues. Yet, evidence of staminate fructification has been accumulated with fair success, and now that the outlines of the disks in a number of species and several genera are known, and the necessity for careful quarry work followed by approved laboratory methods understood, we may not only hope to find better conserved disks and whorls of the types already sparingly observed, but those of hypothetical reduced forms. In fact we even get the clearer suggestion of family differentiation in the more diffuse organs of the staminate series, since lax-spiral ancestral types of ovulate fructification or later reduced types have not yet been clearly connected with cycadophytans—the ovulate strobili so far determined being strictly confined within the same narrow structural limits as in the parallel *Cycadeoidea* ovulate series.

Fig. 16.

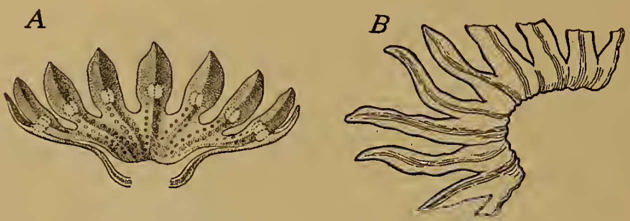

Fig. 16. Early illustrations of Williamsonian staminate disks. (About half natural size.)

A. So-called "carpellary disk" as restored by Williamson;—now referred to *Williamsonia bituberculata*, cf. Nathorst's restoration, fig. 17. × 2/5.

B. *Williamsonia gigas* from the Rajmahal Hills as figured by Feistmantel.

Referring at once to the illustrations of typical staminate fruits, in lieu of further description, the known types of such fructification in *Williamsonia* and the nearest related forms are given in the subjoined table.

List of Staminate Whorl and Disk Species of Williamsonia and Related Forms.

(Provisionally grouped.)

(*A*) *Cycadeoidea.*—Various species of bipinnate frond disks.

(*B*) *Cycadocephalus Sewardi* Nathorst (25).—The type of a family anciently related to *Williamsonia.* Has tetrahedral fern-like microspores borne on large deeply cleft disk of 15± sporophylls.

(*C*) *Williamsonia spectabilis* Nathorst.—Disk 15± bipinnately parted fronds.

Williamsonia setosa Nathorst.—Disk of 18± parted fronds.

" *whitbyensis* Nathorst.—Disk pinnately 15—cleft.

(*C*) *Williamsonia pecten* Nathorst.—(Small disk form.)
" *tuberculata* and *bituberculata* Nathorst.—Disk staminately 15—cleft.
Williamsonia mexicanus (Wieland MS.).—Disk pinnately +10—lobed.
Weltrichia (?) *mirabilis* Fr. Br.—Disk 15—lobed.
(*D*) *Williamsonia* (?) *Lignieri*, Nathorst.—Small, whorled scale-like stamens.
Wielandiella angustifolia Nathorst.—Disk or close-set whorls of small stamens.
Wielandiella punctata, Nathorst.—Disk or close whorls of minute nearly sessile stamens.
Williamsonia rajmahalensis (Wieland sp).—Short whorl of (6+) small elongate staminate scales, or staminophylls.

FIG. 17.

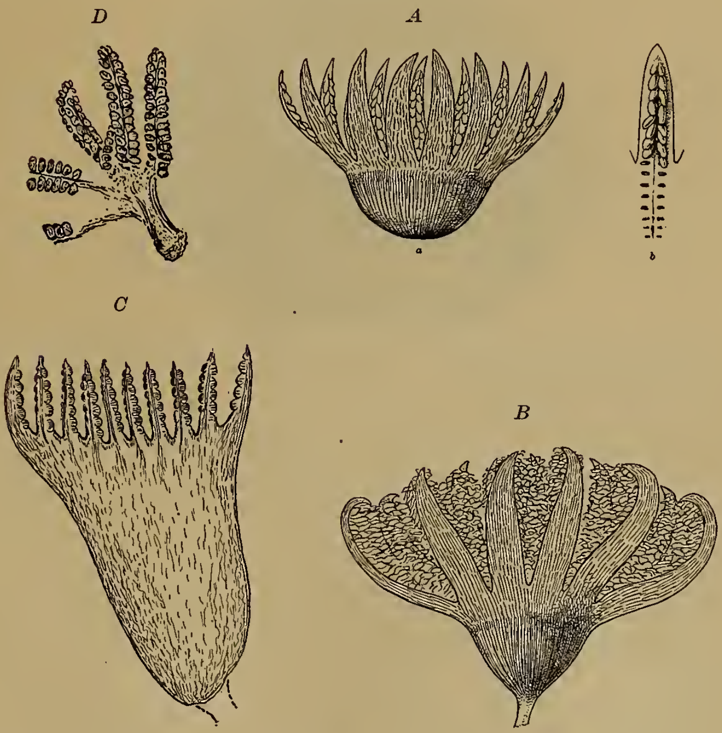

FIG. 17. Four types of Williamsonian pollen-bearing organs. *A* and *B* are shown about half, and *C* and *D* nearly, the natural size.

(*A*) *Williamsonia tuberculata* (Yorkshire coast). Restoration by Nathorst.

(*B*) *Williamsonia spectabilis* Nathorst. Pinnate and possibly unisexual flower from Yorkshire coast as restored by Nathorst.

(*C*) *Williamsonia mexicana* (Wieland MS.). Restoration of Mixteca Alta (Mina Consuelo) disk in segment form.

(*D*) *Williamsonia* (?) *rajmahalensis* (Wieland sp.). After Feistmantel's figure of specimen from Bindrabun, Rajmahal Hills, India. Unisexual whorl. Cf. reference 8, p. 131, and pl. xxxix, fig. 5, 5*a*.

To the above list could of course be added by searching carefully through paleobotanic literature, various more or less suggestive *problematica*. But now confining ourselves to the better known forms, it is at once seen that the specific range of staminate forms is fully as great as that of the ovulate cones in the Yorkshire coast locality, the only one at all carefully studied; while the generic range is actually greater, since the groups A, B, C and D may finally prove to represent families.

A first all-important fact indicating a great specific, generic, and finally family variation, is that in these dozen fruits we pass from flowers of large size with large frondlike microsporophylls to small forms made up of scale and stamen-like fertile organs in which disks are not known to be always present, there even being a suggestion of *emplacement* in short whorls.

Fig. 18.

Fig. 18. *Williamsonia* sp. × 2. Study of features of the cast (positive) of the original in Paris Museum Yates collection, No. 2406. The orientation is uncertain. Note paragraphs in brevier on opposite page.

And secondly, variety of sex type is definitely proven. Conformably to *Cycadeoidea*, the showy staminate collars of *Williamsonia*, now called *Williamsonia bituberculata* (25), together with other Yorkshire coast and Indian forms (cf. fig. 18) evidently split off from the base of large ovulate cones like those of *W. gigas*. So that both from analogy and actual occurrence of fossil forms the presence of bisporangiate *Williamsonia* flowers is reasonably certain. Though the unity of the cones and staminate collars in particular species can not be easily proven, as the forms are not only seen to be numerous, but it is held probable that Nathorst's interpretation of *Williamsonia spectabilis* and *W. pecten* as unisexual flowers of either a monœcious or diœcious form is correct. Also the Oaxacan disk (fig. 17*C*) may quite possibly be unisexual, though the absence of a peduncle leaves the point in doubt. Considerable variance in the explanation of such fossils can arise, whence to avoid confusion the use of the terms *cast*, *mould*, *surface*, and *imprint* requires to be exact.

Thus the attempt to interpret a very beautiful and undoubtedly bisporangiate specimen, No. 2406 of the Paris Museum Yates Collection, has led to some difference of opinion between Professor Lignier and myself. In the first place, following my paper of 1901 (12), Lignier (15) described this specimen as the rugose surface of an ovulate cone with indication of axial prolongation as a more or less pyriform sterile leafy appendage. To this I took exception in my American Fossil Cycads, p. 152, interpreting Lignier's figure as that of the upper portion of a bisporangiate bud showing the short sterile apex of an ovulate cone enveloped by the microsporophylls, the curved rachides of which it was supposed had broken away so as to expose the proximal synangia *en masse* just outside the decurved rachidal tips. But later, when visiting the Paris Museum, I found that the figure on which I had based my opinion is not, as inferred from the legend, that of the specimen itself, but of a mould obtained from it.

Since then Lignier has, in a separate note (19), insisted on the virtual correctness of his original view that the rugose marking is only ovulate, but of course agreeing with me that in any event the series of converging segments indicates a staminate disk of 20 or 21 microsporophylls (not bracts or parts of a leafy apical prolongation). With a cast of the specimen before me now, as kindly given me by Professor Lignier on the occasion of a visit at his house, I still fail to agree fully with his explanation of this fossil. Nor yet can I be sure of its exact interpretation, whether indicating a portion of the base or the summit of a bisporangiate bud,—and in either alternative, whether or not we see the ovulate surface, or either the adaxial, or finally abaxial surface of the microsporophylls, which latter might be rugose as in *Cycadeoidea dacotensis.*

To fully discuss the various possibilities of casts and moulds of surfaces involved would require too much space; but in the appended fig. 18 of the cast (exactly equivalent to the specimen itself) the disk of 20 or 21 members plainly appears, as does also the central axis. The fruit is in my judgment still a "litigious" one, since it is most difficult to read seed characters into the sculpturing on the segments, or to see just how the surfaces of the microsporophylls were appressed to the ovulate center. Equally the character of the latter is in doubt, as but a single large seed might have been present; while Lignier's idea of pyriform extension simply lacks direct evidence. If the rugosity is staminate, a different genus or even family from *Williamsonia* might be represented. This I believe the more likely.

In closing this brief résumé of floral characters in Williamsonian types, the great extent of sex diversity found fixes our attention less by far as a phenomenon *per se* than because of the immense variation it not only theoretically permits, but must actually have involved through very long periods of time. The uniform diœcism of existing cycads might be conceived of as long persistent or not; but not so the bisporangiate strobilus, which must have been a potentially bisexual axis far back toward the time when the ancestral forms attained heterospory. And this floral form, as was insisted upon when the first descriptions were given, must in itself be exactly the one capable of giving rise to the most varied phases of monœcism and diœcism. As showing the value of reasonable attempts at interpretation of the significance and possible extent of these and related floral forms, it is worth while to call attention to the view given in American Fossil Cycads, p. 244, that,—

* * * "We are certainly permitted to conjecture the former existence of members of a Cycadeoidean alliance in which the microsporophylls did not assume a cyclic arrangement, and others with perchance freely branching, less compacted trunk types, in which there was an early reduction of these spirally arranged microsporophylls to a filamentous staminate form, with, as may often happen, a certain coördination between decrease in bulk and increase in number."

And certainly with the subsequent determination of the reduced *Wielandiella* sporophylls and other discoveries of reduced flowers, both on the Yorkshire coast and in the newly found Mexican localities, the correctness of the above view is proven. Only in the one detail of spiral or short-whorl arrangement of the stamens is evidence slow to appear; but such insertion appears to characterize the flower shown in fig. 17 *D*, and in any event smaller flowers with this feature must have been numerous. Indeed, the general accuracy of the hypothesis of a great and varied *Williamsonia* group extending its relationships far beyond the observed limits of the associated foliage and fruits of the Mesozoic, as gradually developed from the wider study of these fossil forms during the past dozen years, is abundantly testified to and proven by a long list of field and laboratory results.

* * * * * * *

In the foregoing pages we have brought into view the main facts known of the Williamsoniæ side by side with those hypothetical views and questions which lend a more vivid interest to the investigation of an extinct group. Naturally the individual worker finds his chief labor in enlarging his store of accurately known material, and so it arises that as the study of first one group and then another is normally extended to material limits, undue significance may inadvertently be given lesser facts of structure or occurrence. But although vigorous field work in the case of the cycads, connoting with accuracy the association of the Mesozoic cycad stems, leaves, and fruits of the localities of the globe, has barely begun, the value assigned their study can scarcely be overestimated.

And just as we have seen that *Cycadeoidea* was the key to *Williamsonia*, so the study of the showy flowers of the latter genus has schooled us in the collection and laboratory study of less conspicuous casts and imprints often exhibiting most unexpected structural detail, and thus finally made us aware of an immense new category of evidence of Mesozoic gymnosperm development unquestionably connected with angiosperm origins. In fact if there is a post-Paleozoic family of fossil plants which may be fairly said to now hold wider interest to students than any other, it must be the Williamsoniæ. At least no other has thus far proven of more elemental interest when considering the possible mode of origin of the higher types of modern plants. While far beyond the great structural interest admittedly belonging to the group as already known, must lie an alluring field of ecologic study. Indeed, with every variety of stem type from Cycadaceous and palm-like to small freely branched shrubs with the secondary wood zones like Cordaitaleans and foliage suggestive of Marattiaceous ancestry on the one hand but undoubtedly leading into net-veined plants on the other, with both stamens and seeds of strictly Paleozoic aspect but Angiospermous emplacement, with flowers under way of varied reduction and microsporophylls small and stamen-like even in the Trias, with the ever present suggestion of relationship to all the great gymnosperm lines as the most generalized type of all, and a probable extension into a vast group of tens of thousands of species occupying the globe at the close of the era of cosmopolitan genera, the Williamsonian tribe truly presents a subject of study broad as the field of Paleobotany.

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(16) 1906.—Wieland, G. R. American Fossil Cycads. Carnegie Institution of Washington, Publication No. 34, viii + 296 pages and 51 pls.

(17) 1907.—Arber, E. A. Newell, and Parkin, J. On the Origin of Angiosperms. Jour. Linn. Soc., vol. xxxviii, pp. 29–80.

(18) 1907.—Zeiller, R. Sur quelques *Lepidostrobus* de la région pyrénéénne. Compte rendu, vol. cxlv, pp. 1122–1126.

(19) 1907.—Lignier, O. Sur un moule litigieux de *Williamsonia gigas* (L. et H.) Carr. Bull. Soc. Linn. de Normandie (6^e Série, vol, i (Caen), pp. 11.

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(21) 1909.—Nathorst, A. G. Paläobotanische Mitteilungen. (8) Ueber *Williamsonia*, *Wielandia*, *Cycadocephalus*, und *Weltrichia*. Kungl. Svensk. Vet.-Ak. Handl., vol. xlv, No. 4, pp. 38 with 8 pls.

(22) 1909.—Wieland, G. R. The Williamsonias of the Mixteca Alta. Bot. Gaz., vol. 48, No. 6 (December), pp. 427–441.

(23) 1909.—Salfeld, Hans. Beiträge zur Kenntniss Jurassischer Pflanzenreste aus Norddeutschland. Palæontographica, vol. lvi, pp. 33 u. 6 Taf.

(24) 1910.—Scott, D. H., and Maslen, Arthur J. On *Mesoxylon*, a new genus of Cordaitales. Ann. of Bot., vol. xxiv, p. 236.

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(27) 1911.—Wieland, G. R. Résumé of Mem. on Fossil Flora of Mixteca Alta. Presented at Summer Session of Sociedad Geologica Mexicana.

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(See Recent Contributions on Cycadophytans, on a later page.)

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

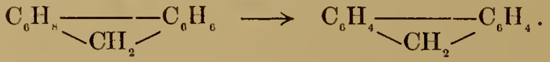
1. *Arsenides of Iron and Manganese.*—Hilpert and Dieckmann have devised a convenient method for the preparation of certain metallic arsenides in the dry way under pressure. They heated finely divided metallic iron with arsenic in sealed tubes of Jena glass to 700° C. for 6 to 8 hours and found that a definite compound, $FeAs_2$, corresponding to the mineral löllingite, was formed. By heating this product at ordinary pressure in a stream hydrogen to the same temperature as before, a part of the arsenic was driven off, and a definite compound, FeAs, was produced. By the same method, using pressure, an arsenide of manganese, MnAs, was prepared, which lost arsenic at ordinary pressure in hydrogen, even at 500°, but gave no distinct halting-point in loss of arsenic, and hence no indication of the existence of a compound, such as Mn_2As, which has been supposed to be formed. The manganese arsenide, MnS, as had been previously observed, has strong magnetic properties, while, remarkably enough, neither of the iron arsenides shows this property.—*Berichte*, xliv, 2378. H. L. W.

2. *The Enrichment of Radio-active Substances by Adsorption.*—Ebler and Fellner propose the use of colloid substances as adsorbents of radio-active bodies in the place of the usually employed processes of fractional crystallization and fractional precipitation. The colloid employed must be one which can be volatilized in some way ; for example, silicic acid, arsenic trisulphide and sulphur, which can be removed in the forms of silicon fluoride, arsenic trichloride, and the last by simple heating. The authors have carried out a number of experiments by the use of colloidal silicic acid prepared by the action of silicon tetrachloride upon water, and the results obtained are promising, especially for the enrichment of small quantities of material.—*Berichte*, xliv, 2332. H. L. W.

3. *The Fluorides of Vanadium.*—Otto Ruff and Herbert Lickfett have prepared a series of vanadium fluorides and oxyfluorides, none of which have been previously known in a pure condition. The compounds described are VF_3, VF_4, VOF_2, VOF_3 and VF_5. They correspond to known chlorides, with the exception of the last one, which is particularly interesting from the fact that it is the only known compound of vanadium with five halogen atoms. This is distinguished from the other fluorides in possessing a pure white color. It has a noticeable vapor tension at room temperature and boils at 111°. It is decomposed by moist air and becomes colored.—*Berichte*, xliv, 2539. H. L. W.

4. *A Constituent of Mineral Coal.*—Up to the present time we have had practically no knowledge of the original compounds

existing in coal, although the distillation products have received a vast amount of attention. Some attempts have been made to extract the constituents with various solvents, but no definite compounds have thus been isolated. AMÉ PICTET and LOUIS RAMSEYER have recently succeeded in extracting with benzol and purifying a small amount of at least one constituent of a French gas-coal. This was found to be hexahydro-fluorene, $C_{13}H_{16}$, a hydrocarbon of the aromatic series which is slowly oxidized in the air, which is gradually polymerized by heating, apparently into $(C_{13}H_{16})_2$, and is converted at a high temperature into fluorene, $C_{13}H_{10}$, a constituent of coal-tar. The hexahydro-fluorene and the fluorene may be represented as follows:



$$\underset{\diagdown CH_2 \diagup}{C_6H_8\text{———}C_6H_6} \longrightarrow \underset{\diagdown CH_2 \diagup}{C_6H_4\text{———}C_6H_4}.$$

Berichte, xliv, 2486. H. L. W.

5. *The Technical Analysis of Brass and the Non-ferrous Alloys;* by W. B. PRICE and R. K. MEADE. 12mo, pp. 267. New York, 1911 (John Wiley & Sons).—This book gives an interesting introductory chapter in which many alloys are described and their compositions are given. The main part of the book is devoted to analytical methods, including electrolytic, gravimetric and volumetric processes. There appears to be very little in this part that is new or original, but very probably some of the methods described here will be found useful to the practical analyst. In some cases there seems to be too little explanation of the reasons for the step taken, if the book is to be used by beginners, and not all of the explanations given are sound, as, for instance, in connection with the determination of sulphur, where directions are given to add $\frac{1}{10}$ gram of sodium carbonate to a strong nitric acid solution of an alloy, it is absurdly stated that this will convert any lead sulphate into carbonate. Some of the descriptions of processes are decidedly bad; for example, where an entirely unnecessary operation, presumably for the separation of manganese, is included as a preliminary step to the determination of nickel by the dimethyl glyoxime method.

H. L. W.

6. *Allen's Commercial Organic Analysis;* Fourth Edition, Entirely Rewritten. Volume V. 8vo, pp. 704. Philadelphia, 1911 (P. Blakiston's Son & Co.).—This volume, like its predecessors, is of great interest and importance. The subjects included are Tannins, Analysis of Leather, Dyes and Coloring Matters (artificial and natural), Analysis of Coloring Materials, Coloring Matters in Foods, and Inks. The contributors are W. P. Dreaper of London, J. F. Hewitt of Surrey, England, W. M. Gardner of Bradford, England, Albert F. Seeker of Brooklyn, N. Y., Percy H. Walker of Washington, D. C., and F. Feilmann of London. The section on Coloring Matters in Foods is new, and it should prove useful to food analysts and others. H. L. W.

7. *Electro-Analysis;* by EDGAR F. SMITH. Fifth Edition, Revised and Enlarged. 12mo, pp. 332. Philadelphia, 1911 (P.

Blakiston's Son & Co.).—The present edition of this valuable treatise on electrolytic analysis shows but few changes from the previous edition, which appeared about four years ago, but the essentials of all that has appeared upon the subject during the interval have been added. The book shows in an impressive way the great advances that have been made in this comparatively recent branch of analytical chemistry, and the large number of determinations and separations that can be conveniently and accurately made in this manner. H. L. W.

8. *The Disintegration Products of Uranium.*—It is now generally accepted that uranium is the primary substance from which ionium and radium with its series of products are derived. In old minerals all α-ray products in radio-active equilibrium with uranium emit an equal number of α-particles per second except uranium itself, which emits twice as many. Consequently either two α-particles are emitted at the disintegration of each atom, or the uranium is in equilibrium with an unseparated α-ray product. Furthermore, it is known that uranium-X is a direct product of uranium, but at present no definite transformation product of the former has been obtained. Also, some irregularities in the behavior of uranium-X have been noted by several investigators.

An important advance towards the solution of the general problems just suggested has been made by G. N. ANTONOFF. This investigator has established the existence of a new radio-active product which he symbolizes by "Ur Y."

In referring to the work of his predecessors, Antonoff says:—"In all these investigations no evidence of the purity of the uranium preparations has been given." Therefore, the first step in the present investigation was to make preparations of uranium from which all known radio-active impurities had been separated. Special tests afforded definite proof that this condition had been attained. For details of the chemical processes involved in the purification of the uranium salts reference must be made to the original paper. It should be stated, however, that two methods were employed in the separation of uranium-X. The first method consisted in precipitating barium in the uranium solution as barium sulphate, and the second in adding an iron salt to the uranium solution and precipitating it by boiling.

It is known that uranium-X emits both "soft" and "hard" β-rays. The activities of the uranium-X preparations were determined first with the salts uncovered and afterwards when aluminium foil $0\cdot01^{cm}$ thick was placed over the radio-active material. The first measurement gave the total activity, and the second the activity due to the hard rays. Uranium-X separated from uranium by the *barium* method gave exponential decay curves with practically identical periods for both types of rays. Also the absorption curves of such preparations taken at different intervals of time after separation are always of the same shape, indicating that the uranium-X contains no other active product.

On the other hand, when uranium-X is separated by the *ferric* method, *a rapid initial drop* in the decay curve was always observed when the preparation was *uncovered*. The activity of the uranium-X thus prepared, when measured through 0·01^{cm} or more of aluminium, decayed exponentially with the same period as the preparations obtained by the barium method. The absorption curves of the ferric preparations show the presence of a much larger quantity of soft β-rays than is found in the barium preparations.

The decay curves for the new radio-active substance were derived in the following manner: First the decay curves for the uncovered ferric preparation and for the pure uranium-X through 0·01^{cm} of aluminium were plotted to the same scale on the same sheet. By multiplying the ordinates of the latter curve by the empirical constant 2·15 a curve was obtained which corresponded theoretically with the activity of pure uranium-X when uncovered, that is, this curve would have coincided throughout with the decay curve for the uncovered ferric preparation if the latter had contained no radio-active element other than uranium-X. In fact, these two curves do coincide sensibly for points whose abscissæ represent 10 or more days. Therefore, by subtracting the ordinates of the theoretical barium preparation curve from the corresponding ordinates of the experimental ferric curve the decay curve for the newly discovered product was obtained at once.

The new substance was always found to be present in the ferric preparations. It is characterized by the emission of soft β-rays. All attempts to separate uranium-Y in large quantities from uranium were unsuccessful. Furthermore, owing to the very similar chemical properties of uranium-X and the new product, it was not found possible to isolate the latter, for it was always accompanied by uranium-X. The half-value period of uranium-Y came out consistently from all the decay curves as about 1·5 days.

Scintillation experiments indicated both that uranium-Y emits some α-rays, and also that the half period was about 1·5 days, as before. It should be remarked that the number of α-particles observed was small compared with what would be expected from the β-ray activity of the product. A study of the initial portions of the absorption curves of uranium-Y also leads to the conclusion that α-rays are emitted. The absorption coefficients for the α- and β-rays are given respectively as $\mu = 2500\,(\text{cm.})^{-1}$ and $\mu = 300\,(\text{cm.})^{-1}$. Finally, as regards the position of uranium-Y in the radio-active series, Antonoff concludes from all the experimental evidence that uranium-Y is a *lateral* disintegration product of uranium and is produced in small quantity as compared with uranium-X.—*Phil. Mag.* (6), xxii, 419. H. S. U.

9. *On a Method of making Visible the Paths of Ionizing Particles through a Gas.*—It has been found by C. T. R. WILSON that the tracks of individual α- or β-particles, or of ionizing rays of any kind, through a moist gas may be made *visible* by condensing water upon the ions set free. Not only is it possible to see the paths of the particles, but Wilson has even succeeded in *photographing* these paths.

Since the apparatus employed was simply a specially adapted form of the well-known Wilson expansion chamber, it does not seem desirable to enter into details of the experimental method in this place. All of the results obtained by Wilson's experiments are in complete accord with the previously accepted interpretations of the various ionization experiments, which could not, in the very nature of the case, appeal directly to the sense of vision. Such an appeal is, of course, not at all necessary for scientific progress, but a concrete or graphical representation of a phenomenon is very satisfying to many minds.

The clouds formed with large expansions, ($V_2/V_1 > 1{\cdot}38$), in the absence of ions showed a uniform distribution of drops.

In photographing the ionization produced by α-rays a radium-tipped metal tongue from a spinthariscope was placed inside the cloud-chamber and the expansion was made after removal of the dust particles. The clouds are beautiful and chiefly consist in segments of straight lines which radiate from the radium "point." It is probable that the most sharply defined lines, about $0{\cdot}1^{mm}$ wide, alone represent the actual distribution of ions immediately after the passage of the α-particles, before any appreciable diffusion has had time to take place.

When ionization was produced by β-rays two or three absolutely straight, thread-like lines of cloud were generally seen radiating from the source. In addition, other similar lines were occasionally seen crossing the vessel in other directions, and these were probably due to secondary β-rays from the walls of the vessel.

When the air in the cloud-chamber is allowed to expand while exposed to the radiation from an X-ray bulb, the whole of the region traversed by the primary beam is seen to be filled with minute streaks and patches of cloud, a few due to secondary X-rays appearing also outside the primary beam. The photograph, which is reproduced in the paper, shows that the cloudlets are mainly small, thread-like objects, each not more than a few millimeters long, and many of them are much less than $0{\cdot}1^{mm}$ broad. Few cloudlets are straight and some form complete loops. The results are in agreement with Bragg's hypothesis that the whole of the ionization by X-rays may be regarded as due to β- or cathode-rays arising from the X-rays. The question whether the original X-radiation has a continuous wave-front, or is constituted in the different ways suggested by Sir J. J. Thomson and Bragg, remains as yet undecided.—*Proc. Roy. Soc.*, vol. lxxxv, 285. H. S. U.

10. *On the Dynamical Nature of the Molecular Systems which emit Spectra of the Banded Type.*—Many attempts have been made to construct a model of a molecule which will possess such dynamical properties as to radiate channeled spectra. Most, if not all, of these analytical investigations have been unsatisfactory either because they have led to very complicated transcendental equations which are too general to admit of comparison

between their roots and the observed frequencies of spectral lines, or because they have been based on hypotheses and assumptions which are apparently inadmissible. The present paper by E. T. WHITTAKER is, on the whole, free from these objections.

The author begins by recapitulating the experimental evidence which has led most spectroscopists to believe that band spectra are due to vibrations of the molecules and not of smaller constituents of the radiating matter. Attention is then called to the fact that many properties of chemical substances are of the "additive" kind. From this fact it may be inferred that atoms retain in large degree their individuality when they are combined with one another to form molecules, so that a molecule is to be regarded not as a complete rearrangement of the electrons or other elements of which its atoms are composed, but rather as a system in which the atoms exist with comparatively little alteration in their internal structure, but with mutual connections such as may be expressed by additional terms or other modifications in the dynamical equations. Therefore Whittaker builds up his model from two constituent systems representing the two atoms of a diatomic molecule. For mathematical simplicity he also supposes the atoms to be alike, so that the molecule represented is that of a chemical element.

This dynamical model is next investigated according to the well-established laws and processes of analytical mechanics, with the result that a final equation is obtained which expresses the frequencies of the possible vibrations of the diatomic system explicitly in terms of suitable parameters, etc. This formula presents a certain peculiarity, in that the frequency of vibration occurs in it *linearly*, whereas in the equation for determining the free periods of dynamical systems in general the frequency enters by its square. In the course of the analysis the permissible types of connection between the atoms in the molecule are arranged in three classes, each of which is discussed at some length. Whittaker shows that the gyroscopic type of connection is the one which accords best of all with many of the chemical and physical properties of atoms and molecules. Thus, all of the assumptions underlying the mathematical analysis are very plausible and are consistent with experience.

When certain terms of the final formula are omitted, an equation results which is precisely of the same form as the empirical formula for band spectra as discovered by Deslandres. Since the laws of Deslandres, as embodied in his formula, are generally looked upon only as first approximations to a more general law of nature, Whittaker points out that the retention of the terms of his equation will suffice to satisfy the more general case. Finally, it is shown that a special set of legitimate assumptions leads to Balmer's empirical formula for the series spectrum of hydrogen.—*Proc. Roy. Soc.*, vol. lxxxv, 262. H. S. U.

II. GEOLOGY AND NATURAL HISTORY.

1. *Recent Contributions on Cycadophytans;* by G. R. WIELAND.—After the article on the Williamsonian tribe (pp. 433–466 of this Journal) was in type, two highly important contributions on the subject by Nathorst and Schuster came to hand and are here added to the literature cited with comments:—

(29) 1911.—NATHORST, A. G. Paleobotanische Mitteilungen 10. Ueber die Gattung *Cycadocarpidium* Nathorst nebst einige Bemerkunger über *Podozamites*. Kungl. Svenska Vet.-Ak. Handl., vol. xlvi, No. 8, pp. 11 and pl.

In this brief paper Professor Nathorst again displays his gift for making scanty plant remains reveal the presence of little suspected ancient groups. As it now turns out, *Cycadocarpidium* (Nathorst, 1886) is a loosely compacted strobilus of very leafy two-seeded megasporophylls, and is so intimately associated with, and so like the leaves of *Podozamites* as to leave no doubt but that the fossils referred to these genera are leaf and fruit of the same plant.

On the basis of the strobilus alone, a primitive leafy cycadaceous type (such as is readily pictured from abnormal cones of *Encephalartos* described by Thiselton-Dyer, or those of *Zamia* brought to notice by Wieland) would at once be inferred. But it is also shown by Nathorst that the leaf-laminæ of *Podozamites* are not all laterally borne pinnules of a once pinnate frond as hitherto considered, but are in part the spirally borne leaves of small scale-covered stems of presumably limited growth and distinctly coniferous habit; from which it is obvious enough that *Podozamites* is perhaps the first form ever determined from that unknown borderland between cycads and conifers.

Thus the correctness of my rather free—even if qualified—reference of *Podozamites* to the Williamsonian alliance is brought under suspicion. Though it must be remembered that the presence of the small branches accompanying *Cycadocarpidium* (or better *Podostrobus*) does not take away from the possibility that the as yet wholly unknown microsporophylls were of more or less distinctly leafy to Williamsonian type.

(30) 1911.—SCHUSTER, JULIUS. *Weltrichia* und die Bennettitales. Kungl. Svensk. Vet.-Ak. Handl., vol. xlvi, No. 11, pp. 57 and 7 pls.

It is always interesting to note how repeated consideration of problematical fossil structures may serve to hasten the day of their elucidation. Nor can a better instance be cited than the curious disk *Weltrichia mirabilis* (Fr. Braun, 1848). In the *Plantes Jurassiques* Saporta refigured this fossil and for the first time divined its affinity to *Williamsonia*, although utterly misapprehending its true function in supposing it to be a funneliform termination of the strobilar axis, of which there is after all no definitely known instance in any Williamsonian form.

Yet *Weltrichia* seemed to be for a second time passing out of view when two years since Nathorst again figured it, called attention to it as an undoubted example of a staminate disk, and further laid stress upon the fact that Braun himself had shrewdly noted the close association of these disks with *Otozamites* fronds. And now, sixty-three years after the early description of this *problematica*, there lies before us the accurate restoration not only of the flower it proves to be, but of the remarkable plant type which bore it. This entire study is, as we understand, based on collections made sixty and more years ago by the local collector Weltrich and Fr. Braun in the upper Rhät of Bayreuth (Theta, Fantasie) and Veitlahm, Franconia.

Fig. 20.

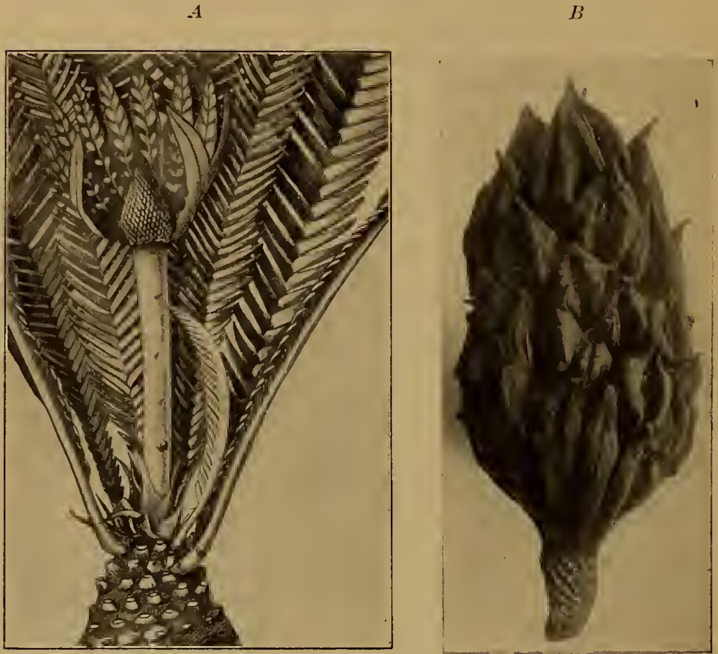


Fig. 20. *A. Weltrichia mirabilis* Fr. Braun (× 2/5). From restoration by Schuster. *B.* Bisporangiate strobilus of a magnolia—Cuernavaca, Morelos. The scars of the dehiscent stamens retain like the leafy carpels the ancient spiral order. [Reviewer's figure. Natural size.]

As shown in the accompanying figure 20, *Weltrichia* with its *Otozamites* foliage and terminal flower does not at first sight appear very different from the picture that might be formed of some *Williamsonian* species, the secondarily elongated naked instead of short bract or scale-leaf ensheathed flower-stalk of course reminding one of recent cycads. But there are two fundamental differences: firstly, the microsporophylls are far more leafy; and secondly, the seed cone not only retains an original foliar spiral in which the fertile and sterile organs regularly alternate, but the seed stems, although bearing a single terminal seed enveloped by the pericarp of interseminal scales as in *Cycadeoidea*, also retain several lateral pairs of abortive seeds, being as truly carpellary leaves as in the case of *Cycas.*

Weltrichia thus unites a noteworthy series of characters and is a far older type than either *Cycadeoidea* or *Williamsonia;* while the retention of carpellary features, with both fertile and nonfertile organs of the ovulate cone in the original spiral order, places beyond further controversy the reviewer's interpretation of the homology of these organs as given in his American Fossil Cycads (pp. 230–232, etc., etc.). At the time that work was written no undoubted examples of related flowers with spiral insertion of sporophylls could be pointed out, though Mexican ovulate cones of Williamsonian nature with spirally inserted sterile (?) organs of the basal region (cf. fig. 14) were later found. Schuster properly lays much stress on this primitive feature and gives a clear diagram explaining once and for all how by simple increase in number of nonfertile organs with lateral appression and compensating change of form the original spiral order comes to be hidden in the ovulate cone of *Cycadeoidea.* And may not these alternant fertile and nonfertile organs of the *Weltrichia* strobilus go to explain the ovuliferous scale of the conifers if *Cycadocarpidium* fails to do so?

Easily the most remarkable character of *Weltrichia* is of course the retention of carpellary leaf characters in a cone so far advanced in the direction of *Cycadeoidea;* and it goes without saying that with such rare evidence before him Schuster has been in a position to make still more tangible the idea that types like *Weltrichia* and *Williamsonia* are very close indeed to the ancestral forms leading into the Ranales. And to say the least, this opportunity has been used in a highly effective and interesting manner. The source of the dicotyledonous foliage is at once referred to the old *Pterophyllum* line, while the facile suggestion is made that in *Nelumbium* it is the series of organs in the position of the interseminal scales of *Cycadeoidea* which is fertile.

With regard to the strict monophyly of the Angiosperms we cannot of course follow Schuster without some reservation of doubt. The Williamsonian Tribe as the known expression of an enormous Mesozoic-Paleozoic complex may have given rise to lines of descent altogether too varied to fairly accord with any ordinary limit or conception of monophyly.

That it has, on the other hand, become more difficult than ever before to cite real differences between the Cycadaceans and the Williamsonian alliance can finally escape no one. In fact it appears more and more likely that in pre-Rhätic or Permian time the lines leading into these larger Cycadalean groups were virtually identical. But that the apparent restriction of *Weltrichia* *mirabilis* to Franconian horizons is evidence of either "rarity" or "possible monotypic occurrence" seems unlikely. Such forms are easily overlooked, or may fail of collection. That for instance the Helmsdale and Eathie rocks of Sutherlandshire, Scotland, the Rajmahal series of India, and the Oaxacan series contain horizons of the same age as the Rhaetic plant beds of Bayreuth can scarcely be questioned; and that these several regions are far from exhausted is as certain as the testimony of Hugh Miller, Oldham and others to the immense wealth of fossil plants they contain. Their study afield and in the laboratory is but begun.

2. *A Botanical Expedition to Newfoundland and Southern Labrador;* by M. L. FERNALD. Rhodora, XIII, pp. 109–162, 1911.—This very interesting paper presents in Part I the journal of the expedition (109–135), while Part II treats of the geographic origin of the flora of Newfoundland. It is this second part which interests geologists, and especially students of Pleistocene earth movements and life.

The flora of Newfoundland so far as worked out by Fernald is made up of 783 forms, of which about 200 species are clearly introduced by man. The indigenous plants can be arranged in four groups as follows:

Boreal plants which occur to the north of Newfoundland. Of these there are in Newfoundland 466 species or 59·5 per cent of the entire flora.

Western or Canadian plants not reaching Labrador; 27 species or 3·5 per cent of the entire flora.

Southwestern types (Canadian, Alleghanian and Carolinian); 274 species or 35 per cent of the entire flora. More than 7 per cent of the entire flora is restricted to the coastal sands represented by the New Jersey Pine Barrens. In a recent letter to the reviewer Professor Fernald states that his second expedition to southeastern Newfoundland has added "nearly 80 species of coastal plain origin."

Endemic plants or species unknown on the American continent; 16 forms or 2 per cent of the entire flora.

The chief interest for geologists lies in the finding in Newfoundland of the New Jersey Pine Barrens flora. The author holds, and correctly, that this flora could have gotten to Newfoundland only by a continuous land bridge composed of coastal siliceous sand that must have been in existence in post-Glacial times.

"To summarize briefly, the indigenous flora of Newfoundland consists primarily of plants which occur to the north, in Labrador, or to the southwest, chiefly along the Atlantic seaboard or the Coastal Plain; the typical Canadian plants, unless their northeastern range extends to the north side of the Straits of Belle Isle, being essentially absent from the island. The distance between Newfoundland and Labrador is not sufficiently great to prevent ready interchange of species across the Straits of Belle Isle, but the distance between Newfoundland and Cape Breton is so great that the plants of the latter region rarely if ever span it.

Birds, ocean-currents, drifting logs and ice, and winds prove to be ineffective in carrying to Newfoundland the plants from the southwest, so that an ancient land-bridge is suggested. This is the more demanded from the presence in Newfoundland of a vole and a muskrat, mammals closely related to species of our coastal region. The amount of water withdrawn from the ocean to form the Pleistocene glaciers was apparently sufficient to leave exposed nearly, if not all, the old coastal plain which now forms the submerged bench off our coast, and in addition there is unquestioned evidence that since the Glacial Period this coastal bench has been much higher than it is now; so that upon this now submerged plain, as the ice-front receded northward, the southwestern plants, most of which still occur on Cape Cod, Long Island, or in the Pine Barrens of New Jersey, must have spread to Newfoundland, where they form now an isolated flora."

The author states that he will be glad to supply a copy of the paper here reviewed to those geologists who wish to have it.

C. S.

3. *Topographic and Geologic Survey of Pennsylvania.* Richard R. Hice, State Geologist. 1908–1910. Pp. 103; 6 plates, 4 figures. Harrisburg, 1911.—The present Survey of Pennsylvania was established in April, 1899, when an appropriation for joint work with the U. S. Geological Survey was made. The chief work contemplated was the preparation of a contour topographic map on a scale of 1:62,500 with 20-foot contours; for this an annual appropriation of $20,000 for two years was made. The present volume, besides showing what progress has been made thus far, emphasizes the fact that as the mineral production of the state is so large, amounting in 1907 to $658,000,000, or more than $100,000,000 in excess of all the states west of the Mississippi River, the present appropriation is entirely inadequate. It is urged that a sum not less than $40,000 be authorized for each of the next two years to do the work planned. This volume also contains two papers, one on the natural gas development in Pennsylvania by Frederick G. Clapp, and another by Percy E. Raymond, giving a preliminary list of the fauna of the Allegheny and Conemaugh Series in Western Pennsylvania. In regard to the former subject, the conclusion is reached that the disappearance of natural gas production from the state is certainly many years distant.

4. *Virginia Geological Survey. Bulletin No. VI. Report on the Mineral Production of Virginia during the Calendar Years 1909 and 1910;* by Thomas Leonard Watson. Pp. v, 123; one figure. Charlottesville, 1911 (University of Virginia).—The general facts in regard to the mining industries of Virginia during the years 1909 and 1910 are given in this bulletin. The total mineral production in 1910 amounted to nearly $22,800,000, having increased from about $18,000,000 in 1908. The products are varied, but those of greatest importance are coal, iron, and clay. The bulletin also discusses the distribution, occurrence, and development of the mineral products, some forty in all, now

exploited in the state. It is interesting to note that the most prominent of these have been worked since early colonial days.

Geological Map.—A geological map of Virginia, on a scale of 1:500,000, has recently been issued. Included on the same sheet are five generalized columnar sections taken from the folios of the U. S. Geological Survey.

5. *Hexahydrite, a New Mineral;* by A. A. JOHNSTON. Summary Report, Geol. Sur. Branch of the Dept. of Mines, Canada, 256, 1911.—This mineral was found on the east bank of the Bonaparte river, about half way between Cargill and Scottie creeks, in the district of Lillooet, British Columbia. It occurs in the form of seams varying in width up to one-half inch, also in scattered patches in an altered schistose rock. In general the structure is coarse-columnar but occasionally delicately fibrous; a poor prismatic cleavage was observed. The mineral has a pearly luster with a greenish white color. Before the blowpipe it intumesces but does not fuse. In the closed tube it gives a large amount of neutral water. It has a bitter, saline taste and is readily soluble in water. In solution it gives tests for magnesium and sulphuric acid. Sp. gr. = 1·757. The formula derived from the following analysis is $MgSO_4.6H_2O$. The name of the mineral was derived from the six molecules of water which it contains. In column I the results of the analysis are given, in column II the same recalculated omitting the silica as an impurity, and in column III the theoretical percentages for $MgSO_4.6H_2O$. The mineral epsomite has the formula $MgSO_4.7H_2O$.

	I	II	III
SO_3	34·52	35·19	35·09
MgO	17·15	17·48	16·54
H_2O	46·42	47·33	47·37
SiO_2 (insol.)	1·78	----	----
	99·87	100·00	100·00

W. E. F.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *A Study of Chiriquian Antiquities;* by GEORGE GRANT MACCURDY, Ph.D. Pp. i–xx, 1–249; pls. I–XLIX, figs. 384 Memoirs of the Connecticut Academy of Sciences. Vol. III, March, 1911. New Haven, Conn. (Yale University Press.)—It is fortunate for the science of archeology that the men and the means have been found to produce in such excellent style the work on Chiriquian antiquities to which Dr. MacCurdy has devoted himself for so many years. It also speaks volumes for the feeling of reciprocity existing among the patrons of archeology, the museums, and the students of this day, that Dr. MacCurdy has had free access to the numerous collections from the Chiriquian area, and on account of these facilities in examining great series of material, the work has the scope, knowledge and adequacy which are its chief characteristic.

The work begins with a historical introduction in which the principal sources are cited, and then takes up the description of the antiquities under the various heads of classification. Everyone who writes on this subject must make acknowledgment, as Dr. MacCurdy has done, to Professor William H. Holmes, whose work on the art of Chiriqui was the first (1884–1885) which laid down most thoroughly the principles for such studies.

The description of these collections must necessarily be confined to artifacts of stone, pottery and metal, which can survive long burial, and, therefore, must be limited as to other arts such as weaving, basketry, wood-carving, etc. Nevertheless, the book illustrates sufficiently the culture status of the tribes of ancient Chiriqui, who rank in art only in small degree lower than the Mexicans and Peruvians. In this case it is not wholly a question of mere material—rather, the skill in classifying and describing what is at hand. Since most of the antiquities were taken from the graves about 50 years ago, and most of the first-class sites exhausted long ago, it is hardly possible to accomplish now field work that will have adequate bearing on the collections in museums. As illustrations of culture history, the Chiriquian antiquities fulfill their purpose, and as survivals of the ideas of the prehistoric artist, they are of surpassing interest, irrespective of dates, tribal provenance and other data, valuable if procurable.

Dr. MacCurdy's work shows that the symbolic art lavished in the decoration of the artifacts has great scientific value and also economic value to students of design. Numerous examples are given of the transmutations of pictorial motives, such as the armadillo, alligator, fish, serpent, and frog, which furnish an important though difficult field for the study of symbolic art. Dr. MacCurdy concludes that there is a general phylogenetic trend in the development of Chiriquian art as a whole ; he states also that "the results of the present study point to the forces from within rather than to those from without, as being the chief factors in the development of Chiiiquian culture, which contains many elements of fundamental importance to a complete history of primitive art."

A good bibliography and index accompany the work, the illustrations are numerous and excellent, and the description of the artifacts is according to a high standard of accuracy and fulness.

WALTER HOUGH.

2. *National Academy of Sciences.*—The autumn meeting of the National Academy of Sciences was held at the Public Library in New York City on November 21, 22. President Remsen occupied the chair and upwards of sixty members were in attendance, a record probably never exceeded. A reception to the Academy was given at the American Museum of Natural History by the President and Trustees on Wednesday afternoon ; other social events added to the attractions of an unusually interesting meeting.

The list of papers presented is as follows :

SIMON FLEXNER: Mode of infection in infantile paralysis.
JACQUES LOEB: Oxidations in the cell.
ALEXIS CARREL: Manifest and non-manifest life of the tissues.
E. G. CONKLIN: Cell-size and nuclear-size.
R. G. HARRISON: Protoplasmic movement in embryonic cells.
WILLY KÜKENTHAL: The biological significance of the so-called hairs of the hairy frog, *Astylosternus robustus* (Blgr.)
T. H. MORGAN: Sex limited inheritance.
C. B. DAVENPORT: Recent advances in the study of eugenics.
HENRY F. OSBORN: The problem of continuity or discontinuity in the origin of unit characters in heredity.
ALÉS HRDLICKA: Ancient man in South America in the light of recent researches.
WM. TRELEASE: The leafy mistletoes of North America.
A. W. GRABAU: A comparison of the basal Paleozoic in Northwestern Europe and Eastern North America.
J. F. KEMP: New data on the bed-rock channel of the Hudson River. The source of the Saratoga mineral springs.
ALEXANDER SMITH: Recent experiments on the effect of the absence of moisture upon the chemical dissociation of calomel and other salts.
B. B. BOLTWOOD: Proposed International radium standard.
M. I. PUPIN: Conductors rotating in alternating magnetic field.
T. B. OSBORNE and L. B. MENDEL: The rôle of different proteins in nutrition and growth.
C. S. PEIRCE: A method of computation. The reasons of reasoning, or grounds of inferring.
CHARLES D. WALCOTT: Biographical memoir of Samuel Pierpont Langley.
GEORGE F. BECKER: The remainders of certain mechanical quadratures.
H. L. WELLS: A color-effect in isomorphous crystallization.

3. *American Association for the Advancement of Science.*—The regular winter meeting of the American Association will be held in Washington, D. C., during the week beginning December 27. Dr. Charles E. Bessey of the University of Nebraska is the President. The meetings of the usual affiliated societies, twenty-eight in number, will take place at the same time. Information relating to the meeting may be obtained from L. O. Howard of the Smithsonian Institution.

OBITUARY.

LOUIS JOSEPH TROOST, the veteran French chemist, died on September 30 at the age of eighty-five years.

Professor AUGUSTE MICHEL-LÉVY, the French geologist, Director of the Geological Survey of France, died on September 25 in his sixty-eighth year.

Sir HERBERT RISLEY, the eminent English anthropologist, died on September 30 at the age of sixty years.

Dr. FLORENTINO AMEGHINO, the well-known paleontologist of the Argentine Republic, died on August 6.

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*This Index contains the general heads, CHEMISTRY (incl. chem. physics), GEOLOGY, MINERALS, OBITUARY, ROCKS, ZOÖLOGY, and under each the titles of Articles referring thereto are mentioned.

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