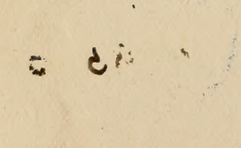

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[FOURTH SERIES.]

Art. I.—*Paleogeography and Diastrophism in the Atlantic-Arctic Region during Paleozoic Time;* by Olaf Holtedahl.

With their vast continent, where richly fossiliferous Paleozoic sediments occur and may be studied throughout wide areas, North American stratigraphers naturally became leaders in Paleozoic paleogeography. Europe, split up into a large number of nationalities, speaking many different languages, with the strata of the older systems much more tectonically disturbed and metamorphosed over considerably greater areas, offers far less attractive conditions for unravelling the geographies of Paleozoic time.

While a great many paleogeographic maps illustrating the conditions of Mesozoic, and especially Cenozoic, time have been published, those treating of the Paleozoic of Europe have been very few. We have the well known, world-embracing maps of Frech, Lapparent, Haug, and in quite recent times those of Arldt, wherein a summary of older views is given, but these maps embrace far too long a time, especially for the Ordovician and Silurian periods, since but one map is given for the whole of each period. On the other hand, some districts of northern Europe have been treated in a number of special maps, as those of the British Isles by Jukes-Browne, and those of Russia by Karpinsky; the suggestions made by these authors have to a considerable extent been followed in some of the maps here presented. For the North American continent the maps of Schuchert (1910 and 1915) have been used. Other American authors, as Weller, Bassler, and Grabau, have presented maps embracing, besides parts of North America, European and Arctic European districts also.

For the regions in which the present author has made personal investigations, the Scandinavian Peninsula[1] and the Arctic districts,[2] to the north, the maps mentioned are generally not very satisfactory, and especially for older Paleozoic times, and as a good deal of knowledge concerning the stratigraphy of northern lands has been accumulated during recent years, an attempt is here made to present new maps illustrating certain Paleozoic geographies of those regions. As has so eminently been shown by American students of paleogeography, the deciphering of the geography of the past is of great importance to several fundamental problems in geology: for the natural delimitation of the periods, to show the extent and nature of crust movements, for the proper understanding of the geographic relations of land and water, and the development of life. For these questions, a knowledge of the paleogeographic features, not only of a single continent but of the whole earth, is of great importance; therefore this contribution, even if small, may be of interest.

The fact that a very great part of the region under consideration is covered by the ocean adds greatly to the difficulties of presenting reliable maps showing the distribution of the ancient lands and seas. For large areas in each one of the maps the author is therefore able only to indicate the *probable* conditions.

Description of the Paleogeography.

Cambrian Time (see figs. 1 and 2).—We do not at present know very much about the distribution of Cambrian sediments in the boreal regions; indeed, so little

[1] Th. Arldt, in his review of paleogeographic maps in "Handbuch der Palaeogeographie," Leipzig, 1917, Bd. 1, p. 21, mentions two maps by Nathorst, illustrating "Kambrium und Silurmeer in Schweden," published in Nathorst's book, "Sveriges Geologi," Stockholm, 1894, pp. 138-139. The maps here referred to are, however, not paleogeographic, but maps showing the present distribution of Cambro-Silurian sediments in two Swedish districts.

[2] An attempt at describing the geographic development of the Arctic regions in Paleozoic time, without maps, has been made by O. E. Meyer in Neues Jahrb. f. Min., Beilage-Band 31, 1911, in an article stimulated by his studies on a part of the paleontological material collected during the second Norwegian expedition in the "Fram." Largely because of later investigations, the views of the present author differ in many respects from those of Meyer.

FIG. 1.

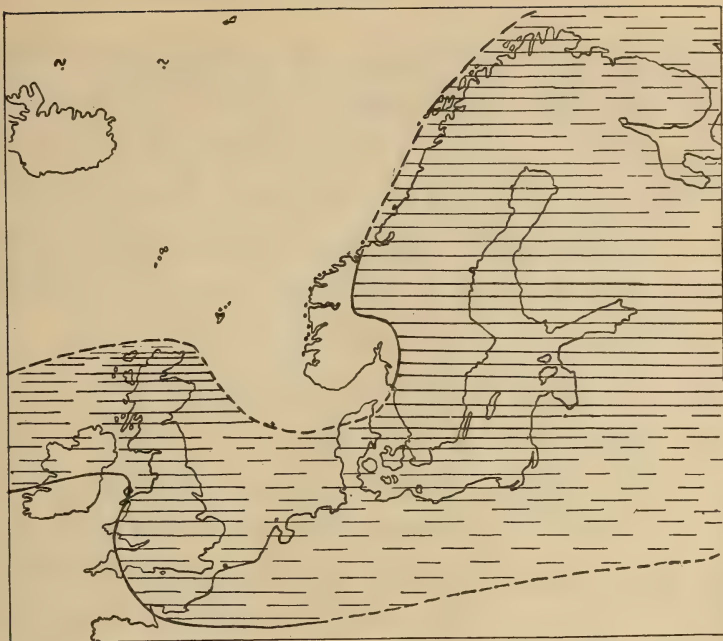


FIG. 1.—Later Lower Cambrian. White areas are lands; ruled, the seas; broken lines, the probable seas.

FIG. 2.

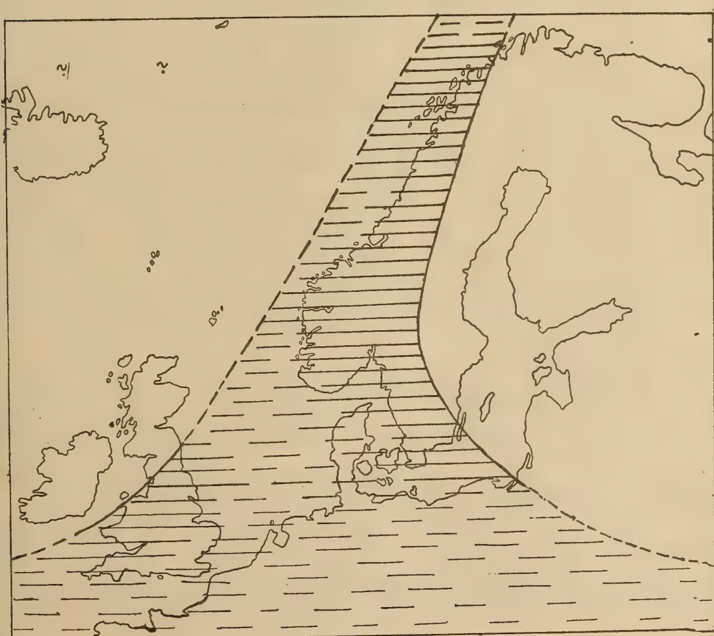


FIG. 2.—Later Middle Cambrian.

is known that the author does not think it advisable to depict on maps the distribution of Cambrian seas in the Arctic. Especially little is known of Lower Cambrian deposits. That these are represented in Ellesmereland, as suggested by Meyer, is very improbable. The invasion of the sea in this district does not seem to have taken place until middle and possibly not even until late Cambrian time. This invasion of North America came from a northern or western direction, the sea being in connection with the Cordilleran geosyncline.

The invasions in the northwestern part of Europe are, on the contrary, fairly well known, and their extent was very variable during the Cambrian period. All of southwestern Norway must have been relatively high land during Lower Cambrian time. A remnant of pre-Cambrian mountains still existed here, and from them were derived the huge masses of feldspathic sandstones (sparagmites), quartz sandstones, and conglomerates of the "Sparagmite division" of the central and eastern part of southern Norway and the adjacent districts of Sweden. Possibly it was in a more western part of this highland that the material of the Torridon sandstone of northern Scotland originated, and was then transported toward the south. The deposition of the Torridonian, however, must be regarded as having taken place at an earlier time, as that division is separated from the Lower Cambrian series by a period of crust movement and erosion. On the other hand, the sandstone materials of Norway just mentioned pass gradually into the oldest Cambrian fossiliferous beds (with *Discinella, Volborthella, Holmia,* etc.). Farther east, the geology of the Baltic provinces shows, in the "blue clay" that lies below corresponding fossiliferous beds, the existence here of a quiet sea, probably with no high land near, at a time when the coarse sandstones were being washed down farther west.

The geography of Middle Cambrian (Paradoxides) time is a very different one, telling of a relatively rapid movement of the shore-line in the late Lower Cambrian. The highland of southwestern Norway had in the meantime been base-levelled, and was now invaded by the sea, while to the east, in the Baltic region, the older sea-bottom became dry land. Thus, already in very early Paleozoic time, the "positive" character of this region is clearly shown.

Middle Cambrian time passes quietly into that of the Upper Cambrian, and the distribution of the sea seems to remain much the same, along with continued deposition of the black (alum) shales so characteristic of the sea shown in the map.

Ordovician Time (see figs. 3 and 4).—While in a larger part of the region considered in the previous maps the Cambrian seems to pass very gently and with much the same kind of sediments into the Ordovician, yet the conditions in the most northern part of Norway are very different. The present author, in the February 1919 number of this Journal, indicated the presence here of a large northern land that has yielded the material of the thick sandstones of Finmarken, presumably deposited in Ozarkian and Canadian time. This fact, then, may have some connection with the rapid movement of the shore-line in the Cambrian-Ordovician transition time.

The earliest Ordovician was not a very quiet time throughout the more southern parts of the British-Scandinavian region. In Carnarvonshire, northern Wales, a considerable uplift took place, causing a very powerful denudation between Tremadoc and Arenig time, and in the most southern part of the Kristiania region, the absence of lowest Ordovician sediments tells the same story of crustal upheaval.

With the beginning of Ordovician time, we have a better knowledge of the distribution of the sea also in the Arctic region, and therefore in the accompanying map showing Lower Ordovician (Canadian) geography, it is possible to consider a much larger area of the earth. The most significant geographic feature is the existence now of two ocean basins (the characters of which have been treated by the author in several recent publications), water-ways that were very effectively separated by a narrow Scandinavian-Scottish land barrier.

A similar land barrier, but of somewhat different shape, must be assumed also for Middle Ordovician time, if one may depend upon the present stratigraphic and faunal knowledge.

In the northwestern part of the British-Scandinavian geosyncline there was considerable, and in places exceedingly strong, volcanic activity in several districts as early as the Lower Ordovician; in Middle Ordovician time we notice in the northwest important crustal defor-

Fig. 3.

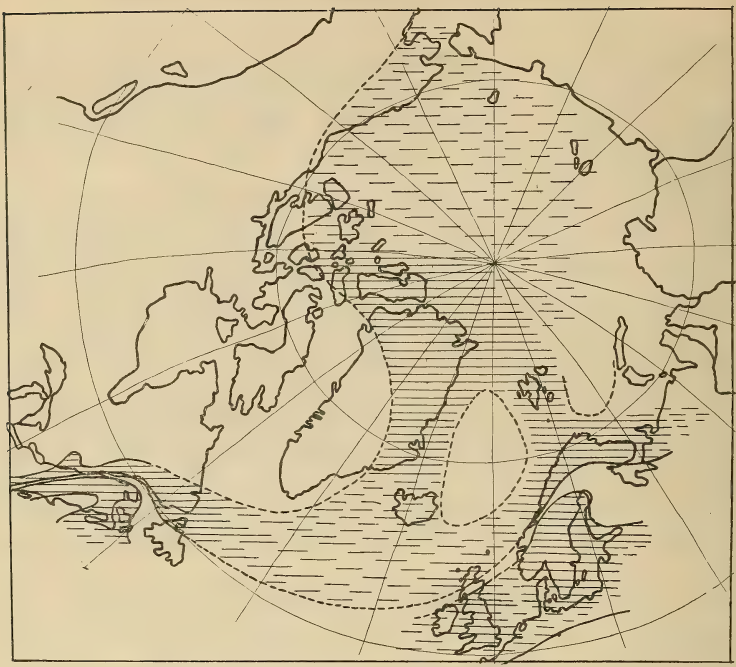


Fig. 3.—Lower Ordovician, Dictyograptus time.

Fig. 4.

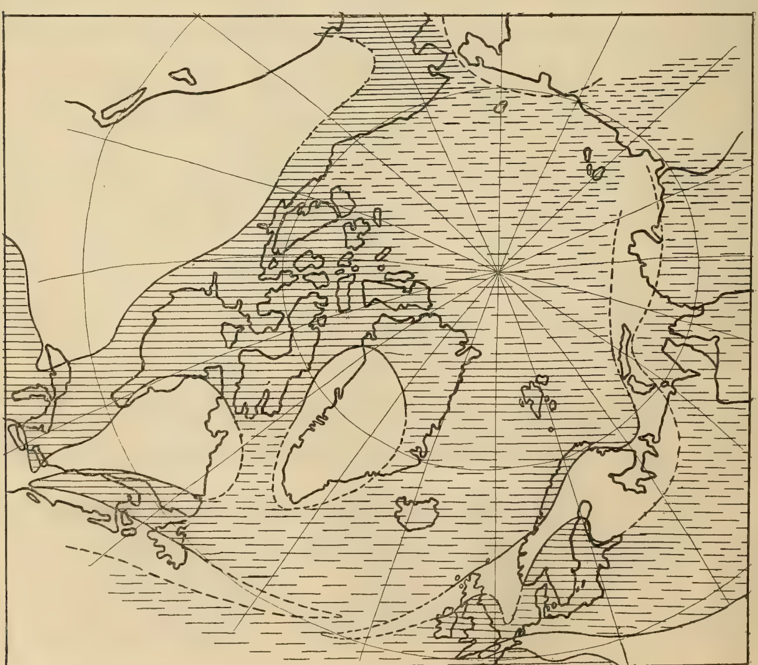


Fig. 4.—Middle Ordovician, Chasmops time.

mations. In the western part of the Girvan area, in the Llandeilian series, there are locally huge masses of coarse conglomerates which lie unconformably above the Arenig rocks, which make up the material in the boulders; in the Trondhjem district of Norway there is a "greenstone conglomerate," the pebbles of which consist of Lower Ordovician volcanics and intrusives that are younger than the volcanic series. A very considerable uplift followed by extensive erosion must therefore have taken place in this region. This deformation might be called the Trondhjem disturbance. As probable contemporary movements the writer considers the folding of the Raipas series of western Finmarken, and the fractures leading to the Varanger fault in the eastern part of that district.

There was also considerable volcanic activity during youngest Ordovician time in the same geosyncline, as is seen in different parts of Britain and in the Stavanger-Trondhjem belt of southern Norway. Furthermore, considerable warping took place, causing the emergence of much land, especially in the British Isles. In southern Scandinavia, strata of Upper Ordovician age have a very wide distribution, and these are very often of a coarse character, with conglomerates, changing much from place to place. In the central part of the Kristiania region, the sequence demonstrates temporary and local emergence, and in the Trondhjem region there are very thick and often coarse conglomerates. The barrier of the preceding time is no longer in existence, but in its place there are shallow water-ways, perhaps rather narrow, yet sufficient for a free communciation between the previously separated ocean basins.

Silurian Time (see figs. 5 and 6).—As in the Appalachian geosyncline, so on the European side there are considerable areas emerged in Lower Silurian time, and especially in England; while further to the northeast the Baltic region seems to have been dry, although the land was very low. In the more central part of the Scandinavian sea the sediments often have a rather coarse character.

Middle Silurian time, as is well known, is one of very large marine transgression, and over large areas of the northern lands, especially in North America. Yet if we consider the whole northern area, we may also see, in local districts, a widening of the land. In fact, the Cale-

Fig. 5.

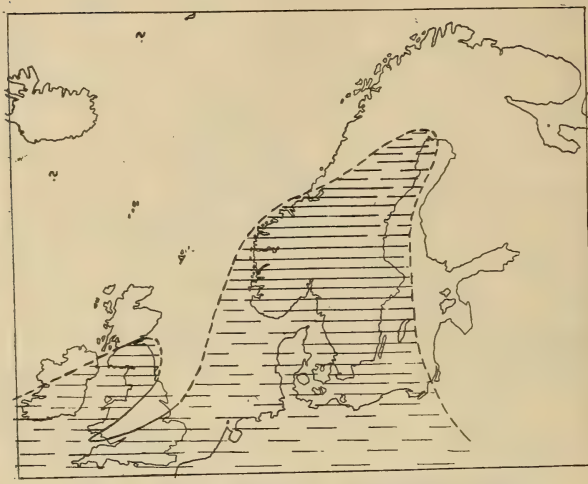


Fig. 5.—Early Silurian, Llandovery time.

Fig. 6.

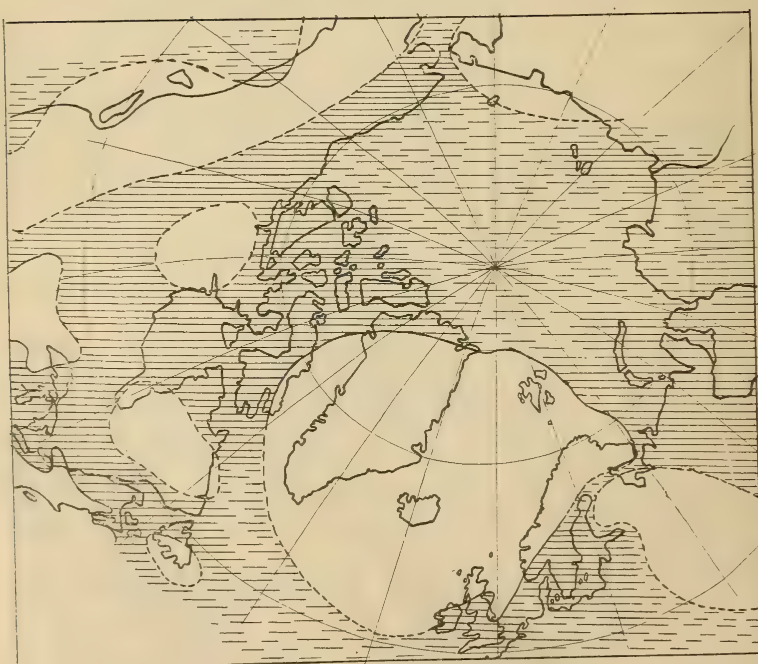


Fig. 6.—Middle Silurian, Wenlock time.

donian deformation is now in full development in regions that in Lower Silurian time were covered by the sea, as for instance, in the northwestern part of southern Norway. The very important recent discoveries of unmetamorphosed sandstones of Downtonian age, resting unconformably upon the deeply eroded remnants of Caledonian mountain ranges, in Spitzbergen and in southwestern Norway, make it very probable that this gigantic deformation began rather early in the Silurian, that is, after Llandovery time. Is it not, then, natural to infer that the Middle Silurian transgression is a direct concomitant of this rising of a land, a rising that must be supposed to have taken place, to a large degree, in areas previously covered by the sea?

The Caledonian deformation must have continued for a very considerable time. In southern Scotland and England the chief movement took place immediately preceding the deposition of the Lower Old Red, as here the Downtonian is also folded. On the other hand, in the Kristiania region the Downtonian sandstones pass gradually into marine Ludlow beds and all of these strata have been subjected to considerable folding. In fact, there can be no doubt that in the arc of the geosyncline the deformative movement has been vertical to the axes of folding. This zonal wandering of the axes of movement is, as is well known, a phenomenon observed also in other mountain belts.

In figure 7 I have shown, in a very generalized sketch, how this spreading of the deformation across present southern Norway may be thought to have taken place. In this connection it is of great interest to note that somewhat similar conditions are also known in Scotland. Here, at Stonehaven, not far to the north on the east coast, the Downtonian rests unconformably on intensely folded rocks of very old (Upper Cambrian?) age, and passes upwards through a transition series into Lower Old Red Sandstone. Southwest of Edinburgh, as in England, the Downtonian passes conformably below into marine beds (as at Kristiania), and above is separated from the true Old Red by a marked unconformity.

At present I will not go into detail as to the varying nature of the Caledonian deformation in the Scandinavian Peninsula, where much work has been done during recent years to clear up the tectonic problems connected with that imposing revolution. But I must point out that the view which has been so ably advocated by Törnebohm and other prominent Swedish geologists, viz., that, as in Scotland, the thick and widespread pressed igneous masses lying above undoubted Cambro-Silurian sediments along the eastern part of the mountain belt of Scandinavia are Archean masses, thrust into their present position from regions far to the northwest, is a view that is not shared by any of the Norwegian geologists who in more recent times have studied these mountain prob-

FIG. 7.

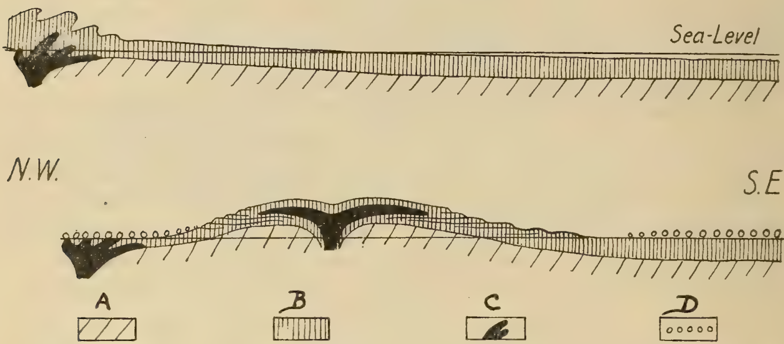


FIG. 7.—Two highly generalized sections illustrating the wandering of the deformative processes in early Silurian time in the region of present southern Norway. A third section would show a folding also of the Downtonian (and older beds) to the east, this folding gradually dying out in that direction. Denudation during the upheavals not taken into consideration. A, pre-Cambrian, B, Cambro-Silurian marine strata; C, intrusions; D, Downtonian continental strata.

lems. In fact, many Swedish geologists have more recently also abandoned Törnebohm's theory, at any rate in its extreme form. The gneissic masses mentioned are in general to be considered as highly pressed *younger intrusive* masses, and of different kinds, which during the deformation of the crust broke forth and moved under enormous pressure from the central belt outwards (see fig. 7). In this connection, attention should also be directed to the island district of Lofoten in northern Norway, which has in recent publications by foreigners been pointed out as an Archean area, and corresponding to that of the Hebrides, etc., but which must be regarded as Caledonian intrusive masses.

The Caledonian intrusions of Spitzbergen have also been of gigantic dimensions. Here the northwestern corner, previously thought to be an Archean district, proved to consist of younger material. If the regions farther east on the north coast (in West Spitzbergen and in Northeast Land), also previously thought to be Archean, are found upon further investigation to contain Caledonian igneous masses, the zone containing Caledonian intrusives here in the far north will be found to be exceedingly wide, about 350 km., in a west-east direction. However, the zone containing corresponding igneous masses in districts of Norway is also very wide, 200 km.

FIG. 8.

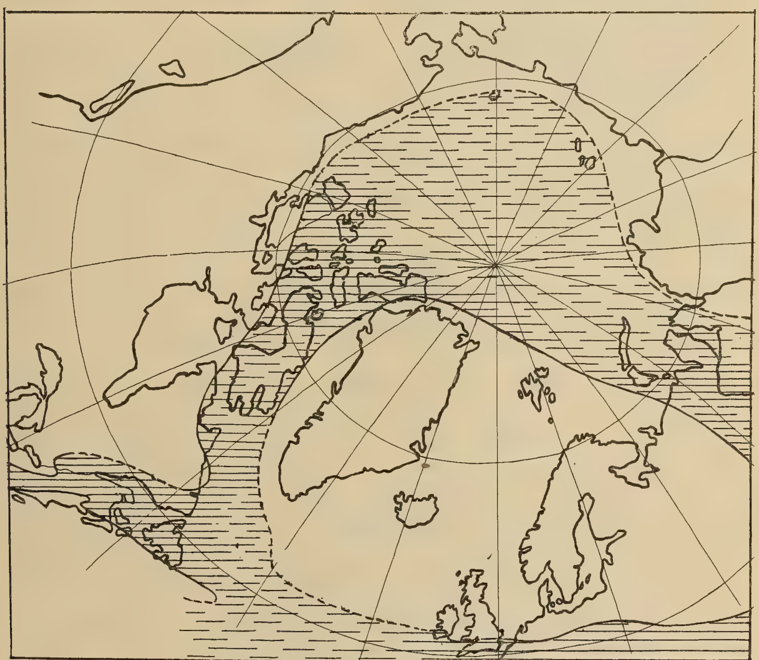


FIG. 8.—Early Lower Devonian.

Devonian Time (see figs. 8 and 9).—While in Britain, Norway, and Spitzbergen no true folding, though much faulting, took place in Devonian time, we have recently learned from another far northern district that strata of this time were folded. K. Rasmussen and L. Koch, in a short preliminary report, have determined the age of Feilden's Cape Rawson beds of northern Greenland and Grinnell Land to be of the same time as Schei's series C of Ellesmereland. This series comes in between the lower division, B, which according to the present author is considered contemporaneous with the Keyser of the Appalachian valley, and D of Lower Helderberg time. Furthermore, as the very distinctly folded Cape Rawson beds are, according to Feilden's observations, unconformably overlaid by later Devonian beds, the two Danish explorers seem justified in regarding the folding in the far north of Greenland—the strike is here southwest-northeast—as a continuation of the Caledonian deformation of Spitzbergen and Europe. As the folding in Spitzbergen occurred in pre-Downtonian time, that of Greenland must be regarded as a delayed Caledonian movement.

I will not describe the younger Paleozoic history of the region under consideration further than to say that for a very long time the existence of the large North Atlantic continent was a prominent geographic feature. Even though this continent appears to have been a rather constant geographic element, yet it was certainly far from being a quiet and stable one. This unrest is seen in the Devonian sediments in the districts bordering the Norwegian Sea, for the Skandik of De Geer tell of enormous deposition of terrigenous material. This immense denudation must have come from a highland district now covered by the sea, and the materials indicate a constant rejuvenation of a land (through isostatic adjustment?) by upheaval, through faulting. Also in several of the present land areas which were once parts of the North Atlantic land, as in Scotland, Norway, and Spitzbergen, faulting is a common phenomenon of Devonian time, and in the two first mentioned countries it is locally connected with volcanic activity. Of especial interest is the volcanic activity of the Kristiania region, probably belonging to very early Devonian time and not to Carboniferous time as stated in text-books, because we find here in a small district an astonishing variety of rocks, abyssal and volcanic, which have gained a world-wide reputation among petrologists.

The shore-line of the Devonian continent was moved very considerably to the northwest both on the southeastern and the northwestern side, from Lower to Upper Devonian time. This movement on the American side is very distinct in Ellesmereland, where the lower and middle part of the Devonian period is represented by richly fossiliferous marine beds, the Upper Devonian by

Fig. 9.

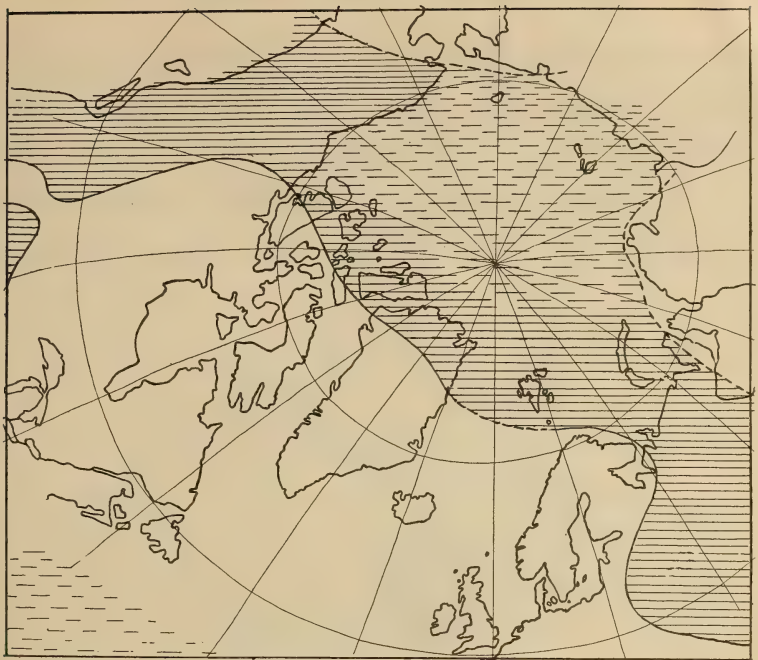


Fig. 9.—Upper Devonian, middle part.

Fig. 10.

Fig. 10.—Early Lower Carboniferous or Mississippian.

continental ones. The conditions in Baffin Land are less certain, but even here it seems natural to assume for Lower Devonian time a water-way connecting the Ellesmereland region with the eastern part of the continent of North America. The Helderbergian faunas of the two districts are indeed so similar that an open oceanic connection must have existed.

Carboniferous (with Permian) Time (see figs. 10 and

Fig. 11.

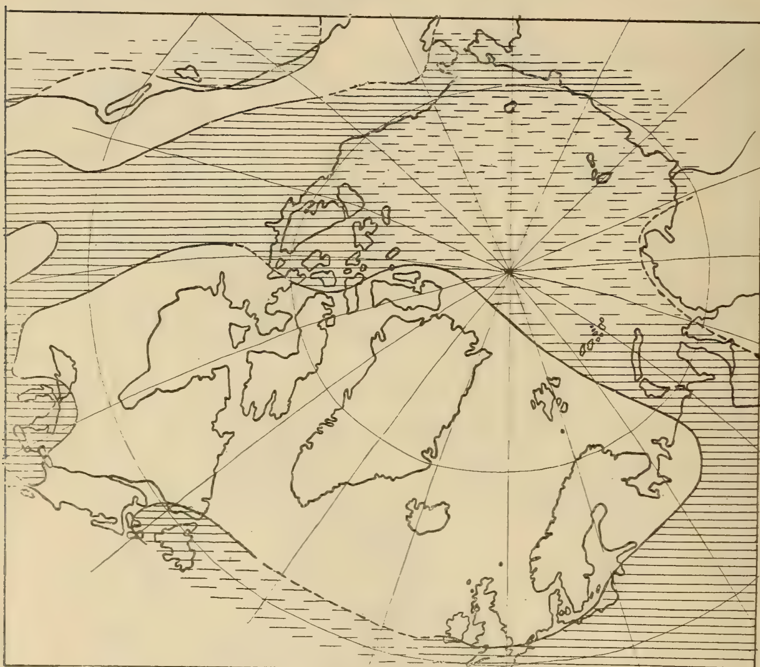


Fig. 11.—Early Upper Carboniferous or Pennsylvanian.

11).—The very large North Atlantic continent, including North America (=Eria of Dawson), is the dominating feature of this time, and a mighty faulting still continues which is most distinct in Bear Island and Spitzbergen. In the latter district, the marine Carboniferous in some places rests on the continental Lower Carboniferous, which may be more than 1000 m. in thickness; in other places this division has been totally denuded and the marine beds then lie on the Devonian. In Bear Island there have been several periods of local uplift and strong denudation during Carboniferous time.

The invasion of the Arctic sea southward on the peneplained northern coastal district of the large continent of Eria took place in Middle Carboniferous time, or, according to the Russian stratigraphic standard, in the Moscovian. In Spitzbergen, only a few meters of conglomerate separate the invading base from the higher limestones where the reef-building corals are a dominant element, while in the southern island the limestone deposition is preceded by a very considerable thickness of sometimes rather coarse conglomeratic beds.

It is a fact of considerable interest that the invasion of the sea in the north must have been more or less contemporaneous with the important regression in the south. This is but another indication of the wave-like movement of the large positive area of the crust, mentioned here as the North Atlantic continent.

We shall not here treat of the great orogenic movements of Carboniferous (Mississippian-Pennsylvanian) time occurring in areas partly represented in the maps (some of these movements are, however, noted in the accompanying table), nor shall we deal with the geographical conditions of Permian time, as we know very little about this chapter of geological history as far as the Arctic regions are concerned.

Discussion of the Diastrophism and the Geosynclines.

For American geologists, the *older* Paleozoic history of the region that has been especially treated on the preceding pages, that is, northwestern Europe with the Arctic districts farther north, may be of considerable interest, as we are in fact dealing with parts of the earth's surface that geologically may be designated as a direct continuation of the eastern part of their continent. By the demonstration of the American character of the sediments deposited in the greater part of the extensive and now folded northwest European geosyncline which extends beyond Spitzbergen and thence into Arctic North America, and of the probable existence of a barrier, on the southeastern side of which were, at one time, deposited the same types of sediments and fossils as occur in the Acadian area of North America, we see repeated

TABLE OF PRE-CARBONIFEROUS DEFORMATIONS IN APPALACHIAN-N.W. EUROPÊAN GEOSYNCLINAL BELT.

		N. Appalachian geosyncline	British Isles	Southern Norway: Trondhjem district	Southern Norway: Kristiania district	Northern Norway Finmarken	Spitzbergen
Devonian	Up.	Shickshockian (Acadian) disturbance; Volcanism	Faulting and local volcanism at different times	Probable faulting at different times	?	?	Faulting at different times
	Mid.						
	Low.				Faulting. Intrusions, volcanism		
Silurian	Up.		Caledonian deformation	Caledonian def. Intrusions	Caledonian def. (not of pre-Cambrian floor)	Caledonian def. Intrusions	Caledonian def. Intrusions
	Mid.						
	Low.						
Ordovician	Up.	Taconic disturbance	Considerable upheaval in large areas	Volcanism Local denudation	Local upheaval	?	?
	Mid.		Volcanism; Strong local upheaval in Scotland	Upheaval, intrusions, deep denudation (Trondhjem disturbance)		?Folding (in N.W.) Upheaval	
	Low.		Local upheaval (N.W. Wales)	Volcanism	Slight local upheaval	Volcanism (Raipas)	
Cambrian	Up.					Rising of a vast northern land	

some of the chief characteristics of the northern part of the Appalachian geosyncline. If we assume a curving for the geosyncline to the south of Eria similar to that of the northern one crossing from Europe to Arctic America, we find curving troughs around the greater portion of this old land.

On a preceding page I have shown in tabular form the more important orogenic movements occurring in pre-Carboniferous Paleozoic time in this Appalachian-northwest European-Arctic geosynclinal belt, the more gentle warpings that have caused no unconformity not being taken into consideration.

The occurrence of a period of folding in northern Greenland at a somewhat later time than that of the Caledonian deformation of Europe seems strongly to support the supposition that the late Devonian movements in the northern part of the Appalachian geosyncline may well be looked upon as a delayed Caledonian deformation. With the older and very marked diastrophic movement in the Appalachian field, the late Ordovician "Taconic" disturbance, there certainly took place great contemporary warpings in Europe. Here, however, we have still older deformations of Middle Ordovician time that appear to be of wide occurrence. This would mean, then, that these pre-Silurian movements of Paleozoic time also began at a somewhat earlier date on the European side than on the American. Furthermore, the fact that volcanic activity, partly on a very large scale, has occurred at least twice in western Norway during the Ordovician, and in the British Isles at various places practically throughout the same period, strongly indicates that the British-Norwegian part of the geosyncline was the central, originating region of the old Paleozoic crust movements. These movements spread gradually to the southwest and as well to the north, finally vanishing in the extreme end of the trough. Other deformative features, however, such as the appearance and disappearance of the separating longitudinal barriers, seem to be somewhat parallel phenomena.

In this connection, it is a fact of further interest that the pre-Carboniferous deformations on the American side were especially well marked in the region *nearest Europe*, i. e., in the northeastern part of the Appalachian geosyncline. Moreover, this early and intense diastro-

FIG. 12.

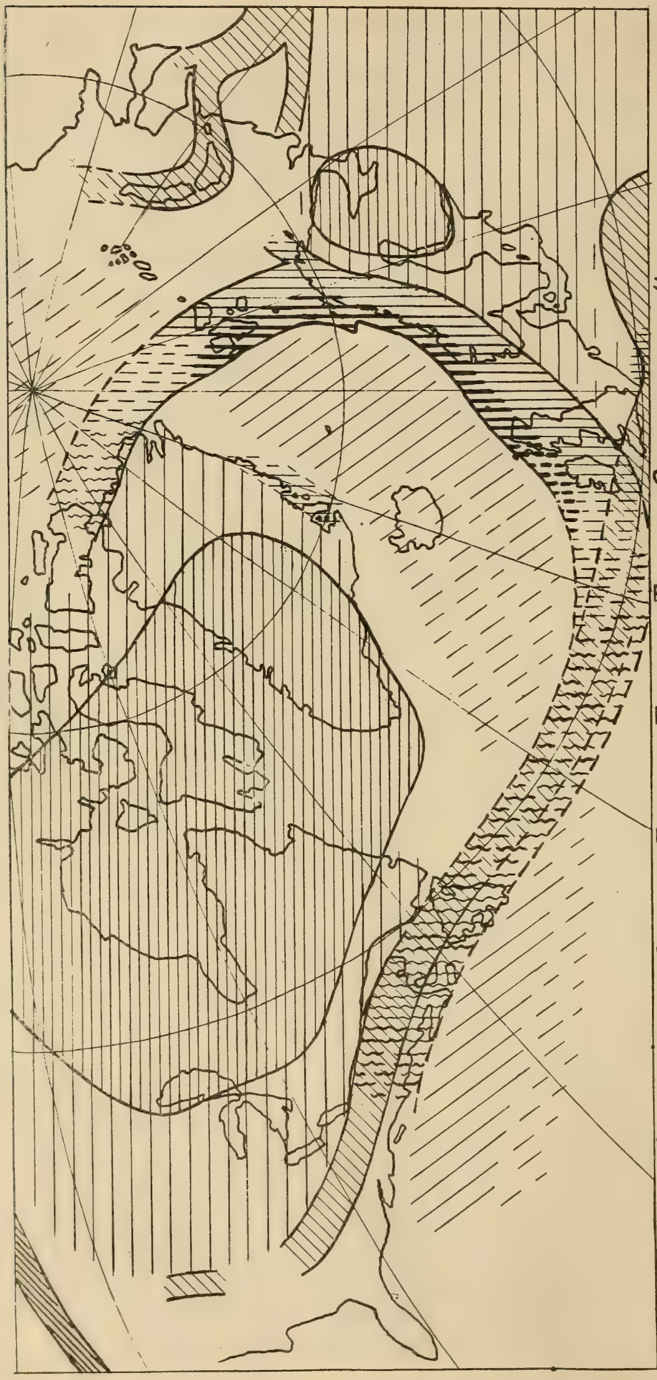


FIG. 12.—The structural elements of the North Atlantic—Arctic regions. A and B, the stable areas: A, the shields or positive areas; B, the neutral areas. C to G, the post-Ordovician zones of folding: C, pre-Downtonian time; D, pre-Devonian time; E, Devonian; F, Late Paleozoic; G, post-Paleozoic. H, areas of postulated greatest vertical movement.

phism on the European side is of course a phenomenon that must be considered in our explanation of why the European part of the belt lost its geosynclinal character so much earlier than did the American.

The axis of Caledonian folding in eastern Finmarken, northern Norway, has a rather easterly direction, that is, northeast, or even still more toward the east. On the other hand, when we note that the direction of the axis in Spitzbergen is south-southeast and parallel with the west coast, and that the same direction prevails also in Bear Island, it seems to be necessary to assume that we have in northern Norway the proximal end of an *eastern branch* of the Caledonian zone of deformation. This must not be mistaken for the slight west-east or west-northwest – east-southeast folding of eastern Finmarken which has been thought by some authors to indicate a *younge*r system of folds, and regarded as the continuation of the late Paleozoic Timan chain of North Russia. This idea of a time of younger folding has not been confirmed by the recent investigations of the author. The very slight west-east running folds exist only close to the southern margin of the sedimentary region of Finmarken, a region bordered by a once relatively steep wall of Archean rocks occurring to the south of the Varanger fault. It was against this wall that the Caledonian folds, like waves meeting the shore, had to take an easterly direction, even if the normal direction of the folds, as seen on the north coast of the Varanger Peninsula, was northeast.

Even if these northeasterly striking folds cannot, without a good deal of curving, be made to meet those of the Timan ranges, they are nevertheless a feature of interest. When compared with the geological structure of North America, such a branch, pointing toward a region of younger folds—Ural-Nova Zembla—might be regarded, together with the Timan, as a structural parallel to the Quachita range of America, representing in a way a connecting belt between an older and a younger folding zone, the Appalachian-Cordilleran folds.

If we thus take into consideration, not so much the absolute as the relative age of the folded zones, we see a quite remarkable likeness between the geologic structure of northern Europe and that of the North American continent. When we consider especially eastern North America and northwestern Europe, the likeness is exceedingly great, except that the arrangement of the different elements is reversed. First, we have the two well-known shields, which Suess pointed out as decided geological elements. Between the "positive" Canadian mass and the Appalachian geosyncline comes a "neutral" area, belonging to the rigid part of the continent but differing from the shield in having a cover of sedimentary rocks that tells of an average low level in regard to the sea. A similar "neutral" area exists on the European side, where Sweden and the southeastern part of Norway belong to it. It must be borne in mind that, even though folding occurs far to the east in the Scandinavian Peninsula, and in the greater part of the Kristiania region, the real zone of deformation is limited to a narrower and more western belt. The folding to the east has not affected the basal pre-Cambrian floor; the folding of the sedimentary beds above the older floor is therefore of a secondary character, caused indirectly, so to speak, by the deformative processes (especially thrusting) that took place in the more central (northwestern) zone. This distinction between zones of only indirect deformation, where the basal rock floor has been left undeformed, and the true zone of deep-ranging deformation, is certainly a point of great importance, and one often neglected in the discussion of the nature of the deformations of folding ranges. In the Scandinavian Peninsula, with its highly elevated, and in large areas uncovered, pre-Cambrian floor, there is a singular opportunity of studying the deformation of the more compact part of the crust.

Crossing over, then, to the next element which has already been considered, the geosyncline itself, in America we reach the ancient land of Appalachia (and Acadia), a region of uncertain width. A dominant character of this land (or lands) bordering the geosyncline to the east must be the power of rejuvenation, since it is thought to have been the source of the huge masses of sediments deposited through a number of geological periods. This, as we have indicated, was also a characteristic feature of the Paleozoic land west of the northwest European-Arctic geosyncline, a land that is the *natural parallel to that of Appalachia.* The rising of the northern land became especially effective in the later part of Silurian time, probably preceding and in part contemporaneous with the folding of the districts now bordering the Norwegian Sea. In the more southern American region we have an especially strong *rising* movement of the corresponding land-mass in younger Devonian time, which was here one of folding. Here is indeed a similarity that may have a wide bearing on our views as to the nature of diastrophism.

Most American geologists believe in a rather high degree of permanency of the great features of the earth-relief. The old land of Appalachia is therefore generally thought to be a relatively narrow one, and the geosyncline to be an unstable belt near the border of the continent—near the deep oceanic basin. This view is thus the opposite of that of Haug, who holds that the geosynclines in general have been originally bordered by two continental masses. With the knowledge that may be gained from the studies of the region considered in this article, the view as to the northwest European geosyncline must be that it is bordered on one side by a stable continental element (as shown on Haug's well-known structural map of Europe), on the other by a large area of the crust which through long geologic periods had the tendency to rise. Furthermore, we see how this same area, like the eastern part of Appalachia, has sunk deeply, and at the present time very considerable oceanic deeps exist in it. In the light of the entire geologic history, this area, if given a designation, might be called the *element of greatest vertical movement.*

It certainly will be hopeless for the advocates of permanency of the oceanic basins to apply the theory to the Norwegian Sea. In places, *e. g.,* at Spitzbergen, the shelf, as is shown in Nansen's map, is very narrow, and great depths are found not far to the west of the place where the huge continental sandstones of Devonian time—many thousand feet in thickness—are still to be seen. Land must have existed where there is now deep sea. A consequence of this view is that the greater density of the sub-oceanic crust areas must be regarded as due to secondary processes during and after the subsidence.

Our interpretation of the nature of the areas lying outside the geosynclines naturally influences in the most definite way our view as to the nature and causes of the crust movements met with in the geosynclinal belts. Willis's theory of the "sub-oceanic spread," applied to the Appalachian zone of deformation and illustrated by Ulrich in his "Revision," p. 439, has as a requirement a bordering deep oceanic basin. The planes of fracture and thrust must, as a consequence of the pressure from a deep-seated mass, be directed obliquely upward. Comparing with this view the well-known geologic structure of northwestern Scotland, where the thrust planes are directed obliquely downward, toward the southeast, we meet here exactly the opposite condition; hence a pressure from the side of the present ocean (we have then to assume what seems very probable, an underthrust and not an overthrust movement) can in this case hardly be thought to have come from the deep.

It is in the nature of the region under consideration that the movements of the shore-line are of quite another character than those of the North American continent, a part of the crust that, with the exception of the bordering belts, has behaved like a rather compact mass, the surface of which was subjected only to warpings of no very great importance. The continent has thus behaved in a certain passive way, the moving of the shore-line, as assumed by American paleogeographers, being caused by movements chiefly *outside* the present continent, especially by the more or less periodic vertical movements of the bottom of the surrounding ocean basins. In the region here treated, the movement of the shore-line is for large areas chiefly due to an active movement of the crust *in these areas themselves.* It is the uplift in the region itself that causes the emergence, not a movement in a far-away ocean basin. The effect of these latter movements is generally only of secondary importance. From the fact, then, that the crustal movements to a great degree occur at different times in different places, it will be understood how difficult or rather impossible it will be to apply in a satisfactory manner to northwestern Europe and the Arctic regions farther to the north the method natural for North America of delimiting the geological epochs and periods according to the history of transgressions and regressions. A crust movement that may in one district cause transgression, in another causes regression, while in a third, conditions are practically unaltered. Even for the relatively stable areas of northwestern Europe, the transgressions and regressions seem to appear in totally different ways in the different areas. As middle and younger Cambrian times are characterized by a vast transgression on the American continent, both in the south and in the far north, the Lower Cambrian sea was laid dry in the Baltic area in Middle and Upper Cambrian time. Judging from the Scandinavian-Baltic area, it seems that the supposition of Haug, that a regression in the geosyncline generally corresponds with a transgression in the areas outside of the geosyncline, agrees well with the actual conditions, at least so far as the area east of the geosyncline is concerned. This is, in fact, a necessary conclusion to which the present author has been led through summarizing the geographic features of the northern regions during Paleozoic time: that often we note a *wave-like motion* of the elevated portions of the crust within the region. This elevation and sinking may, on the one hand, be due to purely vertical movements, as appears to be true in the case of the wandering of the shore-lines of the large northern continent in Devonian and Carboniferous time, and on the other be connected with folding, as in younger Silurian time in the region of present southern Norway and Scotland.

As to the possible causes of such movements, they do not seem to be easily explained by the theory of contraction in its more simple form. If the deformed belts represent zones of relative "weakness," in the sense that they offer little resistance to tangential pressure caused by a shrinking globe, we should rather expect the deformation to be continually acting in precisely the same zone in which deformation was initiated. The wave-like motion mentioned certainly suggests another explanation that has been given concerning the cause of crust deformations, namely, that they are due to movements of the masses below the crust, magmatic flow in a horizontal direction, as suggested by Amferer and others. This horizontal flow might be a consequence of vertical ones, the possible occurrence of which and the importance of which were pointed out by Fisher in this Journal in 1906. Certainly this possibility of underflow (*Unterströmung*) as a cause of deformation in the crust must be taken into consideration when discussing the problems as to the nature of these movements. I might here also recall Daly's theory of intrusions in the deeper part of the crust as a cause of deformations in the uppermost part, the only one that we can study.

Taking the deformation zone of Norway, for example, where, as has been emphasized, a fairly deeply situated part of the crust may be studied, the amount of intruded material is so enormous that it does not at all seem unreasonable to consider these masses as having played a more important rôle than that of a passive element only, for which the way was opened from the abyss to higher zones by the deformation. That intruded masses are not known from all folded ranges may not necessarily mean that they do not occur at greater and inaccessible depths.

Yet if we consider how, as becomes more and more evident, orogenic movements, speaking generally, occur again and again in the same main belts of the earth, it is difficult to understand how this may be explained by the theory of magmatic flow only.

Even if we do not at present understand why these belts are the ones especially subjected to folding, or why the geosynclines come into existence just here, the repeated movement in these zones, with periods of quiet between, seems without doubt to harmonize with the old theory of contraction. If we apply the theory of underflow, we must have a more *primary* condition explaining the remarkable location of the orogenic movements. Certainly the occurrence of the orogenic zones along the ocean borders is a fact of fundamental importance, as has been pointed out by Andrée (Ueber die Bedingungen der Gebirgsbildung, Berlin, 1914, pp. 60-61), and A. Wegener[3] supposes the shelves to be belts of weakness because the salic zone here is thought to be relatively thin, and further, because the difference in density between adjacent areas, oceanic (simic) and continental (salic), is rather important. Yet as has been previously emphasized, the northwest European geosyncline was

[3] I shall not enter here into any discussion of the very daring—in my opinion far too daring—hypothesis of Wegener (Die Entstehung der Kontinente und Ozeane, Braunschweig, 1915), according to which the separation of America and Europe was caused by a horizontal movement of the upper or salic zone of the crust, a movement that, so far as the northern part of the Atlantic area is concerned, is supposed to have taken place in Quaternary time. Far from being more easily explained in the light of this hypothesis (which postulates the existence of a coherent continental mass embracing both the new and the old world, with no Atlantic "fissure," in pre-Cenozoic time!), several of the facts mentioned in the preceding pages do not at all harmonize with it.

not *at the time of the Caledonian deformation* situated at the border of a deep ocean, but at that of a land-mass, and the folded zone thus did not have the characters of a shelf.

If, however, in the light of the previous discussion, we consider this land area, like that of Appalachia, as an especially unstable one, we might, *through vertical movements here,* get conditions favoring a magmatic underflow in the bordering (geosynclinal) zone, this underflow causing folding of the crust. This bordering zone between the unstable area and the stable continental one would naturally be one of large sedimentation, the latter being especially great when the unstable area was highly elevated. Through isostatic adjustment, this accumulation of sediments might cause a continual sinking of the crust, and we would thus have here the characteristic features of a geosyncline. The primary process of crust movement in the geosynclinal belts would, according to the above view, be the vertical movements of the unstable, now oceanic areas, which movements then in turn have to be explained.

I shall not go further into these theoretical speculations, which are a natural consequence of the present paleogeographic study. I hope it will be understood that the northern region especially considered in this article, though having no youthful mountain ranges and though hiding much of its ancient geography behind the impenetrable veil of highly metamorphic rocks and under the cover of the sea, may yet, through constant and detailed work, contribute in considerable degree to the knowledge of paleogeography and the nature of diastrophism.

Kristiania, Norway, May, 1919.

ART. II.—*The Generic Relations of the American Ordovician Lichadidæ;* by AUG. F. FOERSTE. With Plates I to IV.

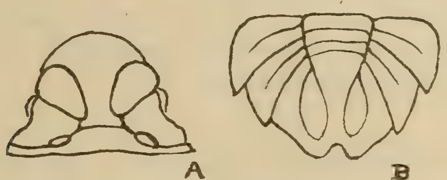
1. *Two prevalent types of glabellæ among European Ordovician Lichads.*

The glabellæ of most European Ordovician Lichads have one of two types of structure. In one of these types, the posterior margin of the anterior pair of lateral glabellar lobes frequently is more or less indistinctly limited from the second pair, the second pair of lobes usually is indistinctly differentiated from the median part of the glabella, and the posterior pair of lobes, even when of small size, is distinctly defined (Plate III, figs. 7A, 8A; plate IV, figs. 1, 4A, 5A, 6A). In the other type, the anterior and second pairs of lobes, on each side of the glabella, have coalesced into a single oblong lobe, posterior to which is the posterior pair of lobes, usually of small size (Plate IV, figs. 7A, 8A, 9A, 10A). The presence of the posterior pair of lateral glabellar lobes is common to both types of structure. In a third, but much rarer type, all of the lateral lobes of the glabella have coalesced into a single pair of side lobes (Plate IV, fig. 11 B).

2. *American species doubtfully referred to the European genera Platylichas and Hoplolichas.*

In American Ordovician Lichads, posterior lateral glabellar lobes are found only in a single described species, namely *Lichas halli* Foerste (Plate II, figs. 8A, B), from the Corryville member of the Maysville formation, at Cincinnati, Ohio. This species appears most nearly related to *Lichas margaritifer Nieszkowski* (Text figs. A, B), from the Borkholm limestone of the East Baltic areas. The latter species is the genotype of *Platylichas,* proposed by Gürich in 1901. The pygidia of both species are closely similar. The important differences are found in the lobation of the glabella. In typical *Platylichas* the posterior pair of lateral glabellar lobes is not in contact with the anterior pair, and it seems necessary to regard the intervening area as consisting of the second pair of lobes, although the latter are not differentiated from the free cheeks. In the Corryville species, on the contrary, the posterior pair of glabellar lobes is distinctly larger, and is in direct contact with an anterior pair, departing in this respect from the generic type of *Platylichas*. The reference of *Lichas halli* to *Platylichas* therefore is founded on resemblance rather than on strict agreement in structure with the European type.

The pygidium figured by the writer from the Whitewater member of the Richmond, at Richmond, Indiana (Jour. Cincinnati Soc. Nat. Hist., **22**, pl. 1, fig. 2, 1917; also Plate II, fig. 10 in present paper), resembles that of *Lichas halli* in the presence of free tips on all the ribs, and of a diagonal furrow on each of the posterior ribs; moreover, the axial lobe narrows and widens again posteriorly. Provisionally this pygidium may be referred



Platylichas margaritifer Nieszkowski. Genotype.

to the same genus as *Lichas halli*, under the name *Platylichas* (?) *miseneri* Nov. sp. In the absence of the cranidium, however, the reference of this pygidium to *Platylichas* is necessarily more uncertain than that of *Lichas halli*, of which the entire structure is known.

A remarkable pygidium found in the Kimmswick limestone at Cape Girardeau, Missouri, Pl. II, fig. 9, has free tips at the ends of all of the ribs, the posterior pair of ribs is not crossed by a diagonal furrow, and the furrow limiting the posterior margin of the second axial ring dies out before reaching the dorsal furrows outlining the sides of the axial lobe. All of these characteristics are found also in all species of *Acrolichas*. But the axial lobe of the Cape Girardeau specimen does not narrow to a point posteriorly, as in *Acrolichas*; on the contrary, it narrows very rapidly at about mid-length and then expands slightly at about one-third of the length of the pygidium from its posterior end. Among European Lichadidæ, the Cape Girardeau specimen resembles the pygidium of *Hoplolichas tricuspidatus* Beyrich, Pl. IV, fig. 7B, in the absence of the diagonal furrow on the posterior pair of ribs and in the slight expansion of the posterior part of the axial lobe. However, the disappearance laterally of the ends of the furrow limiting the posterior margin of the second axial ring is a feature not known in *Hoplolichas,* and, in the absence of any knowledge of the cranidium of the Cape Girardeau specimen, it seems very doubtful whether the latter is a genuine species of *Hoplolichas.* Under these circumstances the Cape Girardeau specimen is regarded provisionally as an aberrant form of *Acrolichas cucullus* (Meek and Worthen), with which it is associated stratigraphically. It forms number 10771 in the Walker Museum, at Chicago University. The writer is greatly indebted to Prof. A. D. Hole of Earlham College, at Richmond, Indiana, for the privilege of using this and other specimens from the museum of Chicago University, since these specimens form part of the material discussed in his paper on American Ordovician Lichadidæ of the Mississippi Valley, still unpublished.

3. *American species definitely referred to the European genus Hemiarges.*

Another genus found in the Ordovician formations of both Europe and America is *Hemiarges,* proposed by Gürich in 1901, with *Lichas wesenbergensis* Schmidt as the genotype. This genus, however, belongs to an entirely different division of the Lichadidæ from that of any of the forms discussed in the preceding lines, the difference in structure being most marked in case of the pygidium. *Corydocephalus* belongs to the same subdivision as *Hemiarges* but is not identical generically. In *Corydocephalus* the second pair of lateral glabellar lobes is prominent and rises to the same level as the median lobe; the anterior pair of lobes is distinctly less prominent than the second pair and is depressed in the space between the second pair and the frontal extension of the median lobe; the third or posterior pair of lobes is small but is readily recognizable. In *Hemiarges,* on the contrary, the anterior pair of lobes is the more prominent pair; both the second and posterior pairs are much smaller and usually are weakly defined; the second pair, in fact, usually can not be differentiated distinctly from the other two. This produces a type of cranidium distinct from that of *Corydocephalus*. In America, *Hemiarges* is represented by *Lichas* (*Arges*) *wesenbergensis paulianus* Clarke (Geol. Minnesota, 3, pt. 2, 1894, p. 744, figs. 62-64; see also Pl. II, figs 6A-C, in present paper) from the Prosser limestone of Minnesota; *Arges tuberculatus* Weller (Geol. Surv. New Jersey, Pal. 3, p. 199, pl. 15, figs. 11-13, 1903) from the Trenton of New Jersey; and an undescribed species from the Kimmswick of Missouri. *Hemiarges wesenbergensis* occurs in the Wesenberg formation of the East Baltic provinces, a horizon corresponding approximately to the upper Trenton of America.

4. *Acrolichas proposed for twelve American and one Irish species.*

All other described species of American Ordovician Lichads, not mentioned in the preceding lines, belong to a recently named genus for which the name *Acrolichas* was proposed, with *Lichas cucullus* Meek and Worthen as the genotype. This genus possesses the following characteristics:

The glabella is three-lobed, with one median and two apparently simple side lobes. These side lobes have resulted from the coalescence of the first, second, and third pairs of lateral glabellar lobes, as seen in other Lichadidæ. Posteriorly, the median lobe is nearly rectangular or widens slightly; anteriorly, the lobe widens rapidly so that the width of the frontal part frequently is double that of the posterior end. The side lobes are reniform in outline, the convex side adjoining the middle and posterior part of the median lobe. Posteriorly, these lateral lobes border for their entire width on the occipital furrow. The occipital ring extends for a short distance beyond the posterior lateral extremity of the side lobes of the glabella. Anterior to the glabella the cranidium presents a very narrow border, frequently not exceeding half a millimeter in length in specimens of average size.

The axial lobe of the pygidium narrows posteriorly to a point which reaches the notch separating the free tips of the two posterior ribs. Usually there are only two annulations on the axial lobe, and the lateral ends of that furrow which limits the posterior margin of the second annulation usually terminates before reaching the dorsal furrows. There are three pairs of lateral ribs, all with free tips. Each of the anterior pair of ribs is traversed by a diagonal furrow starting near the anterior margin of the rib. The diagonal furrow on each of the second pair of ribs starts farther back from the anterior margin of this rib. The third or posterior pair of ribs is without any distinct trace of a diagonal furrow, the latter evidently having become obsolete in this generic group of species. (Ohio Journal of Science, **19**, p. 402, 1919; Bull. Denison Univ., **19**, p. 72, 1919, pl. 17, figs. 4 A, B.)

The following seven species (one of which is from Ireland), known both from their cranidia and from their pygidia, evidently belong to *Acrolichas*. (For bibliographic references see Bassler's Bibliographic Index of American Ordovician and Silurian Fossils, 1915.)

Lichas minganensis Billings, Pl. III, figs. I A, B, C, from the Chazyan of eastern Canada, Vermont, New York, and Virginia.

Lichas cucullus Meek and Worthen, Pl. I, figs. 1 A-G, from the Kimmswick, Prosser, and Trenton of Missouri, Illinois, Wiconsin, Minnesota, and in the Lake Winnipeg and Ottawa areas of Canada. Also from the Richmond of northern Michigan.

Lichas trentonensis (Conrad), Pl. I, figs. 3 A, B; Pl. III, figs. 4 A-D, from the Trenton of Pennsylvania, New Jersey, and New York. (Not identified with certainty from Canada or Missouri.)

Lichas (*Conolichas*) *cornutus* Clarke, Pl. I, fig. 5; Pl. III, figs. 5 A-C, from the Trenton of New York.

Amphilichas conifrons Ruedemann, Pl. I, figs. 4 A-C (Bull. New York State Mus., No. 189, p. 90, Pl. 30, figs. 5-8), from the Trenton of New York.

Lichas harrisi Miller, Pl. III, figs. 6 A-C, from the Liberty member of the Richmond, in Ohio.

Lichas hibernicus (Portlock), Pl. III, figs. 9 A, B (Geol. of Londonderry, Tyrone, and Fermanagh, 1843, p. 274, Pls. IV and V), from the Llandeilo of Ireland.

To this list probably should be added the following five species, known only from their cranidia:

Lichas jukesii Billings, Pl. II, figs. 1 A, B, from the Chazyan of eastern Canada.

Lichas (*Hoplolichas*) *robbinsi* Ulrich, Pl. II, fig. 2, from the Prosser of Minnesota.

Lichas (Hoplolichas) bicornis Ulrich, Pl. II, fig. 3, from the Maquoketa of Minnesota.

Amphilichas clermontensis Slocom, Pl. II, fig. 7, from the Maquoketa of Iowa.

Amphilichas rhinoceras Slocom, Pl. II, fig. 4, from the Maquoketa of Iowa.

Finally, there is added the following new species, *Acrolichas narrawayi,* known only from the pygidium; the addition of this species brings the total described forms of *Acrolichas* up to thirteen.

Acrolichas narrawayi nov. sp.; pygidium with a narrow notch between the free tips of the posterior pair of ribs; the free tips of all ribs are rounded, especially in case of the posterior pair; furrow limiting posterior margin of second axial ring not very distinctly defined. From a quarry at Wright's or St. Clovis' dam, near Hull, opposite Ottawa, Canada; in the collection of James E. Narraway, at Ottawa.

5. *The area of origin of Acrolichas.*

Surely there must be some significance in the fact that twelve species of *Acrolichas* are known from northern America and only one species from Europe, the European form occurring only in Ireland. While the center of origin of the Lichadidæ may have been somewhere near the Baltic areas of northern Europe, judging from the relative number of generic types found there in early Ordovician strata, the center of origin of the American genus *Acrolichas* must have been nearer the North American continent. The number of American species of *Acrolichas* is greater than the twelve here listed. When the forms at present included under *Lichas minganensis, Lichas cucullus,* and *Lichas harrisi* are more closely discriminated, at least five additional species will become known. The Irish species, *Lichas hibernicus,* probably represents some migrant from American waters. Even Murchison noted that certain American genera reached Ireland in Llandeilo times without extending their geographical range as far as the European continent. In the same manner, *Acrolichas,* although occurring in Ireland, is not known on the continent of Europe itself, unless some Baltic forms, at present referred to *Amphilichas,* eventually should prove to be typical forms of *Acrolichas.*

6. *American species of Acrolichas formerly were referred to the European genus Amphilichas.*

The cranidium of *Acrolichas* practically is identical in structure with that of *Amphilichas,* a genus of Lichads from the Baltic areas. For this reason Raymond provisionally referred *Lichas minganensis* to his genus *Amphilichas,* and Slocom later placed both *Amphilichas clermontensis* and *Amphilichas rhinoceras* in that genus. Recently Bassler, in his Bibliographic Index, added *Lichas bicornis, L. cucullus, L. jukesii, L. robbinsi,* and *L. trentonensis* to the list of American species referred to *Amphilichas,* thus making a total of eight species then listed under *Amphilichas,* all of which here are placed under *Acrolichas.*

The name *Amphilichas* was proposed by Professor Percy E. Raymond, in 1905, for the group of species *Lichas lævis* Eichwald, *Lichas dalecarlica* Angelin, and *Lichas holmi* Schmidt, and he referred to the first of these species as the type. In 1910, Raymond compares *Lichas minganensis* Billings not with *Lichas lævis* but with *Lichas lineatus* Angelin. However, in this case the term *Lichas lineatus* refers to the same species as that described by Schmidt under *Lichas lævis,* as shown by a footnote (Ann. Carnegie Museum, vol. 7, p. 73) in which the Revision der Ostbaltischen Silurischen Trilobiten, II, 1885, pl. 6, fig. 5, 1885, by Schmidt, is cited as giving information regarding *Lichas lineatus.* This figure 5, however, consists of three views of a cephalon described by Schmidt under *Lichas lævis.* Evidently it is the East Baltic specimen (Pl. IV, fig. 11A, in the present paper), and not the Scandinavian form (Pl. IV, figs. 12A, B), which is the genotype.

In structure the cranidia of *Acrolichas* and *Amphilichas* are practically identical, offering an excellent illustration of parallelism of structures in different genera. The pygidia, on the contrary, are quite dissimilar. In the pygidia of typical *Amphilichas* the axial lobe does not narrow posteriorly to a point terminating at the notch between the free tips of the posterior pair of ribs, as in *Acrolichas.* In the pygidium associated by Schmidt with the genotype of *Amphilichas* (Pl. IV, fig. 11B, in the present paper) the axial lobe narrows posteriorly for about half the length of the pygidium and then widens again; moreover, the posterior pair of lateral ribs bears a diagonal furrow, a feature unknown in *Acrolichas*. This association of glabella and pygidium in the genotype of *Amphilichas* needs verification.

7. *The pygidia of Acrolichas compared with those of Metalichas.*

The pygidia of *Acrolichas* also offer an illustration of parallelism. Raymond, in 1910, regarded the pygidium of *Lichas minganensis* as similar to the pygidium assigned by Schmidt to *Lichas cicatricosus* (Pl. IV, fig. 4B, of present paper). *Lichas cicatricosus* Schmidt (non Loven) is the genotype of *Metalichas*, proposed by Reed, in 1902. In this East Baltic species, the axial lobe of the pygidium narrows to a point posteriorly, and the posterior pair of lateral ribs is without distinct diagonal furrows, corresponding in this respect to *Acrolichas*. As a matter of fact, the similarity is greater than Schmidt's figure would suggest, since in the accompanying text Schmidt states that there is a diagonal furrow on the second pair of ribs as well as on the first pair, although in his figure no trace of this furrow can be seen on either one of this second pair of ribs. This feature is shown better by Schmidt's figure of the pygidium of *Lichas St. Mathiæ* (Pl. IV, fig. 5B of the present paper), a species evidently congeneric with *Lichas cicatricosus*. The cranidia of *Metalichas*, however, differ greatly from those of *Acrolichas*. The anterior and posterior pairs of lateral glabellar lobes are distinctly defined, but the space which should be occupied by the second pair of lobes is not even faintly limited from the fixed cheeks.

8. *The pygidia of Acrolichas compared with those of Platopolichas.*

The pygidium of the Bohemian genus *Platopolichas*, proposed by Gürich in 1901, and including the species *Lichas avus* (Pl. III, fig. 7) and *Lichas incola* (Pl. IV, fig. 8), both described by Barrande from lower Ordovician strata, is similar to that of *Acrolichas* in having no diagonal furrow on the posterior lateral ribs, and in having the narrowing of the axial lobe continue to its end, but it differs in not having this narrowing of the axial lobe continue until the latter is reduced to a point at the notch between the tips of the posterior ribs. Instead of this, the posterior end of the axial lobe of *Platopolichas* is still wide enough to embrace the notch. The cranidia of *Platopolichas* have no resemblance to those of *Acrolichas*. The anterior lateral glabellar lobes are not differentiated from the second pair of lobes along the entire length of the intervening line, but the posterior pair of lobes is distinctly defined.

If the pygidia have not been incorrectly associated by European authors with the cranidia in their description of species, then such cases of parallelism occur also between other genera of Lichadidæ. This greatly increases the difficulty of grouping species into genera. Evidently neither the cranidia alone nor the pygidia alone form a satisfactory basis for the erection of genera. Both must be taken into account.

9. *The East Baltic genera Hoplolichas and Conolichas.*

The East Baltic Ordovician genera *Hoplolichas* and *Conolichas* are of interest because three American Lichads, here referred to *Acrolichas,* originally were referred to these East Baltic genera. Using the East Baltic generic names, the original designations of these species were *Hoplolichas robbinsi* Ulrich, *Hoplolichas bicornis* Ulrich, and *Conolichas cornutus* Clarke.

The genotype of *Hoplolichas* is *Lichas tricuspidatus* Beyrich (Pl. IV, figs. 7A, B) from the Reval formation of the East Baltic provinces, approximately equivalent to our upper Stones River strata. The posterior lateral lobes of the glabella always are distinctly defined, but the line of separation between the first and second pairs of lobes may be obsolete in some specimens. The neck ring has a long and prominent spine projecting from its posterior margin, but the presence of this spine scarcely can be regarded as a generic characteristic. The associated pygidia are imperfectly known, but it is certain that the axial lobe does not terminate posteriorly in a point reaching the notch between the tips of the posterior ribs.

The genotype of *Conolichas* is *Lichas aequilobus* Steinhardt (Pl. IV, figs. 8A, B), from the Kegel formation of the East Baltic provinces, corresponding approximately to our Trenton strata. In this genus, also, the posterior lateral glabellar lobes are distinctly defined, but the anterior and second pairs of lateral lobes have coalesced into a single pair of very prominent, bulbous lobes, between which the posterior half of the median lobe is both depressed in level and narrowed in width. The frontal half of the median lobe, moreover, rises obliquely backward into a protuberance, whose posterior side terminates abruptly at a level distinctly higher than the posterior half of the median lobe.

10. *The East Baltic genera Homolichas, Leiolichas, and Metopolichas.*

Other European Lichad genera, hitherto not mentioned, are *Homolichas,* proposed by Schmidt, with *Lichas depressus* Angelin (Pl. IV, fig. 10) as type; *Leiolichas,* also proposed by Schmidt, with *Lichas illænoideus* Nieszkowski (Pl. IV, fig. 6) as type; and *Metopolichas,* proposed by Reed, with *Lichas hübneri* Eichwald (Pl. IV, fig. 1) as type. *Lichas hübneri* is found in the Dubowiki formation, approximately corresponding to our upper Chazyan strata.

Recently it has become customary to assign to the East Baltic Ordovician genus *Metopolichas* several typically Silurian Lichads, whose pygidia are characterized by the absence of free tips on the posterior pair of ribs, the axial lobe and posterior pair of ribs being bounded posteriorly by a continuous convex margin, only the first and second pairs of ribs having short free tips. There is no evidence whatever that the genotype of *Metopolichas, Lichas hübneri* (Pl. IV, fig. 1), had pygidia of this structure. On the contrary, judging from the straightness of the posterior part of the glabellar furrows on the cranidia of *Lichas hübneri,* these cranidia have no generic relationship to those of the Silurian species in question. In the absence of any knowledge of the pygidia of *Lichas hübneri,* the choice of this species as a genotype is unfortunate. In my opinion the American species referred to *Metopolichas* belong to typical *Lichas,* with *Lichas laciniatus* Wahlenberg as genotype.

As a matter of fact, even the Ordovician Lichads of America show remarkably little relationship to those of the East Baltic provinces. *Hemiarges* is definitely known to be present in American strata. *Lichas halli* appears at least closely related to the type of *Platylichas.*

The other American species here are referred to *Acrolichas.*

11. *The Bohemian Silurian genera Corydocephalus and Dicranopeltis.*

In Silurian times the number of Lichad genera common to both America and Europe increased, and included not only the typical Baltic genus *Lichas* but also the Bohemian genera *Corydocephalus* and *Dicranopeltis.* Neither *Corydocephalus* nor *Dicranopeltis* occur in the Silurian rocks of the Baltic area so that these genera may have reached us by some more southern route. They are represented in the Saint Clair limestone of Arkansas, in the Laurel of Indiana, in the Racine of Illinois and Wisconsin, and in the Cedarville of Ohio. *Corydocephalus halli* Foerste and *Dicranopeltis nereus* (Hall) occur in the Rochester shale of New York. Judging from their earlier appearance in Arkansas, an entrance of the Bohemian genera into American waters by way of the Gulf of Mexico is at least a possibility. The type of *Dicranopeltis nereus* retains only the thorax and pygidium; the glabella figured as though belonging to this type in reality is a stray fragment of a species of *Arctinurus,* probably *A. boltoni,* lying in about the same position in which the head belonging to this type should occur. *Arctinurus,* a strictly American genus, also makes its appearance in the St. Clair limestone of Arkansas. The Baltic genus *Lichas* is represented most nearly in American strata by the Silurian species at present referred to *Metopolichas,* a genus restricted to the Central States, and making its first appearance in the Medinan.

In place of *Corydocephalus* the term *Trochurus* was employed in the Bulletin of Denison University, vol. **17**, p. 251, 1917, pl. 11, fig. 1; pl. 12, figs. 1-4.

12. *The distribution of American species of Acrolichas.*

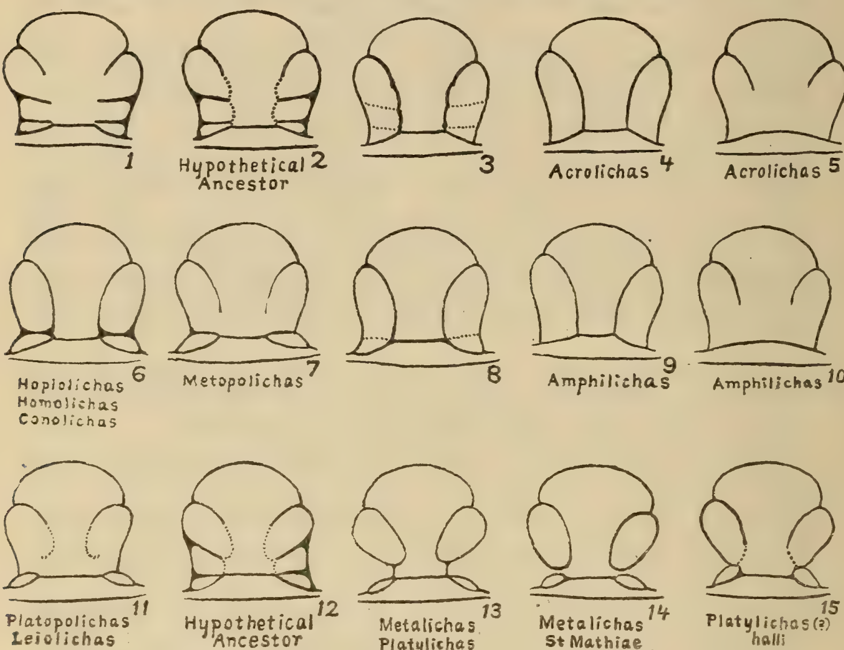
The distribution of American Ordovician Lichads is essentially a northern one. The Chazyan species, *Acrolichas minganensis,* ranges as far south as Lexington, Virginia. *Acrolichas trentonensis,* a Trenton species, is listed by Safford (Geol. Tennessee, 1869, p. 290) from the Middle Nashville. The value of this reference is destroyed by the fact that we do not know exactly what horizon here is signified by Middle Nashville. Apparently it included not only Catheys but also Leipers fossils. Ulrich, in the Columbia Folio, in 1903, lists no Trenton species, but only *Lichas halli,* from the Leipers equivalent of the Maysville formation in Central Tennessee. Since the first known specimen of *Lichas halli* Foerste was figured by Hall erroneously under *Lichas trentonensis,* there is a possibility that Safford, following Hall, had a specimen of *Lichas halli* before him when he listed *Lichas trentonensis.* No Lichadidæ have been recorded from central or southern Kentucky, although the species known from the Corryville member of the Maysville, in the Cincinnati area, including *Lichas halli,* undoubtedly occur also on the Kentucky side of the Ohio river.

In Chazyan times, *Acrolichas* is known only in the St. Lawrence and Champlain basins, extending thence southward as far as the Virginia embayment.

In late Black River, and in Trenton times, *Acrolichas trentonensis* occurs as far south as New Jersey; no species is known in these times from Ohio, Indiana, or Kentucky, and the occurrence of *Acrolichas* in Tennessee in Trenton strata may be regarded as very doubtful. In Kimmswick strata *Acrolichas* is known as far south as Alexander county, at the southern end of Illinois. Farther north, however, *Acrolichas cucullus* ranges from Illinois and Missouri to Minnesota, Wisconsin, and Lake Winnipeg, and thence eastward to the Ottawa area of Canada. *Hemiarges* in a similar manner is represented by a species in Missouri, and *Hemiarges paulianus* ranges from Minnesota as far eastward as the Ottawa area.

From the Catheys, Cynthiana, Utica, Eden, and Maysville formations *Acrolichas* is absent. When the genus reappears again in Richmond times its range again is northern. *Acrolichas harrisi* occurs in the Liberty member in Ohio and Indiana. *Acrolichas clermontensis* and *A. rhinoceras* are found in the Maquoketa of Iowa, and *Acrolichas bicornis* is found in the Maquoketa of Minnesota.

Since the genus must have been preserved somewhere in the interval between Trenton and Richmond times, the area of retreat could scarcely have been southward. Why not northward? Northward, where so often it appears difficult to discriminate between Trenton and Richmond strata. The present paucity of Trenton and Richmond strata over a large part of the northern part of the North American continent can be no index since it



Diagrams illustrating hypothetical origin of generic characteristics among Lichad glabellæ:

1. Hypothetical ancestral glabella, with lateral furrows. 2, with connecting furrows. 3, with second and third pairs of lateral furrows becoming obsolete; giving rise to 4, in Acrolichas. 6, 8, 9, similar results may be produced by the disappearance of the second pair of lateral furrows, followed later by the third pair, leading to Amphilichas. 5, 10, in both Acrolichas and Amphilichas the posterior connecting furrows may disappear. 7, 11, a similar change takes place in Metopolichas, Platopolichas, and Leiolichas. 12, 13, 14, 15, *Platylichas halli* may have been derived from typical Platylichas, 13, the chief characteristic of the genus being the disappearing of part of the dorsal furrow.

is well known that the faunas of the distant outliers so far found do not indicate faunas developed in restricted basins, but appear like parts of the much larger faunas found in larger areas of exposure elsewhere.

13. *The origin of generic types among the cranidia of the Lichadidæ.*

The glabellæ of the ancestors of the Ordovician Lichads, in conformity with that of other trilobites, must have consisted of five consolidated segments, of which the occipital ring formed the last, the three pairs of lateral glabellar lobes located the position of three additional segments, and the frontal extension of the median lobe indicated the position of the anterior segment. The lateral glabellar lobes of these hypothetical ancestors increased in size anteriorly. The glabella was limited laterally by the dorsal furrows and the lateral lobes were separated from each other by pairs of lateral glabellar furrows (fig. 1). At an early stage the inner ends of these lateral glabellar furrows must have been joined together by "connecting" furrows (fig. 2). Most of the later changes of generic value center around the second pair of lateral glabellar lobes.

In *Metalichas* and *Platylichas* (figs. 13, 14, 15) that part of the dorsal furrow which borders on the outer margin of the second pair of lobes becomes obsolete and this second pair of lobes appears to merge laterally into the fixed cheeks. In *Platopolichas* and *Leiolichas* (fig. 11) the second pair of lateral furrows and the middle pair of connecting furrows have disappeared, and in typical *Metopolichas* (fig. 7) not even a trace of these lateral furrows remains.

In several genera the first pair of lateral glabellar furrows and the succeeding pairs of connecting furrows have coalesced into a single longitudinal strongly indented furrow. In *Hoplolichas, Homolichas,* and *Conolichas* (fig. 6) this coalescence is accompanied by a disappearance of the second pair of glabellar furrows. The disappearance also of the third pair of glabellar furrows would lead to the structure found in *Amphilichas* (fig. 10). The simultaneous disappearance of both the second and third pairs of lateral glabellar furrows would lead to the structure found in *Acrolichas* (figs. 4, 5), without the intermediate stage found in *Hoplolichas* and other genera (fig. 6) in which the posterior lateral lobes are still preserved. In other words, *Acrolichas* and *Amphilichas* may have arrived at identical types of glabellar structure through different lines of development.

In both *Acrolichas* and *Amphilichas* the rear connecting furrows may disappear leaving only the anterior pair of glabellar furrows and a variable amount of the immediately adjacent connecting furrows.

In various species of *Acrolichas* the compound nature of the single longitudinal pair of glabellar furrows can be recognized by slight deviations in the direction of these furrows and by slight depressions or pits in their bottom. For instance, in the cranidium of *Acrolichas cucullus* figured from Hull, opposite Ottawa, in Canada (Pl. I, fig. 1A), the basal part of the median lobe is widened slightly into a pedestal, immediately anterior to which the glabellar furrows make a short curve with the concave side directed outward (see also fig. 3). These curved portions correspond to the second pair of connecting furrows, bounding the inner side of the second pair of glabellar lobes; at the anterior end of these curved portions there usually is a tendency toward a slight pit, locating the inner end of the second pair of lateral furrows. Another slight pit, locating the inner end of the first pair of lateral glabellar furrows, exists near the point where the anterior part of the glabella begins to curve strongly downward. Slight changes in the curvature of the surface of the side lobes of glabellæ suggest that the anterior pair of lateral glabellar furrows was very oblique, and that the general aspect of the glabella was similar to that of *Dicranopeltis.* Although this genus is not known until Silurian times, the structure of its glabella appears to have been very primitive, resembling that of the supposed ancestral Lichad (figs. 2, 12).

How largely hypothetical the derivation of Lichad genera must remain for some time is shown by the far departure from ancestral types shown by the earliest Lichads known. The earliest American Lichads are of Chazyan age and belong to *Acrolichas.* The earliest East Baltic forms occur in the Walchow formation, apparently of much earlier age than the Chazyan, and they belong to *Metopolichas.* The earliest Bohemian Lichads belong to *Platopolichas,* and these also appear to be of much earlier age than the Chazyan.

14. *The free checks, hypostoma, and thorax of Acrolichas.*

Our knowledge of the Lichadidæ usually is confined to the cranidia and the pygidia. Rarely are these found connected by the thorax. In the type of *Acrolichas harrisi* eleven thoracic segments are present. In the type of *Acrolichas cornutus* only ten thoracic segments are exposed, but the cephalon evidently has been crowded back on the front of the thorax, and the complete specimen might show eleven segments. The normal number of thoracic segments in Lichadidæ evidently is eleven. Eleven thoracic segments appear in that specimen of *Platylichas* (?) *halli* which was figured by Hall erroneously under the species then called *Acrolichas trentonensis* (Pal. New York, **1**, pl. 64, fig. 1e, 1847). Eleven thoracic segments occur in the Silurian species *Arctinurus boltoni* (Bigsby) and *Dicranopeltis nereus* (Hall), both figured by Hall; and also in *Corydocephalus palmatus* (Barrande) and *Dicranopeltis scabra* (Beyrich), both figured by Barrande.

The free cheeks of *Platylichas* (?) *halli* Foerste have been found attached to the cranidium (Pl. II, fig. 8A); this falcate type of free cheek appears common among the Lichadidæ. The very imperfectly preserved free cheeks belonging to the type of *Acrolichas cornutus* are interpreted as similar in form. One free cheek of *Acrolichas cucullus* (Pl. I, fig. 1D) from the Kimmswick limestone of Illinois shows the same tendency toward a falcate outline.

The hypostoma of a number of species of *Acrolichas* is known, but has not yet furnished material for generic differentiation of species. That of *Acrolichas cucullus*, figured on Plate I, is well preserved. (Bull. Denison Univ., **19**, 1919, pl. 17, figs. 3A, B; pl. 18, fig. 6.)

15. *Notes on American species of Acrolichas.*

On the preceding pages attention has been concentrated on the generic differences presented by American Ordovician Lichads, especially on the proposed genus *Acrolichas*. It was not intended to present here all of the information so far accumulated regarding the individual species. Only a few of the observations regarded as most interesting are recorded here.

Acrolichas jukesii, Pl. II, figs. 1A, B. The transverse groove noted by Billings (Pal. Foss., 1, 1865, p. 335) may indicate the line of separation between the first and second pairs of lateral glabellar lobes.

Acrolichas minganensis, Pl. III, figs. 1 A, B, C. Raymond (Ann. Carnegie Museum, 7, 1910, p. 72, pl. 18, fig. 6; pl. 19, fig. 14) figured two small cranidia from a locality near Chazy, New York, in which the glabellar furrows do not reach the occipital furrow but terminate at a considerable distance from the latter, with a short, outwardly directed curve, ending in a sort of pit. In one specimen a second pit occurred in the glabellar furrow, about half way between the posterior end of the furrow and the frontal border. Interpreting the anterior one of these pits as the inner end of the first pair of glabellar furrows, and the posterior pit as the inner part of the second pair of glabellar furrows, the lobe outlined by this furrow must correspond to the anterior lateral glabellar lobe of other Lichads, and the space intervening between the posterior margin of this anterior lobe and the occipital ring must correspond to both the second and the third pair of lateral glabellar lobes of other Lichads, these two pairs having coalesced in the specimens at hand. This would agree with the structure of most other Lichads in which the anterior lateral glabellar lobes are the largest, and the posterior pair are the smallest of the series.

It is possible that these small cranidia do not belong to *minganensis* but represent a distinct species. In analogy with *Amphilichas,* the young of *Acrolichas* might be expected to be characterized by glabellar furrows ending abruptly posteriorly without any change in curvature (producing a result similar to that figured in the adult of *Amphilichas lævis,* in figure 11A, on Plate IV).

Acrolichas champlainensis (Whitfield), Pl. III, fig. 3. Raymond (Ann. Carnegie Museum, 3, 1905, p. 355) refers *Lichas champlainensis* to the species *minganensis.* In *Lichas champlainensis,* however, the notch between the tips of the posterior pair of ribs is narrow, while in the pygidium of *Lichas minganensis* figured by Raymond (Pl. III, fig. 1*c*) the tips of these ribs are divergent. Differences as great as this are not known in other Lichadidæ in the same species. Apparently several species of Lichads exist in the Chazyan of New York, which have not yet been differentiated.

Acrolichas cucullus, Pl. I, figs. 1 A-G. The genotype of *Acrolichas* is the species described by Meek and Worthen from the Kimmswick limestone in Alexander county, Illinois, under the name *Lichas cucullus.* The type specimen was a well preserved cranidium, and, in vol. 3 of the Geol. Surv. of Illinois, in 1868 (Pl. 1, figs. 6a, b, c), three illustrations are presented of this type, two additional ones being presented by the present writer in the Ottawa Naturalist, in 1917 (Pl. 6, figs. 26A, B).

Lichas cucullus apparently has a very extensive geographical range. In the Kimmswick limestone it ranges from Alexander county, at the southern end of Illinois, northward to various localities in Jefferson county, Missouri; Calhoun county, Illinois (Pl. I, fig. 1D, G); and Ralls county, Missouri (Pl. I, figs. 1C, F). In the Prosser limestone it is known at Wykoff in Minnesota. In strata regarded as of Black River age, it occurs at Janesville, Wisconsin, and on Lake Winnipeg, in Canada. In the collection of James E. Narraway, of Ottawa, Canada, both cranidia and pygidia occur, from the Trenton of Hull, immediately across the river from Ottawa (Pl. I, figs. 1A, B, E). Lichas is listed also from l'Original, nearly 50 miles east of Ottawa, and from the east end of Seche Bay, in Mansfield township, about 50 miles northwest of Ottawa. As far as known *Lichas trentonensis* does not occur north of the Frontenac axis, in Canada, so that these citations of Lichas from l'Original and Seche Bay may belong to *Lichas cucullus.*

Considering the great geographical range of *Acrolichas cucullus,* and its occurrence apparently at several distinct horizons, it is not unlikely that eventually, when the associated cranidia and pygidia become better known, several species will be differentiated among the specimens now referred to the single species *cucullus.* Differences are noted more frequently among the pygidia, of the forms here discussed, than among the cranidia. For instance, in the pygidium from the Kimmswick on Sanders Branch, in Ralls county, Missouri (Pl. I, fig. 1F), provisionally regarded as typical of the species, the free tips of the ribs are more pointed than in the pygidium from Hull, in Canada (Pl. I, fig. 1E).

In the Richmond on the eastern shore of Little Bay de Noquette, in Northern Michigan, a cranidium was found (Ottawa Naturalist, **31**, Pl. 6, figs. 27A, B, 1917) which could not be distinguished from the type of *Acrolichas cucullus.* The pygidium, if known, might offer differences.

Acrolichas robbinsi, Pl. II, fig. 2. This cranidium, from the Prosser limestone of Minnesota, bears a striking resemblance to *Metopolichas longerostratus* (Schmidt) (Pl. IV, fig. 2) from the East Baltic provinces of Europe in the rostral extension of the median lobe. There is no generic relationship, and the European species apparently is of pre-Chazyan age.

Acrolichas trentonensis, Pl. I, figs. 3A, B; Pl. III, figs. 4A-D. The type of this species was found in the Trenton, at Carlisle, Pennsylvania, but the species occurs also in the Trenton of New Jersey. The cranidium figured on Plate I was obtained from the Trenton near Iliff's Pond, and forms No. 10371 in Walker Museum, at Chicago University. The fragment of a pygidium figured by Hall (Pal. New York, **1**, pl. 64, fig. 1b, 1847) from the Trenton at Carlisle, Pennsylvania, has been redrawn in outline (Pl. III, fig. 4C) with the margin restored. As already noted, the species is not known to range north of New York. It is incorrectly listed from Missouri. It is unknown in the Mississippi valley.

Acrolichas cornutus, Pl. I, fig. 5; pl. III, figs. 5 A, B, C. This is a very interesting specimen, notwithstanding its imperfect preservation. It is from the Trenton, at Trenton Falls, New York. The cranidium is very poorly preserved and in addition appears to have been compressed diagonally from the right, so as to expose the right side of the glabella fairly well, while the left side of the glabella is seen askew. Traces of the surface of the free cheek suggest that the genal ends were falcate, somewhat as in *Acrolichas cucullus* (Pl. I, fig. 1 D). It will be noted that in the figure presented on Plate I the genal spine on the right is more acute and more falcate than that on the left; the former is regarded as nearer the fact, although the state of preservation is too imperfect for accurate determination. The anterior part of the median lobe projects upward and forward (Pl. III, fig. 5 C) and is surmounted by a spine of unknown length, only the base being preserved. In the anterior and upward elongation of the median lobe, this species resembles *Conolichas schmidti* Dames (Pl. IV, fig. 9 B) from the East Baltic provinces. However, there is no generic relationship. The East Baltic species comes from a horizon approximately equivalent to the Trenton of New York.

Acrolichas conifrons, Pl. I, figs. 4 A. B. C. This is another interesting species, also from the Trenton, at Trenton Falls, New York. Since the original publication of the species (Bull. N. Y. St. Museum, No. 189, 1916, p. 90, pl. 30, figs. 5-8) sufficient of the posterior end of the glabella has been freed from the matrix to give a better clue to the structure of this part of the cranidium (Pl. I, figs. 4 A, B, restored posteriorly). A different interpretation has been given to the termination of the tips of the posterior pair of ribs (Pl. I, fig. 4 C). In the free tips of various species of *Acrolichas,* the crest of some of the granules is elongated in a direction diagonally transverse to the length of the rib; in some cases a narrow ridge extends for the width of three or four granules. One of these narrow ridges extends nearly across the width of the free tip of the right posterior rib, in the type here discussed, apparently along its posterior edge, but traces of the surface ornamentation beyond this ridge make it unnecessary to postulate the presence of truncated free tips for the posterior ribs, and the interpretation here presented is offered instead.

In the Kimmswick limestone, near Batchtown, in Calhoun county, Illinois, cranidia of an *Acrolichas* occur (Pl. II, figs. 5 A, B) which probably represent a species distinct from *Acrolichas conifrons,* but the differences presented by the cranidia are so slight that they are difficult of recognition. In *Acrolichas conifrons,* the frontal lobe is more vertical and less convex; the median lobe, posterior to the frontal lobe, also is less convex, and there is a slight tendency toward median angulation of the upper half of the frontal lobe, best seen when the cranidium is viewed from above (Pl. I, fig. 4 A). All of these features, small in themselves, combine to make the point where the median lobe descends into the frontal lobe more angular than in the Kimmswick specimens, and thus warrant the term conifrons. The pygidium of *Acrolichas conifrons,* however, is characterized by a remarkably abrupt bend at the middle of the furrow limiting the posterior margin of the second ring on the axial lobe, and nothing similar to this has been found in any part of the Kimmswick limestone in the Mississippi valley.

Lichas harrisi, Pl. III, figs. 6 A-C. The type, obtained somewhere near Waynesville, Ohio, presumably in the Waynesville member of the Richmond, exposes the under side of the pygidium, thorax, and hypostoma. Other pygidia, having the same general aspect, have been found in the upper part of the Liberty member of the

Richmond, both in Ohio and Indiana. Although the pygidia from both horizons are characterized by short, rounded free tips at the end of the ribs, the granules on the surface of the Liberty specimens are coarser, and the accompanying transverse narrow ridges are bolder than in the Waynesville type, so that the specimens from the Liberty division may represent an undescribed species. Finally, pygidia of the same general type occur also in some part of the section at Richmond, Indiana, a fragment, including all except the anterior pair of ribs, occurring in the Misener collection.

Three species of *Acrolichas* are known from the Maquoketa member of the Richmond, in the Mississippi valley. *Acrolichas bicornis*, Pl. II, fig. 3, from Minnesota, and *Acrolichas rhinoceras*, Pl. II, fig. 4, from Iowa, have the glabella ornamented with slender spinose extensions. *Acrolichas clermontensis*, Pl. II, fig. 7, from Iowa, is characterized by the rapid widening of the median lobe of the glabella toward the front.

16. *Possible occurrence of Acrolichas in Baltic areas of Europe.*

Since at present in America only pygidia having a median lobe terminating posteriorly in an acute point are known definitely to be associated with glabellæ resembling *Amphilichas*, it is natural to assume that similar associations are to be expected in typical species of *Amphilichas* in the Baltic areas of northwestern Europe. Such pygidia might be sought in the forms associated by Schmidt with the glabellæ of *Metalichas cicatricosa* Loven and *Metalichas St. Mathiæ* Schmidt. Neither of these pygidia, however, is sufficiently similar to that of *Acrolichas* to demand its association with *Amphilichas*, on the supposition that *Acrolichas* is identical with *Amphilichas*.

In *Metalichas cicatricosa* the furrow limiting the posterior border of the second axial ring is indistinct medially, instead of at the two ends. In *Metalichas St. Mathiæ*, the furrows traversing the lateral ribs lengthwise terminate at the angles between the free tips of these ribs, a feature unknown not only in *Acrolichas* but also in all other described lichads.

The mere presence of a pointed posterior termination of the axial lobe is not sufficient to stamp a pygidium as belonging to *Acrolichas* or *Amphilichas*. The tendency toward such pygidia in *Platopolichas avus, Platopolichas incola,* and in various species of *Dicranopeltis* is sufficiently strong to indicate the possibility of such pygidia as those associated by Schmidt with *Metalichas* in genera not closely related to either *Acrolichas* nor *Amphilichas.*

At present, the identity of *Amphilichas* rests upon the glabella figured by Schmidt, in his figure 5 on Plate 6, under the name *Lichas laevis* Eichwald. This is a most peculiar glabella, with elongate elliptical rather than reniform side lobes, resulting in a rotund outline of the glabella as a whole. The anterior glabellar furrows tend to terminate posteriorly before reaching the occipital furrow, especially in case of the outer surface of the test.

In such species as *Lichas holmi* Schmidt and *Lichas dalecarlica* Angelin, the reniform side lobes of the glabella suggest closer relationship with *Acrolichas,* but, in the absence of pygidia of the *Acrolichas* type, strict identity remains uncertain.

Under these circumstances it seems preferable to emphasize the wide range of species of the *Acrolichas* type in America, and the lack of definite knowledge of corresponding pygidia in the Baltic areas of Europe, than to assume that similarity of glabellæ alone is sufficient to establish the identity of *Acrolichas* with *Amphilichas,* thus, by inference, assuming that the European species of *Amphilichas* also have the *Acrolichas* type of pygidium. To the present writer it seems preferable to await the results of further research.

17. *Bibliography.*

A full bibliography of American Ordovician and Silurian Lichads is presented by Bassler, in his Bibliographic Index of American Ordovician and Silurian Fossils, published in 1915. Under the genus Lichas, references to all the more important foreign publications on the Lichadidæ are presented. Among these the following are of especial interest, in connection with the recognition of generic types: Dames, Zeitschrift d. deutsch. geol. Gesell., 29, 1877, pp. 793-815. Gürich, Neues Jahrbuch Min. Geol. Pal., 17, Beilage Band, 1901. Schmidt, Mem. l'Acad. Imp. Sci. St. Petersbourg, 33, 1885. Reed, Quart. Jour. Geol. Soc. London, 58, 1902. To this should be added, especially for Silurian genera, Hawle and Corda, Abh. d. k. Böhmischen Gesell. d. Wiss., 5, 1847. The names of genera proposed in other publications either have since been found to have been preoccupied or to be synonyms of others already published.

EXPLANATION OF PLATES.

PLATE I.

FIG. 1. *Acrolichas cucullus* (Meek and Worthen). A, cranidium; B, lateral view, from Trenton at Hull, opposite Ottawa, Canada; in Narraway collection. C, anterior view of cranidium, from Kimmswick in Ralls county, Missouri. D, fragment of free cheek, Kimmswick limestone, near Batchtown, Illinois (20673, Chicago Univ. Museum). E, pygidium, from Trenton in bed of creek at head of Front street, in Hull, Canada; in Narraway collection. F, pygidium, in Kimmswick on Sanders Branch, in Ralls county, Missouri. G, hypostoma, from Kimmswick near Batchtown, Illinois (20676, Chicago Univ. Museum).

FIG. 2. *Acrolichas narrawayi* Foerste. Pygidium from Trenton, in quarry at Wright's or St. Clovis' dam, near Hull, Canada; in Narraway collection.

FIG. 3. *Acrolichas trentonensis* (Conrad). A, cranidium; B, lateral view; from Trenton near Iliff's Pond, New Jersey (10371, Chicago Univ. Museum).

FIG. 4. *Acrolichas conifrons* (Ruedemann). A, glabella; B, lateral view; both considerably restored posteriorly. C, pygidium, as interpreted by present writer. Type specimens, from the Trenton at Trenton Falls, New York (12950-2, Museum, New York State Geol. Survey).

FIG. 5. *Acrolichas cornutus* (Clarke). Cephalon very poorly preserved, drawn as interpreted by present writer; the right half probably is almost correct; the left half is viewed at the wrong angle to give the correct outline for the side lobe of the glabella, but it gives a fair idea of the location and size of the palpebral lobe. The tips of the pleural segments on the right side of the thorax, and almost the entire length of the segments on the left side, are restored. There are 10 pleural segments. The pygidium is well preserved. Type specimen, from the Trenton at Trenton Falls, New York (13703-1, Museum, New York State Geol. Survey).

PLATE II.

FIG. 1. *Acrolichas jukesii* (Billings). A, cephalon; B, cranidium; from Chazyan at Cow Head, Newfoundland, (Pal. Foss., 1, 1865, p. 335, fig. 323a; p. 282, fig. 269b).

FIG. 2. *Acrolichas robbinsi* (Ulrich). Cranidium, from the Prosser, near Wykoff, Minnesota (Amer. Geol., 10, p. 271, fig. 1a, 1892).

FIG. 3. *Acrolichas bicornis* (Ulrich). Cranidium, from Maquoketa at Spring Valley, Minnesota (Amer. Geol., 10, p. 272, fig. 2a, 1892).

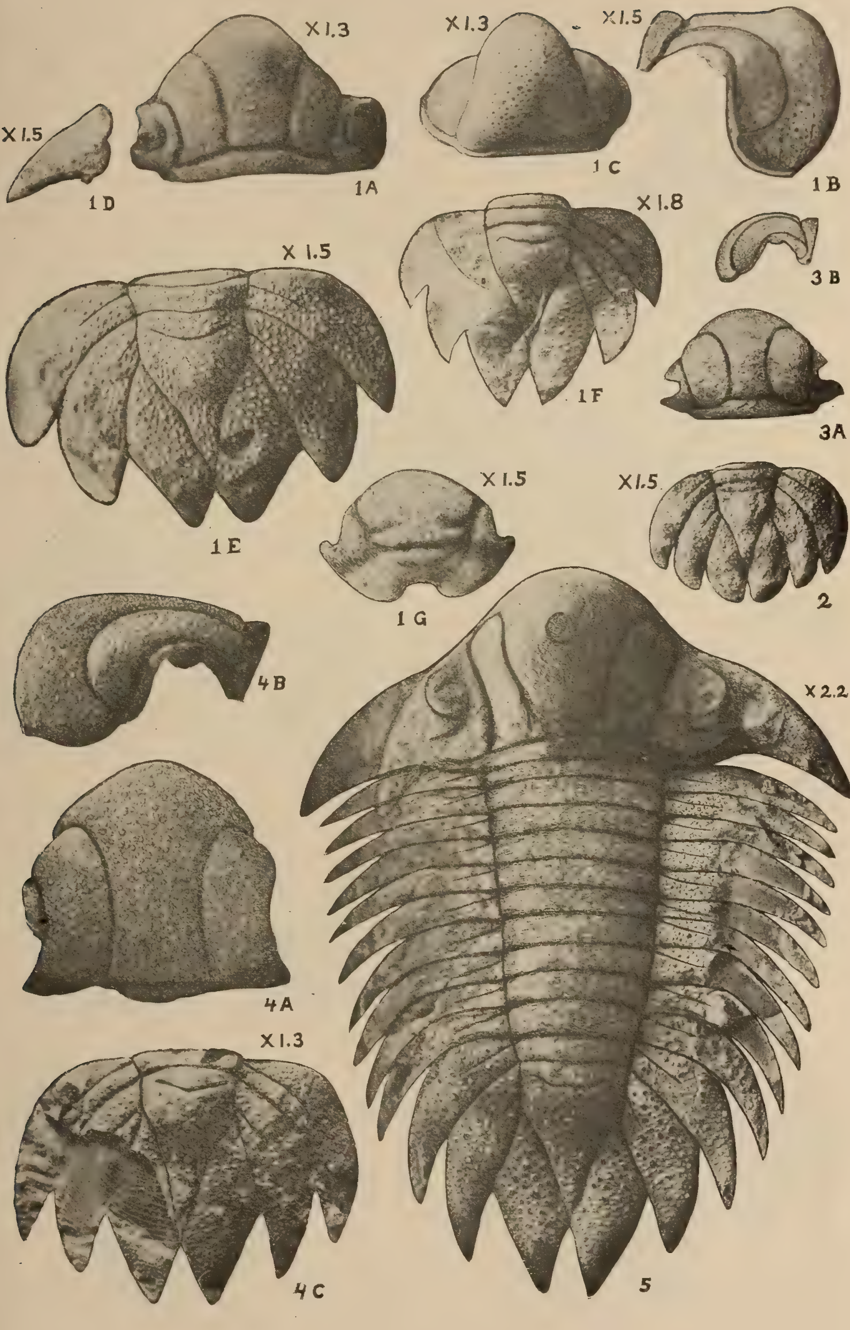
FIG. 4. *Acrolichas rhinoceras* (Slocom). Glabella, from Maquoketa at Elgin, Iowa (Field Mus. Nat. Hist., Geol. Ser., 4, No. 3, 1913, Pl. 15, fig. 5).

FIG. 5. Acrolichas cf. *conifrons* Ruedemann. A, cranidium; B, lateral view; from Kimmswick, near Batchtown, Illinois (20674, Chicago Univ. Museum).

FIG. 6. *Hemiarges paulianus* (Clarke). A, cranidium; B, lateral view; C, second cranidium with broken neck ring, from Trenton near Hull, Canada (in Narraway collection).

FIG. 7. *Acrolichas clermontensis* (Slocom). Glabella, from Maquoketa, at Clermont, Iowa (collected by A. W. Slocom).

FIG. 8. *Platylichas(?) halli* (Foerste). A, cranidium and part of thorax (Bull. Lab. Denison Univ., 3, p. 118, Pl. XIII, fig. 4, 1888); B,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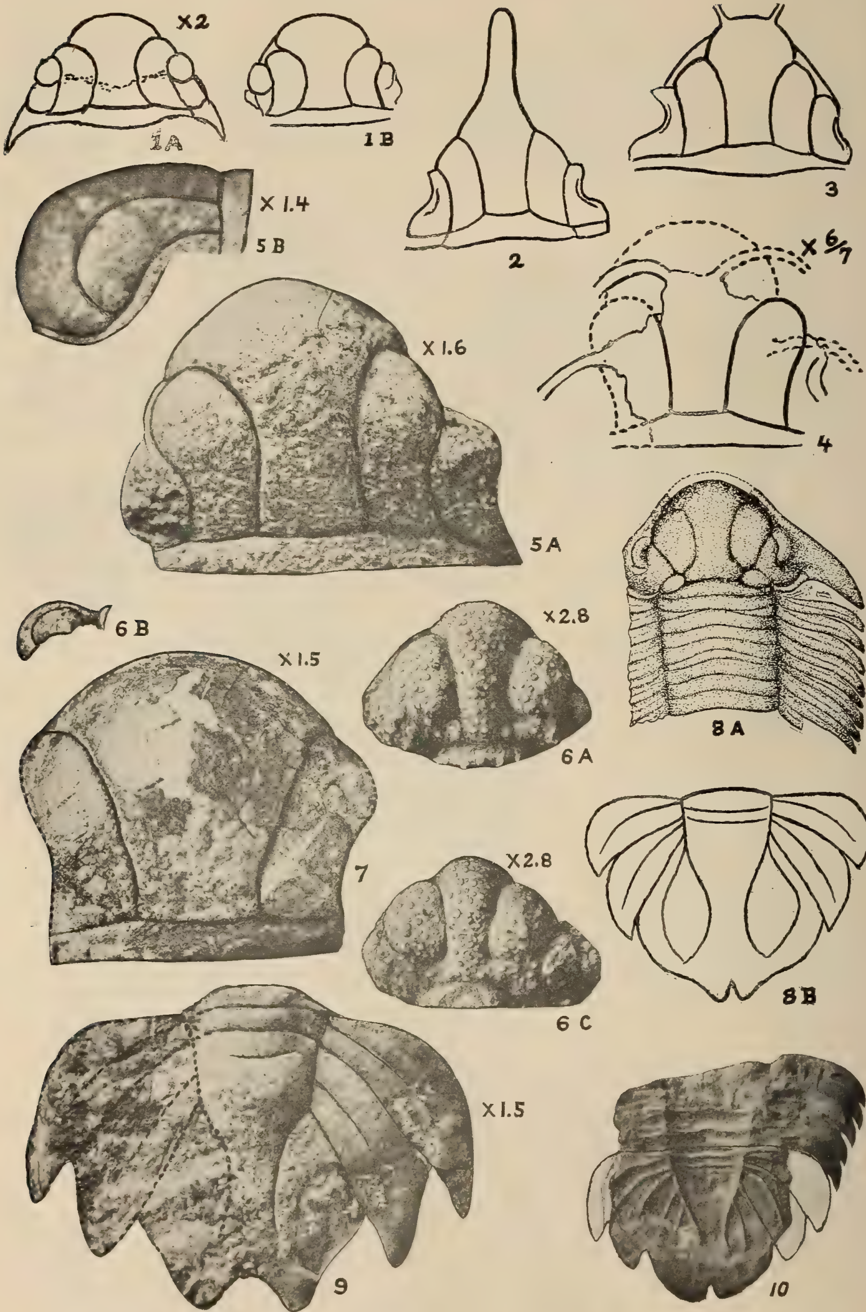

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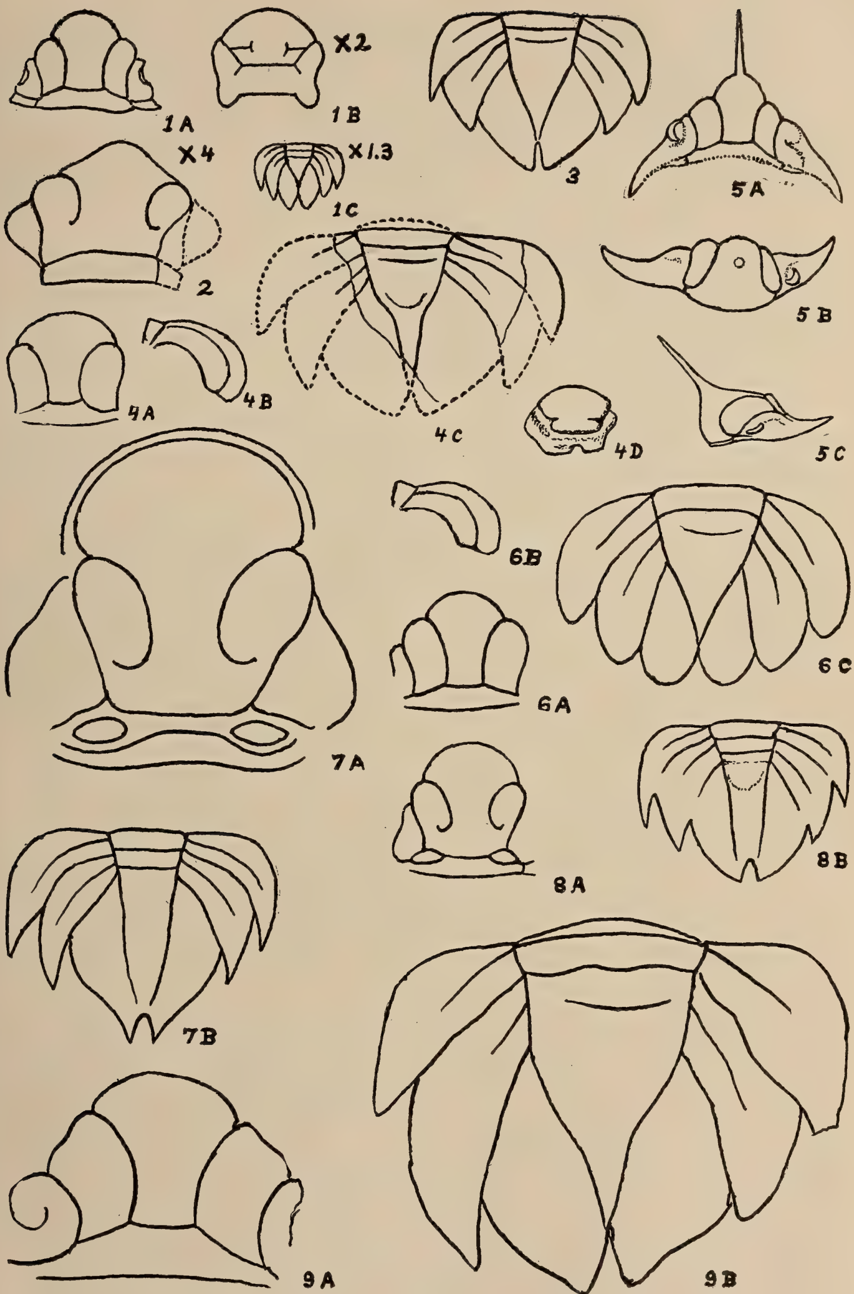
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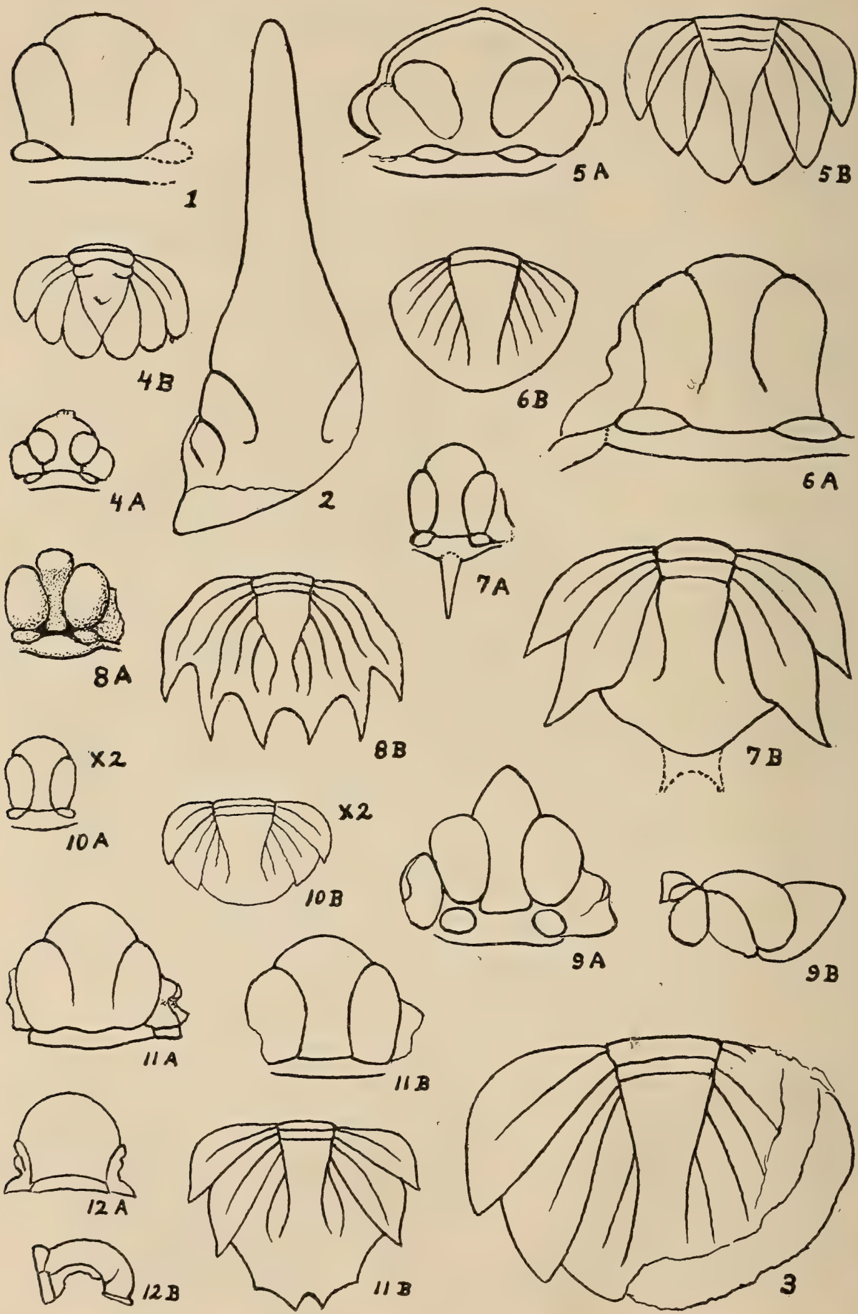
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pygidium; both from Corryville member of Maysville; A, from Clermont county; B, from Cincinnati, Ohio.

FIG. 9. *Hoplolichas(?) welleri* (Foerste). Pygidium, from the Kimmswick, at Cape Girardeau, Missouri (10771, Chicago Univ. Museum).

FIG. 10. *Platylichas(?) miseneri* (Foerste). Pygidium, from the Whitewater member of the Richmond, at Richmond, Indiana (Jour. Cincinnati Soc. Nat. Hist., 22, Pl. I, fig. 2, 1917).

PLATE III.

FIG. 1. *Acrolichas minganensis* (Billings). (Raymond, 1905, Pl. XIV, figs. 1, 3, 2) A, cranidium; B, hypostoma; C, pygidium; from the Chazyan.

FIG. 2. *Acrolichas* cf. *minganensis.* (Raymond, 1910, Pl. XIX, fig. 14) Cranidium, from Chazyan, near Chazy, New York.

FIG. 3. *Acrolichas champlainensis* (Whitfield). Pygidium, type specimen. (Bull. A. M. N. H., 1, 1881, p. 342, Pl. 33, figs. 6, 7.) From Chazyan on Isle la Motte, Vermont.

FIG. 4. *Acrolichas trentonensis* (Conrad). Glabella; B, lateral view of same; from Trenton of New Jersey (collected by Weller, preserved in Chicago Univ. Museum). C, pygidium, restoration of imperfect specimen figured by Hall (Pal. New York, 1, 1848, Pl. 64, fig. 1b), from Trenton of Carlisle, Pennsylvania; type specimen. D, hypostoma, from Trenton of New Jersey; (Geol. New Jersey, 3, Pl. 15, fig. 20).

FIG. 5. *Acrolichas cornutus* (Clarke). A, cephalon viewed from above; B, viewed with top of glabella parallel to line of sight; C, left side. Type specimen, with spine restored in A and C. From Trenton of Trenton Falls, New York.

FIG. 6. *Acrolichas harrisi* (Miller). A, glabella; B, lateral view; from Liberty member of Richmond, at Weisburg, Indiana. C, pygidium of type specimen (Jour. Cincinnati Soc. Nat. Hist., 1878, p. 106, Pl. III, fig. 9); from Waynesville member of Richmond, at Waynesville, Ohio.

FIG. 7. *Platopolichas avus* (Barrande). Genotype. A, cranidium, from Rokitzan; B, pygidium, from near Vosek, Bohemia. (Syst. Sil. du Centre Bohème, 1, 1852, Pl. 6, fig. 22, and Pl. X, fig. 17.) From the horizon d_1 in the Ordovician.

FIG. 8. *Platopolichas incola* (Barrande). A, cranidium; B, pygidium; near Vosek, Bohemia, from horizon d_1 in the Ordovician. (Syst. Sil. du Centre Bohème, 1, 1852, Pl. V, fig. 21, and Pl. X, fig. 7.)

FIG. 9. *Acrolichas hibernicus* (Portlock). A, cranidium; B, pygidium; from Llandeilo of Ireland. (Geol. of Londonderry, Tyrone and Fermanagh, 1843, Pl. V, fig. 2, and Pl. IV, fig. 1c.)

PLATE IV.

FIG. 1. *Metopolichas hübneri* Eichwald. (Schmidt, Pl. I, fig. 13a.) Genotype. Glabella, type specimen, from Reval.

FIG. 2. *Metopolichas longerostratus* Schmidt. (Schmidt, Pl. I, fig. 12a.) Glabella, from Reval.

FIG. 3. *Metopolichas pachyrhinus* Dalman. (Schmidt, Pl. I, fig. 11.) Pygidium, with the free ends of the posterior pair of ribs not preserved. From Rogo Island.

FIG. 4. *Metalichas cicatricosus* Schmidt. (Schmidt, Pl. V, figs. 25a, 26.) Genotype. A, cranidium; from Borkholm; B, pygidium, from Habbat.

FIG. 5. *Metalichas St. Mathiæ* Schmidt. (Schmidt, Pl. V, figs. 11, 16.) A, cranidium, from St. Mathias; B, pygidium, locality uncertain.

FIG. 6. *Leiolichas illænoides* Nieszkowski. (Schmidt, Pl. III, figs. 27a, 30a.) Genotype. A, cranidium; B, pygidium. From Poll.

FIG. 7. *Hoplolichas tricuspidatus* Beyrich. (Schmidt, Pl. II, figs. 14,

13.) Genotype. A, cranidium, from Gostilizy; B, pygidium, from erratic block.

FIG. 8. *Conolichas æquilobus* Steinhardt. (Schmidt, Pl. V, figs. 5, 10.) Genotype. A, cranidium, from Sommerhusen; B, pygidium, from Ristninna.

FIG. 9. *Conolichas(?) schmidti* Dames. (Schmidt, Pl. IV, figs. 36a, b.) A, cranidium; B, lateral view; from Paesküll.

FIG. 10. *Homolichas depressus* Angelin. (Schmidt, Pl. IV, figs. 2, 4.) Genotype. A, glabella, from Erras; B, pygidium, from Baltischport.

FIG. 11. *Amphilichas lævis* Eichwald. (Schmidt, Pl. VI, figs. 5a, 8, 10.) Genotype. A, glabella, type, of Amphilichas, from Kosch; B, glabella, from Oddalem; C, pygidium, from Oddalem.

FIG. 12. *Amphilichas lineatus* Angelin. (Angelin, Paleontologia Scandinavica, 1854, Pl. 38, figs. 12, 12a.) A, cranidium; B, lateral view.

Figures 1-11 are copied in outline from Schmidt, Revision der Ostbaltischen Silurischen Trilobiten, Mem. Acad. Imp. Sci. St. Petersbourg, 33, 1, 1885, from the plates and figures indicated above.

Dayton, Ohio.

ART. III.—*On Ammonoids from the Abo Sandstone of New Mexico and the Age of the Beds which contain them;* by DR. EMIL BÖSE.

The Abo sandstone of New Mexico is the lowermost member of a group of sedimentary Paleozoic rocks comprised under the name of the Manzano group, the higher members of which are the Yeso formation and the San Andreas limestone. The fauna of this group has been described by G. H. Girty, who judged that the whole group belonged to the Pennsylvanian.

While studying the species figured by Girty, I had the impression that the fauna of the Manzano group as a whole repesented a curious mixture of Carboniferous and Permian types. The species cited and described from the Yeso formation and the San Andreas limestone have certainly more Permian affinities than Carboniferous. In this opinion I was confirmed when together with Mr. Charles L. Baker, I collected a number of fossils in the Yeso formation between Anton Chico and Encino in northeast Torrance County, New Mexico. But at the same time there remained some doubt about the age of the Abo sandstone, which contained brachiopods of apparently Pennsylvanian character.

Fortunately Mr. Baker and Dr. N. F. Drake discovered a locality near Tularosa (1.25 miles due east on the road to the Mescalero Apache reservation), New Mexico, which contained a great number of ammonoids promising a better determination of the age of the beds. Mr. Baker had the kindness to submit those ammonoids to me for further study, the result of which I shall give in the following pages.

The beds which contain the ammonoids, as well as a great number of other fossils, are shales in the lower part of the Abo sandstone. The ammonoids are preserved in greater part as pseudomorphs after limonite and are generally of small size, while the larger ones are calcareous.

Although the number of ammonoids collected at Tularosa is relatively very great, only two genera appear to be represented: *Gonioloboceras* and *Gastrioceras.* The number of species is very small, *Gonioloboceras* being represented by only one, and *Gastrioceras* by about four. All of the species so far found are new, but two at least belong to well known and characteristic groups, as will be seen in the following pages.

The most important species of our collection belongs to *Gonioloboceras.* This genus was created by Hyatt[1] for a species from New Mexico: *Goniatites goniolobus* Meek, characterized by flattened flanks, narrow rounded venter and extremely angular lobes. Unfortunately neither the horizon nor the locality where this species was found is known, but it is merely said to have come from the Carboniferous of New Mexico.

This species is entirely different from ours, notwithstanding that *Gonioloboceras* is a rather rare genus and that both forms come from the same state. It has much more rounded flanks and the venter is not flattened at all, while our species shows extremely flat flanks and in mature specimens a flattened venter or even a slight longitudinal depression on it, although no real furrow seems to be developed in medium sized individuals. The whorls of *G. goniolobus* are deeper embracing, and the cross-section is nearly elliptical, while in our species it is almost sagittal. The greatest difference, however, exists in the suture. On the whole, the lobes of *G. goniolobus* seem to be still more angular, although there is a general resemblance. The siphonal saddle which divides the ventral lobe in Meek's form is of an entirely different shape,—narrower and rather pointed, with an indentation at its end,—while in our species it is high and broad, with a tongue-like prolongation.

J. P. Smith[2] has described another species belonging to *Gonioloboceras, G. welleri,* from the Cisco formation of central Texas; and this form is much more intimately related to ours. The shape of the shell is very similar, but in our species the flanks are still flatter, while the venter is generally more rounded and does not show a real deep furrow like the adults of *G. welleri.* Still, the flattening of the venter and the development of a slight longitudinal depression in our species show that the relation between the two is very intimate; they certainly belong to the same group although they are specifically different.

The greatest difference appears in the younger indi-

[1] A. Hyatt, in Eastman-Zittel, Textbook of Paleontology, p. 551, 1900.

[2] J. P. Smith, The Carboniferous Ammonoids of America, U. S. Geol. Survey, No. 42, p. 125, pl. 20, figs. 9-11; pl. 21, figs. 1-7 6, 1903.

viduals. An immature specimen of about 7mm. diameter shows one constriction in *G. welleri* and three in our species. The cross-section of such a specimen is subquadrangular in *G. welleri* and nearly semicircular in ours.

There is little if any difference in the sutures of adults in both species, but the young ones are much more distinct, those of *G. welleri* showing more archaic features than those of the species from New Mexico.

While Hyatt regarded *Gonioloboceras* as belonging to the family Magnosellaridæ, J. P. Smith has shown that the suture of immature specimens of *G. welleri* has the character of *Muensteroceras,* a genus from the Lower Carboniferous, probably derived from *Aganides* (*Brancoceras* Hyatt 1884, not Steinmann 1881), and belonging to the family Glyphioceratidæ. I have been able to confirm these observations of Smith by others made on the young of our species from Tularosa. An immature individual of about 10mm. diameter already shows some marked differences from the adults. The flanks are slightly rounded and the venter is rather broad and rounded, the cross-section being helmet-shaped. The whorls are deeply embracing but indented to only one-fourth by the preceding volution. The border of the umbilicus shows a rather sharp edge and the wall has an inclination of 45 degrees, while that of the adult has a rounded border and its wall is less steep. The immature individual has an ornamentation consisting of fine sigmoidal lines on the flank which on the venter suddenly curve strongly backwards. The specimen shows one constriction on the oldest part of the external volution while the mature specimens have none at all. The youngest part of the immature specimen shows a suture quite similar to that of the adults, although the siphonal saddle is relatively somewhat lower. But only a quarter of a volution backwards, this siphonal saddle is already reduced in size to about one-fourth of the height of the external saddle, becomes much narrower and more slender in shape, and shows a distinct indentation at the front end. At the oldest part of the volution this saddle is still more reduced and the external saddles become less sharp and somewhat rounded at the point. The first lateral saddle also becomes gradually lower and relatively broader.

Another specimen of about 7mm. diameter shows still greater differences: the shell is in general similar to that of the preceding specimen but the flanks are more rounded, especially on the older half of the external volution where the cross-section appears to be nearly semicircular, although the flanks are still a little flatter than the well rounded venter. The border of the umbilicus shows a sharp edge and the wall is very steep (about 75 degrees). The ornamentation is similar to that of the preceding specimen. The cast shows three deep constrictions, nearly radial, but very slightly curved backwards on the flank and more strongly so on the venter.

The suture is remarkably simple. The ventral lobe is broad and divided into two parts by a low siphonal saddle, both prongs being still rather sharply pointed in the youngest suture of the external whorl and rather blunt in the oldest. The first lateral lobe becomes gradually wider at the end and less pointed at the bottom and is nearly as deep as the ventral. The siphonal saddle is of pyramidal form, truncated and indented at the front, and only one-fourth as high as the external saddle. The external saddle becomes more and more round at the end and broad at the base, and also more or less symmetrical. The first lateral saddle becomes very low and rather resembles a broad undulation.

Thus the smallest individual described has all the features of *Muensteroceras* in form as well as in sutures; it seems to resemble especially the young of *M. oweni* Hall,[3] although the similarity between its sutures and those of *M. parallelum* Hall,[4] the type of the genus, is rather striking.

The similarity between our new species and *Goniloboceras welleri* Smith is so great that there can be scarcely any doubt about their being more or less of the same age. They certainly belong to a group different from that of *G. goniolobus*. The new species is rather common at the locality near Tularosa, our collection containing about thirty specimens. Our species is so well characterized that we may distinguish it under the name of *Gonioloboceras discoidale* n. sp.

Another species of certain importance belongs to the genus *Gastrioceras*. It evidently forms part of the

[3] J. P. Smith, op. cit., pl. 19, figs. 5, 6.
[4] J. P. Smith, op. cit., p. 121, pl. 16, fig. 3; pl. 19, figs. 1-2.

group of *G. subcavum* Miller and Gurley and is so similar to the type that at first I thought it might even be specifically identical with it, but a close study showed a number of small but constant differences which allow us to separate it under the name of *Gastrioceras subtilicostatum* n. sp.

The group of *G. subcavum* is characterized by extremely angular umbilical shoulders and a wide, deep, funnel-shaped umbilicus without strong nodules on its border. Our species shows both these characteristics, but the umbilicus is still a little wider than in the type. The cross-section is nearly the same, although the inner whorls have a venter that is possibly a little more rounded. The suture is very similar in all species of *Gastrioceras* but the siphonal saddle is larger than that figured by Smith,[5] and as the author says that *G. subcavum* agrees with *G. globulosum* Miller and Gurley in its septa, I presume that his figure is taken from an immature specimen. The suture of our species is very similar to that of *G. globulosum* except that the siphonal saddle is somewhat stouter.

The main difference between the New Mexico species and *G. subcavum* appears to consist in the ornamentation and the form of the constrictions. Our species shows a greater number of constrictions (5 to 7) and these are strongly curved forward on the venter, while in *G. subcavum* there are only about four constrictions, which show a very slight sinuosity.

The differences in ornamentation are still greater. *G. subcavum* shows only very faint lines of growth and according to Smith has no umbilical ribs. Our species, on the contrary, shows a very distinct ornamentation. On the umbilical wall we count over thirty very fine but well defined radial ribs or costæ which on the umbilical shoulder swell into small nodules; from each of these, one or two even bundles of three and four fine costæ (much finer still than those on the umbilical wall) start and run over the venter strongly curved forward. All this ornamentation is very coarse in immature specimens but in adults it becomes gradually finer and on fragments of the largest individuals where the shell is well preserved the fine umbilical ribs are rather distant from each other but very distinct, although extremely delicate.

[5] Op. cit., p. 97, pl. 17, figs. 15-17.

The nodules on the umbilical shoulder are scarcely noticeable, and the costæ on the venter disappear altogether, leaving only traces of faint lines of growth; but in this stage of development we observe a very great number of fine but distinct spiral costæ separated by wide interstices. On the umbilical shoulder, three or four of these spiral lines become very distinct, and their crossing with the umbilical ribs and the fine radial costæ which disappear on the venter causes two, three or four rows of fine tubercles. These spiral lines can also be observed on the well preserved shell of small individuals (5mm. diameter and less) but there they are so fine and the strong radial sculpture is so prominent that they easily escape observation.

In our immature specimens the nodules of the umbilical shoulder recall somewhat those in *G. montgomeryense* Miller and Gurley,[6] but in the larger individuals this ornamentation is extremely fine and nearly disappears on the casts.

Nothwithstanding the difference in ornamentation, I am inclined to include our species, as well as *G. montgomeryense,* in the group of *G. subcavum,* which may have descended from forms like *G. entogonum* of the Mississippian.

The ornamentation described above nearly disappears from casts, and these thus appear remarkably similar to *G. subcavum.* This latter species was first described from the upper Pennsylvanian of Montgomery County, Illinois, but was also found in the Cisco formation of Graham, Young County, Texas, about 600 feet below the contact of the Permian. It is very common in the Abo beds of Tularosa, our collection containing at least forty specimens of it. It may be known as *G. subtilicostatum,* n. sp.

As we have already mentioned, the genus *Gastrioceras* is represented at our locality by quite a number of species, not all of them as characteristic as the above described type but of sufficient interest to be mentioned here.

There are two species which to a certain degree resemble the one described on the foregoing pages. Both have the deep funnel-shaped umbilicus with a rather sharp edge on the umbilical border although somewhat less than in the preceding form. Both are much less

[6] J. P. Smith, op. cit., p. 95, pl. 5, figs. 8-10.

evolute, one of them more than the other. In both the venter is much more rounded and the cross-section is more subelliptical than crescent-shaped. The ornamentation is very similar in both, consisting of fine radial costæ on the umbilical wall which scarcely swell into fine nodules on the umbilical shoulder; from each of these start two fine costæ, which run across the venter curving strongly forward. No spiral lines were observed, even in very well preserved shells. Both have three to four constrictions on the external whorl which curve toward the front. The septa are of the common gastrioceran type. The differences between the two species are not very great, it being even possible that both represent variations of the same type. I do not know of any species very similar to these two although one might compare them to a certain degree with *Gastrioceras welleri.*

Quite different from the foregoing species is another one which seems to be related to *Gastrioceras illinoisense* Miller and Gurley although it is much less evolute. This species is characterized by strongly rounded flanks and venter, very narrow and deep umbilicus with a well round border, nearly semicircular cross-section, and the complete absence of nodules on the umbilical border. The ornamentation consists of fine radial striæ which begin on the umbilical wall, bifurcate on the flank and are slightly curved forward on the venter. Each volution shows four deep constrictions which are only very slightly curved forward on the venter. The septa are of the common gastrioceran type.

The nearest Carboniferous form is probably *G. illinoisense,* but it is much more globose than our species.

In its external shape our species resembles rather surprisingly the very young individuals of *Gastrioceras roadense* Böse[7] from the lower Permian of the Glass Mountains, Texas, although the adults of this species are entirely different. Also similar to a certain degree is *G. modestum* Böse from the lowermost Permian of the Glass Mountains, but this form is much more globose.

All of the foregoing species of *Gastrioceras* are extremely common in the Abo beds of Tularosa, every one of them being represented by dozens of individuals of different sizes; but our collection contains several other

[7] Compare especially Böse, Permo-Carboniferous Ammonoids of the Glass Mountains, Univ. of Texas. Bull. No. 1762, pl. 2, figs. 28-34, 1917.

forms represented only by a single shell each. None of them is very characteristic, or intimately related to any known form. One of these species shows a sculpture different from that of all the other species of the locality. It consists of thin radial costæ slightly curved forward on the venter; on the umbilical border, which is well rounded, they are crossed by rather strong spiral lines which cause a kind of crenulation, but which seemingly become very faint or disappear entirely on the venter. Unfortunately the suture could not be made visible.

Another form is characterized by a very great number of septa; the flanks of the external saddles of the different septa touch each other. The species is rather involute, has a deep narrow umbilicus with a well rounded border, well rounded flanks and venter, and a nearly semicircular cross-section. Three rather shallow constrictions are visible on the whorl. The specimen is a cast and does not show any ornamentation.

Another form has very numerous septa but the umbilical border is rather sharp; no ornamentation is preserved on it.

There is still a further species in our collection, the generic position of which has not been quite ascertained. It is represented by four specimens of different sizes, the largest one having a diameter of about 12mm. The suture resembles that of *Muensteroceras,* although the lobes are not quite as angular as in that genus and the first lateral saddle is rather high and not extremely broad. On the umbilical border we find a row of rather strong tubercles; each volution has four to five deep constrictions which are curved forward on the venter. The umbilicus is moderately narrow and with a rather sharp border; the wall is steep.

These specimens may be the young of some *Gonioloboceras* different from the one described above, or they may belong to a new genus. This question cannot be decided until more material has been found.

The fauna of ammonoids from the lower Abo beds of Tularosa is of considerable interest as it gives a quite precise determination of the age of this formation.

There is not a single form related to Permian species, but everything indicates that the beds belong to the Pennsylvanian and especially to the upper part of this system. *Gonioloboceras* is certainly a form characteristic of the upper Pennsylvanian, notwithstanding that J. P. Smith has described some species from the Mississippian[8] which he doubtfully refers to this genus. Still more important is the circumstance that our *Gonioloboceras* is very intimately related to *G. welleri* from the upper Pennsylvanian (Uralian) of Texas (about 600 feet below the Permian contact); this makes it almost certain that they are more or less of the same age.

Gastrioceras is a genus which occurs throughout the Carboniferous and the Permian, but the groups which are represented in our collection distinctly belong to Pennsylvanian types and especially to those from the Uralian. In the Permian most of the species of *Gastrioceras* belong to the very characteristic group of *G. zitteli,* while the Pennsylvanian types are rather rare in this system. In the Abo sandstone of Tularosa, on the contrary, the group of *G. zitteli* is entirely absent, while Pennsylvanian forms occur in abundance.

Thus we have to conclude that the Abo beds belong to the Pennsylvanian and that they belong in the upper part of this system (Uralian).

This is confirmed by still another fact. Mr. Baker, while studying the younger Paleozoic of the upper Pecos Valley in New Mexico, found that the Abo sandstone there rests unconformably on the Magdalena beds, which in their upper part also contain an upper Carboniferous fauna. Near Pecos village we collected in the lowermost Abo beds a number of brachiopods and pelecypods (mainly *Productus* and *Myalina*) among which not a single Permian form was present. Unfortunately the higher part of the Abo beds in this portion of the Pecos valley is entirely barren of fossils. It is covered by the so-called Glorieta sandstone, the age of which was unknown up to the present, but Mr. Baker and the author have followed the formation toward the south to Los Griegos and the Blanco Cañon, where it is unconform-

[8] Haug, Traité de Géologie, p. 751, wants to replace the term Mississippian by the term Dinantian because the former name was used by Marcou in an entirely different sense (= Cambrian). Haug himself recognizes (p. 786) that the term Mississippian has been extremely well chosen, as no region is known where the lower Carboniferous is as well developed as in the Mississippi basin. It seems to me that the name Mississippian should be accepted as part of the universal nomenclature, because it is well chosen and has been in general use in America for a long time. Marcou's use of this name for the Cambrian never has been accepted and should simply be abandoned.

ably underlain by the Yeso formation and forms the base of the continental Trias. The Glorieta sandstone is a rather constant member of the Trias; it can be followed eastward to the Pecos Valley in the region between Anton Chico, Santa Rosa and Puerto de Luna, where it frequently contains bones of reptiles and shells of *Unio* and *Anodonta.*

The result thus gained appears to make it necessary to abandon the name "Manzano group," as this term would include Pennsylvanian and Permian beds. Perhaps "Manzano group" could be restricted to the Yeso and San Andreas formations, while the Abo sandstone could be united with the lower series, the Magdalena beds.

We have here one of the rather frequent cases in which unconformities do not always separate two different series but divide formations which belong to the same series, their contacts being entirely concordant. I have already had an opportunity to cite a similar case in the Glass Mountains of western Texas where an unconformity traverses the lower part of the Permian, while the lowest beds of this system rest conformably on the Schwagerina beds of the Uralian.

Santa Rosa, New Mexico.
November 6, 1919.

ART. IV.—*The Origin of the Dighton Conglomerate of the Narragansett Basin of Massachusetts, and Rhode Island;* by EDWARD H. PERKINS.[1]

INTRODUCTION.

The Dighton Conglomerate forms the upper portion of the Carboniferous series of the Narragansett Basin. The rocks consist of coarse quartzite and granite conglomerates interstratified with sandstones, shales, and, in some cases, coaly beds. Since the time of deposition this formation, along with the lower members of the series, has undergone severe dynamic metamorphism. A careful study of this metamorphism has been made by Lahee.[2] As the result of this action the rocks have been so deformed that the determination of original structures and the shapes of the pebbles is difficult. This is especially true in the southern part of the basin. Once spread over an area at least 40 miles long by 15 miles wide, the conglomerate is exposed today in a series of synclines surrounded by the older formations. (Fig. 1.)

The field work upon which this paper is based was carried on during parts of the summers of 1916, 1917 and 1918. Realizing that the determination of the origin of the formation must be a comparative study, attention was also given to other conglomerates. The Roxbury conglomerate and the Squantum tillite of the Boston Basin, the Triassic conglomerate of the Connecticut Valley, and the Lafayette and Columbian formations near Washington, D. C., were examined in the field. Tills, aqueoglacial deposits and beach gravels were also studied.

The writer wishes to express his indebtedness to the Geological Faculty of Yale University, especially to the late Professor Barrell. It was the latter who first interested him in problems of sedimentation. Professor Charles Brown of Brown University also aided by helpful advice in regard to the field work.

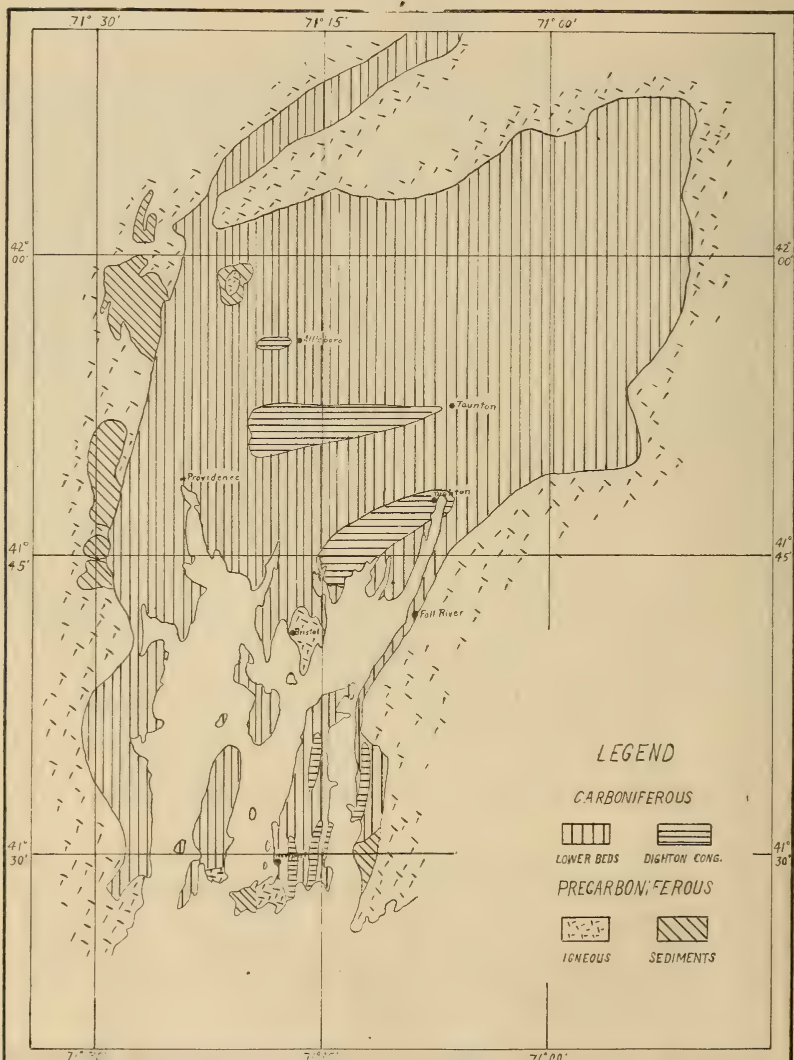
[1] The present paper is a digest of a dissertation accepted for the degree of Doctor of Philosophy in Geology at Yale University, June, 1919.

[2] Lahee, F. H., Relations of the Degree of Metamorphism to Geological Structure and to Acid Igneous Intrusion in the Narragansett Basin, R. I., this Journal (4), 33, 249-262, 354-372, 447-469, 1912.

General Description of the Basin.

The Narragansett Basin occupies the eastern half of the state of Rhode Island and a considerable area in

Fig. 1.



southeastern Massachusetts. It lies between 71° 30′ and 70° 48′ east longitude and 41° 25′ and 42° 10′ north latitude.

Topographically, the basin may be divided into two distinct areas, a northern and a southern. The southern section consists of Narragansett Bay, its islands and a narrow belt on either shore. The bay is a drowned valley, while the islands are hills rising from the old valley floor. The hills on Aquidneck Island rise to 260 feet above sea-level. MacSparran and Hammond hills on the west shore are nearly the same height. The topography is in a state of early maturity. Some of the hilltops have fairly large areas of level land, especially in the north-south direction. The bay section of the basin tends in a north-south direction. The rocks are highly metamorphosed.

The northern, or inland section, on the other hand, tends in a northeast-southwest direction, while the rocks, especially toward the east, are much less metamorphosed than further south. The country is rolling in character, similar to the drowned section further south. The highest elevation is Great Meadow Hill which is 263 feet above sea-level. This hill, like the higher portions of Aquidneck island, is a syncline and owes its elevation to the resistant Dighton Conglomerate. The surrounding country underlaid by the weaker Coal Measures is lower.

At its northwestern corner the basin is connected with the smaller Norfolk Basin. At all other points it is surrounded by intrusive granites and highly metamorphosed sediments.

The Carboniferous sediments which make up the basin consist of shales, sandstones, arkoses and conglomerates. The series is as follows:

Table I. Formations of the Narragansett Basin.

Dighton Conglomerate		1,000–1,500	ft.
Rhode Island formation	Coal Measures Aquidneck shales	10,000	"
Wamsutta series	Kingston series Attleboro sandstones	1,000	"
Pondville conglomerate and arkose		100	"

(Modified from Woodworth.)[3]

In this paper the lower formations will be considered only as they throw light on the origin of the Dighton conglomerate.

[3] Shaler, N. S., Woodworth, J. B. and Foerste, A. F., Geology of the Narragansett Basin, U. S. Geol. Survey, Mon. 33, 134, 1899.

The sediments have been compressed into a series of folds, which in the southern half of the basin run nearly north and south, and in the northern half of the basin tend a little north of east. The Dighton conglomerate is found in the axes of the synclines. The chief areas of the conglomerate are the Newport synclines in the south, the large Dighton and Taunton synclines in the central part of the basin, and the little Attleboro syncline in the extreme northwest.

The Dighton Conglomerate.

The various features of the conglomerate will be considered under the heads of structure, matrix, larger fragments, color, fossils and associated sediments. Emphasis will be placed on criteria by which the method of origin may be determined.

Structure.

Almost without exception the structure of the conglomerates is what is known as pell-mell. The outcrops show jumbled masses of pebbles, cobbles and bowlders. The long axes are tipped at all angles and with no, or at least very slight, traces of bedding. In certain outcrops, especially in the Newport area, pressure has elongated the pebbles in parallel lines. This is clearly a secondary feature and gives no clue to the arrangement of the pebbles at the time of deposition. Pell-mell structure may be the result of glacial deposition, very rapid fluviatile deposition or the slumping of unconsolidated bedded deposits of any origin. The wide extent of the structure in the Narragansett Basin negatives the last suggestion and leaves ice and river action as possibilities.

Although the conglomerate beds themselves show little signs of bedding, they are interstratified, especially in the lower portions of the formation, with beds of other types. These beds consist of sandstones, shales and black coaly shales. Vertical variation is well shown in many parts of the area. Lateral variation is best shown in exposed cliffs around Newport. Some sections show lateral variation nearly as well developed as anything in modern flood-plains. This variation in the composition of the beds is characteristic of stream rather than of marine deposition, and speaks of deposition by currents changing in direction and velocity.

Lenses indicate the same thing. These are very common throughout the Dighton formation and its associated beds. Sandstone lenses in conglomerate were noted in about 30 per cent of the outcrops. Gray shale lenses were found in two localities, while coaly shales were found in four outcrops. The finer beds may also hold conglomerate lenses. These occur in seven different localities. Marine beds may contain lenses of different material from the surrounding rock. These beds will be formed parallel to the coast line. In streams, on the other hand, the lenses will be parallel to the course of the stream. The lenses of the Dighton are interfingered in various directions and so indicate changes in the depositing currents.

Both the interstratified beds and the lenses show cross-bedding, this feature being especially well developed in the finer beds. The conglomerates themselves, as a rule, give no indications of bedding. The cross-bedding is extremely irregular and is of the same type as that shown in glacial flood-plains. Both the angle and the strike of the laminations change repeatedly in a small exposure. The best exposures to study are along the coast, as inland the weaker beds which show cross-bedding are eroded out.

Associated with cross-bedding were found a few cases of contemporaneous erosion. The best examples were in the Coal Measures at the Thatcher Road bridge near Attleboro and on the Newport cliffs. In both cases streams have cut into the underlying beds and the channels later filled in. At the Attleboro location the new deposits are gray and contain fragments of the underlying red beds.

At three inland localities and at various places along the Newport cliffs, shale pebbles were found in the conglomerate. These appear to be of the same material as the neighboring shale beds and may indicate contemporaneous erosion.

At various places in the basin and especially along the Sakonnet River cliffs, pebble bands occur in the finer beds. These bands often cross each other and form an irregular network over the surface of the exposure. The pebbles of a band may be close-set, or they may be scattered a little distance apart. Gregory[4] mentions these pebble bands as a common feature of stream action in the arid regions of the southwest. The writer has also found them on several occasions in Pleistocene outwash plains.

The scattering of isolated pebbles through sands and shales is a common feature of river work. Gregory[5] mentions it as common in the stream deposits of the southwest. The author has found these scattered pebbles in glacial outwash deposits, in the Columbian deposits around Washington and in the shale beds connected with the Squantum tillite. In the Dighton formation the sandstones that are interbedded with the conglomerate contain isolated pebbles in about one-third of the outcrops noted.

Isolated bowlders and cobbles may occur in similar situations to those in which the isolated pebbles are found. These larger fragments are transported by tree or ice rafts. Such rafted bowlders are found in Pleistocene outwash deposits, and also occur in the shales associated with the Squantum tillite. The only case of undoubted rafting in the Narragansett Basin was found at Rocky Point, where a granite cobble and a quartzite bowlder lie isolated in a fine-grained sandstone. The beds are well up in the Rhode Island formation.

In addition to pebble bands and isolated pebbles, the sandstone layers of the Dighton formation contain nests of pebbles. These consist of a little bunch of pebbles in the finer rocks. These nests of pebbles might be explained in two ways: an ice cake might strand on a river bar and on melting deposit the pebbles it carried in a limited area, or a pebble lodged on the stream bed might catch and hold other pebbles either by contact or by lessening the velocity of the water in its vicinity.

The thickness of the Dighton conglomerate is estimated by Woodward to be from 1000 to 1500 feet. The outcrops extend from Newport 40 miles north to Attleboro, while the synclines extend 12 or 15 miles in an east and west line. This indicates a mass of material far in excess of the amount of material in the usual marine conglomerate. To quote Gregory:[6] "As preserved in

[4] Gregory, H. E., The Formation and Distribution of Fluviatile and Marine Gravels, this Journal (4), 39, 487-508, 1915.
[5] Gregory, H. E., op. cit.
[6] Gregory, H. E., op. cit.

the sedimentary record a stratum of marine conglomerate exceeding 15 miles in breadth and 100 feet in thickness would be anomalous. As compared with marine action, vigorous streams may carry gravel during a single cycle 3-300 times farther and distribute it much more widely."

Matrix.

The chief features of the matrix to be explained are: the unsorted condition of the material, the great variation in amount, and the presence of decomposable minerals.

Like the coarser material, the matrix is made up of large and small grains irregularly distributed. In almost every specimen the grains range from fine grit up to the small pebbles of the conglomerate. As a rule, however, the coarser material predominates. Although a careful search was made, nothing as fine as rock flour was found, in the matrix of the Squantum tillite. The condition of the matrix thus indicates a degree of sorting above what we would find in a glacial till, but still very imperfect. This would suggest a fluviatile rather than a marine origin.

In certain outcrops, especially in the Newport region, the matrix is almost wanting, the cobbles being laid in contact with each other. This condition may be due in part to compression, which has granulated the quartz grains and caused the development of a large amount of sericite, especially over the surfaces of the cobbles. Further north in the other synclinal areas the amount of matrix varies greatly in the same outcrop. This change may be either gradual or sudden and shows no regularity as to direction. In the case of a marine conglomerate, one would expect a gradual increase in the amount of matrix away from the old shore-line. No such gradual change is found in the Narragansett Basin.

In many cases either particles of feldspar or the kaolinized remains of such particles were found. In specimens in which the particles were too fine to be distinguished by the eye, the clayey smell of kaolin could be detected. In a few cases particles of biotite were found, and in the northern syncline where there has been slight metamorphism the rocks contained scattered fragments of muscovite which did not appear to be of secondary origin. The matrix was apparently formed under conditions which did not permit the chemical decomposition of such minerals as feldspar. Two kinds of climate are characterized by such a condition: a warm arid climate and a cold moist one. The evidence of the matrix is therefore in favor of fluviatile origin under one of the above climatic conditions.

Larger Fragments.

The larger fragments of the Dighton conglomerate consist of quartzite, granite, vein quartz and small amounts of shale, sandstone and felsite. The first greatly predominates. The percentages of quartzite in the various areas going north through the basin are as follows: Newport 95, Dighton 88, Taunton 80, and Attleboro 58. The percentages for granite in the same areas are: Newport 5, Dighton 12, Taunton 11, and Attleboro 23. Thus granite increases in amount as one goes north, while the quartzite decreases.

There is also a decrease in size of the fragments as one goes north and west. This is shown in both granite and quartzite but is most noticeable in the latter. About Newport, bowlders one and two feet in diameter are not uncommon while specimens may be found five or six feet through. It is this great size of the fragments which is the most impressive thing about the Newport exposures. At the northern edge of the basin about Attleboro few cobbles over six inches and none over a foot in diameter were found. Many of the fragments contain Upper Cambrian brachiopods (*Obolus*). No outcrops of similar quartzites have been found nearer than Newfoundland. It seems probable that there was an area of Upper Cambrian quartzite exposed to erosion a very short distance to the southeast.

The granite and other pebbles to the north might be derived as readily from the west as from the east as far as their composition is concerned. However, the increase in size toward the eastern side of the basin indicates a source in that direction.

The characteristics of the larger fragments of the Dighton formation and other conglomerates and gravels were studied. The points noted which seem of value in the determination of the origin were the following: presence of bevelled surfaces; amount of rounding; shape, either blunted or pointed or rhombic; and concave fractures. The results are shown as percentages in Table II.

Table II. Characteristics of Conglomerate Pebbles.

	A	B	C	D	E
Beveled surfaces	83	93	98	31	58
Well rounded	23	11	5	19	48
Moderately rounded	57	48	53	39	32
Slightly rounded	20	41	42	42	20
Blunted and pointed pebbles	7·6	24	29	0·6	8·3
Rhombic pebbles	6·2	15	14	1·2	5·5
Concave fractures	58	81	92	6·8	24

A, Dighton conglomerate; B, Tills; C, Aqueoglacial gravels; D, Fluviatile gravels; E, Marine beaches.

Under the head of beveled surfaces are classed fragments having one or more flattened surfaces. These may have been formed either as a result of wear or from joints or other planes of weakness in the parent rock.

It will be seen that the Narragansett Basin conglomerates have a higher percentage of flat surfaces than marine or fluviatile deposits and tills. The percentage for marine deposits is high from the fact that many of the marine beaches studied were formed of glaciated pebbles. The average for the fluviatile deposits is low, due to the fact that the coastal plain deposits which were studied were made up of fragments which had travelled a considerable distance and had suffered a proportionate amount of wear. The evidence from the beveled surfaces indicates an erosive agency which furnished a large number of angular fragments, and also a moderate amount of transportation.

The amount of rounding in the fragments of the Dighton conglomerates seems to be less than that found in the marine gravels, and more than the average for tills. However, the degree of rounding is more dependent on the nature of the fragments and the amount of erosion than on the agent. Hence the degree of rounding is not decisive evidence in determining the method of origin of a conglomerate.

Two types of pebbles have been found to occur in all tills and aqueoglacial deposits examined: rhombic, and blunted and pointed. The idea that rhombic pebbles might be a criterion of glacial origin was suggested by Professor Charles Brown of Brown University, while forms blunted at one end and pointed at the other were first found in the Dighton conglomerate and then looked for in other deposits. Table II shows the high percentages of both these forms in glacial and aqueoglacial deposits as well as the low percentages for fluviatile gravels. The percentage of these special shaped pebbles in marine beach deposits is due to the fact that most of the beaches studied were made up of glacial pebbles. It could be seen, however, that the waves were destroying the rhombic and blunted forms instead of producing them.

Neither of the forms under consideration is dependent on the composition of the pebbles. They have been found in both granite and quartzite. In some cases these forms may be produced by breaking along planes of weakness. The small number found in fluviatile deposits may be explained in this way. The percentages for the Dighton conglomerate are much higher than those of fluviatile deposits and lower than those of glacial or aqueoglacial origin. In fact, the averages for the Dighton, blunted and pointed 7·6 and rhombic 6·2 per cent, are not far from the averages for the marine beaches formed from Pleistocene deposits, blunted and pointed 8·3 and rhombic 5·5 per cent. The forms of the pebbles in the Dighton may, like those of the marine deposits, be an inheritance from former glacial action.

Concave fractures caused by the pressure of one pebble on another have been held to be a mark of glacial origin. These fractures may occur, however, during dynamic metamorphism. Several instances were noted in the Dighton formation where the corner of one pebble was lying imbedded in the side of another. For this reason the presence of these fractures in the Dighton cannot be considered as a good criterion of origin.

Color.

Over the greater part of the basin the color of the conglomerates and sandstones is gray or blue-gray. The shales are either the same color or black with organic matter. Many of the outcrops are iron-stained, showing that there is a certain amount of that element in the rocks. The light colors therefore indicate that the iron is in the ferrous form. In the neighborhood of the coaly shales this may be due to reduction by organic matter. However, the same light color persists through great thicknesses of rock which have no carbonaceous beds in their immediate vicinity. It seems most likely that the material of the formation was eroded and deposited under conditions which did not permit the oxidation and dehydration of the iron. Plenty of ground-water would perhaps be the most efficient agent for such work. The water would fill the pore spaces in the loose unconsolidated material, keeping out atmospheric oxygen and at the same time making drying of the deposits a slow process. In warm moist climates where chemical action is rapid, red deposits are now being made. The blues and grays of the Dighton beds are, then, an indication of a moist cool climate.

Fossils.

No marine fossils have been found in the rocks of the Narragansett Basin. Vegetable forms are dominant, a list of twenty-six species, mainly from Pawtucket, and identified by Leo Lesquereux, being given by Woodworth.[7] This flora is equivalent to that of the Upper Carboniferous in Pennsylvania. As the beds in which the plants were found represent the lower half of the Coal Measures, there is nothing in this evidence to prevent placing the Dighton conglomerate several thousand feet higher up in the Permian. The same beds which yield the flora mentioned have given fourteen species of insects.[8] These, with "the impression of an annelid worm, several shells of *Spirorbis*, and what appears to be the track of a gastropod mollusk" are the only traces of animal life which have been found in the basin.

Associated Sediments.

The sediments associated with the Dighton conglomerate consist of arkoses, conglomerates, sandstones, shales, coal and graphite beds and carbonaceous shales. The series starts with a basal arkose, lying between the

[7] Shaler, N. S., Woodworth, J. B., and Foerste, A. F., op. cit. p. 204.
[8] Op. cit., p. 202.

granites and the upper beds. The rocks are very granitic in appearance and in places are hardly distinguishable from the nearby granites. These arkoses pass into and contain layers of the basal conglomerates the pebbles of which are small and angular. The composition of these beds closely resembles the arkose.

Following the basal beds come the 10,000 feet plus or minus of the Coal Measures. While conglomerates still occur in small beds, the dominant deposits are sandstones and shales with coal and graphite beds. The sandstones still contain feldspar, and the shales have a clayey smell, but evidently decomposition was more important than it had previously been. A rich vegetation developed, partly on the site of deposition and partly nearer the headwaters, as is indicated by the drift logs found in the gray sandstone. Apparently the climate was becoming still more moist, allowing the formation of coal swamps over the delta. The mantle of vegetation in the headwaters may have covered the ground so as to permit the erosion of only fine material.

The Coal Measures pass through an alternation of shale, sandstone and conglomerate layers into the Dighton formation. The writer found no indication of an unconformity between the two formations. The zone of passage seems to indicate a progressive rhythmic change from conditions which permitted the formation of the Coal Measures to those which permitted the formation of the great thickness of Dighton conglomerate.

Summary of evidence.

I. Evidence favoring a fluviatile origin.
- A. Structure.
  1. Pell-mell structure common.
  2. Absence of definite though considerable thickness of conglomerate.
  3. Great vertical and horizontal variation in composition of beds.
  4. Lenses of shale, sandstone and conglomerate of various sizes interlaced in different directions.
  5. Extremely irregular cross-bedding common.
  6. Pebble bands common.
  7. Isolated pebbles common in the sandstone layers.
  8. Thickness 1,000 to 15,000 feet.
- B. Matrix.
  1. Rapid variations in amount.
  2. Grains angular and unsorted.

C. Larger fragments.
1. Large and small fragments mixed, unsorted.
2. Pebbles and cobbles more angular than those of a normal marine conglomerate.

D. Associated beds.
1. The series from arkose through sandstones and shales to conglomerate is typical of continental rather than marine origin.
2. Large amounts of coal and coaly shale.
3. Contemporaneous erosion.
4. Irregular cross-bedding.
5. Rain-prints and mud-cracks.

E. Fossils.
1. Absence of remains of animal life.
2. Abundance of plant fossils.

II. Evidence of ice action.

A. Directly as glaciers in zone of deposition forming tillites. No evidence.

B. Indirectly at headwaters of streams forming aqueoglacial deposits.
1. Large percentages of beveled surfaces on pebbles.
2. Rhombic and blunted and pointed pebbles common.
3. Concave fractures common.
4. Rafted bowlders in associated deposits.
5. The great number of large bowlders in the Newport area seem to require either the wedge work of ice or the plucking power of a glacier for their production.

III. Evidences for a cool climate.
1. See evidences for ice action above.
2. Freshness of material.
3. Abundance of feldspar in matrix.
4. Preservation of plant fossils from decay.
5. Blue-gray color indication of absence of dehydration of iron by heat.

IV. Evidence for a moist climate.
1. See evidence for stream and ice action above.
2. Abundance of plant life.
3. Lack of dehydration of iron.

Conclusions.

1. The Dighton conglomerate is believed to be a fluviatile deposit.

2. The great size of the fragments indicates a rapid and vigorous erosion at no great distance from the site of deposition. The deposit is therefore believed to have been formed at the base of a mountain range.

3. As the coarser material is in the eastern and southeastern part of the basin, the range is believed to have

been located to the east of our present coast-line. The streams which deposited the Dighton flowed to the west.

4. The stream or streams to the south flowed from a country where the bed-rock was upper Cambrian quartzite, while the streams to the north flowed from a more granitic country. It might be argued that the granite pebbles to the north, being smaller, might be deposited along the lower courses of the streams which deposited the Purgatory quartzite conglomerate. The quartzite nature of the southern beds, however, extends down into the finer basal conglomerates and even into the Sakonnet sandstone. In the same way the finer conglomerates to the north are as granitic as the upper beds.

5. The production of the coarse material of the Newport region seems to require some stronger erosive agent than normal river and atmospheric action in a temperate climate. Vigorous frost action with the possible assistance of glaciers would furnish the material to the streams. The great abundance of angular pebbles, with a consistent percentage of rhombic and blunted and pointed pebbles, as well as concave fractures in the least metamorphosed parts of the basin, also point to ice action. There is no evidence that the ice-sheets ever reached the plain in the Narragansett Basin. It is entirely possible that the Newport beds were deposited in front of an advancing glacier which later covered the region. If such a thing ever happened, its beds have been entirely lost through erosion.

6. When the Dighton conglomerate is considered in connection with the entire Carboniferous series of the basin, it is seen to be at the end of a more or less gradual climatic change. A broad area of country was so situated through a long period of time that disintegration covered the surface with a deep mantle of arkose and broken rock. Locally conditions permitted the formation of red rocks. Toward the latter part of the Pennsylvanian the climate became more moist, perhaps accompanied by an upheaval of the old land mass. The increased run-off swept the arkose and broken rock into the valleys and started the series of basin beds. As the climate became more moist and cooler, erosion continued, and a broad alluvial fan or series of fans was built out to the west. Over these fans were scattered wooded swamps which were buried by the ever-increasing débris from the mountains, only to be replaced by new swamps.

As time went on the climate became still more damp and cold. There were climatic fluctuations,—periods of rain when pebble beds were carried far out on the plains, and drier periods when mud and sand were deposited,—but all the time the tendency was toward a wetter and a cooler climate. The pebble beds increased in thickness and number and in the size of their fragments. Erosion increased in the headwaters. Perhaps as the cold became more intense the vegetation became less, leaving exposed rock surfaces; perhaps the mountains rose above tree level. Frost and finally ice acted vigorously on the bare rock surfaces and pebbles. The streams were now strong enough to sweep the detached fragments out of the plain where they formed the deposit now preserved as the Dighton conglomerate. The finer material was carried farther from the mountains and may have formed the Carboniferous rocks of central Massachusetts.

Here our record ends for the Narragansett Basin, but to the north, in the Boston Basin, the glaciers reached the piedmont slope and deposited one or more beds of till. These were apparently replaced in turn, as the ice retreated, by lakes and flats in which beds of fine mud were deposited.

The history of the Narragansett Basin is the history of one of the mountain and climatic movements which led to the final great up-folding of the Appalachian revolution. In the Devonian delta of Pennsylvania we have the record of one of the earlier preparatory movements.[9] In the remains of the piedmont of Rhode Island we have the record of one of the last of the great upheavals which finally ended the history of Appalachia.

It is to the last of these upheavals that we owe our knowledge of the Dighton conglomerate and its history. For although Appalachia itself passed away along with most of its piedmont, four great masses of the gravels were folded far below the surface and there preserved. Subsequent erosion has revealed them to us as the Newport areas, and the Dighton, Taunton, and Attleboro synclines.

Rhode Island State College.
August, 1919.

[9] Barrell, J., The Upper Devonian Delta of the Appalachian Geosyncline, this Journal (4), 36, 429-472, 1913; 37, 87-109, 225-253, 1914.

Art. V.—*Sulphohalite from Searles Lake, California;*[1] by Wm. Foshag.

Sulphohalite was described by Hidden and Mackintosh in 1888 and its composition established by Penfield in 1900. At the time Penfield studied this mineral only four specimens were known and so far as the writer is aware none have been reported since.[2] It is interesting to note, therefore, that three more crystals have been found in material in the U. S. National Museum.

Sulphohalite has been found only in the famous Searles Lake (sometimes called Borax Lake, but not to be confused with Borax Lake in Lake Co., Calif.) in San Bernardino Co., California. It occurs in the saline layers below the surface crusts and in close association with hanksite. Penfield mentions sulphohalite grown upon hanksite and one of the new finds had a small fragment of hanksite attached to it.

The first crystal found in the new lot came from a sample labeled "Well G75, Searles Lake, 75′-85′" recently turned over to the Museum by the U. S. Geological Survey It is an octahedron showing also two cubic and two dodecahedral faces. It measures 10mm. and weighs ·85gm. A small fragment chipped from it dissolved in water leaving a slight residue that effervesced with acid and is probably calcite. The solution reacted for both chlorine and sulphate. Its index of refraction measured by the immersion method was 1·455. Specific gravity measured on a Kraus-Jolly balance was 2·43. In order to place the mineral definitely as sulphohalite the index of refraction of some of the type material (U. S. Museum No. 87376, gift of S. P. Sadtler) was measured and found to be identical with that of the above crystal, 1·455. A second and smaller crystal was found in the same lot. It weighed ·06gm. and showed the octahedron and dodecahedron. It was identified by its index of refraction and lack of strong saline taste.

The third crystal was one of four octahedrons labeled "Halite, Searles Lake, Calif." Its yellowish green color and lack of strong saline taste led to the determination of its index of refraction which proved to be as for the

[1] Published with the permission of the Secretary of the Smithsonian Institution.

[2] Since the above was written the writer's attention has been called to the article on sulphohalite by Gale and Hicks, in this Journal, 38, 273, 1914.

above measured crystals. It measured 17mm. and weighed 2·2gm. It is a well-defined octahedron with one cubic face present.

It is quite possible that many of the so-called octahedral halites if examined closely, especially if they have only a slight saline taste, will prove to be sulphohalite. Its low index, 1·455, is much lower than any of the associated isotropic minerals and is the most convenient means of identifying this mineral.

U. S. National Museum, Washington, D. C.
October 7, 1919.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Application of Rotating Reductors in the Determination of Iron.*—Walter Scott has described the use of rapidly rotating cylinders of zinc or aluminium for the reduction of ferric sulphate solutions in order to determine the iron by titration with permanganate. The rapidity and efficiency of this method of reduction in the case of vanadic acid has been previously demonstrated by Professor Gooch and the present author and was described in this Journal in 1918 (**46**, 427), and the investigation under consideration was also carried out in the Kent Chemical Laboratory at the suggestion of Professor Gooch.

It was found that zinc cylinders rotating at 700 or 800 revolutions per minute and exposing a surface of about 75 sq. cm. to the liquid the volume of which was about 50 cc., the reduction was complete in 2 or 3 minutes with small quantities of iron, and in only a slightly longer time with larger quantities, such as 0·7 g. The reduction was somewhat more rapid when the operation was started at the boiling point of the liquid than when the liquid was cold. It appears that aluminium gives a somewhat more rapid reduction than does zinc. It is evident, since excellent results were obtained, that the method furnishes a satisfactory substitute for the well-known "Jones reductor" process where the solution is passed through a column of amalgamated zinc fragments. In some of the experiments the rotating cylinders were made anodes by passing an electric current to an immersed platinum cathode but this device appeared to give no particular advantage.—*Jour. Indust. and Eng. Chem.*, **11**, 1135. H. L. W.

2. *Solubilities of Inorganic and Organic Compounds;* by Atherton Seidell. Large 8vo, pp. 843. New York, 1919 (D. Van Nostrand Company. Price $7.50 net).—This is the second edition, enlarged and thoroughly revised, of a most valuable book of reference for chemists. Data of solubility are important not only in connection with the scientific investigation of the laws governing solution, but they are very frequently required in connection with various other kinds of chemical work. The author has performed an enormous task in the preparation of this book, and for the present editions many journals have been examined page by page in order that data might not be overlooked. The tables of solubilities are excellently presented with frequent useful notes, while the very numerous references to the literature are conveniently arranged in the form of an author index. A good chapter on methods for the determination of solubility is included. H. L. W.

3. *The Metals of the Rare Earths;* by James Frederick Spencer. 8vo, pp. 279. London, 1919 (Longmans, Green & Co. Price $4.50 net).—This is one of the important series of Monographs of Inorganic and Physical Chemistry, edited by Dr. Alexander Findlay. It gives an excellent account of the subject, including the history of the discovery of the rare earths, their occurrence in minerals, the methods used for their separation, their compounds, the determination of their atomic weights, their positions in the periodic system of the elements, and their practical uses.

A particularly useful feature of the work is a table of more than 1000 references to the literature of the subject. There are also full name and subject indices. H. L. W.

4. *The Analysis of Silicate and Carbonate Rocks;* by W. F. Hillebrand. 8vo, pp. 285. Washington, 1919 (U. S. Geological Survey, Bulletin 700; Government Printing Office).—This is a revised and enlarged edition of Bulletin 422 bearing the same title, and there have been several still earlier editions of this important hand-book. The great value and reliability of Dr. Hillebrand's advice in regard to rock analysis is so well-known, and these bulletins have been so widely used by mineral analysts, that it is sufficient here to merely welcome the new edition, to say that changes that have been made in it appear to be most excellent, and to thank the author for it. H. L. W.

5. *Report of the International Committee on Atomic Weights for 1919-20.*—This report is signed by F. W. Clarke of this country, T. E. Thorpe of England and G. Urbain of France. No new table has been presented since the one for 1916, but in spite of the considerable period that has elapsed there are but few changes in the table now given for 1920. These changes give the new values: Argon = 39·9, Boron = 10·9, Gallium = 70·1, Nitrogen = 14·008, Thorium = 232·15 and Yttrium =

89·33 in the place, respectively, of 39·88, 11·0, 69·9, 14·01, 232·4 and 88·7. Most of these changes are either very slight or they involve very rare elements, but the change of about 1% in the value for boron is of considerable importance.—*Jour. Amer. Chem. Soc.*, **41**, 1881. H. L. W.

6. *James Cutbush, an American Chemist, 1788-1823;* by Edgar F. Smith. 16mo, pp. 94. Philadelphia, 1919 (Printed by J. B. Lippincott Company).—In this little book Provost Smith has made an interesting addition to his valuable biographical studies of early American Chemists. The story of Cutbush's short, brilliant and varied career is very well told. Several of his papers were published in the early numbers of this Journal. No evidence has been found that he was ever a regular student either of chemistry or of medicine, but his writings display evidence of an unusual education, and he became a U. S. Army surgeon, and was in his last years professor of Chemistry at West Point. H. L. W.

7. *Sensibility of X-Ray Analysis and the Absorption Spectrum of Radium.*—The presence of chemical elements in various materials may be detected by means of X-rays in three general ways, which are: (a) by incorporating the material in the surface of the anticathode and then analyzing spectrally the primary radiations excited by the impact of the cathode rays, (b) by placing the specimen (outside of the bulb) in the path of the primary rays from the tube and analyzing the secondary X-rays emitted by the constituents of the substance, and (c) by recording the edges of the absorption bands arising when the primary rays from a bulb are allowed to pass through a thin layer of the material in question.

In a recent paper by Maurice de Broglie attention is called to the facts that method (a) is the most sensitive, but by far the most troublesome and time-consuming. Method (b) is more convenient and it has the great advantage of conserving all of the specimen employed. The author mentions two practical examples of the application of method (b), namely: "Certain oxides deposited on the filament of a wireless telegraphy lamp having three electrodes were studied (from the point of view of their constituents of high atomic weight) without opening the lamp bulb; a plate of gilded brass contained in a microphone of a submarine was identified as gilded brass without taking the apparatus to pieces."

In case (c) the contrast on the two sides of the edge of an absorption band may be measured by

$$\frac{I_1}{I_2} = e^{-(\mu_1-\mu_2)x},$$

where x is the thickness of the absorbing screen. For elements having atomic weights in the neighborhood of 100, μ_1 is of the order of $8\mu_2$ and μ_2 about 100 c.g.s. units, so that the contrast is measured by the Napierian base raised to the power -700 x. Therefore, when $x = 0{\cdot}1$ mm. the ratio of the intensities at opposite sides of the discontinuity is about e^{-7}, that is 1100 : 1. In practice, de Broglie finds that the unavoidable fogging of the photographic plates combined with the masking effect of the superposition of more penetrating radiations of higher spectral orders requires that the calculated ratio of intensities shall exceed 2 : 1 in order to give distinct contrast.

To check these deductions experimentally the author made a few quantitative tests to find how great a dilution might be used without destroying the necessary contrast. For wave-lengths inferior to 2×10^{-8} cm., the vessel should be made of celluloid, since the absorbing power of glass and aluminium is about nine times as great as that of celluloid and of water. A solution of 5 grams of barium chloride in a liter of water showed quite distinctly the barium band ($\lambda 0{\cdot}328 \times 10^{-8}$ cm.) when the thickness of the absorbing layer was 3 cms. With slightly greater thicknesses, the presence of barium in a solution containing 1 gram of the salt per liter could still be detected. In the last case, the mass of barium in the actual path of the beam of X-rays was inferior to one milligram.

Having thus shown that the metallic constituents of dilute solutions can be detected by X-ray absorption analysis, de Broglie applied this method to the element radium. The author says, in substance: ''A solution containing about 25 mg. of radium chloride per cm^3. was enclosed in a tube of acetate of cellulose, having a diameter of 2 mm. and thin walls (there being 20 mm^3. of solution and about 0·5 mg. of radium chloride), and the region of wave-lengths from $0{\cdot}5 \times 10^{-8}$ cm. to $1{\cdot}2 \times 10^{-8}$ cm. was then explored. Two characteristic bands, L_1 and L_2, of the element radium were discovered, their respective wave-lengths being $0{\cdot}802 \times 10^{-8}$ cm. and $0{\cdot}668 \times 10^{-8}$ cm.'' A weak band of uncertain origin was also observed at $\lambda\ 0{\cdot}707 \times 10^{-8}$ cm. These results were confirmed by using another preparation of radium chloride which was so much purer than the preceding one that the strong band of barium (the chief impurity) had practically disappeared. Within the limits of experimental error, the frequencies for the bands L_1 and L_2 conform to Moseley's law and the atomic number 88, hence the radioactive properties of radium seem to have no appreciable influence on the absorption of this element for X-rays of the hardness thus far tried.—*Jour. de Phys.*, **9**, 31, 1919. H. S. U.

8. *The Spectra of Isotopes.*—In the year 1917 Aronberg made a careful comparison of the line $\lambda 4058$ as radiated by ordinary lead and by uranio-lead obtained from Australian carnotite. He found that the wave-length both of this line and of its satellite was greater by about 0·004 Angström unit for the

uranio-lead than for common lead. This important result has been recently confirmed both qualitatively and quantitatively by the second investigation of the problem by T. R. MERTON. The author says: ". . . the results show that there is a small but real difference in the spectra, which agrees closely with the value found by Aronberg. A difference has also been found between the wave-length of the principal line in ordinary lead and lead from Ceylon thorite." Merton has also found evidence in favor of the belief that the thallium in pitchblende is an isotope of ordinary thallium, the former probably having the greater atomic weight.—*Nature,* **104,** 93, 1919. H. S. U.

9. *Helium Series in the Extreme Ultra-Violet.*—The formula for the helium series first discovered in a terrestrial source by Fowler indicates that lines may be expected at the approximate wave-lengths 1640·1, 1214·9, and 1084·7 Angström units. With the aid of his vacuum spectrograph, TH. LYMAN has finally succeeded in establishing the existence of the first two of these predicted lines. The experimental evidence relating to the line of highest frequency is not conclusive.

The author says: "With a powerful disruptive discharge in helium, a sharp, fairly strong line appears at 1640·2; no trace of it is found in hydrogen under the same electrical conditions, and it does not occur in helium when the discharge circuit is free from capacity. Under the same violently disruptive condition the line at 1216, always present in helium and hydrogen, develops a satellite on its more refrangible side; this satellite is not well resolved, but its wave-length appears to be about 1215·1."—*Nature,* **104,** 314, 1919. H. S. U.

10. *The Realities of Modern Science;* by JOHN MILLS. Pp. xi, 327. New York, 1919 (The Macmillan Co.).—"The present volume is intended for the general reader, interested in modern science, who finds few clews to recent advances in his memories of the formal instruction of school or college days." "The general reader is under no compulsion from a traditional curriculum and may pick and choose his sources of information. To the study of science he may, however, need an introduction and this need the present volume attempts to satisfy."

The ground covered in the text is so extensive as to preclude the possibility of doing justice to it in a short notice. The most concise idea of the contents of the volume may be obtained from the following titles of the twenty-two chapters, which are: The Beginnings of Knowledge; The Machines of the Ancients; Weights and Measures; The Beginnings of Science; The Beginnings of Experimentation; The Realities of Science; The Molecular Composition of Matter; The Electron; Energy; Some Uses of Mathematics; Rates; Force, a Space Rate of Energy; Molecular Motions and Temperature; Motion of Electrons; The Interactions of Moving Electrons; The Continuity and Correspondence of Molecular States; Molecular Mixtures; Electrolytic Dissociation; Equilibria and Their Displacement; Molecular Magnitudes; Molecular Energy; Electronic Magnitudes.

The gradation of the material and presentation from the most elementary to the very advanced has been admirably accomplished. The author's style is clear and smooth, and the verbal illustrations are very apt and pleasing. Mathematical analysis has been intentionally reduced to a minimum. The originality of the exposition is such as to cause the book to merit the serious attention not only of the "general reader," for whom it was primarily written, but also of all teachers of physics who feel that the time is ripe for cautiously breaking away from traditional methods and for introducing the principles and well-established results of modern research into the first, or at least the second, year courses. The writer of this notice desires to take the liberty of expressing the opinion that a text-book on magnetism and electricity from the pen of the original author would doubtless be of great help in bringing about the necessary advances and transitions in the pedagogy of college physics.

H. S. U.

II. Geology and Natural History.

1. *Contributions to the Geology and Paleontology of the West Indies;* prepared under the direction of Thomas Wayland Vaughan: (1) *Tertiary calcareous algae from the islands of Saint Bartholomew, Antigua, and Anguilla,* by Marshall A. Howe; (2) *Fossil Foraminifera from the West Indies,* by J. A. Cushman; (3) *Fossil Bryozoa from the West Indies,* by Ferdinand Canu and R. S. Bassler; (4) *Tertiary mollusks from the Leeward Islands and Cuba,* by C. C. Cooke; (5) *West Indian Tertiary decapod crustaceans,* by Mary J. Rathbun. Carnegie Institution of Washington, Pub. No. 291, 184 pp., 53 pls., 8 text figs., 1919.—We are rapidly coming to know, through the great activity of Mr. Vaughan and his colleagues, the invertebrate faunas that are at the basis of the stratigraphy of the Cenozoic deposits of the Gulf of Mexico, the Caribbean islands, and bordering continents. (1) Mr. Howe describes 5 species (4 new) of calcareous algæ. (2) The Foraminifera are more diversified and Cushman remarks on, or describes, 117 forms, of which 100 are specifically determined (34 new). And yet he says; "The area as a whole has still been scarcely more than touched"; a far greater harvest is therefore to be expected and a more detailed stratigraphy will follow. It is interesting to note here an abundance of larger orbitoid genera, forms of the greatest value in intercontinental stratigraphic correlation. (3) The paper by Canu and Bassler is noticed below. (4) Of mollusks, Mr. Cooke notes about 100 forms and of these 71 are specifically

determined (46 new). Of brachiopods there are 2 new species. (5) Miss Rathbun describes 31 forms of decapods and of these 22 are specifically determined (17 new). Much of the material is better preserved than is usual for crabs, and is a great addition to our knowledge of West Indian Cenozoic crustaceans. The illustrations are excellent throughout. C. S.

2. *Fossil Bryozoa from the West Indies;* by FERDINAND CANU and RAY S. BASSLER. Carnegie Institution of Washington, Pub. No. **291**, pp. 73-102, pls. 1-7, 1919.—In this little work are described and illustrated forty-two species of Oligocene and Lower Miocene Bryozoa from the West Indies and Costa Rica. Twenty-five species are new to science, along with three genera (*Cupuladria, Acanthodesia, Corynostylus*). Some of the species have a very wide distribution in America, Europe, and elsewhere, and therefore are excellent time markers and checks on intercontinental correlation. Here an older Frenchman and a younger American are knitting together their knowledge of bryozoans for the benefit of American stratigraphers. C. S.

3. *The Silurian Geology and Faunas of Ontario Peninsula, and Manitoulin and adjacent Islands;* by M. Y. WILLIAMS. Geol. Survey of Canada, Mem. **111**, 195 pp., 34 pls., 6 text figs., 2 geol. maps, 1919.—This is a thorough work describing and mapping the various Silurian formations throughout the Province of Ontario, and correlating them with equivalent strata in New York, Ohio, Illinois, and Michigan. The Devonian formations are also mapped. In chapter six are described the economic products and in chapter seven are discussed or described twenty Silurian species of fossils, of which ten are new. The characteristic fossils of the various formations are illustrated on plates II to XXVII. The author is to be congratulated on this good piece of work, begun in 1912. C. S.

4. *Geology of the Disturbed Belt of southwestern Alberta;* by J. S. STEWART. Geol. Survey of Canada, Mem. **112**, 71 pp., 5 pls., 1 map, 1919.—This interesting report describes the physiography, geology, and economic products of 2000 square miles at the eastern base of the Rocky Mountains in southwestern Alberta. The formations are sedimentary ones, ranging from the Lower Cretaceous to the Pleistocene, with a thickness of over 14,000 feet. The great bulk of the deposits are of Cretaceous age, five formations making an almost complete sequence of the sea of this protracted time. All are now intensely folded and faulted. C. S.

5. *New Species of Pelecypods from the Cretaceous of Northern Alberta;* by F. H. MCLEARN. Geol. Survey Canada, Mus. Bull. **29**, pp. 9-12, pls. 3-5, 1919. *Cretaceous, Lower Smoky River, Alberta;* by F. H. MCLEARN. Geol. Survey Canada, Summ. Rept. 1918, Part C, 8 pp., 1919.—Here are described nine species of bivalves, two from the Cretaceous and seven from the

Comanchean equivalents. It is interesting to note, in the second paper, the rapid discerning in Alberta of "Lower Cretaceous" formations, and that their fossils indicate a sea that "probably came in from the north or northeast." The seaway is, therefore, not a transgression from the Pacific eastward across Canada into Alberta. What the relations of these Comanchean formations are to the Kootenay is not yet known. C. S.

6. *The Discovery of a Portage Fauna in the Mackenzie River Valley;* by E. M. Kindle, Geol. Survey Canada, Mus. Bull. **29**, pp. 1-8, pls. 1, 2, 1919.—It is interesting to learn that something of the Upper Devonian Portage fauna of New York (12 species) occurs in the far north in the Mackenzie River Valley, and that it is overlain by that of *Spirifer disjunctus.* Beneath the Portage shales lies the Stringocephalus fauna of Middle Devonian time, which is hardly known in the United States. C. S.

7. *On a new Exogyra from the Del Rio Clay and some Observations on the Evolution of Exogyra in the Texas Cretaceous;* by Emil Böse. Univ. of Texas, Bull. No. **1902**, 22 pp., 5 pls., 1919.—This paper sets forth something of the evolution of American Exogyras, with the statement that "all of the [American] species, even the largest which are practically smooth, came originally from a rather small costate form." The new species is *E. cartledgei,* but the young stages of *E. arietina* Roemer are also described. C. S.

8. *Present Tendencies in Geology: Sedimentation*; by Eugene W. Shaw. Jour. Washington Acad. Sci., **9**, 513-521, 1919.—The great desideratum that many workers should take up the problems of sedimentation is being voiced more and more. The author here points out some of the things that are being done and that should be done along this line. The field of endeavor is great and many young enthusiasts are needed.

C. S.

9. *Manual of Suggestions for Teachers, to accompany Elementary Biology;* by Benjamin C. Gruenberg. Pp. iv, 95. Boston and New York, 1919 (Ginn & Co.).—This little manual is designed to aid the teacher in securing and preparing illustrative material for class use, with many helpful suggestions for stimulating the interest of the pupil and encouraging him to make independent observations outside the class-room. There are also lists of works of reference both for the teacher and for assignment to the pupil. W. R. C.

10. *A Laboratory Manual for Elementary Zoology;* by L. H. Hyman. Pp. xvi, 149. Chicago, 1919 (University of Chicago Press).—This manual was originally prepared for use in the class in elementary Zoology in the University of Chicago. It consists of explanatory directions for the dissection of the frog, the study of its histological structure and its embryology, followed by the study of a representative type of each of the more

important phyla. There are also directions for exercises on heredity, comparative anatomy, classification and ecology. The directions are clear and practical and should be of service in college courses in zoology where the instructor does not feel the necessity of supplying his own direction sheets. W. R. C.

III. Miscellaneous Scientific Intelligence.

1. *The Jubilee Number of Nature.*—On November 4, 1869, fifty years ago, the first number of the new weekly journal of science, Nature, was published. It is very interesting that the history of this undertaking with the details of the original plan should be now[1] presented by the founder, Sir Norman Lockyer, a gentleman to whom science owes much in many directions. It is fitting, also, that number XLI of the series of Scientific Worthies, which have been published from time to time by Nature, should be given to him (pp. 191-195); this notice, by M. Deslandres of the Meudon Observatory, is accompanied by an admirable portrait. During the past fifty years, Nature has won for itself a unique place among the scientific publications of the world, and it is remarkable, notwithstanding the growth of science, that the plan originally adopted should be almost identical in its details with that being carried out to-day. On the other hand, the departments of scientific activity have multiplied far beyond what anyone could have anticipated in 1869. This is well brought out by the series of chapters, about 40 in number, written by various specialists. Conspicuous among the newer developments of science here presented are those dealing with the properties of gases and the structure of matter, including radium and the electron, and the ionization of gases. The four chapters devoted to these subjects are, respectively, by Sir J. J. Thomson, Sir Ernest Rutherford, Professor Frederick Soddy, and Professor J. S. Townsend. Many other subjects included might also be mentioned as marking the progress of science during the past half-century, indeed the entire number should be read by all interested in learning the main facts as to what science has accomplished in this period. It is also noteworthy that four of the writers, whose chapters in this number are somewhat longer and more comprehensive than most of the others, were contributors to the earliest issues of this journal. They are: Sir Archibald Geikie, Sir E. Ray Lankaster, Professor Bonney and Canon Wilson. The service rendered by Nature to the science of the world is so well recognized as to call for no further notice in this place; it is now, as it has been from the beginning, the model of a weekly scientific periodical.

The issue following the Jubilee Number, that for November 13, is appropriately devoted in part (pp. 281-295) to the many

[1] Nature, No. 2610, vol. 104, November 6, 1919.

congratulatory messages received from scientific academies, societies, universities and individuals.

2. *Geografiska Annaler.*—A new periodical, with this title, has been established at Stockholm by the Swedish Society for Anthropology and Geography. The editorial staff consists of Prof. Gunnar Andersson, Axel Wallén and Hans W. Ahlmann. As now planned, it is to appear in at least four numbers each year, aggregating from 400 to 500 pages. It will contain original articles, brief reviews and notices of books in geography, geophysics and pure ethnography. Two numbers have thus far been received; prominent articles in these are the following: "Geomorphological Studies in Norway" (parts I and II) by Hans W. Ahlmann and "On the physiographical evolution of Spitzbergen" by Gerard de Geer.

3. *The American Association for the Advancement of Science.*—The seventy-second meeting of the American Association will be held in St. Louis during the week from December 29 to January 3. Dr. Simon Flexner, of the Rockefeller Institute for Medical Research, will preside. The address of the retiring president will be given by Dr. John Merle Coulter, of the University of Chicago, at the opening general session of the Association; this will be followed by an informal reception to members of the Association and of the affiliated societies. When the Association last met in St. Louis, fifteen years ago, the membership of the Association was only 4,000; the membership of the Association now numbers nearly 15,000.

4. *The French Academy of Sciences.*—At a meeting of the Academy held on November 24, Dr. Charles D. Walcott, Secretary of the Smithsonian Institution in Washington, was unanimously elected an associate member.

5. *The Story of Milk;* by Johan D. Frederiksen. Pp. xx, 188. New York, 1919 (The Macmillan Company. Price $1.50).—A concise illustrated handbook of reference both for the student of home economics and for the general public is "The Story of Milk." For those more deeply interested in any phase of the use and handling of this product there is an appended bibliography. The author writes with the practical knowledge of one who has had forty years of work in the manufacture and distribution of dairy and milk food products.

A. F. M.

Obituary.

Louis Valentine Pirsson, professor of Physical Geology in the Sheffield Scientific School of Yale University, and since 1899 an associate editor of this Journal, died on December 8 at the age of sixty years. A biographical notice will be given in a later number.

Dr. John Aitken, the English meteorologist, died on November 14 at the age of eighty years.

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VOL. XLIX FEBRUARY, 1920.

Established by BENJAMIN SILLIMAN in 1818.

THE AMERICAN JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

FOURTH SERIES

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WILLIAM GILSON FARLOW

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

WILLIAM GILSON FARLOW.

DEC. 17, 1844—JUNE 3, 1919.

(Reprinted from the Harvard Graduates Magazine of December, 1919.)

To those who had seen Dr. Farlow during the early months of the present year, when his vigor of mind and body seemed quite unimpaired, his brief illness and unlooked-for death, which resulted from a rapidly increasing weakness of the heart, brought surprise as well as sorrow. It is seldom the privilege of a scientific man to retain, as he did, almost undiminished and to the very end, not only his physical and mental powers, but his interests and enthusiasm. One can but feel thankfulness that, in the last years of his life, he was hampered by few of the disabilities which so often afflict old age, and was granted the privilege of continuing, almost without interruption and with little hindrance, the activities to which his long and fruitful life had been devoted.

Dr. Farlow was born December 17, 1844, in Boston, where he lived with his parents until his fourteenth year, when the family, which included five other children, moved to the suburb of Newton. During the whole period of his early education, however, he attended schools in Boston, and at the Quincy Grammar and English High was awarded Franklin Medals for good scholarship.

His father, John Smith Farlow, was born in Boston in 1817 and was educated there; a public-spirited citizen, member of the State Legislature, President of the Massachusetts Reform Club; a successful business man later interested in railroads, but also a lover of the humanities; for many years President of the Newton Public

Library. In music and horticulture he found his greatest pleasure, and was for a time President of the Handel and Haydn Society of Boston. Although he had no special knowledge of botany, he was very fond of plants and flowers, and was a member of the Massachusetts and Newton Horticultural Societies at whose exhibitions he was awarded many prizes.

Dr. Farlow's mother, Nancy Wight (Blanchard) Farlow, came of an old Massachusetts family; but although she had the appreciation and taste of an educated woman, she does not appear to have had any unusually pronounced tastes. It is thus from his father, if from either of his parents, that he seems to have inherited the two chief interests of his earlier life, namely botany and music.

After a year of intensive study at the Boston Latin School where he worked, for the most part by himself, in Mr. Francis Gardner's room, not reciting with the school classes, he entered Harvard College in 1862, graduating with his class in 1866. During his college course he turned his attention especially to music and natural history; he was a member, and for a year secretary, of the Pierian Sodality, in which he played the piano, and was several times soloist at its public concerts. His unusual musical ability was recognized by Mr. B. J. Lang, under whom he studied and who then enjoyed in Boston a high reputation as a teacher, and he was even urged by Professor J. K. Paine, then fresh from his studies in Germany, to take up music as a profession.

Although he retained his fondness for playing the piano throughout his subsequent life, as well as his musical interests generally, his innate love of natural history, and especially of botany, as well as the influence of Asa Gray, with whom he early formed a close friendship, combined to determine his choice of a career: and despite the fact that at graduation he wrote in his class report that he had no definite plans for his future, botany was without question his predominant interest. He was a member of the Harvard Natural History Society, concerning which he has written a very amusing account, and which at that time maintained a miscellaneous collection of objects of Natural History. These included, in addition to a crocodile, a human skeleton and a turkey buzzard, an Herbarium, of which he had the honor to be appointed Curator, a guardian of whose ministrations it seems to have been sadly in need; since, as he remarks, it was then arranged "partly on the Linnæan, partly on the Natural and partly on the Alphabetical System." His reputation as a scientific light among his fellow members is said to have been such that his name was always mentioned by them with "awed respect." He was also secretary and treasurer of the O.K. Society in his Junior year, and was greatly interested in the theatre and in private theatricals in which he often took part; his star performance being an impersonation of a ballet dancer in short skirts, which is said to have been quite inimitable. The estimation in which he was held by his classmates generally may be inferred from the fact that, at the Senior Class election, he was chosen Class Secretary.

Although he speaks at the time of his graduation of having "no definite plans for life," he appears to have kept up his botanical interests, and within a year to have made a definite decision. At this period the medical course was almost the only means by which one could acquire the training necessary for a scientific career. For this reason, and in order that, should the pursuit of botany as a profession prove impracticable, he might have another to fall back upon, he followed the advice of Gray, himself a graduate in medicine; and, after studying anatomy for a time with Dr. Jeffries Wyman in Cambridge, entered the Harvard Medical School in November, 1867. Although he never seems to have had any intention of practising medicine, he evidently took his medical studies with great seriousness; since, at the close of his third year, he won a coveted appointment as surgical intern at the Massachusetts General Hospital, under the distinguished surgeon Dr. H. J. Bigelow. That his proficiency, in surgery at least, was regarded as beyond question, seems clearly indicated by the fact that, after finishing his hospital service, when he came up for his final examinations, the only inquiry addressed to him by the examiner in this subject was, "Where do you intend to practise, Mr. Farlow?"

Where he intended to practise, he made quite clear, after receiving his medical degree in May, 1870; since immediately thereafter he betook himself to Cambridge and to Asa Gray, helping the latter with his classes, and continuing his botanical studies until, in the following July, he was appointed Gray's Assistant by the University.

In this position, which he held for two years, he took full advantage of the rare opportunity presented to gain an extensive knowledge of the vascular plants as a whole, in close association with a master whose broad-minded outlook, wide knowledge and contagious enthusiasm were in themselves an inspiration. His predominant interest, however, was in the lower plants and especially in the Marine Algæ; and his studies on the last-mentioned group in various parts of New England and especially at Woods Hole, where, in the summer of 1871 he joined a scientific party under the charge of Professor S. F. Baird of the Smithsonian, had already made him an authority in this subject. Since, however, it was almost impossible, in America, to learn anything of the other groups of the lower plants, he decided, by the advice of Gray, to seek this knowledge in Europe; desiring at the same time to come into personal contact with some of the leading European botanists, and to familiarize himself with the new botanical points of view and methods of teaching and investigation then rapidly developing on the Continent. He therefore sailed for England in June, 1872, going thence immediately to Denmark, Norway, Sweden and Russia, where he had an opportunity to see a number of distinguished botanists, and especially algologists, with whom he found that he was able to meet on equal terms.

After a short trip to Moscow, of which he wrote that what most nearly appealed to him was the railroad station by which he left it, he took the long journey across Russia to Germany, visiting Berlin and various other German cities and finally settling in Strassburg early in October, where he had decided to study with Anton De Bary, then Professor of Botany and Regent of the University of Strassburg, whose reputation was at the time second to that of no other European botanist.

His sojourn in Europe extended over two years which were spent, for the most part, in De Bary's laboratories; but included some weeks devoted to an intensive study of the Lichens, with Dr. J. Müller at Geneva; and of the Algæ, with Bornet and Thuret at Antibes, all of whom were men preëminent in their specialties. During this period he corresponded regularly with Asa Gray; and his letters, which are preserved in the Gray Herbarium, are not only extremely interesting from a botanical standpoint, but are otherwise very entertaining and suggestive. While working under De Bary, he was not only able to acquire a knowledge of this master's methods of teaching and investigation, and to be impressed with his ideas of care and exactness, but had an opportunity to fill the most serious lacuna in his botanical education by acquiring a good knowledge of the Fungi, on which in later years he became the leading authority in America.

Of all the friendships which resulted from this most important period of his life, that with Bornet seems to have been the closest; and was cherished, both by personal visits and uninterrupted correspondence, up to the time of the latter's death in 1911.

Before completing his studies, Dr. Farlow visited Paris several times, as well as various German cities; his itinerary including, also, Switzerland, Italy and England; and he was thus able to meet many distinguished botanists and to examine the more important Herbaria. When he returned to America in the summer of 1874, he was by far the best equipped Cryptogamic botanist in this country, and almost the only person who was competent not only to teach something beyond the rudiments of his subject, but to do original work, and to initiate it in others.

Immediately after his return, he received an appointment as Assistant Professor of Botany in Harvard, the first special provision made in this country for instruction in Cryptogamic Botany. The earlier years of his service in the University were passed at the Bussey Institution, where he taught special students primarily interested in the economic aspects of his subject; although he also gave a certain amount of regular instruction in Cryptogamic Botany at Cambridge, and taught for several years in the Summer School. His work and publications on various important fungous diseases of plants, while he was stationed at the Bussey, may be truly said to have laid the foundations of American Phytopathology; a branch of botany in the development and practical applications of which this country has outstripped all others.

Conditions at the Bussey were, however, not at all to his liking, and he found his work hampered and interfered with to such an extent that the situation finally became quite intolerable. It was thus a great relief to him when, in 1879, he was transferred to Cambridge, and appointed Professor of Cryptogamic Botany; and found himself free to carry out his own plans and ideas without interference or hindrance. These plans involved the accumulation of the great Herbarium which bears his name, and is now the property of the University, and of his private library; the carrying on of original investigations; and the further development of instruction in his subject.

The nucleus of the Herbarium was the famous Curtis Collection of Fungi, assembled by the Rev. M. A. Curtis, and extremely rich in authentic material from Berkeley, Schweinitz, Ravenel and others of the early mycological pioneers. This collection was purchased for Dr. Farlow by Asa Gray, while the former was in Strassburg, and around it has accumulated an extensive and unique Herbarium of non-vascular Cryptogams.

Dr. Farlow's writings, which cover a variety of topics dealing chiefly with the algæ and fungi, comprise nearly two hundred titles, including his biographical notices and public addresses, and are models of clearness, conciseness, accuracy, and originality. It is greatly to be regretted that he should have left unpublished two of his most important works; namely, the monumental bibliographical index, prepared in collaboration with Mr. A. B. Seymour, a small portion of which, only, was issued in 1905 by the Carnegie Institution; and a sumptuous work on American Fleshy Fungi, the plates for which were completed many years before his death.

As a teacher and lecturer he had few rivals, and his instruction, which possessed the attraction more or less inseparable from that of a master of his subject who speaks *ex cathedra* on a majority of the topics which he discusses, was made doubly effective by reason of his capacity for lucid, well-balanced and interesting presentation, in which he succeeded in bringing essentials into strong relief. Never leaving his work to be done by an assistant, he came into close relations with all his students, and had a faculty for giving an impression of personal interest in each individual; so that the time spent in his laboratory was, for most, an experience the pleasure of which was not to be forgotten. The influence which, over a long period of years, he exerted on the development of his subject in this country through his writings, his students and his personal example, in setting a high standard of work in his chosen field, can hardly be overestimated and is, perhaps, his most important professional contribution. Among those who have come in contact with him as a teacher, or who have been associated with him in botanical work, few would not acknowledge that their ideals had been thus fundamentally influenced.

Although in 1896 he withdrew from active teaching, in order that he might have his whole time free for other activities, he continued occasionally to give attention to advanced students in whose work he felt a special interest; and retained, until his death, his place on the Faculty, of which, after a continuous service of forty-five years, he had become the senior member.

After his appointment as Professor, his life was passed almost wholly in Cambridge; although he made several brief visits to Europe, and went twice to Bermuda and to Florida. In 1885 he accompanied Asa Gray to Mexico and California; but otherwise his field work was done almost wholly in New England; for the most part in the vicinity of Boston; at Eastport, Maine; at Shelburne, N. H.; and in the White Mountains, more recently at Chocorua, where his summer home, overlooking the lake, was situated in a mycologist's paradise.

In Cambridge he was at one time a parietal officer, and at various periods occupied rooms in several dormitories, where he used to give memorable entertainments to his students; but in 1893 he bought the Putnam house on Quincy Street, next to the Colonial Club, where he kept bachelor's hall until, in 1900, the great happiness of his marriage to Miss Lilian Horsford transformed it into a home to be shared by a beloved companion.

Dr. Farlow's memory was phenomenal, and his estimate of values keen and sure. He actually read the literature of his subject, not contenting himself with summaries or abstracts, or confining his reading within narrow limits. His first-hand knowledge of multitudes of forms thus combined to make his judgments and opinions those of an expert in almost all of the larger groups of cryptogams, and in questions relating to his specialties and their literature he was justly regarded as a court of last resort.

His professional reputation was quite as great in Europe as in America, and his correspondents included a majority of the more prominent members of his profession throughout the world. In addition to the degrees of A.B., A.M., M.D., and the honorary LL.D. which he received from his Alma Mater, he was given the honorary LL.D. by the Universities of Wisconsin and of Glasgow, and that of Ph.D. by Upsala. He was a member of the National Academy of Sciences, the American Philosophical Society, the American Academy of Arts and Sciences, the Linnæan Society of London, the Paris Academy of Science, and of numerous other scientific bodies in this country and abroad, in which he held various offices, including the presidency of the American Association for the Advancement of Science and of the Botanical Society of America.

In his private relations, Dr. Farlow was a loyal friend, thoughtful, kind, generous and sympathetic; a delightful companion and charming host. Dullness he abhorred. Incapable of uttering the banalities of ordinary social intercourse, his talk was always interesting, original, and witty. Contact with him almost always left one with some new idea, or point of view, or bit of interesting news, or humorous conceit that served to relieve the monotonies of life. He had a fund of rare and quiet humor which he often used effectively to drive home some point, as well as to enliven his utterances. This habit was so characteristic, and is so well illustrated in his presidential address before the American Association in 1905, that it seems worth while to quote its opening sentences. Introducing his subject, which was entitled "The Popular Conception of the Scientific Man at the Present Day," with a brief reference to the conception of Progress of Science, Dr. Farlow says, "What is or is not progress, depends, of course, on the point of view. Some are so far ahead of the majority that they cannot see how much progress is made by those behind them. Others are so far in the rear that they cannot distinguish what is going on ahead of them. We must also admit that there are different directions in which progress may be made. You have all seen the agile crab, and been surprised to find how rapidly he gets over the ground, although he never seems to go ahead, but to scramble off sidewise. The crab perhaps wonders why men are so stupid as to try to move straight forward. It is a popular belief, but, not being a zoölogist, I cannot vouch for its correctness, that the squid progresses backward, discharging a large amount of ink. One might perhaps ask: Is the Progress of Science sometimes like that of the crab, rapid, but not straightforward; or, like the squid, may not the emission of a large amount of printer's ink really conceal a backward movement.''

In his earlier life, especially, Dr. Farlow often gave the impression of being overbiting and sarcastic in his condemnation of what appeared to him to be pretension and superficiality, and he had many pet aversions—people who thank one in advance for favors, or are unable to find time to spell ''through'' correctly—and his often amusing tendency to view people, and things in general, with a comprehensive pessimism might have led one to conclude that he believed most things in this world to be sadly out of joint. Those who understood and knew him well, however, did not need to be told that this habit was a mannerism, of little real import; and that beneath it lay warm feeling, understanding and appreciation, and an unbounded readiness to be of service.

There have been few members of the academic family at Harvard whose individuality was more cleanly cut than that of Dr. Farlow, or whose aspect marked him more clearly as one of the elect; a personality quite apart from the more commonplace entities who tend to predominate in the human race. Even those to whom he was not personally known cannot but miss his familiar figure: small, slightly stooping in later years; his striking features somewhat downcast as if his thoughts were far away from his immediate surroundings, little of which, however, escaped his quick side-glance; a sheaf of papers or books under his arm, as he walked rapidly from his house in Quincy Street to the Museum, where not many days passed, even till within a few weeks of his death, that did not find him there and at work. To his friends, it will be difficult to realize that this striking personality, with its stores of learning, wit, humor, kindliness and sympathy is a memory only.

Roland Thaxter.

Art. VI.—*A New Description of Amesite;* by Earl V. Shannon.[1]

The name amesite was given by C. U. Shepard to a pale green chlorite occurring in intimate association with diaspore at the old emery mine in Chester, Mass. The mineral which was analyzed by Pisani[2] is described as in hexagonal plates; foliated, resembling the green talc from the Tyrol. Hardness 2·5-3·0; specific gravity 2·71; sensibly uniaxial, optically positive; color pale apple-green; luster pearly on the cleavage face. Composition approximating to $H_4(Mg,Fe)_2Al_2SiO_9$.

Tschermak[3] later took amesite as representing a fundamental end member and explained the constitution of the orthochlorites by assuming them to be isomorphous mixtures of the amesite molecule and the serpentine molecule. Considerable interest thus attaches to the mineral which has been found only at this exhausted locality. Since no other analysis of amesite than that of Pisani appears to have been made and in order to determine the refractive indices on analyzed material, the mineral has recently been reanalyzed, abundant material for investigation being supplied by a specimen in the museum collection. This specimen is labeled ''amesite and diaspore, Chester, Mass.'' in the handwriting of C. U. Shepard and the label bears also the words ''Coll. by E. Messia,'' by which is probably meant Macia, a French Canadian, for many years foreman at the emery mine and an ardent collector of minerals. The specimen consisted of a large flat mass of diaspore showing pale grayish-pink cleavages several inches broad where broken and containing small cavities filled with interlacing needle-like crystals of diaspore. One side of the specimen is completely coated with a layer of flat amesite crystals of a pale green color somewhat iron stained. Scattered through the mass of the diaspore there are variously oriented crystals of amesite, large octahedrons of magnetite and crystals of dark red to black rutile. The amesite occurs in tabular hexagonal crystals with dull prismatic faces. They reach an extreme diameter

[1] Published by permission of the Secretary of the Smithsonian Institution.
[2] Pisani, C. R., 83, 166, 1876.
[3] Theil, Ber. Ak. Wein, 99 (1), 174-267, 1890.

of 1cm. with a thickness of 3 to 5mm. By breaking up the diaspore, clean crystals were readily secured and these crystals when ground were used for analysis. The material analyzed was perfectly homogeneous and free from impurities as shown by optical study.

Physical Properties.—The amesite is of a uniform pale bluish green color. The luster is pearly to somewhat metallic on cleavage surfaces. In thick pieces the mineral is translucent to almost opaque. Thin fragments are transparent. The powder is white with a very faint tinge of green. The mineral has a micaceous basal cleavage which, however, is not nearly so perfect as in most crystallized chlorites. Laminæ are rather brittle and break in a manner suggesting a very imperfect prismatic cleavage. The hardness is about 2·3 as it scratches gypsum readily but is scratched with great ease by calcite. The specific gravity as determined on approximately 3 grams of coarse fragments in a pygnometer is 2·77.

Optical Properties.—Cleavage plates of the amesite are dark in all positions between crossed nicols. Examined in convergent light a black cross is obtained which separates slightly on rotation of the stage indicating that the mineral is biaxial with the axial angle, 2V, very small, acute bisectrix normal to the perfect cleavage. The optical character is positive. The mineral is colorless as seen under the microscope. The refractive indices measured by the immersion method were found to be as follows:[4]

$$\alpha = 1{\cdot}597 \pm {\cdot}003$$
$$\beta = 1{\cdot}597 \pm {\cdot}003$$
$$\gamma = 1{\cdot}612 \pm {\cdot}003$$
$$\alpha - \gamma = {\cdot}010 \pm {\cdot}003$$

Chemical Properties.—Heated before the blowpipe the amesite swells somewhat and exfoliates slightly becoming silvery brownish white in color. It is infusible. It does not become magnetic when roasted on charcoal. It yields considerable water in the closed tube. The main portion of the water is basic coming off only at a dull red heat. The mineral is partially decomposed by boiling in sulphuric, nitric or hydrochloric acid with separation of flocculent silica. Upon analysis the pure powder yields the following results:

[4] Values confirmed by E. S. Larsen.

Table I, Amesite, Chester, Mass.

SiO_2	20·95
Al_2O_3	35·21
FeO	8·28
CaO	·58
MgO	22·88
MnO	trace
H_2O—110°C	·23
H_2O+110°C	13·02
Total	101·15

This analysis yields the following simple ratios:

SiO_2	·3474	or 3·01	or ± 3	or 1
Al_2O_3	·3445	2·99	3	1
FeO	·1152	1·00	6	2
CaO, MgO	·5779	5·02		
H_2O	·7355	6·38	6	2

This gives the formula

$$2(Fe,Mg)O,Al_2O_3,SiO_2.2H_2O$$

or Pisani's formula

$$H_4(Mg,Fe)_2Al_2SiO_9.$$

This analysis differs from that of Pisani only in the ratio of ferrous iron to magnesia. The definite ratio of $MgO:FeO = 1:5$ shown by this analysis may be accidental and the percentages of these two oxides probably vary reciprocally in different specimens. The close agreement between the values found and the theoretical values is brought out in the following table:

Table II, Amesite.

	I.	II.	III.
SiO_2	20·95	20·82	21·40
Al_2O_3	35·21	35·28	32·30
FeO	8·28	8·27	15·80
MgO(+CaO)	23·46	23·20	19·90
H_2O	13·25	12·43	10·90
	101·15	100·00	100·30

I. Amesite, Chester, Mass., anal. by Shannon.
II. Amesite, values to conform with formula $H_4(5Fe,Mg)_2Al_2SiO_9$.
III. Amesite, Chester, Mass., anal. by Pisani.

ART. VII.—*Contributions to the Stratigraphy of Eastern New Mexico;* by CHARLES LAURENCE BAKER.

The purpose of this paper is to present a short summary of results accomplished in a geologic exploration of about 50,000 square miles of eastern New Mexico, mainly in the territory between the Rio Grande and the Rio Pecos, from the latitude of Las Vegas on the north to beyond the Texas boundary on the south. The field study was made during the summers of 1917, 1918 and 1919. It is the intention to describe in greater detail the stratigraphy and the numerous igneous rocks, give lists of fossils collected, and to present generalizations on the structure, physiography and mode of origin of the sedimentary rocks in a later report. Doctors N. F. Drake and Emil Böse were associated with the writer in most of the field work, the former in 1918 and the latter for about half the field season of 1919.

The region covered embraces portions of three geologic provinces: the Rocky Mountains, the Basin Ranges, and the Great Plains.

Structural Geology.

The high summits of the Rocky Mountains extend as far south as the southern end of the Sangre de Cristo Range, but the long regional folds of the Rocky Mountains extend from the Sangre de Cristo Range as far south as Torrance and Vaughn in central New Mexico and divide the plains west of the Pecos River on the east from the interior basins of central New Mexico on the west. The isolated outcrops of the Basement Complex in central New Mexico lie in these folds. The eastern folds of the Sangre de Cristo Range have steeper dips on their east flanks, the easternmost or Front Range fold proper being locally overturned and overthrust-faulted north of Las Vegas. The mountains composed of post-Cretaceous igneous rocks, situated between Torrance on the north and Tularosa on the south, lie in a large synclinal basin separating the Rocky Mountain folds from the mountains of the Great Basin system on the south and west. The Basin Ranges of central and south-central New Mexico lie along three great asymmetric anticlines, each characterized by one long gentle dip slope with an opposite facing escarpment of much greater dip and in some cases, at least, locally broken by upthrust faults. It is probable, however, that not all of these steep escarpments are fault scarps. In most places erosion is too far advanced to exhibit the usual physiographic criteria of fault scarps. The western of the three great anticlines of the Basin Ranges begins on the north with the Sandia Mountains, northwest of Albuquerque, continues to the south in the Manzano Mountains, thence swings southwest in the Sierra de los Pinos and gradually decreases in altitude towards Socorro on the Rio Grande. The escarpment in these ranges faces the valley of the Rio Grande. The intermediate structural axis begins on the north with the Sierra Oscura with steep scarp on the west, forms a faulted anticline in the Little Burro Mountains, south of which the scarp passes to the east side in the San Andreas Mountains and continues thus southwards into the Organ and Franklin mountains; the structure coming to an end at El Paso, Texas. The easternmost main structure rises on the north out of the synclinal basin of Upper Cretaceous sediments and igneous rocks of the Sierra Blanca *massif* into the Sacramento Mountains overlooking with steep western scarp the Tularosa Basin, then swings east of south in the southern Sacramentos, in the southern extremity of which it gives off several low folds continuing southward into the Hueco Mountains, the main axis being shifted many miles to the east into the Guadalupe Mountains. In the northern part of the latter range the anticline passes for a short distance into an upthrust fault with displacement at a maximum of over 1000 feet, thence southward passes into an anticline with northwest-southeast axis and steeper dip on the southwest flank, again passing into an upthrust fault near the Texas line which continues as a fault to a short distance south of Guadalupe Point, thence apparently passing into an anticline in the northern Delaware Mountains of Texas and ending in a southward-plunging broad-ended anticline in the vicinity of the Texas and Pacific Railway. The gentle eastward dip slope of the Sacramento Mountains is 70 miles broad between Cloudcroft and Roswell, and the same general dip, becoming less in amount, extends eastward for probably a hundred miles farther. The Sacramento-Guadalupe-Delaware structure, with the southern Sangre de Cristo Range and its southward extension in southward-plunging anticlines extending as far as central New Mexico, form the eastern front range of the western Cordillera in New Mexico and northern Trans-Pecos, Texas.

Intermontane alluvium-covered basins lie between the Basin Ranges. The Otero or Tularosa Basin is without exterior drainage and was the site of a Quaternary lake. To the southeast the Otero Basin is separated from the Salt Basin, west of the Guadalupe and Delaware mountains, by a low divide formed partly by the San Andreas limestone, partly by alluvium. The Salt Basin has no exterior drainage. The other intermontane depressions, the Jornada del Muerto (structurally a syncline) and the Hueco Bolson, have been drained by the Rio Grande. Evidence is, indeed, in hand, although not yet perhaps conclusive, that the basin of the Rio Grande, from Santa Fe on the north to beyond El Paso on the south, was in former times part of a region without exterior drainage.

The Estancia Valley, an enclosed basin of central New Mexico, is in origin partly structural and partly erosional. Later anthracolithic sediments dip towards the center of the Estancia from the Manzano Mountains on the west and the Hills of Pedernal on the east, the laccolithic uplifts of the San Pedro and Ortiz mountains form its north and northwest boundaries, but its southern border is the erosion escarpment of the Chupadero Mesa in which early Permian Yeso and San Andreas sediments dip gently to the south. The other enclosed basins of central New Mexico, such as the White Lakes east of the San Pedro Mountains, the Encino Basin, and the Pinos Wells Basin, have been formed by ground settlement brought about as a consequence of solution of beds of gypsum and salt in the Yeso formation.

The Great Plains cover half the surface of the area examined. They extend eastward from the Front Range of the Cordillera. From approximately north of the line of the Belen cut-off of the Santa Fe Railroad, eastward to the Llano Estacado, the plains are traversed by a series of low broad folds with axes running slightly at variance with north-south strikes, but parallel with the structure of the southern Rockies on the west. A broad syncline of Upper Cretaceous sediments is east of the

Front Range of the Sangre de Cristo, the south flank of which syncline lies in a high Dakota-capped mesa escarpment extending east-west for 40 miles a short distance south of Las Vegas. Some low folds of small extent lie west of the Pecos River and east of the Sacramento and Guadalupe mountains. On the whole, the Permian, Triassic, Cretaceous and Cenozoic deposits of the Great Plains have generally a gentle eastward dip. Sink-holes, of the same origin as those of the small basins of central New Mexico, are abundantly scattered over the plains surface. In the great syncline at the north they are found also in the Benton Cretaceous, but may have been formed through solution of underlying lower Permian salt and gypsum.

Igneous and metamorphic rocks make up the cores of the mountain ranges. Paleozoic and Mesozoic sedimentary rocks of relatively few formations occur on a large scale and cover most of the area; post-Cretaceous igneous rocks of acidic types, mainly intrusive but in small part volcanic, outcrop in many localities in east-central, central-northern, and central-southern New Mexico; and unconsolidated deposits of the later Cenozoic cover intermontane and solution basins, long piedmont alluvial slopes, and valley areas. Early Tertiary sediments were noted only in the upper Rio Grande Basin.

The oldest rocks of the region form a greatly varied complex of metamorphosed sedimentary and igneous rocks, cut by large masses of later plutonics. This ancient complex forms the basement rocks of the Sacramento, San Andreas, Manzano, Sandia, Sangre de Cristo, Los Caballos, Fra Cristobal, Oscura, and Los Pinos ranges; the quartzites of the Pedernal Hills and isolated knobs of granite west of Pinos Wells and east of Torrance in central New Mexico are directly overlain by the Yeso formation of the early Permian. The younger intrusives of this complex are granites and quartz porphyries in large masses and dikes of pegmatite, aplite, quartz and diabase. The older rocks are gneisses, schists, quartzites, slates and greenstones. In the southern portions of the San Andreas and Sacramento mountains they are overlain by upper Cambrian sediments; in most of the region they are overlain directly by the Magdalena group of the Pennsylvanian. In the low isolated hills of central New Mexico, the Yeso formation of the lower Permian lies directly upon them; and in places in the Sangre de Cristo Range the Abo formation of the late Pennsylvanian rests directly upon them.

The Paleozoic Succession.

Early Paleozoic Sedimentary Rocks.—Early Paleozoic strata, though well distributed in southwestern New Mexico and Trans-Pecos Texas, are found only in the central southern part of the region here treated: in the southern San Andreas and Sacramento mountains, in the Organ Mountains, and in the Fra Cristobal and Los Caballos mountains bordering the Rio Grande. The only detailed section made is that of the southern Sacramento Mountains. Here supposedly Pre-Cambrian plutonics, but with the upper contact not well exposed, are followed in upward succession by quartzites, quartzose sandstones and quartzose conglomerates, pink, green, buff, brown and red in color, with glauconitic coarse sandstone from 17 to 20 feet above the base, the whole 110 feet in thickness. No fossils being found, these strata are tentatively referred, on grounds of lithologic similarity, to the upper Cambrian. Ordovician strata follow, with lower Ordovician fossils from 50 to 80 feet above the base, and Richmond fossils 300 feet above the base, but no middle Ordovician fossils were found. The Ordovician begins with 50 feet of calcareous quartzitic sandstone and is overlain by gray siliceous cherty limestone; the entire thickness of the Ordovician is 385 feet.

Lying upon the Ordovician are 50 feet of strata, dark gray limestone below and light gray saccharoidal-textured crystalline limestone above, referred to the Niagaran.

Upper Devonian, with *Spirifer whitneyi,* follows with strata of black, drab and gray sandy and limy fissile shale interbedded with nodular and concretionary argillaceous and arenaceous limestone, locally compact, crystalline and cherty, the whole being 80 feet thick. All strata below the Devonian have undergone an age metamorphism, which has made them very hard, and greatly fractured them, the fissures having been re-cemented with calcite and chert.

On the opposite side of the Tularosa Basin, in the southern San Andreas Mountains, substantially the same section of earlier Paleozoic strata overlies unconformably the Basement Complex of various crystalline rocks. Proceeding northward in the San Andreas Mountains, the earlier Paleozoic formations are cut out one by one in descending order by pre-Pennsylvanian erosion until the basal strata of the Magdalena group of the Pennsylvanian rest directly upon the Basement Complex of the north end of the San Andreas Range.

Anthracolithic Sedimentary Rocks.—The anthracolithic strata of eastern New Mexico are divided into four distinct depositional assemblages, separated each from the other and from the rocks below and above by well-marked unconformities. Although the continuity is intercepted by these epochs of erosion, during which the total original thicknesses were greatly reduced, there yet remains a maximum thickness of over 11,000 feet of anthracolithic sediments. The Mississippian of Kinderhook and possibly of Burlington age lies at the base, followed by the great depositional groups of the Magdalena, Manzano, and the Guadalupian-Pecos Valley red beds, in upward succession. During the time of deposition of all three of the later anthracolithic groups, seas of clearer water lay to the south and the west, in which directions limestones very largely replace terrigenous sediments of the north and the east.

Mississippian.—The following section of strata of Mississippian age was measured in the vicinity of Little Agua Chiquita Creek in the southern Sacramento Mountains:

Base, resting on Upper Devonian strata.

1. Blackish brown crystalline limestone, either phosphatic or bituminous, with dark brown chert in lenticular layers forming about one half of the member. Limestone full of crinoid stems....... 14′
2. Covered .... 6′
3. Thin-bedded, fine-grained, gray, argillaceous limestone, with nodular chert. Small complete crinoid found 23 feet above base....................... 50′
4. Fossiliferous dark blue-gray limestone, with chert nodules. Some of the fossils silicified; fossils mainly brachiopods. The beds average about 9 inches thick. This member forms a conspicuous cliff in the San Andreas Mountains further west. Member about one half chert..................... 100′

5.	Covered	40′
6.	Fine-grained light gray siliceous limestone with much chert. Much fractured and cemented with calcite veins	75′
	Total thickness	285′

The Mississippian strata were found by the writer only in the southern Sacramento and southern San Andreas Mountains.

The Pre-Pennsylvanian Unconformity.—The long erosion interval prior to the deposition of thick Pennsylvanian sediments, occurring, so far as known, throughout the southwest, denotes a very important time break in Paleozoic sedimentation in the mountain areas of eastern New Mexico. Later Mississippian and earliest Pennsylvanian strata are probably everywhere lacking. Earlier Paleozoic is also lacking except in south-central New Mexico. Subsequent to the marked deformation of the Basement Complex, there is no evidence of orogenic deformation until late in the Pennsylvanian. In eastern New Mexico, as in the Rockies farther north, Paleozoic strata of widely varying ages lie directly on each other without evidence of angular unconformity and, indeed, often without clear stratigraphic evidence of the great time breaks indicated by the fossils. From the northern San Andreas Range to the northern limits of our region, the Magdalena strata rest on a remarkably even surface of the Basement Complex. Farther to the north, however, the surface of the Basement Complex must have been one of marked relief, for the Magdalena sediments in the Sangre de Cristo Range contain much arkose.

Magdalena Group.—The greatest thickness yet measured of Magdalena, in the Pecos Cañon near the sources of that river in the Sangre de Cristo Range, is 2450 feet. The thickness may be greater along the Front Range farther northeast. Magdalena rocks are entirely lacking at some localities in the Sangre de Cristo Range and around the small crystalline areas of central New Mexico. It is probable, as will be explained farther on, that the Magdalena is lacking in a large area in central New Mexico. The Magdalena covers a large area on the summits and the flanks of the Sangre de Cristo Range, and forms the eastern dip slopes of the Sandia Mountains and the southern Manzano Mountains east of Albuquerque;

it is sharply overturned and in fault contact with the Basement Complex in the southern Manzano Range and in the Sierra de los Pinos, east of which overturn it forms an eastward dip slope for a short distance; it forms the upper escarpment and much of the eastern dip slope in the Sierra Oscura; forms the top of the outer escarpments of the San Andreas and Sacramento mountains; and has been brought to the surface by the laccolithic intrusion of the San Pedro Mountains.

The Magdalena of the Sangre de Cristo Mountains consists mainly of a remarkable alternation of beds of arkoses and limestones, many of the limestone beds being themselves arkosic. Nodular and lenticular chert is abundant in the limestones. Real shale is almost totally lacking; sandstones are not particularly abundant. A thin bed of sub-bituminous coal, 255 feet above the base, has been traced for 15 miles in the cañon of the Upper Pecos. The unweathered color of the limestone and sandstone is some shade of gray, but some of the fine sands in the upper Pecos Valley, especially near the top of the group, are purple, red and green. A thin bed of coal is also found in the Sierra Oscura and a number of thin carbonaceous layers, locally coal, are found within 400 feet of the top in the Sangre de Cristo Range.

The Magdalena group covers the summit portion of the Sangre de Cristo Range of New Mexico between the Truchas-Jicavita *massif* on the south and the Wheeler Peak *massif* on the north. This portion of the range is lower in altitude than the northern and southern portions. Steeply dipping Magdalena dark green micaceous shaly sandstones outcrop on the east side of Palo Flechado (Taos) Pass on the west border of the Ute Park depression. Between the pass and the town of Taos the Magdalena consists of folded strata of limestone, conglomerate, sandy shales and sandstone. The group along the lower reaches of Pueblo Creek, a short distance east of Taos Indian Pueblo, dips to the west and consists of dark green and buff ferruginous sandstone, conglomerate and gray fossiliferous limestone, apparently resting upon the crystallines of the Wheeler Peak *massif* farther north and east. At the west base of the mountains east of the county-seat of Taos, the Magdalena dips eastward. The high summits of the Truchas-Jicavita *massif* are formed of Magdalena. The group is probably limited on the west near the summit divide of the Santa Fe Range, east of the town of Santa Fe, by a great fault, doubtless the northern continuation of the Apache Cañon fault. The thick series of Magdalena at the headwaters of the Pecos River dips westward, while the summit divide and most of the western flanks of the Santa Fe Range are composed of crystallines. In the Los Pinos and southern Manzano ranges the Magdalena is about 1850 feet thick, consisting mainly of limestones with some sandstones. There are beds of arkose in the lower part of the section there. The actual base was not found, because of faulting. In the San Andreas and Sacramento mountains of the southern region, the Magdalena, about 1250 feet thick, is almost entirely thick-bedded limestones, but some clays and sandstones are found near the top, being apparently thicker towards the north.

The fauna of the Magdalena, so far as known, is in the main composed of brachiopods belonging to the common later anthracolithic genera. Crinoid stems are numerous, *Fusulina,* surprisingly rare, is found near the top and bottom. Bryozoa and a few genera of corals are relatively abundant. Several species of trilobites were found. Molluscs are apparently not very abundant, being represented principally by pelecypods. No ammonoids were found, but quite a number of nautiloids. Cochliodonts alone represent the vertebrates. *Lepidodendron* is found in the lower beds. Although a fauna of perhaps 150 species was collected, it has not yet been studied. As *Chonetes mesolobus* was discovered near the base and a large *Pseudomonotis* near the top, the time represented by the deposits includes the upper part of the Lower Coal Measures and at least the lower part of the Upper Coal Measures. Neither the earliest nor the uppermost Pennsylvanian appears to be represented in the Magdalena.

Manzano Group.—This group of rocks has been named, subdivided, and described by Willis T. Lee[1] and the discussion here will be almost altogether limited to the regions not visited by him. The group was divided by Lee into three formations: the Abo red beds, mainly of sandstone, but with considerable shales and clays and a

[1] Lee, Willis T.: The Manzano Group of the Rio Grande Valley, New Mexico. U. S. Geol. Surv., Bull. 389, 1909.

small amount of conglomerates at the base; the Yeso gypsum-bearing red beds of sands and clays and thin gray limestones; and the San Andreas at the top, massive gray limestone. As might be expected, the lower two formations exhibit in the region herein discussed some characteristics different from those of Lee's type localities farther west, but his subdivisions are entirely valid throughout eastern New Mexico.

Abo Formation.—Everywhere in central New Mexico where the contact has been noted between the Abo and Magdalena, there is erosional unconformity. In most places this unconformity is an *angular* one as well. Gentle folding of the Magdalena occurred in the Sacramento and Sangre de Cristo mountains, accompanied and followed by great erosion before the deposition of the Abo. Some of the Abo arkose in the latter range may have been derived from Magdalena arkose but locally in that range Abo rests directly upon the crystallines. The great thickness of arkose in the Abo of the northern Sacramentos was probably derived from exposed crystalline areas farther north in central New Mexico. Abo sediments in the southern part of the San Andreas and Sacramento mountains were deposited in somewhat clearer waters than those farther north.

The Abo outcrops on the flanks of the folds of the southern Sangre de Cristo Mountains, on the east dip slope of the Sandia, Manzano and Los Pinos ranges, and in the median strike valleys of the Sacramento and San Andreas mountains. It probably was never deposited around the crystalline masses of central New Mexico. It doubtless underlies from one third to one half of the entire area of New Mexico, east of the Rio Grande.

The Abo formation of Glorieta Mesa in the vicinity of Rowe and Pecos villages has an estimated thickness of about 800 feet, including the lower unconsolidated brick-red uncemented beds which are very poorly exposed in the strike valley east of the mesa. The basal beds, one and one-fourth miles north of Fulton station on the Santa Fe main line, lie unconformably upon the Magdalena, with a reworked limestone conglomerate at their base, and immediately above the base a massive cross-bedded gray arkosic and conglomeratic sandstone with fragments of crystallines and Magdalena limestone. Just east of Rowe the base is marked by a thin conglomerate above which are heavy clayey sands. The latter are almost if not entirely lacking two or three miles southeast of Rowe. In the vicinity of Fulton the Abo is thicker than farther northwest. The Abo rests with angular unconformity upon the Magdalena in the south bluff of the Pecos one mile west of the iron bridge between Pecos Village and Valley Ranch. Here 120-140 feet above the base of the Abo a gray sandy arkose contains bowlders of Magdalena limestone up to three feet in size and has a fauna of poorly preserved *Composita, Myalina,* horn corals, large *Productus* and plant fragments. A few fossils occur in the basal calcareous arkose and in a crystalline crinoidal limestone from 40 to 80 feet above the base.

Lee in his Rowe section has included in the Abo beds several hundred feet of Magdalena limestones and conglomerates. He was doubtful of the age of these lower red beds along the flanks of the Sangre de Cristo range, but Dr. Böse and the writer in tracing them south found them overlain by the Yeso, hence they are almost certainly a part of the Abo.

It is difficult to estimate the total thickness of the Abo red beds on the east flank of the Sangre de Cristo Range at Las Vegas Hot Springs, because of faulting and the uncertainty in identification of the Glorieta sandstone, the basal bed of the Upper Trias. However, strata undoubtedly Abo have here a thickness of 425 feet. Farther north along the Front Range, east of Mora Bruce, Martin reports several thousand feet of Abo arkoses and red beds.

The Abo contains many fossils in the Sacramento and San Andreas mountains. Near Juniper Tank in the southern Sacramento Mountains there is eleven degrees difference in dip between Magdalena and Abo on the contact; the basal Abo red bed here has silicified tree trunks with diameters as large as three feet and also well-rounded pebbles of igneous rocks. In the lower end of La Luz Cañon, east of Alamogordo, the lower massive cliff-forming limestone of the Magdalena is unconformably overlain by Abo conglomerates, shales, limestones and sandstones. The conglomerates contain bowlders of Magdalena limestone in sizes up to two feet. The basal Abo bed here contains more *Fusulina* than any other stratum noted in eastern New Mexico.

The exposed Abo strata in the Coyote Basin, west flank of Sacramento Mountains at their north end five miles north of Tularosa, have a thickness of about 1400 feet, the base not being exposed there. This section is characterized by the presence of heavy arkose, interbedded with sandstones, clayey and shaly sands and fossiliferous limestones. In the Juniper Tank section of the southern Sacramento Mountains, the entire thickness of the Abo is only 350 feet, the upper two thirds of which is mainly thin- to medium-bedded blue-gray limestone. The exposures in the central and northern San Andreas Mountains do not greatly differ from that at Juniper Tank.

The Abo of the southern San Andreas Range rests on the massive cliff-forming limestone of the lower Magdalena. The Abo here consists of medium-bedded brown and greenish brown sandstone interbedded with fossiliferous limestones. The sandstone is calcareous and usually shaly. These strata are about 1000 feet thick.

Little of definite value can be said concerning the age of the Abo until the fossil collections from south-central and central-southern New Mexico have been fully studied. A large collection of fossils made one mile east of the business center of the town of Tularosa, from strata about 200 feet above the base of the Abo, contained several species of ammonoids which Dr. Böse correlates with about the same horizon as the ammonoids from the Cisco formation at Graham, Young County, Texas.

Yeso Formation.—The Yeso formation is characterized by the presence of bedded gypsum. In central New Mexico it is mainly red beds with gypsum and thin-bedded, siliceous, fine-grained, blue-gray, limestones. In its southernmost outcrops, limestones largely replace red beds, and the amount of gypsum greatly decreases. The Yeso is not found about the flanks of the Sangre de Cristo Mountains. Farther south it is exposed over vast areas of rather featureless plains with sink-hole topography. It rests directly on the crystallines of central New Mexico and overlies the Abo on the flanks of the Sandia, Manzano, Los Pinos, Oscura, and San Andreas and Sacramento mountains. It makes up most of the surface exposures of the Chupadero Mesa and is exposed beneath the Upper Trias in the anticlinal axes along the Pecos River from Ribera southwards to beyond Puerto de Luna and in Cañon Blanco, a tributary entering the Pecos a few miles below Anton Chico. It is also exposed for many miles in upper Pintada Cañon and forms the surface of a large area west of Fort Sumner. Altogether, it covers or probably underlies fully half of New Mexico east of the Rio Grande.

Going southward from the Rocky Mountains proper, the Yeso is first seen in the basin of the Pecos River near Anton Chico, where it overlies the Abo and is overlain by the Glorieta sandstone of the Upper Trias. In all central New Mexico it has about the same lithologic characteristics as in the sections described by Lee. Well borings in the Pecos Valley east of the Sacramento Mountains show that it contains thick salt beds.

The Yeso section of Coyote Basin, northern Sacramento Mountains, is 1300 feet thick, with red beds, clay, sandstone, limestone, and much gypsum. This section contains a number of sills of gray-colored porphyry. The Yeso is but 900 feet thick east of Juniper Tank, southern Sacramento Mountains, nearly three-fourths of which is thin- and medium-bedded gray limestone. Here there are but two horizons of gypsum, one of which, interbedded with clay, sandstone and limestone, makes up the lower 157 feet, the other, together with its interbedded limestone, occupying 15 feet in the middle of the formation. In the southern San Andreas Mountains the Yeso contains a thin bed of gypsum at the base and a 50 foot bed a few feet above the middle.

The Yeso four miles north of Wilkerson's Ranch house, along the western escarpment of the northern Guadalupe Mountains, has an exposed thickness of 960 feet, the base there not being seen. No red beds are found where the detailed section was made, but some were noted a short distance to the south. This section shows a large amount of gypsum, interbedded with light-colored limestone and clay. Farther south along the west scarp of the Guadalupe Mountains in the east wall of lower Dog Cañon, some five miles north of El Paso Gap, about 250 feet of upper Yeso is exposed. The lower beds there seen are thin-bedded nodular cherty limestone carrying a small *Chonetes,* interbedded with gypsum. Above is about 200 feet of light blue-gray, thin- and irregular-bedded, markedly nodular limestone, full of small caves, underlain by medium-bedded gray limestone with nodules of chert, this limestone carrying a *Hustedia,* a small *Productus,* and crinoid stems. On weathered surfaces the limestone has almost entirely dissolved out and has left narrow oval cavities between the cherts.

Distinctive fossils prove the age of the Yeso to be lower Permian (Artinskian).

San Andreas Limestone.—The maximum thickness of the San Andreas limestone is found only in the Guadalupe and Sacramento mountains and in wells in the Pecos Valley east of the mountains, where it reaches 1100 feet. The original thickness of the San Andreas limestone is unknown, as it is everywhere unconformably overlain either by other lower Permian or later strata.

Caverns in the San Andreas limestone form channels for the artesian water of the lower Pecos Valley of New Mexico.

The San Andreas is not known north of the line of the Belen cut-off of the Santa Fe Railroad. It is found in the uplifts of the Los Pinos, San Andreas, Sacramento and Guadalupe mountains. It forms the cap rock of much of the extensive area occupied by the Chupadero Mesa and its outliers and has been brought to the surface by the large intrusive mass of the Capitan Mountains. It forms the surface of the long eastern dip slope of the Sacramento and northern Guadalupe mountains and of the country farther north, east of Torrance and Corona. Its base is often marked by a bed of saccharoidal cream-colored sandstone, fully 200 feet thick. Aside from this the San Andreas is entirely limestone, generally heavy-bedded and very hard. Chert is entirely wanting in some localities and very abundant in others. Lee Hager reports that the upper beds a few miles west of Roswell are bituminous. Geodes of calcite are quite characteristic of the limestone. The fossils are generally large forms of *Productus, Spirifer, Bellerophon, Euomphalus,* nautiloids, corals, echinoid spines and crinoid stems.

The Guadalupian-Pecos Valley Red Beds.—The Guadalupian strata outcrop in the Guadalupe Mountains and along the foot of the east flank of the Sacramento Mountains, and underlie the alluvium in the lower Pecos Valley of New Mexico. Southward in Texas they have a great development in the Guadalupe, Delaware, Glass and Chinati mountains. The Guadalupian unconformably overlies older anthracolithic strata. The following section shows the stratigraphic relationships of the Guadalupian and underlying beds in the western escarpments of the Guadalupe Mountains about one-half mile north of Bone Springs, Texas, a locality a few miles south of the New Mexico line.

Base.

1. Blue-gray limestone, rather uniform-bedded, with brown chert nodules. Strata average about 6 inches in thickness .... ± 200′
2. Thin-bedded blue-gray limestone, with lenses and nodules of brown and black chert. Chert forms about one half of total. The member is traversed at places about 100 feet and 300 feet above the base and at the top by thrust planes cutting diagonally across the bedding. The limestone is a prominent cliff-former from about 290 feet above its base to its top. There is a steep cliff 100 feet high beginning 430 feet above the base. Both silicified and non-silicified fossils noted in upper half. Abundant casts of *Lyttonia* at top. Spines of *Archæocidaris* as much as four inches long. Many Bryozoa and *Orthopecten vanvleeti* (field determination) at top. This member forms a prominent scarp at westernmost base of the Guadalupe Mountains at this locality. The member dips gently to the south along the major axis of the range, only a few feet being exposed at the mouth of Guadalupe Cañon. Total thickness ± 600′
3. Limestone, heavier-bedded than that below, weathering light gray or buff, with cherty nodules and many concentric brown chert concretions up to two feet in size, forms steep slopes. *Archæocidaris* spines near base .... 150′
4. Limestone, massive, very cavernous, weathering brown, containing nodular chert, with an irregular contact at base. Caverns contain spongy and stalactitic limonite. Large *Lyttonia*...... 20-50′

Irregular erosional unconformity.

5. Sandstone, brown, thin platy-bedded .... 25′
6. Gray sandy limestone with chert, thin-bedded ... 18′
7. Sandstone, yellow-brown, thin-bedded and evenly laminated in the lower part where there is some gray sandy shale; thicker-bedded above and calcareous at top. Forms a prominent bench in the scarp profile. Many molds of *Fusulina elongata* as well as other fossils .... 550′

Strata subdivided as follows:

a.	Sandy limestone	5′
b.	Shaly sandstone	80′
c.	Sandy limestone	5′
d.	Shaly sandstone, at a few places argillaceous and carbonaceous, in beds from one to three feet thick	200′
e.	Smooth shaly to massive arenaceous limestone	20′
f.	Shaly sandstone	25′
g.	Limestone, cherty, fossiliferous	20′
h.	Shaly sandstone somewhat calcareous towards top	200′

Followed one mile to the northwest, 300 feet of the lower strata of members 5, 6, and 7 are found lacking through non-deposition, and member 4 has increased in thickness to 200 feet. In a distance of one fourth of a mile farther north-northwest, another 100 feet of member 7 has disappeared.

The contact between members 4 and 5 is marked by irregular depressions in the underlying limestone filled with sandstone, blocks of the underlying limestone being included in the sandstone. The unconformity and basal conglomerate were traced southward beyond Guadalupe Point.

Members 5, 6, and 7 are the Delaware Mountain formation, overlain here by more than a thousand feet of massive white Capitan limestone. The Delaware Mountain formation gradually thins out to the north and entirely disappears from the section where the next exposure of the lower rocks is seen, near El Paso Gap in the Guadalupe Mountains of New Mexico. Here the lower San Andreas limestone is directly overlain by the Capitan limestone. The Delaware Mountain formation wedges out both above and below north of Bone Springs, the upper beds passing to the north into limestone only a little less massive than the overlying Capitan.

Capitan Limestone.—The Capitan limestone is more than 2000 feet thick in the eastern Guadalupe Mountains. The limestone is in large part dolomitic and exhibits many secondary structures, such as pisolites, stalactites, wavy-bedded travertines and cave-fillings. Locally it is uniform-bedded, but passes along the strike into massive rock without bedding planes. The prevailing color is glaring white. Chert is very sparsely represented. There are a number of beds of brown sandstone in the Capitan limestone in the summit range of the Guadalupe Mountains. There is a quite thick member of brown sandstone near the base of the Capitan at the north end of the main western escarpment. Rhombohedral calcite and pseudomorphs of limonite after pyrite are quite characteristic of the limestone. The Capitan in the northwestern area of its outcrop contains very few fossils; all noted by the writer belonged to three common gastropod species. In El Capitan Peak and to the southward (in Texas) fossils are more abundant, thick beds being composed almost entirely of *Fusulina elongata*. The heavy limestone phase of the Capitan is found in a roughly triangular area between the mouth of Dog Cañon on the northwest, Guadalupe Point and the escarpment running from Guadalupe Point to near Carlsbad on the southeast, and the Breaks of Seven Rivers on the northeast. This region comprises the northeastern dip slope of the Guadalupe Mountains, and the prominent higher cliffs of the western escarpment. The large caves of the Guadalupe Mountains are in the Capitan limestone.

Near the east base of the Guadalupe Mountains the Capitan changes along the strike into the Pecos Valley red beds. The transition is well seen in the walls of Rocky Arroyo, 20 miles west of Carlsbad. The strata in the Breaks of Seven Rivers at the upper end of the narrows of Rocky Arroyo consist of red clay, gray and red sandstone, light gray limestone, with many interbeds of gypsum. Traced two miles down the Arroyo the red beds and gypsum pass into thin-bedded limestone, weathering brown, underlain by brownish sandstone. A mile farther down, the limestone becomes heavy-bedded and represents typical Capitan.

The typical Capitan limestone dips beneath the Pecos Valley alluvium about two miles west of Carlsbad. Six miles east of Carlsbad in Section 4, Township 22, Range 28, is the Andrews boring, 2890 feet in depth, samples from which were chemically analyzed at the University of Kansas. The record of this boring follows:

Thickness	Rock	Depth.
14 feet	Gypsum	14 feet
106 "	"Red cavey sand	120 "
55 "	Soft limestone, with water	175 "

45 feet	Light sandy clay	220	feet
46 “	Red mud and cavey sand	266	“
2 “	Anhydrite	268	“
32 “	Light shale	300	“
185 “	Light crystalline anhydrite, locally iron-stained	485	“
20 “	Coarse salt	505	“
5 “	Anhydrite	510	“
108 “	Coarse salt	618	“
22 “	Granular anhydrite	640	“
5 “	Grayish anhydrite	645	“
5 “	Blue granular anhydrite	650	“
170 “	Coarse salt	820	“
10 “	Granular anhydrite	830	“
288 “	Coarse salt	1118	“
67 “	Bluish anhydrite	1185	“
125 “	White anhydrite	1310	“
55 “	Grayish anhydrite	1365	“
455 “	White anhydrite	1820	“
25 “	Red anhydrite with iron oxide	1845	“
200 “	White anhydrite	2045	“
20 “	Dark anhydrite	2065	“
45 “	Light anhydrite	2110	“
90 “	Dark anhydrite	2200	“
20 “	Anhydrite with 15% limestone	2220	“
160 “	Light anhydrite	2380	“
50 “	Dark anhydrite containing lime	2430	“
25 “	Light anhydrite	2455	“
10 “	Soft shaly limestone	2465	“
5 “	Bluish limestone, trace of oil	2470	“
10 “	Calcareous shale	2480	“
20 “	Dark hard limestone	2500	“
10 “	Light blue limestone	2510	“
25 “	Dark blue limestone	2535	“
25 “	Light blue limestone	2555	“
5 “	Sandstone	2560	“
70 “	Sand	2630	“
70 “	Dark limestone	2700	“
35 “	Light fine sand, water-bearing	2735	“
10 “	Very coarse sand	2745	“
75 “	Fine white sand	2820	“

Dark limestone to bottom.

There are 1571 feet of anhydrite in this section, of which no less than 1337 feet are in continuous beds. The salt totals 586 feet, interbedded with anhydrite above the thickest bed of anhydrite. The strata from 2455 to 2820 feet in this boring probably belong to the Delaware

Mountain formation, and the strata from 266 to 2455 feet are regarded as the equivalent of the Capitan limestone.

Logs of artesian wells in the Pecos Valley between Lake McMillan and Roswell show red beds, salt and gypsum above the San Andreas limestone. The deeper borings in the vicinity of Roswell penetrate both the upper red beds and the lower Manzano red beds, the two series being separated by the intervening San Andreas limestone. Sink-holes are scattered abundantly over the surface of the upper Pecos Valley red beds east of the Pecos River. These upper red beds and gypsum beds are also exposed along the east base of the Guadalupe and Sacramento mountains from the Breaks of Seven Rivers northwards to beyond Roswell. The northern limit of outcrops of the Pecos Valley red beds is not known at present. Southward they extend into the Toyah Basin of Texas and eastward under the Llano Estacado. On the eastern flanks of the Sacramento Mountains and of the northern Guadalupe Mountains the Pecos Valley red beds lie directly on the San Andreas limestone.

The Mesozoic Succession.

Upper Triassic (*Keuper*).—The Upper Triassic red beds outcrop in or underlie perhaps one third of the total area of New Mexico. In the eastern area they extend from the flanks of the Sangre de Cristo Range eastward to beyond the eastern margin in Texas of the Llano Estacado. West of the Pecos River they extend at least as far south as the Belen cut-off of the Santa Fe Railroad, while east of the Pecos they extend southward to beyond the Texas line. The Trias can be roughly divided into a lower coarser member with conglomerates and with dark purple and gray sandstones and fine sands characterized by the abundant occurrence of mica, and an upper member of brick-red and gray fine sands, sandstones and sandy clays. The upper member has yielded no fossils and may not be Triassic.

The Upper Triassic sediments are entirely of terrestrial origin, in the main river and stream deposits and to a subordinate extent æolian. They contain bones of Phytosauria and Labyrinthodontia, shells of Unios and a large amount of silicified wood, plant impressions and local small lenses of lignite. The total assemblage makes up an immense alluvial fan deposit laid down by streams rising in higher lands to the north and northwest. In mode of origin the Triassic is similar to the Cenozoic of the Llano Estacado and High Plains, to the later Cenozoic and recent deposits of the Great Valley of California, and the Pampas of Argentina.

Near the top of the strata here referred to the Upper Trias is a conspicuous bed of white much cross-bedded sandstone which was traced from the southern Sangre de Cristo Mountains eastwards to beyond Tucumcari. This may represent the Zuni sandstone of northwestern New Mexico.

The basal member of the Upper Trias, the Glorieta sandstone, outcrops along the valley of the Pecos from the Glorieta Mesa downstream to somewhere between Puerto de Luna and Fort Sumner. It outcrops at Santa Rosa.

The thickest section measured of strata here included under the Upper Trias—and the lower part of which is certainly Upper Trias—is the one with vertical or slightly overturned beds in the east flank of the Rocky Mountain Front Range fold just east of Las Vegas Hot Springs. The thickness here is 1770 feet, the upper part of which may possibly include some Jurassic.

A bed of gypsum about 50 feet in thickness, underlain by thin dark brown flaggy and very bituminous limestone, occurs on the east flank of the Sandia Mountains about 30 miles north-northeast of Albuquerque. The gypsum lies near the top of the strata here referred to Upper Trias. On top of the gypsum is a heavy bed of red sandstone followed by greatly cross-bedded, massive buff sandstone. It is likely that the last mentioned bed is the equivalent of one of the same nature in the southern Sangre de Cristo Mountains and eastwards to beyond Tucumcari. The bed of gypsum extends west to the Mt. Taylor region. In places the massive sandstones above the gypsum are absent and this statement especially applies to the country east of the Rio Grande. The gypsum bed is not known in the Rocky Mountains and in the High Plains to the east. What is probably the same gypsum bed is found at the top of the Triassic section at the mouth of Navajo Cañon, near the junction of the Arroyo

Seco with the Rio Chama, in Rio Arriba County, on the road between Abiquiu and Tierra Amarilla. A generalized section of the Trias at this locality, beginning with the base, follows:

1.	Shinarump sandstone and conglomerate, probably the equivalent of the Glorieta sandstone farther east and southeast. Color varies from purple to light buff but is generally brown, often stained on the surface with black oxide. Sandstone cross-bedded. Lower portion conglomeratic, with well rounded pebbles and bowlders of crystallines. Rests unconformably on Permian red sandy clays	± 150′
2.	Sandy clays, dark maroon, streaked and mottled with light gray, blue and green. At least	200′
3.	Sandstone, massive, friable, fine-grained, with curved joints, weathering by exfoliation into alcoves. Much cross-bedded locally, and in all probability at least partly of eolian origin. Color in lower half varies from buff to brick-red, becomes buff above, and is light yellow in upper 50′	± 200′
4.	Alabaster gypsum, resting on irregular surface of (3). Erosion channels in the gypsum filled with buff sandstone. Maximum thickness	± 50′
Unconformity.		
5.	Sands and sandy clays, pink, purple, buff and drab in color	± 350′
6.	Sandstone, buff	± 200′
7.	Clays, whitish	40-±50′
8.	Clays, drab, weathering in badlands. At least	200′

The total thickness of strata between the top of (1) and the top of (6) is about 1600 feet, hence the estimates of thicknesses given above are too small. The location of this section is on the west flank of the anticline marking the southeastern end of the San Juan Mountains uplift. Along this anticline, north of Abiquiu, several hundred feet of Permian red beds are exposed. The age of beds (5) to (8) is unknown, but beds (1) to (4) inclusive are Upper Trias. The above sedimentary rocks are concealed to the south and east by great thicknesses of volcanic pyroclastics and flows (rhyolite, andesite and basalt in upward succession). These volcanic rocks fill the basin of the upper Rio Grande in New Mexico and form the extensive mesa surfaces of the San Pedro, Valles, Jemez and Nacimiento mountains of southwestern Rio Arriba County and central-northern and northeastern Sandoval County.

Jurassic (?).—Strata lithologically similar to the Morrison of regions farther north overlie the upper series of red beds on the flanks of the Sangre de Cristo and Sandia mountains. It is probable, from the facts stated in the preceding paragraph, that an epoch of erosion followed the deposition of the upper red beds.

The strata tentatively referred to the Morrison are light to dark brownish-green sandy shales and sandstones. The sandstone is generally stained brown with limonite. The light green shales contain concretions of calcium carbonate, generally coated dark reddish brown with iron oxide, and often tuberous. The clay weathers like a joint clay. The sand beds are generally nodular and not persistent. This member at Las Vegas Hot Springs consists of heavy bedded brown sandstone interbedded with green sandy shale and shaly sandstone, the whole totalling 250 feet in thickness. These strata disappear to the eastward in the High Plains region between Las Vegas and Tucumcari.

Upper Comanchean (Tucumcari) Beds.—The following section was measured on Tucumcari Mountain, four miles south of the town of Tucumcari:

Base. Upper Triassic.

1. Purple-red and dark brick-red sandy clay, with some thin gray bands and blue-gray to greenish irregular bands in lower portion. Referred to the Upper Triassic .... ± 100′

Upper Comanchean (Tucumcari beds).

2. Soft cream-colored sands, unconsolidated below but showing stratification.
3. Limonite-speckled, thin-bedded, gray-buff, medium-grained, poorly indurated sandstone, with thin beds of laminated clayey and marly light blue-gray sands with *Gryphæa tucumcarii* 50 feet below the top; at top, contorted, marly, light brown sands with *Turritella* and *Cardium*. Total thickness of (2) and (3) ...... 325′

Unconformity.

Cretaceous.

4. Dakota sandstone, buff, cross-bedded, ferruginous,

locally quartzitic and conglomeratic; ripple-marked .... ± 100′

Unconformity.

Cenozoic.

5. Caliche, cream-colored, cementing sands and gravel .... 10′

A small section exposed in a bluff on the north side of a small arroyo 11½ miles west of Tucumcari on the Montoya road yielded more definite evidence of the age of the Tucumcari beds. Here tawny yellow nodular very sandy marls have an exposed thickness of 30 feet and are directly overlain by Dakota. At the base is a zone filled with *Gryphæa tucumcarii,* some of which are of very large size. Twenty five feet higher and five feet beneath the Dakota is a zone with *Ostrea quadriplicata, Turritella* and *Cardium. Ostrea quadriplicata* is confined to the strata between the Quarry and Mainstreet limestones of the Denison section of north Texas, the age of which is middle or upper Cenomanian.

Sandstones and sands lithologically similar to and occupying the same stratigraphic position as the Tucumcari beds are found as far west as the southeastern flanks of the Sangre de Cristo Mountains. Their southern limit is found in the high mesas eastwards from south of Las Vegas and their southwestern limit is found two or three miles west of the northwesternmost point of the Llano Estacado.

Cretaceous.—The *Dakota* sandstone has its southern limit in the region of the Sierra Blanca group of intrusives in west-central Lincoln County. It is widely distributed in the region north of the 35th Parallel, where it outcrops in the flanks of the mountain ranges and outcrops in or underlies the High Plains of northeastern New Mexico. It is everywhere very distinctive, possessing the same lithologic characteristics. A description of the strata in the hogbacks along the east flank of the Front Range of the southernmost Rockies will suffice for the entire province of the Dakota in New Mexico. The section in the water gap of Gallinas Creek east of Las Vegas Hot Springs follows:

Base.

1.	Sandstone, heavy-bedded, resistant, brown, ferruginous, and finely conglomeratic. Cut at base with network of fine veins. Upper half more firmly cemented and cream-colored when free from iron	100′
2.	Carbonaceous shale, blue-black, with well indurated brown sandstone interbedded	13′
3.	Sandstone, buff, ferruginous, well cemented, sugary-textured, conglomeratic, veined, laminated and cross-bedded	10′
4.	Sandstone, brown mottled with black, fucoidal markings very abundant in upper half	15′
	Total thickness	138′

In the vicinity of Capitan in Lincoln County, the Dakota is for the most part very dark brown or reddish in color.

The post-Dakota Cretaceous of northern New Mexico has the Great Plains facies east of the Sangre de Cristo Range, and the Intermontane facies west of that range. The Great Plains facies shows only shales and limestones from the base of the Benton to the top of the Pierre; the Intermontane facies west of the Rocky Mountains Front Range is probably more than half sandstone and contains beds of coal in the strata from Benton age upwards.

The following section of rocks of Benton age was made one mile south of Las Vegas:

Base.

1.	Sandstone, coarse-grained, containing an occasional small pebble, generally gray or brown; with fucoidal markings. Lower 10 feet blue-black in color from carbonaceous matter, and full of plant impressions, sandstone medium-grained in this member. The bedding is very irregular, possibly from current action. The beds are thin and contain local lenticles of light buff sandstone, locally quartzitic, and harder than the carbonaceous sandstone.	
2.	Sandstone, soft, shaly, very carbonaceous, with plant impressions	1′
3.	Sandstone, buff, thin-bedded and very irregular, locally quartzitic and carbonaceous	10′
4.	Dark carbonaceous shale	0·5′
5.	Sandstone, buff, thin- and irregular-bedded	6′
6.	Sandstone, cross-, wavy-, and contorted-bedded;	

grayish- or greenish-brown; partially quartzitic; with a few small-sized pebbles; very ferruginous on bedding-planes; contains some small pellet concretions of limonite; fucoid markings abundant. This is certainly a tidal-flat or shore-line deposit and is thought to mark the beginning of Benton deposition .... ± 3′

7. Shale, blue-black, fissile .... 18′
8. Sandstone, dark greenish brown, fucoidal and flaggy 0·5′
9. Shale, typical Benton, blue-black, and bituminous, contains an occasional thin layer of sandstone varying in thickness from a fraction of an inch to six inches .... 45′
10. Limestone, brown, filled with poorly preserved *Inoceramus labiatus* and *Ostrea* .... 0·5′
11. Shale, typical Benton, with two thinly-laminated sandstone layers each about two inches thick in lower 20 feet. Shale is like those of (9) above, and also contains some lenticular concretions of clay iron-stone, in places changed to limonite .... 130′
12. Limestone; beds of brittle, fine-grained, blue-black limestone, containing small, often pyritized fossils each bed about a foot thick alternating with thin, slabby-bedded, argillaceous and bituminous dark blue-black limestone .... 80′

The Mancos formation has a thickness of 2950 feet on the east flanks of the Sandia Mountains east of Algodones. It rests on the Dakota and consists in the lower part of dark brown bituminous shales with thin interbeds of limestone carrying *Inoceramus labiatus,* etc. It passes upwards into beds of massive gray and buff sandstone interbedded with carbonaceous shale and coal and carries Niobrara fossils in the upper part. Overlying it is a thick assemblage of sandstones, shales and coal belonging to the Mesa Verde, the latter being overlain by orange-colored Galisteo sandstone of unknown age but older than upper Miocene.

A remarkable facies of the Benton rests directly upon strata of the Manzano group on the southwest flanks of the San Andreas Mountains about 30 miles north of the Texas line. The Benton rests, with marked erosional unconformity at different localities, on either the basal San Andreas limestone or the upper beds of the Yeso formation. The base of the Benton consists of about 100 feet of grayish, brownish, and reddish concretionary soft sandstone with thin layers of brown limestone carrying *Inoceramus labiatus, Cardium* and *Ostrea*. These beds pass upwards into heavy beds of conglomerate with bowlders of the underlying San Andreas limestone and brown sandstone up to three feet in size. Most of the Cretaceous, which is not far from 1000 feet in total thickness here, consists of red terrigenous sediments probably derived from erosion of the red beds.

The following small section of the lower Pierre was measured in a butte about two miles east of Las Vegas Hot Springs:

Base.

1.	Dark blue-gray sandy shale	± 100′
2.	Dark blue-gray and dark brown sandy shale	30′
3.	Dark brown sandy shale	25′
4.	Layer one-fourth to one-half inch thick of limestone, mainly composed of fish bones and spines.	
5.	Dark brown shale	10′
6.	Shale, sandier, less finely laminated and lighter brown in color than below. Locally with radiating markings	60′

The mesa is covered with gravels and bowlders of metamorphic and plutonic rocks and Magdalena limestone.

The Cenozoic Formations.

The Galisteo sandstone of the Santa Fe Basin may be at least in part of Eocene age. The Santa Fe marls of the same region are Upper Miocene, and probably were deposited in a structural basin. These marls consist of coarse arkoses on the west flanks of the Rockies in the vicinity of Santa Fe, but lower down in the Rio Grande Valley they become for the most part fine sands and silt, although they are probably coarser on the west flanks of the Sandia, Manzano and Los Pinos ranges, where they are buried beneath more recent alluvium.

The only other Tertiary deposits known in eastern New Mexico are those capping the surfaces of the Llano Estacado east of the Pecos River and of the High Plains north and east of the Canadian River. These have been described and interpreted in another publication.[2]

No attempt will be made at this time to discuss the Pleistocene, the importance of which in the southwest de-

[2] Baker, Charles Laurence: Geology and Underground Waters of the Northern Llano Estacado. University of Texas Bulletin (1915) No. 57.

mands a more careful, detailed, and regional study than the writer has been able to make in this exploration.

There has been a truly immense amount of erosion accomplished during the latter half of the Cenozoic. Three factors have probably combined to bring about the subaerial denudation: (1) the comparatively non-resistant nature of almost all the sedimentary rocks later in age than the Magdalena; (2) great elevation of the mountain ranges and surrounding plains, affording steep gradients; and (3) arid or semi-arid climate with sporadic cloudburst precipitation and a sparse vegetal covering. Proof has been given elsewhere[3] that the upper surface of the High Plains and Llano Estacado extended westward with, in all probability, gradually increasing altitude as late as early Pleistocene times. An average rock thickness of at least 1500 feet has been removed from the region between Tucumcari and the southern Rocky Mountains in the later Pleistocene.

Extrusion of *basalt* has occurred since the date of formation of the major features of the present topography. The basalt flows of the northern Tularosa Basin and from Maxon Crater down the Mora River valley into the valley of the Canadian have taken place in Recent times.

List of Orogenic Epochs in Eastern New Mexico.

1. Pre-Cambrian; intense folding, faulting and metamorphism.
2. Pre-Magdalena; possibly of the nature of a broad warping confined to the southern Rocky Mountains (Sangre de Cristo Range).
3. Upper Pennsylvanian (Pre-Abo); gentle folding in the regions of all present mountain uplifts. May also have affected most of the present plains area, where the older rocks are now concealed.
4. Pre-Upper Triassic; gentle folding or warping of probably entire region and almost certainly a large uplift of the southern region of the present Rocky Mountain system.
5. Laramide (near end of Cretaceous); perhaps confined to region of present Rocky Mountain system.
6. Mid-Tertiary (probably late Middle Miocene); affecting the region of present mountain ranges of north-

[3] Op. cit.

central New Mexico and very possibly the other existing mountain regions.

7. (?) Late Cenozoic; probable final uplifting of existing mountain ranges, accompanied by tilting towards the east of the present Great Plains region.

Conclusions.

The most important new stratigraphical facts discovered by this exploration are the following:

1. The lower red beds of the Sangre de Cristo Mountains, at the southern end of the Rocky Mountains proper, belong to the Abo formation of the Manzano Group.
2. The lower part of the Abo formation is upper Pennsylvanian in age.
3. The Yeso formation and San Andreas limestone are lower Permian in age.
4. The Guadalupian-Pecos Valley red beds series lies unconformably upon strata of the Manzano Group.
5. The Glorieta sandstone is the basal part of the upper Triassic.
6. The age of the Tucumcari beds is definitely established as Middle or Upper Cenomanian.
7. A coarse detrital facies of the Benton rests directly upon Manzano rocks in central-southern New Mexico.

Berkeley, California,
October 5, 1919.

Art. VIII.—*The Butler Salt Dome, Freestone County, Texas;* by Sidney Powers.

Contents.

Introduction.

The Butler, or West Point salt dome, has remained in obscurity among descriptions of Gulf Coast salt domes owing, no doubt, to the fact that distance from a railroad has prevented the production of salt there in commercial quantities. With the drilling of the Keechi dome in Anderson County leases were taken on the Butler dome, but when the six tests of the Producers Oil Co. (The Texas Co.) on the south side of the former dome proved the absence of commercial quantities of oil in that very small portion of the dome, drilling for oil in salt domes of the interior ceased. Six wells have been drilled in the vicinity of the Butler dome, one at the Llewellyn (Daniel) gin, two on the southwest and three on the northeast side of the dome, all about 10 years ago. The first well found salt at 400 feet, according to one report, the other wells artesian fresh water. The exact depths of these wells are not known. The well at the gin is supposed to have been about 700 feet deep; those to the southwest, on the Cornwall farm, are about the same depth; one of those to the northeast on the Duncan farm is 1000 feet deep, another 1465 feet; and the depth of the third is unknown. One of the Cornwall wells is reported to have had a show of gas.

Dr. C. Wythe Cook and Dr. L. W. Stephenson, of the United States Geological Survey, have kindly examined fossils collected by the writer at the localities indicated on the map (fig. 1) and pronounced them to be lower Eocene, either Midway or Wilcox, at two localities, Upper Cretaceous at a third. The fossils which occur in the higher and outer fossiliferous bed are a very abundant coral of small size, *Balanophyllia* sp., unidentifiable Bryozoa, and *Venericardia,* resembling *V. perantiqua,* collected 15 miles southeast of Eagle Pass; also *Arca, Trigonarca?* and *Panope?* Those in the inner fossiliferous bed near the junction of the Bonner's Ferry and Oakwood roads include the following:

Cucullaea sp. (internal cast).
Exogyra sp. (small valve).
Trigonia sp. (internal cast).
Cardium spillmani Conrad (?) (internal cast).

Dr. Stephenson writes: "These fossils are undoubtedly from the Upper Cretaceous, but I am unable to state what horizons in the Upper Cretaceous they represent."

The writer is indebted also to Mr. E. DeGolyer, of New York City, for kindly recalling to the attention of the writer the limits of the dome, and to Mr. Wallace E. Pratt, of Fort Worth, Texas, for exceedingly helpful criticism of the manuscript.

Location.

The Butler salt dome[1] or West Point dome, as it is usually called from the name of a former landing on the Trinity River north of the dome, is in Freestone County, Texas, 2½ miles east of Butler, 30 miles east of Teague, and 15 miles west of Palestine. It is about 3 miles from Bonner's Ferry on the Trinity River and is 8 miles in a straight line from the Palestine salt dome. It is on a line with the Palestine (Salt Works), Keechi, and Brooks salt domes and this line may also be drawn through the Steen salt dome at the north end of Smith County. This is one of the lines of weakness emphasized by Harris[2] along which the salt domes have risen. The only other interior salt dome[3] in east Texas, unless the Brenham dome be so classed, is the Grand Saline dome in Van Zandt County.

[1] This name was first used by O. B. Hopkins, The Palestine salt dome, Anderson County, Texas, U. S. Geol. Surv., Bull. 661 G, 1917. The name West Point has been used by E. G. Woodruff (Bull. Southwestern Ass. Petrol. Geol., vol. 1, p. 81, 1917), but it is not retained because the name West Point is not to be found on any map.
[2] G. D. Harris, U. S. Geol. Surv., Bull. 429, 1909.
[3] A term introduced by E. T. Dumble, Origin of the Texas domes, Amer. Inst. Min. Engs., Bull. 143, 1918.

Topography.

Topographically Butler salt dome is the most symmetrical and the most perfectly developed salt dome on the

Fig. 1.

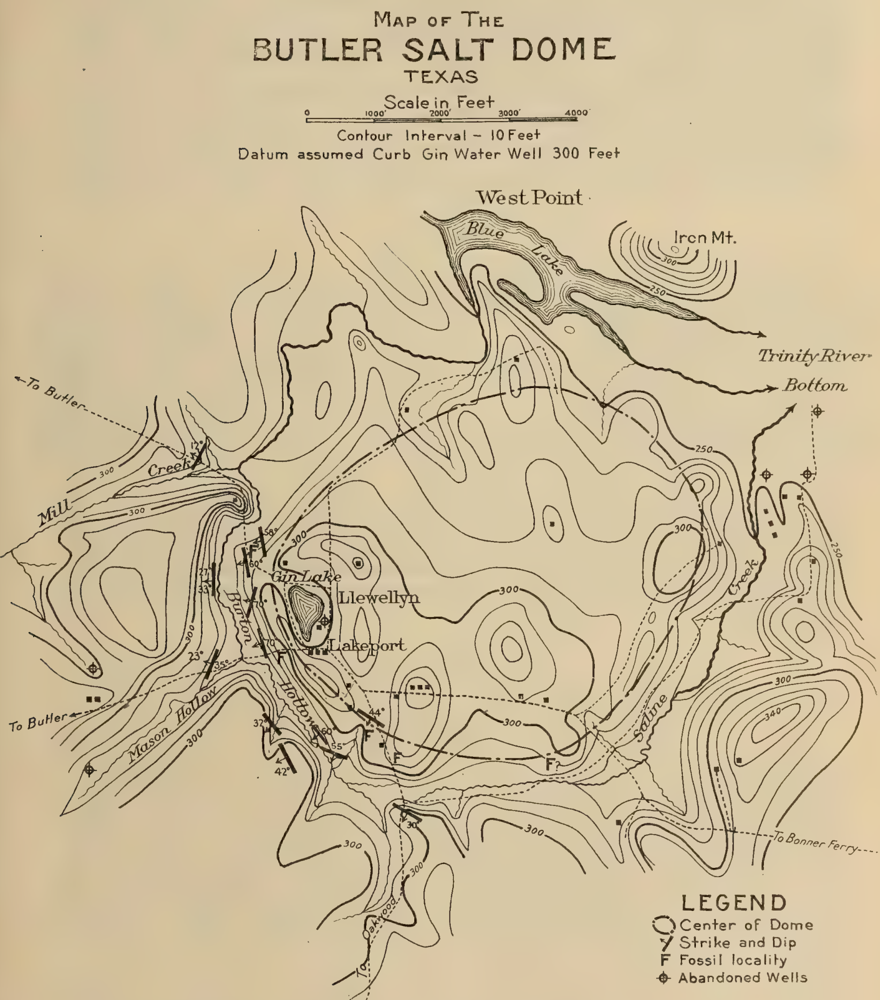


Fig. 1. Map of the Butler salt dome, Freestone County, Texas. Iron Mt. should read Rocky Mt.

Gulf Coast. A saline prairie from 100 to 500 feet in width completely encircles the dome which is about 8000 feet in diameter. From an almost imperceptible divide on the south side of the dome creeks meander in either direction. Burton Hollow creek drains from the south into the saline near the divide and runs northwest and north. It is joined in a radial fashion by short branches from the inside and by long branches from the outside. Of the latter the first two are nameless, the third is Mason Hollow (McCormick branch), and the fourth Mill Branch. Rocky Ford creek probably forms another radius from the north beyond the limits of the accompanying map. Burton Hollow creek expands to form the shallow Blue Lake at the edge of the Trinity River "bottom" (overflow plain) and this lake with its ramifi-

Fig. 2.

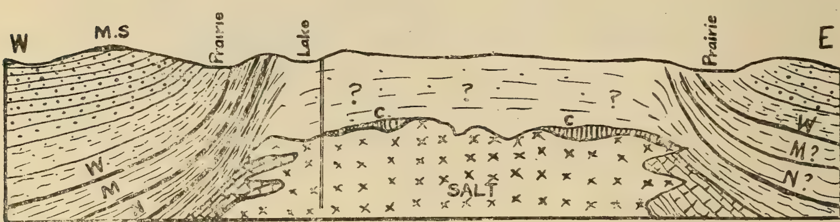


Fig. 2.—Hypothetical cross section of the Butler salt dome, at Llewellyn gin lake showing salt core overlain in part by limestone cap rock (C) and flanked by sediments of Navarro(?) (N), Midway(?) (M), Wilcox (W), Mount Selman (M. S.) ages. The salt core and cap rock are probably overlain by sand and clay to which no age can be assigned. The well at the gin is shown.

cations extends around a hill and eastward draining in obscure channels across the "bottom" and into the river.

At the divide on the south side of the dome Saline creek starts eastward, turns northeast, and is joined by radial branches from the inside and from the outside. The difference in elevation of the Trinity "bottom" and of the divide is about 35 feet, giving the drainage a fall of about 20 feet to the mile. Hence, the prairies are in a condition of mature erosion although the other streams of the region have not advanced that far in the present cycle of erosion.

Hills form a rim around the saline prairie on both sides. Those on the outside are the higher and the greatest relief is between 60 and 70 feet. Rocky Mountain, between Blue Lake and the Trinity River, is still higher. Within the inner circle of hills the top of the dome has little relief. If the true elevation of the Trinity River is 230 feet the assumed datum on the accompanying map is about 20 feet too low. The elevation of the divide becomes 295 feet, that of the higher hills 365 feet, that of the Llewellyn gin lake 315 feet.

Stream adjustment to the dome is also shown in the bend of the Trinity River around Rocky Mountain. The river at one time probably flowed south of the Mountain and at that time formed the depression occupied by Blue Lake. At times of very high water the river flows into the prairies on either side of the saline.

Lakes are one of the characteristic features of the interior salt domes. The Palestine, Steen, and Grand Saline domes have central lakes surrounded by hills. Brooks and Keechi domes have saline prairies, but no lakes. Butler dome has the Llewellyn gin lake just within the inner circle of hills. This lake is intermittent: it dries up in dry seasons and it is never deeper than 5 feet. The water is fresh and no salt incrustation is found near the margin. Formerly the area now occupied by the lake must have been drained either to the northwest or to the south, probably through the former "wind gap." It is evident that the depression was formed by solution of underlying salt probably subsequent to the latest rejuvenation of the streams and to the resultant lowering of the ground water level.

Springs.

Associated with all interior salt domes there are barren prairies partly covered with salt-marsh grass, boggy areas into which one may sink into sand or blue clay to an untested depth, and springs of very slightly mineralized water. Some of these springs are sulphur water, some "soda" water, some "sour" (alum) water. On evaporation "salt licks" result and salt can be extracted by evaporating the white residue on the surface of the ground. During the Civil War salt was procured from several of the interior domes including Butler, the locality being near Blue Lake. The almost tasteless white salt which is common as a thin incrustation on

Eocene sandstones is largely alum and the salt on the surface of the prairies is probably partly alum.

But these conditions are not confined to salt domes and the origin of the salt on the prairies is not from the core of salt underlying the center of the dome. The water is artesian water and ground water. A number of salines in the area covered by the Eocene and Oligocene outcrop in Texas furnished salt during the Civil War. These salines are characterized by more or less circular semi-barren areas surrounded by hills. Abundant sulphur and other springs are found associated with them as well as natural mounds, blue mud holes, and cut-off lakes. Among their number may be mentioned the Posey saline in Anderson County, the Vair saline in Trinity County, the Enal saline in Angelina County. Others are mapped by Harris.[4] Their origin is evidently ascending waters, but nowhere is any evidence of faulting or of uplift seen.

Springs are found surrounding the Butler dome on the outside of the prairie. They rise in small recesses or reëntrants at the base of the hills. As there is no evidence of faulting in the dome and as a single horizon can be traced around a quarter if not a third of the circumference, it is believed that the springs arise from one or more water-bearing sandstones. In front of these springs the soil becomes soggy and is covered with turf and bushes. It shakes when walked on and a heavy weight sinks into sand underlain by blue mud. None of these blue mud springs is as soft as are many of those in east Texas into which a pole can be pushed for 15 feet or more. A mud volcano 5 inches in height was found near one of the springs.

Mounds.

Two ways in which natural mounds are formed may be observed in the prairie surrounding the dome. In one case the springs on the sloping sides of the prairie give rise to small mounds which increase in height with the growth of the turf. When the center of the mound is a foot or two above the level of the prairie on the lower side the whole mass begins a slow creep toward the

[4] Op. cit., pl. 13.

center of the prairie. Cracks a foot in depth and half a foot in width develop on the lower side as the mass moves forward. A fraction of an inch of motion a year and a similar amount of added height develop in the course of time a sizable, symmetrical natural mound with trees securing a foothold on the top. With increasing height and firmness caused by deep-rooted vegetation, together with the forward movement of the whole, the water begins to run around instead of into the mound and it sometimes develops a small channel which isolates the mound. The various stages of the process may be observed in Burton Hollow.[5]

Examples are also seen of the formation of somewhat similar mounds by simple erosion where drainage cuts back on each side of and finally completely through a ridge or terrace three feet or less in height. Mounds clearly of this mode of origin are abundant. They are also abundant on the west side of the Brooks salt dome and in many other localities both in Texas, Louisiana, and Oklahoma. It is the belief of the writer that the abundant mounds of the Gulf Coast, concerning which so much has been written, will ultimately be proven to be in large part erosional in origin.

Surface Geology.

Four formations are exposed in the vicinity of the dome: the Mount Selman, Wilcox, and Midway (?) of the Eocene, the Navarro (?) of the Upper Cretaceous. The Mount Selman consists of ferruginous red sandstones interbedded with sands and some clays. The hard sandstones which cap the hills between Butler and the dome and which also cap Rocky Mountain, north of the dome, probably belong to this formation. No fossiliferous, glauconitic sandstones of the Mount Selman are exposed in the region.

The outer rim of hills around the dome is composed of crossbedded sands and sandy clays with limonite partings and thin lignite beds. These are part of the Wilcox formation. The age of the rocks in which the saline prairie has been eroded is probably in part Wilcox, in

[5] The formation of these mounds is also described by E. G. Woodruff in a brief description of the dome (Bull. Southwestern Ass. Petrol. Geol., vol. 1, p. 81, 1917).

part Midway. Within the prairie the outer rim of hills is composed of blue shales with lenses of limonite and siderite concretions in which fossils of Midway (?) age were collected. Directly underlying these beds are similar shales of blue color practically free from limonite in which Upper Cretaceous fossils were found.

There is a greater uniformity of beds and absence of faulting in this dome than in either of the domes of Anderson County. The beds dip quaquaversally from the dome at angles ranging from 70° near the salt core to horizontal 3000 feet away from its edge. There is probably an unconformity between the Wilcox and Mount Selman formations as described below. A description of outcrops follows.

On the west side of Burton Hollow from the north proceeding south the first exposure is shale, of yellowish color when weathered, with concretionary beds of limonite. In the east-west road sandy shales and sands of yellow and grey color and shales of chocolate color are exposed. The thin beds are separated by heavy beds of limonite. In a small lateral gully farther south there are sandy clays of lavender to grey color, probably stained by the weathering of lignite. Above them is a shale pebble conglomerate composed of pebbles of grey color 1 inch to 4 inches in length crowded together in a bright yellow sand matrix. Similar conglomerates have been found by the writer in the Wilcox formation in four localities in the western portion of Freestone County; in a creek which crosses the "south" Jewett road 2 miles southwest of Donie, on the BBB. & C. RR. survey; in a cut at mile post 200 on the Trinity and Brazos Valley Railroad, 1½ miles north of Freestone; and in a small creek which crosses the Teague-Fairfield road 4 miles from Teague. They are not uncommon in both the Wilcox and Mount Selman formations.

The gully farthest south on the west side of the Hollow shows typical Wilcox sand of red, dull yellow, and grey color with occasional limonitic partings.

The most readily traced horizon on the southwest side of the dome is found on the east side of the Hollow. Rows of sideritic concretions dipping 70 degrees west are exposed above beds of plastic blue clay at the south side of the north road to Butler. The larger concretions are about 1 foot wide and 4 feet long. They consist of an outer layer of cone-in-cone structure[6] from 1 inch to 6 inches in thickness with a center 3 to 8 inches thick composed of calcareous, sandy siderite. Small balls ⅛ inch to 1 inch in diameter also occur in the center and represent small siderite concretions. Fossils, especially small corals, are found throughout the larger concretions, but they are practically destroyed in the cone-in-cone rims. They are not found in the smaller concretions, which are almost wholly limonite replacing siderite without cone-in-cone structure. The shales exposed at the side of the road contain a few flat limonite concretions less than a foot in diameter and the shales are occasionally streaked with yellow. Selenite crystals of small size are also present. The shale breaks up into tiny angular fragments. It is a very pure clay, is very different from the typical sandy shales of the Wilcox and is believed to be of Midway age.

Large unfossiliferous concretions similar to some of those associated with the fossils are exposed north of the Hollow near the bridge and also south of the fossil locality in three places. The latter outcrops show argillaceous sands of white to yellow color.

At the south road to Butler a few fossiliferous concretions and cone-in-cone concretions traversed by selenite veins are exposed above a thick series of blue shales exactly like those at the north road. To the south there are outcrops of heavy limonite beds and there is one outcrop of impure limestone of yellow color.

Another locality where fossils were collected is on the Oakwood road at the top of the hill north of the saline. Other similar concretions, but without fossils, were found between the Bonner's Ferry road and the saline as indicated on the map.

Limestone is practically unknown in the Wilcox formation although concretionary masses of very calcareous shale are occasionally found, as near Farrar and near Freestone. At Mexia and in the Mexia gas field beds of Midway limestone are widespread. It is believed that the siderite concretions were originally thin lenses of very calcareous shale or of limestone and that they are

[6] The origin of cone-in-cone structure is well described by W. S. Gresley, Cone-in-Cone, Quart. Jour. Geol. Soc., London, vol. 50, pp. 731-739, 1894.

of Midway age. Limestone is exposed on the east side of the Steen salt dome, in the northern portion of Smith County, but it is unfossiliferous. It has been considered to be of Midway age.

Near the junction of the Bonner's Ferry and Oakwood roads plastic shale of yellow to brown color with only one ferruginous layer is exposed in a gully. The Upper Cretaceous fossils were collected near the head of the gully, or about 300 to 400 feet stratigraphically below the shales in which fossils of Eocene age were found. Judging from the stratigraphy, the Cretaceous shales belong to the Navarro formation. This exposure represents the lowest horizon exposed in the dome.

Structure.

Nothing is known of the underground conditions at the dome except that salt was found beneath the center at a few hundred feet and that the rocks dip quaquaversally from the center. The shape of the central salt core is unknown, but is believed to be circular as indicated on the map, and 6000 feet in diameter. The diameter of the area underlain by tilted rocks surrounding the core is about 2½ miles. Exploration for salt in other salt domes has shown that the upper surface of the salt body is very irregular and has no relation to the configuration of the surface of the ground.

The thickness of formations on the outcrop may be roughly estimated and compared with data from well logs. The line between the Mount Selman and Wilcox formations can be drawn in the field in a general way from the topography—the former caps hills of noticeable relief forming a "wold." The Wilcox-Midway contact is supposed to be marked by a change from shale below to sandy shale and sand above, but this contact is concealed in Burton Hollow. The Midway-Navarro contact is lithologically indefinite.

In well logs from the Red River and Crichton fields, in Louisiana, it may be noticed that the Annona chalk and Nacatoch sand are overlain by shale and gumbo which extend to the surface giving a thickness of 900 feet or less. The Wilcox formation everywhere covers the surface. Southwest of the Sabine uplift the thickness of this gumbo increases to 1330 feet in Shelby County and to

1600 feet in Anderson County. Overlying the gumbo the logs show predominately sand which attains a thickness of about 1200 feet below the base of the Mount Selman formation. An additional 700 feet of sand which is in part if not wholly of Mount Selman age is found in the lower portion of the synclinorium near the Nueces River in Anderson County.

A comparison of estimates of thickness is tabulated:

Formation		Anderson Co. Hopkins, 1917	Anderson Co. Well logs	Freestone Co. Butler dome
		Thickness, feet		
Eocene	Mount Selman formation..	350–600	700+	200+
	Wilcox formation......	450–650	sand 1200, shale 800±	1000
	Midway formation......	250	800± (Midway formation, Navarro formation, Taylor marl)	400−
Upper Cretaceous	Navarro formation......	600–900		400+
	Taylor marl..	800–1000		
	Austin chalk .	400–500	250	
	Eagle Ford shale......	350–400	900–1150 (Eagle Ford shale, "Woodbine" oil sand)	
	"Woodbine" oil sand....			

The conspicuous discrepancies between the figures of Hopkins and the well log data are the relatively great thickness assigned to the Wilcox formation and the relatively small thickness assigned to the underlying shales in the well logs. Some error in correlation or in measurement is suggested. A thinning of the Cretaceous south of the present outcrop is possible, but a comparison of all the logs of deep wells thus far drilled points to strikingly uniform subsurface conditions.

The estimated thickness of the Wilcox on the sides of the dome is half that in the Anderson County well logs. This is accounted for by an unconformity, the presence of which is indicated by an almost horizontal ferruginous sandstone capping an abrupt hill on the south Butler road about 1000 feet west of the edge of the saline prairie. Only 750 feet east of this hill the Wilcox sands dip 23 degrees west, while 1000 feet west of it irregularly bedded sandstones appear to be either horizontal or to dip slightly toward the dome. On the west side of the Steen salt dome hills above the central lake are similarly capped by almost horizontal ferruginous sandstone suggesting an unconformity. These observations tend to confirm the belief of Deussen (cited by Hopkins) that the interior domes were uplifted in late Wilcox time.

The amount of uplift in the center of the dome is estimated from a comparison of well logs as approximately 3000 feet, but when estimated from Hopkins' section it appears to be only about 1200 feet. The amount of uplift in the Keechi and Palestine domes, according to Hopkins' figures, is 2000-2500 feet and 3000 feet, respectively. That in the Brooks, Steen, and Grand Saline domes, using the figures of Hopkins' stratigraphic section, is 3000, 900, and 400 feet, respectively.

The presence of oil-bearing sands at about the horizon of the Woodbine is questionable as no sands appear to have been found in deep tests in the region except for the showing of oil in one of the wells on the Keechi dome. The Woodbine formation thins rapidly to the south and seems to disappear on the outcrop at the Brazos River.[7] The age of the lower gas rock (Blossom sand) in North Louisiana is Eagle Ford and the age of the Woodbine sands is placed near the base of the Eagle Ford on evidence secured from fossils identified by Dr. L. W. Stephenson,[8] but the rapid thinning of the Woodbine formation to the south suggests that a similar thinning and disappearance of sandy conditions probably takes place in the Eagle Ford.

Other horizons from which petroleum is produced, excluding the higher portion of the Sabine uplift, are the Navarro formation probably producing some oil in the Tracy field, Milam County, Texas; the Nacatoch sand, producing oil on the sides of the uplift in Shelby County, Texas, and at Homer, Louisiana, and producing gas at Mexia, Texas, and Monroe, Louisiana; the Taylor marl producing oil at Corsicana and at Somerset, Texas; the

[7] J. A. Udden et al., Review of the geology of Texas, Univ. of Texas Bull. 44, 3d ed., pp. 78-9, 1919.

[8] G. C. Matson and O. B. Hopkins, The DeSoto-Red River oil and gas field, Louisiana, U. S. Geol. Surv., Bull. 661, p. 115; Mowry Bates, A Concrete example of the use of well logs, Amer. Inst. Min. Engrs., Bull. 137, p. 980, 1918.

Blossom sand producing the oil of the Homer gushers and of the Shelby County wells; and the Austin chalk producing the heavy oil of the Mission and Alta Vista fields, Texas. Indication that these horizons will be productive in the east Texas synclinorium is thus far lacking.

Origin of the Dome.

Each of the interior domes in which Cretaceous sediments are exposed affords some evidence as to the periods at which these domes were uplifted. In the Butler dome the presence of shales which are probably of Midway age forms a marked contrast to conditions in the Palestine, Keechi, and Brooks domes, where no strata of Midway age have been found. Also in the Butler dome hard sandstones, the age of which appears to be Mount Selman, are found nearer to the dome than in any other except the Steen dome. If these two age interpretations are correct the first clearly established uplift and the maximum period of uplift of the Butler dome was toward the close of the deposition of the Wilcox formation. But this uplift must have been gradual as no difference between the Mount Selman sediments near the dome and elsewhere can be seen. It is quite possible that there is a hiatus at the base of the Wilcox because the normal thickness of sandy shales in the basal portion of this formation is not in evidence. Uplift has also taken place since the deposition of the Mount Selman formation.

Stream adjustment has been called upon to prove recent uplift of the interior domes but this adjustment over the relatively small areas covered by the domes is certainly antecedent to the latest stream rejuvenation. The adjustment must date from the period of dissection following the uplift of the peneplain, probably during the Miocene, and subsequent to the deposition of the widespread peneplain gravels (Lissie gravels, Uvalde gravels, Reynosa formation) derived from the Ouachita, Arbuckle, Wichita, and Marathon mountains.

From the stratigraphic conditions in the Palestine and Keechi domes Hopkins concluded that the east Texas domes were probably first uplifted before the deposition of the Midway and the main period of uplift was subsequent to the deposition of the Mount Selman formation.

He finds that the Brenham dome[9] was raised 600 to 900 feet between Cook Mountain, Eocene, and Lagarto, Pliocene, time and that the beds of the latter age are only slightly disturbed.

The coastal domes appear to have had a different history than the interior dome and appear not to be connected in any way with them. They are believed to have arisen later than those to the north[10] and the time of uplift was probably post-Lafayette, pre-Port Hudson.[11]

Emphasis is placed on the structural location of Roumanian salt domes in synclinoria by Professor Mrazec.[12] This limitation may be traced in the domes of North and Central America. The east Texas domes are known to be in a deep synclinal area on the west side of the Sabine uplift, the north Louisiana domes are possibly in a less pronounced synclinal area on the east side of the same uplift. The coastal domes and those of the Isthmus of Tehuantepec are in areas of deep subsidence.

Theories of many kinds, few of which are based on an intensive study of well records and cuttings and of salt mines in salt domes, have been presented for the origin of salt domes. It is to be hoped that a careful, detailed digest and analysis of the hosts of unpublished information about salt domes will soon be forthcoming.

Two theories which meet with greatest favor at present are the volcanic and the tectonic. The former does not explain several difficulties, two of which are as follows. First, the fact that known vulcanism near the domes seems confined to the Upper Cretaceous at about the time of the deposition of the Taylor marl, except for the very doubtful "one small igneous plug of late Tertiary or Quatenary age" which "has recently been discovered between the coastal domes and those in northern

[9] U. S. Geol. Surv., Bull. **661 G**, p. 263.

[10] Alexander Deussen, The Humble oil field, Bull. Southwestern (Amer.) Ass. Petroleum Geologists, vol. **1**, p. 75, 1917.

[11] E. T. Dumble, Origin of the Texas Domes, Amer. Inst. Min. Engrs., Bull. **143**, p. 1635, 1918. William Kennedy dates these domes as Upper Miocene or Lower Pliocene, Coastal salt domes, Bull. Southwestern Ass. Petrol. Geol., vol. **1**, p. 51, 1917.

[12] L. Mrazec, and W. Teisseyre, Aperçu géolgique sur les formations sali-Bucarest, 1910; L. Mrazec, Les plis à noyaux de percement, Bull, Soc. Sci. fères et les gisements de sel en Roumaine, Mon. des intérêts pét. Rou., Nos. 43-51, January-June, 1902; L. Mrazec, L'Industrie du Pétrole en Roumanie, Bucarest, 1910; L. Mrazec, Les plis à noyaux de percement, Bull. Soc. Sci. Bucarest, 1906.

Texas,''[13] and for volcanic ash from west Texas eruptions interbedded in the Jackson formation of Eocene age. In contrast to the single established period of vulcanism there are at least two generations of salt domes, and salt domes grew periodically from Upper Cretaceous to Pliocene and even post-Pliocene time. Second, the fact that salt domes never formed over such igneous masses as that at Thrall, which is still buried, or as the Uvalde buttes, most of which are exposed by erosion, although these igneous masses were covered by the same sediments as the interior salt dome.

The tectonic theory, based on a comparison of these domes with those of Europe, requires a thick body of salt at depth. Granting the existence of the salt, the theory appears to be acceptable. But a Permian age is assigned to this hypothetical salt body although it appears that central Texas was undergoing erosion during the Permian. It is well established that this area was undergoing erosion during the deposition of the Pennsylvanian sediments to the north and west and this land area is supposed to have persisted until Cretaceous deposition. The Central Mineral region is not an uplifted mountain-built area. It is a horst—a positive element—which first affected sedimentation in post-Bend (Pennsylvanian) time. It probably had direct connection with or was an outlier of the main land area. Recent borings east and southeast of this region on both sides of the Balcones fault, starting in one instance in the Tertiary and in the other instances in the Cretaceous, at Waco, Georgetown, Maxwell, San Antonio, and Leon Springs, find pre-Cambrian schist beneath the Cretaceous at depths of 3700, 1100, 3000, 1800, and 1100 feet, respectively.[14] This pre-

[13] G. S. Rogers, Intrusive origin of the Gulf Coast salt domes, Economic Geol., vol. 13, p. 458, 1918. This plug may possibly be the ''porcellanite'' in Grimes County, Texas, along the Brazos River, in which fossil leaves are reported. One suggestion is that the rock is rhyolite. Another is that it is an alteration product caused by the heat of burning lignite.

[14] Two wells have been drilled near Waco, one four miles north and the other in the city. Cuttings from the former well, which had just been completed (Sept., 1919), have been examined by Dr. J. A. Udden and those below 2,700 feet are pre-Cambrian graphitic schist. Cuttings from the latter well, drilled in 1914, were examined by Mr. E. G. Woodruff, of Tulsa, Okla., and Ordovician fossils were found at a depth of 2,300 feet, which is the base of the Cretaceous in both wells. (Personal communication from Dr. Udden, Mr. Woodruff, and Mr. R. T. Hill, of Dallas, Texas.)

The data concerning the schist were taken from J. A. Udden, Amer. Inst. Min. Engrs., Bull. 133, 1918, p. 94; and from Review of the geology of Texas, Univ. of Texas, Bull. 44, 3d ed., 1919, p. 42.

Cambrian area is interpreted as the western edge of an extensive Pennsylvanian land mass and as the old shore line. It is not believed to be a narrow land area, or horst, along the Balcones fault line.

Further information concerning the extent of this former land area, which is of much greater magnitude and importance than the buried granite ridge in Kansas, is being secured by the subsurface discoveries at Healdton, Oklahoma, and at Electra, Burkburnett, and Petrolia, Texas, and in the area south and east of these fields.[15] Granite of pre-Cambrian age has been found beneath the Petrolia field, in Clay County, at a depth of 4,240 feet in the Texas Company Byers No. 41 and in a well 7 miles north of St. Jo, Montague County, at 3,007 feet. Limestone, which has been identified as probably of Ordovician age, occurs above the granite in the Byers well below 3,750 feet and in Ball No. 1, 5 miles north of Myra, Cooke County, below 2,195 feet (identified by Dr. J. A. Udden). However, most of the massive limestone found in the deep wells in the Red River section is supposed to be of Pennsylvanian age, unconformable with the overlying Cisco beds. These buried hills are interpreted as outliers of the main land area to the southeast.

A very plausible Cretaceous age for the hypothetical salt body which furnished the interior domes—basal Cretaceous or basal Upper Cretaceous—and a basal Tertiary age for the salt body which furnished the coastal domes has been suggested by Dumble.[16]

The conditions necessary for the formation of salt domes appear to be; first, a bed of salt of considerable thickness and of sedimentary origin; second, a synclinal area causing deep burial of the salt bed; and third, a system of lines of weakness comparable to a system of joint planes along which there is no actual displacement, but at the junction of which the salt may break through.

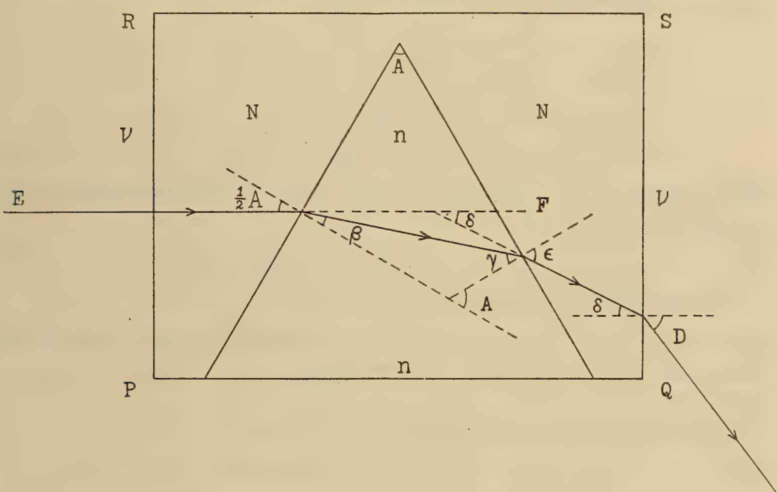
[15] The Ordovician Healdton Hills have been described by the writer, but a question has arisen as to whether the Pennsylvanian section belongs to the Glenn formation or to a formation extending northward from Texas which is covered by progressive overlap (an unpublished opinion by Mr. Ben Belt, of Fort Worth, Texas).

Buried limestone hills at Petrolia were first discovered by Mr. W. E. Wrather, of Dallas, Texas, but recent developments have just been published by Lee Hager (Red River uplift has another angle, Oil and Gas Journal, Oct. 17, 1919, pp. 64-5).

[16] E. T. Dumble, op. cit.

ART. IX.—*Note on the Paper by Ch. Fabry entitled: "Méthode par Immersion pour la Mesure des Indices de Réfraction des Corps Solides"*; by H. S. UHLER.

The article referred to may be found in the *Journal de Physique*, 9, 11, January 1919. A brief outline, by the present writer, of Fabry's paper is also given on a later page of this number. One of the many advantages,—mentioned by the original author,—of the new modification of the general method of immersion is that his innovation requires only such apparatus as may be found in every well-equipped physical laboratory. Since, how-



ever, Fabry's formulae and calculations are restricted to standard prisms of 90° refracting angles, as accurate 60° prisms are usually associated with spectrometers, and as no proof of the fundamental power series (3) is given in the original article, it may not be superfluous to present the following proof of the generalized formula. The series developed below will be useful to practical opticians and to other experimenters who desire to apply Fabry's method to tests on prisms having refracting angles either greater or less than 90°, since it is given in terms of the more general refracting angle A.

The standard prism is so placed that its refracting edge is parallel to the common direction of the slit and of the axis of rotation of the telescope, and its refracting faces are equally inclined to the collimating line, EF. The transparent ends, PR and QS, of the immersion trough are plane-parallel sheets of glass whose planes are normal to the line EF. The problem is to express N as a convenient function of ν, n, A, and D, where

ν = the index of refraction of the air for a given wave-length,
n = the index of refraction of the prism for a given wave-length,
N = the index of refraction of the liquid for a given wave-length,
A = the refracting angle of the standard prism,
D = the total deviation of the ray with respect to EF.

The definitions of the angles β, γ, δ, and ϵ may be inferred from the diagram. By plane geometry and the law of single refraction in a principal plane, it is evident that the following equations hold:

$$\begin{aligned}
&\beta + \gamma = A. \\
&\delta = \epsilon - \tfrac{1}{2}A. \\
&n \sin \beta = N \sin \tfrac{1}{2} A. \\
&n \sin \gamma = N \sin \epsilon. \\
&\nu \sin D = N \sin \delta.
\end{aligned}$$

Elimination of β, γ, δ, and ϵ from these five relations leads at once to

$$(\tan \tfrac{1}{2}A)\,[+\sqrt{(N^2 - \nu^2 \sin^2 D)}] + \nu \sin D + N \cos A \tan \tfrac{1}{2}A = 2\,(\sin \tfrac{1}{2}A)\,[+\sqrt{(n^2 - N^2 \sin^2 \tfrac{1}{2}A)}] \qquad (1)$$

Equation (1) is not in a form suitable for the practical calculation of N, hence the analytical processes must be continued.

Rationalization of equation (1) gives

$$4p^2q^4N^4 + p^2(\nu^2s^2 - 4\nu^2q^2s^2 - 4n^2q^2)\,N^2 + 2\nu prs\,(\nu^2s^2 - n^2p^2)\,N + \nu^4s^4 - 2\nu^2n^2p^2rs^2 + n^4p^4 = 0 \qquad (2)$$

where, to save space, $p = \sin A$, $q = \sin\frac{1}{2}A$, $r = \cos A$, and $s = \sin D$. The algebraic advantage of taking $A = 90°$,—which is the only case discussed by Fabry,—is that this value removes the term in N and reduces the biquadratic to a simple quadratic in N^2.

To obtain the required power series in s assume

$$N = a + bs + cs^2 + es^3 + fs^4 + gs^5 \qquad (3)$$

where a, b, c, e, f, and g are as yet undetermined coefficients. In the following work, terms involving s to degrees higher than the fifth will be neglected as such terms have, in general, no influence on the fifth decimal place in the numerical value of N.

Accordingly

$$N^2 = a^2 + 2abs + (2ac + b^2)\, s^2 + 2\,(ae + bc)\, s^3 + (2af + 2be + c^2)\, s^4 + 2\,(ag + bf + ce)\, s^5 \tag{4}$$

$$N^4 = a^4 + 4a^3bs + 2a^2\,(2ac + 3b^2)\, s^2 + 4a\,(a^2e + 3abc + b^3)\, s^3 + (4a^3f + 6a^2c^2 + 12a^2be + 12ab^2c + b^4)\, s^4 + 4\,(a^3g + 3a^2ce + 3a^2bf + 3abc^2 + 3ab^2e + b^3c)\, s^5 \tag{5}$$

Substituting the expressions for N, N^2, and N^4, given respectively by equations (3), (4), and (5), in equation (2), and equating to zero the collected coefficients of the powers 0, 1, 2, 3, 4, and 5 of s, it will be found that

$$a = n, \qquad e = \frac{\nu^3}{4n^2 \sin A}.$$

$$b = -\tfrac{1}{2}\nu \cot \tfrac{1}{2}A, \qquad f = \frac{\nu^4\,(15 + 24\cos A - 7\cos^2 A)}{128 n^3 \sin^2 A},$$

$$c = \frac{\nu^2}{8n}, \qquad g = \frac{\nu^5\,(\sin^2 A + 2\cos A)}{32 n^4 \sin A \sin^2 \tfrac{1}{2}A}.$$

Replacing these expressions, together with $s = \sin D$, in equation (3) the final general formula is obtained.

In particular, if $A = 90°$ and $\nu = 1$, the preceding coefficients reduce to those given in Fabry's formula (3) and to his very special cases (1) and (2). [Fabry's formula (3) ends with $\sin^4 D$.]

A very convenient alternative series, which converges rapidly, is given below.

$$\tau = \tan \tfrac{1}{2}A, \quad t = \tan \tfrac{1}{2}D,$$

$$N = n + \mathbf{a}t + \mathbf{b}t^2 + \mathbf{c}t^3 + \mathbf{d}t^4 + \mathbf{e}t^5 + \mathbf{f}t^6.$$

$$\mathbf{a} = -\frac{\nu}{\tau},$$

$$\mathbf{b} = \frac{\nu^2}{2n},$$

$$\mathbf{c} = \frac{\nu}{n^2\tau}(\nu^2 + n^2 + \nu^2\tau^2),$$

$$\mathbf{d} = \frac{\nu^2}{8n^3\tau^2}[8\nu^2 - (8n^2 - 11\nu^2)\,\tau^2 - 4\nu^2\tau^4],$$

$$\mathbf{e} = \frac{\nu}{n^4\tau^3}[\nu^4 - (n^4 + 3\nu^2n^2 - 2\nu^4)\,\tau^2 - \nu^2\,(3n^2 + \nu^2)\,\tau^4],$$

$$\mathbf{f} = \frac{\nu^2}{16n^5\tau^4}[16\nu^4 - 8\nu^2\,(8n^2 - 5\nu^2)\,\tau^2 + (24n^4 - 88\nu^2n^2 - 43\nu^4)\tau^4 + 4\nu^2\,(8n^2 - 7\nu^2)\,\tau^6].$$

Sloane Physical Laboratory, Yale University,
New Haven, Conn., December, 1919.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *A New Photographic Phenomenon.*—D. N. McArthur and A. W. Stewart have made an interesting observation. A sensitive photographic plate is placed, film upward, at the bottom of a light-tight box of wood or cardboard; on the film are placed two or more glass microscopic slides, and resting on these supports is laid a negative, also film side upward. The box is then closed and placed in the neighborhood of a Bunsen burner, a bat's-wing flame, or an electrical kettle-heater. After an exposure of some hours, the plate after development shows an image of the negative, but reversed in the form of a positive. Care was taken that no light entered the box, and certain of the experiments were conducted in total darkness. The results were obtained either when the box was left in the open air or was enclosed in an air-tight desiccator. The source of heat appeared to exercise some influence upon the rapidity of the action. A Meker burner gave very poor results. Poor results were given by a Bunsen flame impregnated with calcium salts, while with sodium and lithium salts the effects were more strongly marked. The electric heater gave good results when worked on its lower resistance. The distance between the box and the source of heat was usually about 30-45 cm., but on one occasion results were obtained with a box placed in a cupboard 180 cm. away from a sodium burner, although in this case the exposure was an extremely prolonged one.

A striking peculiarity of these experiments was the fact that when the box was so arranged that the sensitive plate lay between the source of heat and the negative, the results were obtained just as sharply as with the reverse arrangement, and the authors believe that were direct-acting rays concerned in the matter the plate would have been fogged by their passage through it before they reached the negative. It was shown that the results were not due to radioactive material in the neighborhood and that they were not due to light stored up by the negative. The rays which produce the effects are similar to light rays in passing through glass and in being similarly refracted and diffracted. The phenomenon has not yet been entirely elucidated, but an interesting field has been opened up which is being further investigated.—*Jour. Chem. Soc.,* **115**, 973.

2. *The Analytical Chemistry of Uranium.*—C. A. Pierlé has found that the well-known method of precipitating ammonium uranate by means of ammonium hydroxide and igniting to U_3O_8 gives excellent results. He obtained nearly as good results by precipitation with dehydrogen ammonium phosphate and ignit-

ing to uranyl pyrophosphate, but it was found that the latter was decidedly hygroscopic, so that there was a tendency to slightly high results. Precipitations with yellow ammonium sulphide and attempts to ignite to U_3O_8 invariably gave high results, and it was found that the ignited residues always contained sulphate. The method of reducing uranyl sulphate solutions by means of zinc and titrating with permanganate was found to be very unsatisfactory, since no definite point of reduction could be obtained. The most important feature of the investigation appears to be the working out of a method of separating uranium from some of the other rare elements. It was observed by Peligot in 1842 that uranyl nitrate was readily soluble in ether, and upon applying this fact it was found possible to make excellent separations of uranium from vanadium, molybdenum and tungsten by evaporating the nitric acid solutions to dryness, moistening with a little nitric acid and extracting the uranyl nitrate in a Soxhlet apparatus. It was found also that glacial acetic acid of over 95% mixed with 5% by volume of nitric acid of 1·42 specific gravity will extract uranyl nitrate accurately without dissolving any V_2O_5.—*Jour. Indust. Eng. Chem.*, **12**, 60. H. L. W.

3. *Lecture Demonstrations in Physical Chemistry;* by HENRY S. VAN KLOOSTER. 12mo, pp. 192. Easton, Pa., 1919 (The Chemical Publishing Co.).—This book has been prepared for the purpose of furnishing suitable lecture experiments for the illustration of our present conceptions of physical chemistry. The experiments presented have been selected from a wide range of text-books and other literature, and frequent useful references are given to these sources.

The matter is conveniently divided into twelve chapters dealing with various topics, such as diffusion, osmosis, catalysis, electro-chemistry, colloids, actino-chemistry, etc. The experiments are very clearly discussed and described and they are excellently illustrated by diagrams.

The book appears to be a very satisfactory one for the use of lecturers on phyical chemistry, and it should be very useful also to lecturers in general chemistry as the source of many suggestions. H. L. W.

4. *The Physical Chemistry of the Metals;* by RUDOLPH SCHENCK. Translated and Annotated by REGINALD SCOTT DEAN. 8vo, pp. 239. New York, 1919 (John Wiley & Sons).—This translation appears to be a somewhat belated one, as the German author's preface is dated 1908. The translator, however, has incorporated into the text such additions as have seemed necessary and he has revised the numerical data to make them agree with the accepted values. He has also changed the book from lecture to text-book form.

The book deals with the properties of the metals, metallic solutions and alloys, alloys of metals with carbides, oxides and sulphides, including iron and steel, mattes, phase rule, metallurgical reactions, oxidation and reduction, the decomposition of carbon monoxide, blast-furnace processes, the reactions of sulphides, etc. The discussions are interesting and valuable in presenting scientific explanations of many metallurgical phenomena. H. L. W.

5. *The Determination of Indices of Refraction of Transparent Solids.*—The problem of determining the indices of refraction, for monochromatic light, of solid specimens having surfaces which may not be modified or which are unpolished and irregular is one of no little practical importance and hence it has been attacked and more or less satisfactorily solved in late years, the impetus arising largely from the exigencies of the world war. In particular, the method of immersion was applied in an excellent manner by R. W. Cheshire (see **42**, 498, 1916). The most recent, and apparently the most promising, development of the method of immersion is due to Ch. Fabry. This investigator calls attention to two significant facts: (a) the earlier applications of the method of immersion require the experimental realization of exact equality between the indices of refraction of the liquid and of the solid under investigation, and (b) these processes usually enable the determination of only a few units in the fourth decimal place to be made, whereas many of the computations of geometrical optics require for their adequate solution a knowledge of one or two units in the fifth place of decimals. Fabry's development fulfills the last requirement and therefore it seems desirable to give a brief account of it in this place.

The basic idea is to use a differential method involving interpolation within narrow ranges of angular deviation. Some of the advantages thus obtained are (a) saving of time as a consequence of not having to attain exact equality of the indices of refraction of the immersion liquid and the solid in question, (b) many of the parts of the apparatus and the adjustments of the same are only required to approximate fairly roughly to the ideal geometrical conditions, (c) increased accuracy of the final data, (d) simplicity and rigidity of the apparatus, and (e) nothing more elaborate than the ordinary equipment of any physical laboratory is necessary.

The material needed comprises a goniometer (or spectrometer), an immersion trough having glass ends parallel to each other (permissible malconstruction 1°), a set of (5) standardized glass prisms of 90° refracting angle, a set of liquids possessing a fairly wide range of refractive indices, sources of light, etc. The materials of the prisms used by Fabry are designated as: light boro-silicate crown, ordinary crown, light barium crown, dense flint, and very dense flint. The liquids employed were: petroleum ether, carbon tetrachloride, benzol, carbon bisulphide, and bromonaphthalene.

The arrangement of the parts of the apparatus may be very briefly described as follows. The long axis of the trough (a rectangular parallelepiped) is parallel to the optic axis of the collimator, so that the end windows of the vessel are approximately normal to this axis. The standard prism is placed in the liquid with its hypothenuse face in contact with a side wall of the trough, hence its refracting edge and its hypothenuse surface are parallel respectively to the slit and to the optic axis of the collimator. The specimen to be investigated is placed in the liquid in the path of the beam of light, either in front of, or behind, the prism of reference. A suitable aperture in an opaque screen so limits the cross-section of the beam that only light which has traversed the specimen may enter the telescope.

The practical application of the new development to the determination of the index of refraction of a given inviolable lens will now be outlined. By preliminary trials with both a standard prism and the lens in question immersed in a mixture of two liquids,—one of high and one of low index,—it is neither difficult nor tedious to select that one of the calibrated prisms whose index is nearest to that of the lens, and to obtain a mixture bearing the same refractive relation to the lens. The lens being removed, the telescope is carefully focussed on each chosen spectral line (C, D, and F, say) and readings are made both of the position of the ocular with respect to its linear scale and of the angular displacement of the telescope with reference to the direction of the beam emergent from the trough when the prism is not immersed. This gives approximate values of the quantities which require slight correction. The lens is then replaced in the liquid with the result that the telescope is thrown out of focus slightly because of the lack of absolute agreement between the indices of refraction of the liquid and lens material. By adding a drop or two of the appropriate component of the liquid mixture, and repointing and refocussing the telescope, it is a simple matter to obtain two or more pairs of values of the change in the deviation, ΔD, and of the change in the linear displacement of the ocular, Δx. Obviously, the range of liquid mixtures must be so regulated as to "bracket" the value $\Delta x = 0$, thus enabling a graph to be plotted for the observed coördinates $(\Delta x, \Delta D)$ and the value of ΔD_0 corresponding to $\Delta x = 0$ to be obtained by (usually linear) interpolation. The value of the deviation, D, which would have been observed if the agreement between the index of refraction of the liquid and that of the lens had been perfect, is now known. A fairly simple and rapidly converging series formula is given (without proof) in the paper which expresses the index of the liquid, N, in terms of the predetermined index of the calibrated prism, n, and of sin D. By substituting in the power series the value of D, obtained from interpolation, the value of N common to the liquid and the lens may be readily computed.

The rest of the article deals with the determination to the fifth decimal place of the indices of refraction of specimens of prismatic and of completely irregular shapes, with unpolished surfaces, etc. With due regard to the fact that, in general, it takes time to attain a very high degree of precision, the new adaptation of the method of immersion seems to be the most promising one as yet proposed.—*Jour. de Phys.*, **9**, 11, 1919.

H. S. U.

6. *Problems of Cosmogony and Stellar Dynamics;* by J. H. Jeans. Pp. ix, 293; with 45 figures and 5 plates. Cambridge, 1919 (University Press).—The subject of the Adams Prize of the University of Cambridge, for the year 1917, was: "The course of evolution of the configurations possible for a rotating and gravitating fluid mass, including the discussion of the stabilities of the various forms." This prize was awarded to the author for the essay which he wrote and subsequently elaborated in the form of the present volume.

"The main object of the essay is to build a framework of absolute mathematical truth; the backbone of the structure is the theoretical investigation into the behaviour of rotating masses." Six chapters (II to VII) are devoted to abstract theory. The analysis therein contained centers around three fundamental problems, namely, the tidal, the rotational, and the double-star problem. It is shown that in all three problems there are no figures of stable equilibrium except ellipsoids and spheroids. In the course of the analysis the author has made several important contributions to the subject. Two examples may be cited to illustrate this statement. In the chapter on the gravitational potential of a distorted ellipsoid it is pointed out that Poincaré's method of development as far as terms of the second order does not lend itself readily, if at all, to extension to the third order; consequently Jeans has developed a plan of attack that enables him to carry the analysis to the required degree of accuracy, that is, through terms of the third order. Again, in the discussion of the stability of pear-shaped figures, an explanation is found for the conflicting results obtained by Sir G. Darwin and by Liapounoff. The slip was made by the investigator first named who announced the configurations to be stable, whereas instability has been claimed by the second analyst and rigorously demonstrated by Jeans. Of the six chapters referred to above, the first five pertain to the behavior of perfectly homogeneous and incompressible matter, while the sixth is devoted to the general theory of the motion of compressible and non-homogeneous masses, special attention being given to Roche's model and to the adiabatic model.

Beginning with the eighth chapter the author proceeds to clothe the skeleton by applying the abstract results to actual problems of astronomy and cosmogony. For lack of space, mention may be made of only one of the many important conclusions obtained by careful comparison of theory with observation, which is that Russell's theory of the sequence of stellar evolution is fully confirmed.

As regards the manner of presentation no room for improvement seems to remain. The author's style is remarkably clear, and close contact is maintained throughout between theory and observed phenomena. The beautiful plates present striking examples of the various forms of nebulæ. Whenever appropriate, complete summaries recapitulate the results obtained up to that stage of the investigation, so that it is possible to acquire much information from the text without following the purely mathematical steps. Beyond all question, this book not only constitutes a very valuable contribution to the subject but it will also be epoch making in the sense that it will form the model upon which all subsequent works on the field will be based.

H. S. U.

II. Geology.

1. *Fourteenth Report of the Director of the State Museum and Science Department;* by John M. Clarke. New York State Mus., Bulls. **207** and **208**, pp. 211, pls. and maps, 1918 [1919].—This interesting report, issued in September 1919, describes the activities of the State Museum and the State Geological Survey during 1917. It is accompanied by nine geologic, mineralogic, or historic papers. The illustrations of some of the museum exhibits show clearly the up-to-date character of this leading state museum. The restorations of marine Devonian life, and particularly of an orthocerid, a nautilid, and glass sponges, surrounded by algæ, are exceptionally interesting.

C. S.

2. *Outlines of the Geology of Brazil to accompany the Geologic map of Brazil;* by John C. Branner. Bull. Geol. Soc. America, vol. **30**, No. 2, pp. 189-338, 10 pls., 20 text figs., 1 geol. map, 1919.—This is by all means the best geologic map of Brazil so far published, and is large and well printed. In the accompanying text, the stratigraphy of the various periods is briefly described, followed by "Outlines of the general and economic geology and bibliography by states," and there are twenty-one of them. Then are given outlines of the economic geology, taking up first the metallic minerals and next the non-metallic. The work is a labor of love and is Branner's contribution to the

Brazilian people, to whom he says he is strongly attached, and in whose welfare he is deeply interested. C. S.

3. *The Oil and Gas Resources of Kentucky;* by WILLARD R. JILLSON. Dept. Geology and Forestry, Frankfort, Ky., Ser. 5, Bull. 1, 630 pp., 90 pls., 10 maps and diagrams, 1919.—This book gives a review of the oil and gas resources of Kentucky. In 1910, the production had fallen to 468,000 barrels, but in 1919 it is thought there will be about 7,500,000 barrels valued at $19,-500,000. The drilling records of 752 wells are presented (pages 178-544), along with data on oil production, a history of oil and gas development in the state since 1819, etc. Many illustrations and maps accompany the report. C. S.

4. *The Schrammen Collection of Cretaceous Silicispongiæ in the American Museum of Natural History;* by MARJORIE O'CONNELL. Bull. Amer. Mus. Nat. Hist., vol. **41**, pp. 1-261, 15 pls., 5 text figs., 1919.—This carefully wrought out work by Doctor O'Connell treats of 800 specimens of well preserved siliceous sponges found in the Cretaceous of Germany, and chiefly around Hannover. There are 116 genera represented by 222 species, nearly all of which have their structure discussed in detail. This remarkable European wealth contrasts strikingly with the almost total absence in America of fossil Cretaceous sponges. The author also deals with the classification of sponges, and makes the work of Zittel-Broili and Schrammen along this line available to English-speaking students. The most valuable part of the work, because of its wide application, is a chapter summing up the present knowledge of the stratigraphy of the Cretaceous of Europe. The author has gone to the original sources and brings together a clear-cut description of the successive formations of England and western Europe that have the wonderful array of Silicispongiæ. C. S.

5. *Die Grundlagen der Landschaftskunde.* Band I. *Beschreibende Landschaftskunde;* by S. PASSARGE. Pp. 210, 1919 (Hamburg (Friederichsen & Co.).—Dr. S. Passarge, known for his explorations of South Africa fifteen years ago and later as professor of geography at the University of Hamburg, has prepared this volume as an empirical introduction to the observational study of landscapes. His plan is peculiar in excluding, except for unintentional explanatory allusions, all that has been learned in the last century regarding the origin of land forms, on the ground that unprejudiced observation should precede genetic or explanatory description. The number of terms that he thus defines is large; and his plan for the empirical analysis of landscapes is excellent. His volume must, therefore, prove useful to travelers who have no knowledge of modern physiography, yet who wish to make some record of what they see. But the book is also intended as a text for university students; and for them

it cannot be recommended. The content of no other science is first taught empirically before any rational treatment is permitted; such a dry logical method in geography would be as unprofitable as it would be unpalatable. By all means, observe a landscape before describing it, whether the description is to be empirical or explanatory; but it by no means follows from this truism that university students should work through a book of 210 pages containing several hundred empirical terms, before they are permitted to consider the genetic relations of the things that the terms describe. W. M. D.

6. *West Virginia Geological Survey;* I. C. WHITE, State Geologist. Detailed Report on Fayette County; by RAY V. HENNEN. Pp. xxxiii, 1002; with 24 half tone plates and 24 text figures; also accompanied by a separate case of topographic and geologic maps of the entire area of the county in single sheets.—This is the most extensive of the valuable county reports issued by the West Virginia Survey. The authorship is credited to assistant geologist, Ray V. Hennen, and he has been aided in the field by D. D. Teets, Jr. and in the office by R. C. Tucker and A. M. Hagan. Fayette County covers the region where the mining of the New River or Smokeless coals first began on an extensive scale, and these as well as the other coal beds and minerals of this rich county are minutely described and analyzed. The volume thus gives all needed general and detailed information covering the area in question. (Price, charges paid, $3.25. Extra copies of topographic map, 75 cents; of the geologic map, $1.00.)

7. *Virginia Geological Survey, University of Virginia,* THOMAS L. WATSON, Director.—The Virginia Survey has recently published two important bulletins, both prepared in co-operation with the U. S. Geological Survey. These are:

No. 17.—Manganese deposits of the West Foot of the Blue Ridge, Virginia; by G. W. STOSE, H. D. MISER, F. J. KATZ, D. F. HEWETT. Pp. viii, 166; with 22 plates and maps and 16 text figures.

No. 19—The Geology and Coal resources of the coal-bearing portion of Tazewell County, Virginia; by T. K. HARNSBERGER. Pp. vi, 195, with 14 plates and maps.

8. *Ninth Annual Report of the Director of the Bureau of Mines,* VAN. H. MANNING, *for the year ending June 30, 1919.*—The beginning of the year covered by the present report found the Bureau of Mines in full activity co-operating with the Government in war work. The cessation of hostilities, which followed in November, required an extensive rearrangement of its activities. The prominent results accomplished during the year require three pages for their brief enumeration; they are too numerous to be designated here. It is interesting to note that nearly 10,000 miners were trained in first aid and risk methods,

an increase of a thousand over the year preceding. One of the lines of war work most noteworthy was the recovery, on a commercial scale, of the rare gas helium from natural gas. The three plants were located in the Petrolia Field near Fort Worth, Texas. It is stated that about 150,000 cubic feet of the gas in steel cylinders were on the dock at New Orleans awaiting shipment to France when the armistice was signed. The Bureau has published 22 bulletins in the past year; 33 technical papers; 1 miners' circular, and 17 other publications. The titles of the bulletins not previously noted are given in the following list:

BULLETINS.—No. 144. Report of a Joint Committee appointed from the Bureau of Mines and the U. S. Geological Survey by the Secretary of the Interior to study the gold situation, October 30, 1918. Pp. 84, 1 pl., 3 figs.

No. 150. Electrodeposition of gold and silver from cyanide solution; by S. B. CHRISTY. Pp. 171, 8 pls., 41 figs.

No. 154. Mining and milling of lead and zinc ores in the Missouri-Kansas-Oklahoma Zinc district; by C. A. WRIGHT and H. A. BUEHLER. Pp. 134, 17 pls., 13 figs.

No. 62. Removal of the lighter hydrocarbons from petroleum by continuous distillation, with especial reference to plants in California; by J. M. WADSWORTH. Pp. 162, 50 pls., 45 figs.

No. 165. Bibliography of petroleum and allied substances in 1916; by E. H. BURROUGHS. Pp. 159.

No. 166. A preliminary report on the mining districts of Idaho; by T. VARLEY, C. A. WRIGHT, E. K. SOPER, and D. C. LIVINGSTON. Pp. 113, 3 pls., 3 figs.

No. 168. Recovery of zinc from low-grade and complex ores; by D. A. LYON and O. C. RALSTON. Pp. 145, 23 figs.

No. 169. Illinois mining statutes annotated; by J. W. THOMPSON. Pp. 594.

No. 170. Extinguishing and preventing oil and gas fires; by C. P. BOWIE. Pp. 50, 19 pls., 4 figs.

No. 172. Abstracts of current decisions on mines and mining, January to May, 1918. Pp. 160. No. 174, the same, May to September, 1918; by J. W. THOMPSON. Pp. 138.

No. 175. Experiment stations of the Bureau of Mines; by VAN. H. MANNING. Pp. 106, 29 pls., 2 figs.

No. 176. Recent developments in the absorption process for recovering gasoline from natural gas; by W. P. DYKEMA. Pp. 90, 20 pls., 30 figs.

No. 177. The decline and ultimate production of oil wells, with notes on the valuation of oil properties; by C. H. BEAL. Pp. 215, 4 pls., 80 figs.

No. 178. War gas investigations of the Bureau of Mines; by VAN. H. MANNING; issued in four parts, including: War gas investigations; war minerals, nitrogen fixation, and sodium cyanide; petroleum investigations, and production of helium; explosives and miscellaneous investigations.

No. 179. Abstracts of current decisions on mines and mining, September to December, 1918; by J. W. THOMPSON. Pp. 166.

No. 181. Abstracts of current decisions on mines and mining, reported from January to May, 1919; by J. W. THOMPSON. Pp. 176.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Report of the Secretary of the Smithsonian Institution,* CHARLES D. WALCOTT, *for the year ending June 30, 1919.*—The year covered by this report embraces a considerable period of

war activities which exerted their influence upon the Institution; reorganization on a peace basis since the Armistice has, however, gone on rapidly. What is spoken of as an important peace-time event is the plan of collecting of material from Central Africa to be used for comparison with that of Col. Roosevelt, Paul Rainey, and others. It is interesting to note a bequest of fifty thousand dollars by Mrs. Virginia P. Bacon of New York City to be used for a traveling scholarship, the incumbents to study the fauna of countries other than the United States. The numerous lines of special work in research and exploration being carried on are, as usual, spoken of in detail. Of particular interest is the proposed "Museum of History and the Arts," a memorial to Theodore Roosevelt, to contain the extensive collections already in the National Museum of relics and mementoes of illustrious patriots of our country and of the events conspicuous in its history, and also other collections relating to the arts and industries. It is proposed further that the building shall contain the National Gallery of Art; it is to be erected on the north side of the Mall in line with the Natural History building of the National Museum. The place made vacant by the death of Mr. Richard Rathbun, in charge of the National Museum, has been filled by Mr. W. de C. Ravenel. One of the important additions to the Museum is the collection of war relics and particularly of the series of air planes beginning with the original Langley models and coming down to the present time. The International Exchange Service has been enlarged since the close of the war and the increase of packages handled in the year was about four thousand. The work of the Astrophysical Observatory included the observation of the total eclipse of the sun on May 29, 1919, which was satisfactorily accomplished in South America. The solar constant of radiation has also been further studied and it is stated that Volume IV of the Annals of the Observatory approaches completion.

The *Annual Report of the Institution* for the preceding year, ending June 30, 1917 has recently been issued. Pp. xii, 674, with numerous illustrations.

Also in the Department of American Ethnology the following bulletins have been received:

No. 60.—Handbook of Aboriginal American Antiquities. Part I, Introductory: The Lithic Industries; by W. H. Holmes. Pp. xvii, 380, with 223 figures.

No. 70.—Prehistoric Villages, Castles, and Towers of Southwestern Colorado; by J. Walter Fewkes. Pp. 79; 33 plates, 18 text figures.

The National Museum of Natural History, as heretofore, has issued a large number of advance chapters on a great variety of subjects.

2. *Annual Report of the Director of the Bureau of Standards,* S. W. Stratton, *for the year ending June 30, 1919.*—

The activities of the Bureau are so extraordinarily varied that the mere enumeration in the table of contents in the report now issued covers some thirteen pages. It is hardly necessary to add that under the direction of Dr. Stratton, the work of the Bureau has been prosecuted with remarkable energy and success; the value of the Bureau to science and the nation at large has proved to be vastly greater than was anticipated at its inception in 1901. The new publications include 12 scientific and 15 technologic papers and 3 miscellaneous publications.

3. *The National Research Council.*—The pamphlet giving the organization and members of the National Research Council for 1919-20 bears the date of December, 1919. We have now the first number of volume 1 of the Bulletin which discusses "The national importance of scientific and industrial research;" by George Ellery Hale and others. Nos. 2 and 3 are now in preparation.

4. *Memoirs of the Bernice Pauahi Bishop Museum of Polynesian Ethnology and Natural History.*—Volumes recently received include the following:

Vol. V, Part III.—Fornander Collection of Hawaiian Antiquities and Folk-Lore. Quarto, pp. 506-721.—This volume gives the Hawaiians' account of the formation of their islands and origin of their race with the traditions of their migrations, etc., as gathered from native sources. The author is Abraham Fornander and the translations have been edited and illustrated by Thomas G. Thrum. The Mythical Tales include pp. 506-569 and Traditionary Stories pp. 570-693. The Story of Kawelo in six chapters (pp. 694-721) closes the volume.

Vol. VI, No. 1—Fornander Collection of Hawaiian Antiquities and Folk-Lore—Third Series, Part I, Quarto, pp. 1-217. No. 2.—Fornander Collection of Hawaiian Antiquities and Folk-Lore—Third Series, Part II. Pp. 222-358. These volumes discuss other interesting topics having, like the above, to do with the customs, origin and history of the Polynesian race, that of Hawaii in particular.

Obituary.

Dr. R. C. Maclaurin, president of the Massachusetts Institute of Technology since 1908, died on January 15 in his forty-ninth year. He was of Scotch birth, but when only twenty-eight was made professor of mathematics in New Zealand. In 1907 he accepted the chair of mathematical physics at Columbia University, but two years later left this for the position at Cambridge which he filled so brilliantly. His early death is a great loss to the cause of education in this country.

Sir William Osler, the distinguished professor of medicine at Oxford, died on December 29 at the age of seventy years.

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THE AMERICAN JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

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FOURTH SERIES

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. X.—*On Certain Fossil Shells in the Bowlder Clay of Boston Basin;* by Edward S. Morse.

The numerous deposits of bowlder clay, or till, that compose many of the islands in Boston Bay and headlands along the coast, notably Point Shirley and Hull, have been minutely studied by Crosby, Ballard, Upham and others. In these indurated clay deposits fragments of many species of marine shells are found. In pre-glacial days the region known as Boston Basin, including Cambridge and adjacent territory and extending back to the Belmont Hills, was submerged by the sea and formed a large shallow bay, or inlet, in which various species of mollusks, particularly the so-called *Venus mercenaria,* thrived under the most favorable conditions for growth and multiplication. When the great ice-field advanced from the north it scooped up the clay bottom of Boston Basin and with its own detritus of sand and bowlders augmented the terminal moraine as it moved southward. It not only pushed these masses of clay ahead but rode over them and crushed by its enormous weight the shells contained in them. The larger shells, recognized as *Venus mercenaria,* are in all cases broken into fragments and these fragments of various sizes, rarely over an inch in length, are worn and their broken edges rounded by the kneading action of the ice mass. In vol. **48** (pp. 486-496, 1894) of this Journal is a paper entitled "Distribution and Probable Age of the Fossil Shells in the Drumlins of the Boston Basin, by W. O. Crosby and H. O. Ballard." In this communication a map is given of the Boston Basin on which is indicated by numbers the islands and regions on the main land where these deposits are found. Some of these masses of clay have been pushed up by the ice-field to the height of a hundred feet or more. A list is given of the species of mollusks thus far identified. These number fifty species and most of them are found living to-day in Massachusetts Bay. In the list, however, are a number of species which belong to the molluscan fauna south of Cape Cod. These are *Ostrea borealis, Venus mercenaria,* and *Pecten irradians.* The *Ostrea* and *Venus* are still found living in certain restricted localities north of Cape Cod. Some hundreds of years ago these three species must have been abundant and more widely distributed, as the Indian shellheaps along the coast, north of Cape Cod, reveal the presence of the shells of these species in numbers. Dredgings in Portland Harbor for the purpose of deepening the channel exposed a large bed of *Pecten irradians* and associated with these shells was found *Turbinella interrupta,* a shell restricted to a few localities north of Cape Cod, but common south of it.

In these clay deposits of Boston Basin are found sparingly two species of *Arca, A. pexata* and *A. transversa;* these have never been found living north of Cape Cod, nor have they been found in the Indian shellheaps nor in the dredgings of Portland Harbor. All the evidence thus far cited indicates that in pre-glacial times the waters of the ocean bordering the coast had a far higher temperature than that which obtains to-day. Various explanations have been given as to the cause of this condition. The lower temperature of Massachusetts Bay comes from a northern current from the Gulf of Maine sweeping down into Massachusetts Bay bringing with it a northern fauna, while a southern current sweeping up from the south brings with it the southern shells which are found on the southern shores of Cape Cod. Dr. A. A. Gould, in his Report on the Invertebrate Animals of Massachusetts, published by the State in 1841, writes as follows (page 315), in regard to the separation of the northern and southern fauna by Cape Cod. He says:

"The distribution of the marine shells is well worthy of notice as a geological fact. Cape Cod, the right arm of the Commonwealth, reaches out into the ocean, some 50 or 60 miles. It is nowhere many miles wide; but this narrow point of land has hitherto proved a barrier to the migrations of many species of mollusca. Several genera and numerous species, which are separated by the intervention of only a few miles of land, are effectually prevented from intermingling by the Cape, and do not pass from one side to the other. No specimen of *Cochlodesma, Montacuta, Cumingia, Corbula, Janthina, Tornatella, Vermetus, Columbella, Cerithium, Pyrula,* or *Ranella,* has as yet been found to the north of Cape Cod; while *Panopaea, Glycymeris, Terebratula, Cemoria, Trichotropis, Rostellaria, Cancellaria,* and probably *Cyprina* and *Cardita,* do not seem to have passed to the south of it. Of the 197 marine species, 83 do not pass to the south shore and 50 are not found on the north shore of the Cape. The remaining 64 take a wider range, and are found on both sides. Buzzard's Bay and the south shore have as yet been very little explored; and we may yet expect to find many species peculiar to those localities."

If Cape Cod represents the terminal moraine of one or more glacial periods, the conclusion forced upon us is that before this barrier existed the southern molluscan fauna extended along the entire New England shores, to Maine and beyond, as indicated by the southern shells found in the bowlder clays of the Boston Basin. In the quiet and warmer inlets north of Cape Cod a few southern forms are found living.

Dr. W. G. Farlow, in his report on the Marine Algæ of New England, published in the Report of the United States Fish Commission, 1879, regarding southern forms in waters north of Cape Cod, says:

"In the town of Gloucester, near the village of Squam, is a small sheet of water called Goose Cove. The narrow entrance to the cove has been dammed up, and the water from the ocean enters only for a short time at the high tide. In this cove, to my surprise, I found *Rhabdonia tenera, Gracilaria multipartita, Chondria Baileyana* and a large mass of *Polysiphonia Harveyi* and *P. Olneyi.* In short the flora was entirely different from anything I had ever seen before north of Cape Cod, and entirely different from that of the adjacent shore, where the flora is entirely arctic. Furthermore, Squam is on the northern and inner side of Cape Ann, and as there is no connection of Goose Cove with the southern side of Cape Ann, and inasmuch as no vessels ever enter the cove, it is difficult to account for the presence of the sea-weeds which grow there. The water which is confined by the dam is much warmer than that of the surrounding ocean, which would enable the species of warm waters to live if they were once introduced, but how are we to suppose that the spores were brought into the cove? It is hard to believe that they could have been brought by currents, for, as a matter of fact, the currents move in the wrong direction to produce such an effect. Certainly, *Rhabdonia tenera* is quite unknown in any other spot north of Cape Cod, the nearest locality being the coast near Nantucket, and it is very difficult to conceive that spores of that delicate species would survive in a very cold current, which not only must carry them outside of Cape Cod and across Massachusetts Bay, but also around to the sheltered cove at the point where Cape Ann joins the mainland at the north. If we compare the exceptional case of Goose Cove in the north with Gay Head and Montauk in the south, it seems to be the rule that wherever the water is cold enough, we meet arctic species, and wherever it is warm enough we have Long Island species, regardless of the remoteness of localities where the species naturally abound, and, as far as we know, of the absence of currents to transport the spores."

The isolated colonies of southern shells, ranging from north of Cape Cod to the Provinces and even to the St. Lawrence, must not be regarded as survivals from preglacial times but rather as introductions in later days. The plankton of the coast is charged with the swimming and larval stages of invertebrates, and spores of algæ, and when by currents, or other agencies, these objects find lodgment in favorable regions as to temperature they take root and become established. The spores of algæ could unquestionably be transported on the feet of aquatic birds.

The most common species of mollusks in the bowlder clay deposits has been recognized as *Venus mercenaria.* Warren Upham says, in his paper on Marine Shells and Fragments of Shells in the Till near Boston,[1] "In all the localities a single species, the round clam, or quohaug, *Venus mercenaria,* makes up probably ninety-nine per cent of the specimens found, but no entire valve of the shell was obtained among the thousands of fragments."

In nearly every reference to the fragments of *Venus mercenaria* allusion is made to their thick and massive character. Sanderson Smith, in describing the post-pliocene deposits on Gardiner's Island, Long Island Sound, says,[2] "The fragments of *Venus mercenaria* are of very large size and excessively thick and heavy." Prof. A. E. Verrill, in a paper entitled[3] "On the Post-Pliocene Fossils of Sankaty Head, Nantucket Island," regards the *Venus mercenaria* as a distinct variety on account of its

[1] Proc. B. S. N. H., vol. 24, p. 127.
[2] Annals of the New York Lyceum of Natural History, vol. 8.
[3] This Journal, vol. 10, p. 364, 1875.

size and massive character, and considers the variety so distinct as to warrant naming it var. *antiqua* Verrill, and says, "By this name I propose to designate the unusually massive and strongly sculptured variety to which most of the fossil shells belong."

The ponderous character of *Venus mercenaria* as indicated by the thickness of the fragments first arrested my attention in collections made at Hull, and Moon Island. It is somewhat curious that Stimpson, who first wrote on the subject, makes no allusion to this conspicuous feature of the shell. In a very ancient shellheap in Japan I discovered that there were differences between the ancient shells composing the deposits and the recent forms living in Yedo Bay. All varied in their proportional diameters. I reasoned that if any physical conditions of climate, temperature, etc., had changed *Venus mercenaria* so profoundly, other species in the bowlder clay should vary likewise, but only the slightest changes were observed in the few species I studied. A study of a gigantic *Venus* from Florida, for a long time known as *Venus Mortoni* of Conrad, but bearing, at last accounts, the name of *Venus campechiensis,* a shell found in the upper Tertiary of the southern states and living as far north as Chesapeake Bay, leads me to believe that the bowlder clay species which has always been identified as *Venus mercenaria* may prove to be the southern form *Venus campechiensis.* A colony of quohaugs living in Maine at Quohaug Bay, near Freeport, may also be *Venus campechiensis.* The shell is much larger and thicker than the usual *V. mercenaria,* though not so large as *V. campechiensis,* has the same rounded form of the Florida species and has no tinge of purple which is so marked a character of *V. mercenaria.* Is it not possible that all these forms may prove to be geographical variations of *V. mercenaria?*

The fossil beds regarded as post-pliocene at Sankaty Head, on the eastern end of Nantucket, have been carefully studied by Verrill, Scudder, and Rathbun, and before these men Desor and Cabot. Prof. A. E. Verrill, in the interesting communication already referred to, in which is incorporated Dr. S. H. Scudder's careful study of the deposits, gives a complete list of the fossils shells collected by Rathbun and identified by himself, with comments on their distributions along the coast to-day. It is discovered that there are two distinct deposits, or layers, in which fossil shells are found, separated by a few inches of non-fossiliferous material. A catalogue of the species of shells discovered revealed the interesting fact that the lower deposit contained shells belonging to a southern fauna while the upper deposit contained shells belonging to a northern fauna. A number of species are identical in both deposits. Verrill suggests that when the lower fossiliferous bed was deposited a shallow bay existed at this place from which the outer waters were excluded, either by an island to the eastward, or else by a southern prolongation of Cape Cod. The extensive submerged shoals south of Cape Cod and east and southeast of Nantucket may be the remains of such land. If one consults a chart of the United States Coast and Geodetic Survey relating to the waters of the Nantucket region he will observe a number of shoals parallel to Sankaty Head, known a hundred years ago as Old Man, Bat's Rip, Great Rip, Fishing Rip and to the west as South Shoal, and Fish Rips, and running west, shallow soundings to Gardiner's Bay, Long Island Sound. Is it not possible that these various shoals indicate a terminal moraine, like that of Cape Cod, and parallel to it, but worn away by wind, rain and ocean currents, leaving the shoals and shallow soundings above referred to as the last remains of the barrier? This was formed before Cape Cod existed, and before this earlier barrier was made southern shells extended along the coast as already described in this paper, and this accounted for the southern shells found in the lower deposit. After the first terminal moraine was formed the northern molluscan fauna soon established itself accounting for the northern shells in the upper deposit. The prompt way in which a change in fauna may occur is illustrated by the rapid distribution of the common English periwinkle, *Litorina litorea,* which was found in the Bay of Chaleur in the early years of the last century. In the Catalogue of Marine Invertebrata of Eastern Canada, by J. F. Whiteaves, Geological Survey of Canada, 1901, it is stated that Sir J. W. Dawson, writing in 1871, says of *Litorina litorea:* "It occurs abundantly and of large size off different parts of the coast of Prince Edward's Island as it does also on the opposite coast shore of Nova Scotia where I have collected the species more than forty years ago." A period of forty years passed before the shell appeared on the New England coast. In a paper[4] on the "Gradual Dispersion of Certain Mollusks in New England," I described the successive discoveries and dates of appearance of *Litorina litorea* along the New England coast. C. B. Fuller found a few living specimens in Portland Harbor, Maine, in 1870, and in that year found the species also at Kennebunk, Maine, more than twenty miles farther west. Before the year 1872 it had never been found in Salem Harbor. In that year, however, Richard Rathbun found a single specimen and we hunted

FIG. 1.

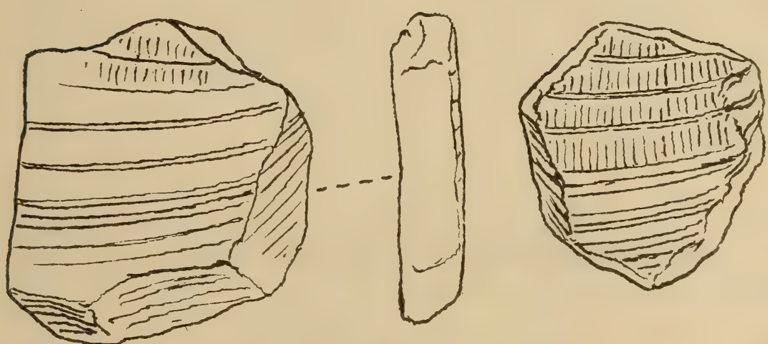


FIG. 1.—Fragments from Hull, nat. size.

for hours for another specimen without success. In a few years it was found by thousands. It arrived at Wood's Hole in 1875 and it reached New Haven in 1879. I found the shell on the southern shores of Long Island in 1885. This species, now the most abundant shell on the coast of New England and extending to the south of Long Island and probably much farther south, has accomplished this occupation from Maine to New Haven in a period of nine years. In some regions the rocks are blackened by their numbers. This rapid advance and enormous multiplication of the periwinkle might also be true of other northern species.

The figure here given (fig. 1) represents the usual appearance of the fragments of *Venus* as found in the various deposits of bowlder clays of Boston Basin. Many of the fragments are much smaller than these figured, a few are larger than these. In a living shell the radiating

[4] Essex Institute Bulletin, vol. 12.

Fig. 2.

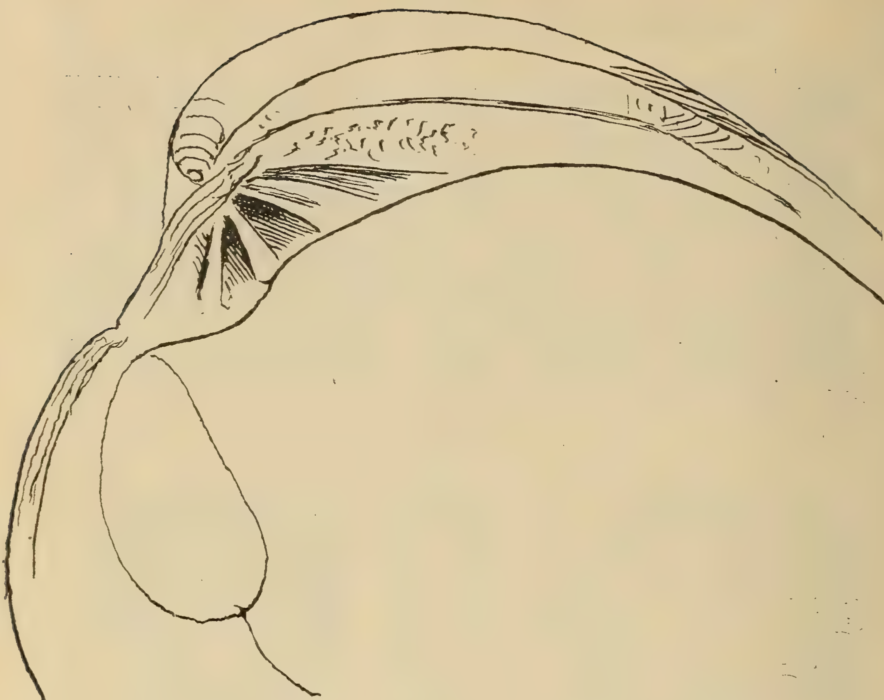


Fig. 2.—Living *Venus campechiensis* from Florida, nat. size.

Fig. 3.

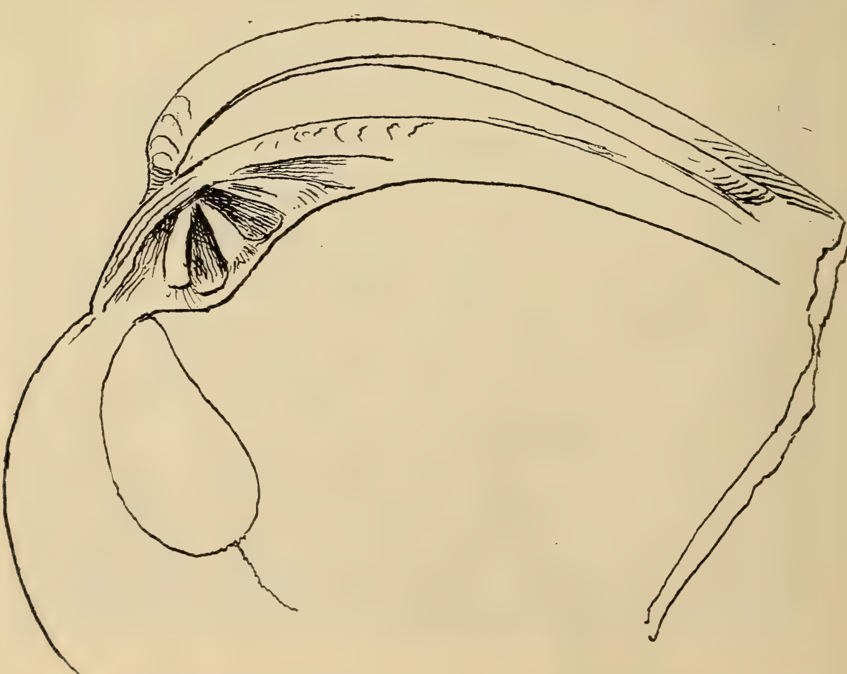


Fig. 3.—Fossil *Venus campechiensis* from Sankaty Head, nat. size.

ribs do not show between the lines of growth, only after great abrasion of the shell or decomposition of the surface as in the shell of *Venus mercenaria* exposed by digging a trench in a marsh in Salem are the radial markings visible. These features also show in the same species which came up in the dredgings in Portland Harbor. The thickness of the shell is shown in the middle outline though much thicker specimens are seen.

In examining the collection of shells made by Scudder from the Sankaty deposits I found a marked difference in the quohaugs. There were many perfect specimens of the *Venus mercenaria* all of uniform size showing traces of the purple markings inside the shell. These were light brownish in color as if stained with iron. The larger and thicker shells in fragments with no stain of purple represent the variety designated by Verrill as var. *antiqua*. These I believe to be *V. campechiensis*. The broken edges of the shells do not show the slightest signs of wear.

I may add that the fragments of shells from Point Shirley seem much larger than those collected at Hull and it may be that as the clay pushed much farther at Hull the shells were more broken and ground than those nearer the place of origin.

I wish to thank Mrs. George L. Chaney of Salem for the Florida Venus, fig. 2.

ART. XI.—*Bismutoplagionite, A New Mineral;* by EARL V. SHANNON, U. S. National Museum.[1]

Some specimens forwarded to the U. S. National Museum for examination and report by Mr. Tim McCarthy of Wickes, Montana, contained a gray, metallic mineral which was identified by Mr. W. F. Foshag as a sulphide of lead and bismuth. As the mineral appeared to be of more than ordinary interest, the sender was asked for a sufficient quantity of the material for detailed investigation which, when received, was turned over to the writer for study. Enough of the gray bismuth mineral was secured for an analysis which indicated that the mineral is a new species having the composition of a plagionite in which the antimony is almost entirely replaced by bismuth. The name bismutoplagionite indicates this chemical relationship.

Nothing is known regarding the locality of the mineral other than that the specimens were sent from Wickes, Montana, but it is presumed that they came from somewhere in that immediate vicinity. Wickes is a small mining town in Jefferson County, about 10 miles southwest of Helena.

The specimens consist in large part of coarse granular pyrite, each grain being a well-defined cubic crystal with the corners truncated by octahedral planes. The bismuth mineral occurs in small, indistinctly fibrous masses intergrown with pyrite in aggregates up to one inch in diameter. Much of the ore contains a soft, scaly, micaceous mineral apparently sericite. The masses of pyrite contain also in places small masses of galena, tetrahedrite and chalcopyrite, and small prismatic crystals of transparent to milky quartz.

In appearance the new mineral does not differ from many of the other sulphosalts of lead. In color it is slightly bluish lead-gray. The aggregates are indistinctly fibrous, the fibers curving around pyrite or quartz crystals, which, when removed, leave molds in the bismuth mineral. There is a rather ill-defined cleavage parallel to the elongation. In one specimen a small cavity between pyrite crystals contained brilliant, deeply stri-

[1] Published by permission of the Secretary of the Smithsonian Institution.

ated prisms of the mineral but these were not terminated and were too minute for measurement. The specific gravity of the mineral is 5·35; hardness 2·8; streak, dark brownish-gray, dull. Before the blowpipe alone on charcoal, it fuses to a brittle globule and yields a coating which is yellow nearest the assay and white in its outer portion. With sodium carbonate, is reduced to a metallic button yielding similar coatings on the coal. In the closed tube, yields a copious sublimate of sulphur; in the open tube, gives abundant sulphur dioxide and, at a high temperature, a heavy sublimate which is yellow while hot and yellowish white when cold. With potassium-iodide-sulphur mixture yields the usual bismuth reaction.

The mineral for analysis, which was free from impurities other than pyrite, was completely dissolved in hot concentrated hydrochloric acid while the pyrite remained for the most part undissolved. The portion given as insoluble in the table below consisted almost entirely of pyrite. Upon analysis the powdered mineral gave the following results:

Bismutoplagionite, Montana.

Insoluble	18·88
PbS	30·21
As_2S_3	trace
CuS	trace
Ag_2S	trace
FeS_2	1·25
Sb_2S_3	3·37
Bi_2S_3	45·62
Total	99·33

Deducting impurities and recalculating to 100% this gives:

PbS	38·13
Sb_2S_3	4·26
Bi_2S_3	57·61
Total	100·00

These values yield the following ratios:

PbS	·1594	or	15·94	or	5·04
Bi_2S_3	·1125		12·65		4·00
Sb_2S_3	·0140				

The new mineral thus agrees almost exactly with the formula $5PbS.4Bi_2S_3$, a small proportion of the bismuth being replaced by antimony. Although but a single analysis was made it is considered improbable that the mineral can be regarded as a variety of galenobismutite. The sample analyzed was selected with extreme care by hand picking, each fragment being examined under the microscope and chunks of the sulphide aggregate which showed any minerals other than pyrite and the fibrous bismuth mineral were not crushed in the lot from which material for analysis was picked. It was necessary to determine sulphur by difference but the value thus obtained is almost exactly that required to convert the metals to their respective sulphides. The iron found in solution is deducted as pyrite. It is surprising that the pyrite was not more completely attacked by the long treatment with hot hydrochloric acid to which it was subjected.

Plagionite, despite its unusual ratios, is a mineral of definite composition and form and that it should have a bismuth analogue is to be expected. The two minerals are isomorphous as indicated by the small antimony content in the present mineral. Liveingite[2] also seems to be a well-defined member of the same group. The formulæ of the three members of this immediate group are then:

Plagionite	$5PbS\ 4Sb_2S_3$
Bismutoplagionite	$5PbS\ 4Bi_2S_3$
Liveingite	$5PbS\ 4As_2S_3$

The composition given in the analysis with the antimony recalculated to bismuth is compared with the theoretical composition of the bismuth compound and with galenobismutite in the following table:

	I	II	III
	per cent	per cent	per cent
PbS	37·34	36·87	31·83
Bi_2S_3	62·66	63·13	68·17

I. Analysis of bismutoplagionite, Sb calculated to Bi and the whole reduced to 100%

II. Composition to satisfy formula $5PbS\ 4Bi_2S_3$.

III. Galenobismutite, composition to satisfy formula PbS,Bi_2S_3.

[2] Min. Mag. 13, 160.

Art. XII.—*The Devonian Formations of Illinois*; by T. E. Savage.

The Devonian rocks in Illinois belong to two distinct provinces; a southern or Mexican Gulf province, and a northern, referred to by Williams as the Interior Continental province. Of these provinces the former contains a much more complete sequence, and greater thickness of Devonian strata. The faunal relations of this southern province ally it much more closely with the New York or Eastern Continental province which was connected with the Atlantic ocean, than to the Interior Continental province which had a connection northward with the Arctic ocean.

Devonian Rocks of the Southern Province in Illinois.

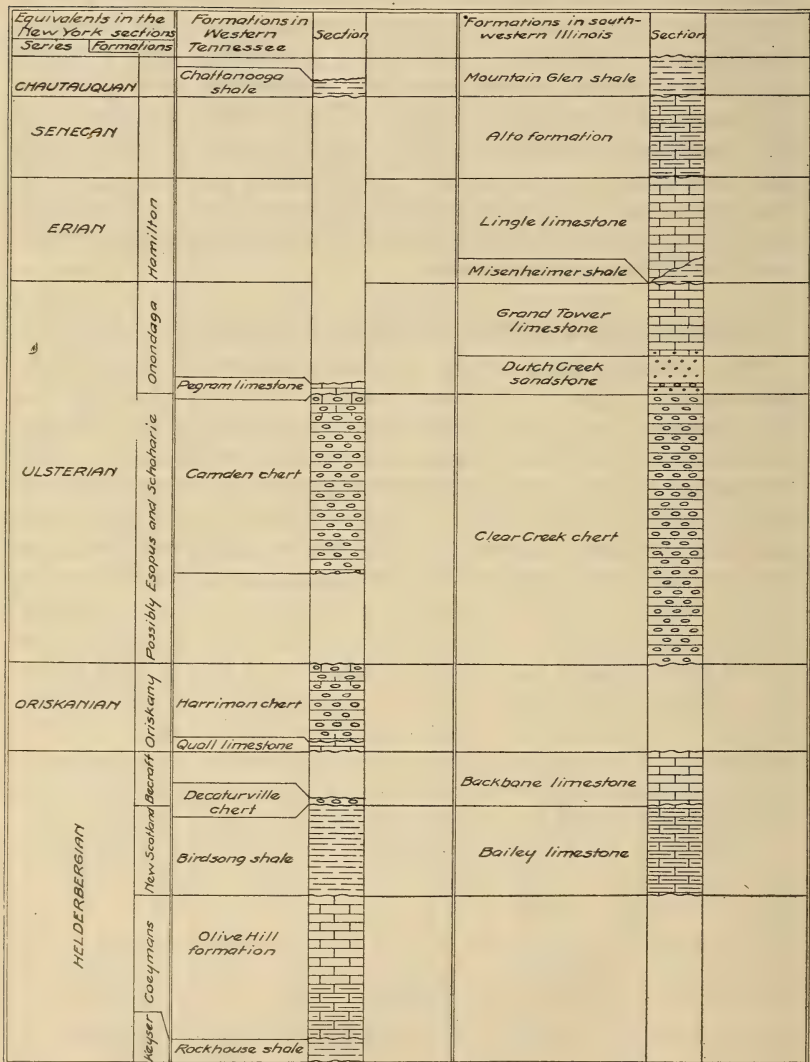
The detailed field study of the geology of the Jonesboro quadrangle in Union County, Illinois, during the past summer, gave the writer an opportunity to restudy the area of Devonian strata in southwest Illinois. The Devonian rocks of this southern province do not extend as far north as St. Louis, and the most of the formations are not certainly known in the state north of Jackson County, although several of them are known in Missouri as far north as Ste. Genevieve County. The eastward limits of this basin are not definitely known, exposures of the rocks being mostly restricted to a belt a few miles wide near Mississippi river. A small area of Middle Devonian (Onondaga) rocks has been reported by Butts[1] in Hardin County in southeastern Illinois, and rocks of corresponding age are present farther east in Indiana and farther south in western Kentucky and Tennessee.

Thickness of Devonian Strata.—The total aggregate thickness of the Devonian rocks of the southern province in southwest Illinois is not less than 800 feet. In this succession of strata, all of the series or larger divisions of the Devonian system recognized in the New York section are represented. The comparative columnar sections of the Devonian formations in southwest Illinois, eastern Missouri, western Tennessee, and eastern Oklahoma, and their equivalents in the New York section, are shown on the accompanying plate,[2] given in two parts on opposite pages.

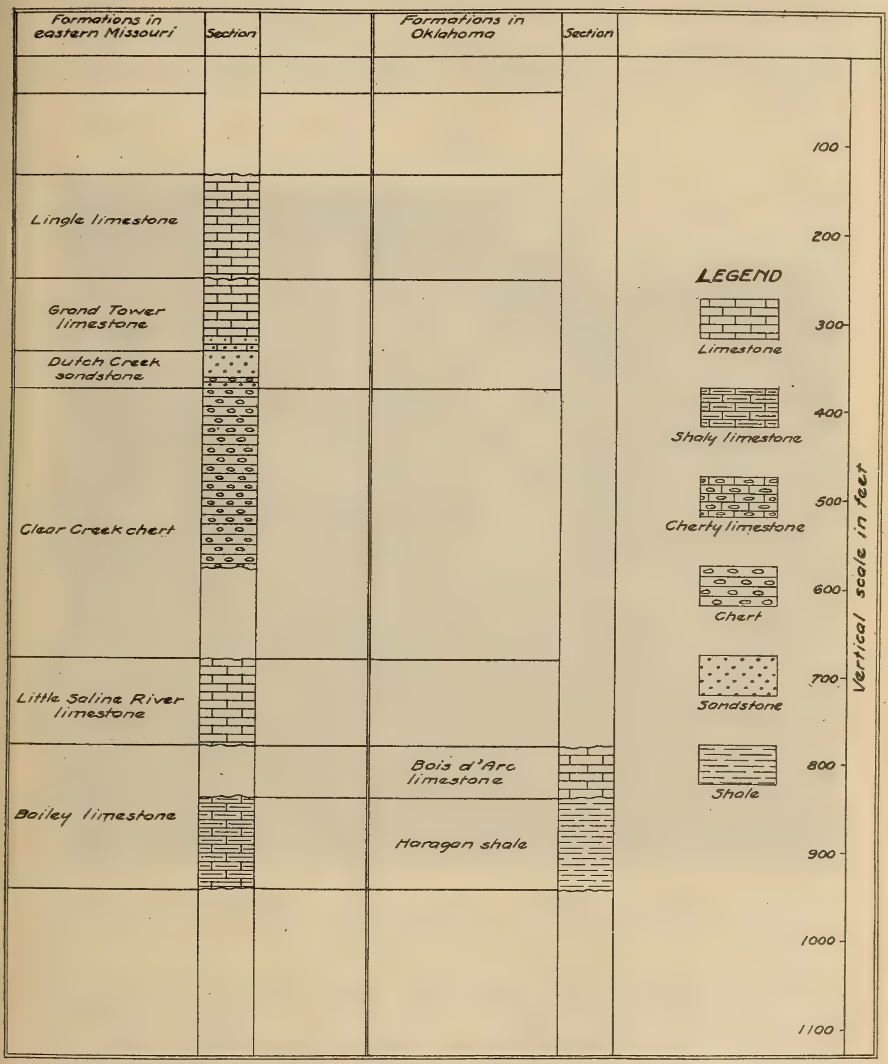
[1] Butts, Charles: Illinois Geol. Survey, Bull. No. 35, p. 75, 1917.

[2] On this plate the thickness of the Grand Tower limestone (125 feet) is indicated too small; and the thickness of the Lingle limestone (90 feet) is indicated too great.

Comparative Columnar Sections of the
Southwestern Illinois, East-



DEVONIAN ROCKS IN WESTERN TENNESSEE,
ERN MISSOURI AND OKLAHOMA



Lower Devonian.

Helderbergian Series.

The oldest rocks belonging to the Devonian system in Illinois are of Helderbergian age and correspond in time to some part of the New Scotland formation of the New York section. These strata consist of rather thin-bedded, cherty, argillaceous limestones, about 90 feet

Fig. 1.

Fig. 1.—Helderberg (Bailey) limestone in the east bluff of the Mississippi river, near the northwest corner of Union Co., Illinois.

thick. Strata of corresponding age have also been described by Weller[3] in Ste. Genevieve County, Missouri. In places in Illinois these rocks are unconformably overlain by rather thick-bedded coarsely crystalline limestones, which are probably equivalent to some part of the Becraft limestone of New York, and [illegible] thick-

[3] Weller, Stuart: Bull. Geol. Soc. America, 25, 135-136, 1914.

ness of about 70 feet. The lower, shaly limestone phase of the Helderbergian in this region was referred to by Worthen as of the age of the "Delthyris shaly limestone," but no separate designation was applied to the upper, more crystalline limestone member of the Helderbergian in this region.

Bailey Limestone.—Ulrich has proposed the name Bailey limestone for the lower, cherty, and shaly Helderbergian strata present in eastern Missouri, from the old steamboat landing known as "Bailey's landing," where Worthen obtained many of the Helderbergian fossils described in Volume III of the reports of the Geological Survey of Illinois. This name can well be applied to the corresponding strata in Illinois. The characteristic fossils of the Bailey limestone are *Stropheodonta punctulifera, Dalmanella subcarinata, Meristella lævis* var., *Spirifer cyclopterus, S.* (*Delthyris*) *perlamellosus,* and *Dalmanites palaceus.*

"Back-bone" Limestone.—The upper or coarsely crystalline limestone member of the Helderbergian is well exposed near the south end of the Devil's Back-bone ridge, a short distance north of Grand Tower, in Jackson County, Illinois, and it is proposed to designate this member the "Back-bone limestone."

The more diagnostic species of the Back-bone limestone are: *Aspidocrinus scutelliformis, Stropheodonta beckii, Oriskania sinuata* var., *Spirifer concinnus, S.* (*Delthyris*) cf. *perlamellosus,* and *Uncinulus nucleolatus.* This fauna appears to be closely related to that of the Becraft limestone of the New York section.

Oriskanian Series.

No rocks of Oriskanian age are known to be present in Illinois, although Weller has found typical Upper Oriskany rocks farther north in Ste. Genevieve County, Missouri, and Dunbar[4] has found corresponding Oriskany strata in western Tennessee where they unconformably underlie the Camden chert. It seems certain that these Oriskany strata were originally deposited in southern Illinois, between the Missouri and Tennessee localities, but they were largely removed by erosion in this intervening area before the earliest of the Middle

[4] Dunbar, C. O.: this Journal (4), 46, 746-749, 1918.

Devonian sediments were laid down. Concealed patches of these rocks may be present in southern Illinois, but there is no known place in the state where they are exposed.

Middle Devonian.

Ulsterian Series.

Clear Creek Chert.—In places in Illinois the Clear Creek chert rests unconformably upon the Back-bone limestone, and in others it lies upon the Bailey limestone. It corresponds in age to the Camden chert of Tennessee, and in this region consists in large part of a succession of chert layers or of alternating chert and limestone layers, 3 to 8 inches thick. At certain levels in the upper half of the formation numerous casts and molds of fossils, mostly brachiopods, occur along the bedding planes, but in the lower part of the formation the chert is more massive and contains few or no fossils. The total thickness of this chert deposit exceeds 300 feet. The more common species of fossils in the formation are the following: *Pholidops terminale, Schuchertella pandora, Chonostrophia reversa, Eodevonaria arcuata, Anoplia nucleata, Rhipidomella* cf. *musculosa, Anoplotheca flabellites, Centronella glans-fagea, Amphigenia curta, Spirifer duodenarius, S. hemicyclus, S. macrothyris, S. worthenanus, Reticularia fimbriata, Metaplasia pyxidata, Acidaspis tuberculata* and *Phacops cristata.* The uppermost layers of chert are in places interbedded with sandstone layers containing Onondaga fossils; the chert passing up into the sandstone without a sedimentary break. In a previous paper by the writer[5] the chert formation was thought to be of Upper Oriskany age, but Dunbar[6] has shown that in western Tennessee the Camden chert, which is equivalent in age to the Clear Creek formation, occurs above the typical Upper Oriskany strata and separated from them by a sedimentary break of considerable magnitude. Many of the species of fossils occurring in the chert are peculiar to this lower Mississippi embayment, and are of South American origin.

However, there are a few species in this fauna that can be considered characteristic of the Onondaga, and

[5] This Journal (4), 25, 436, 1908.
[6] Op. cit., pp. 749-753.

since the stratigraphic relations of the Camden chert (of similar age) in western Tennessee indicate its post-Oriskany age, and there is a lack of any hiatus between the Clear Creek chert and undoubted Onondaga strata, the Clear Creek chert is now referred to the basal portion of the Ulsterian (Onondaga) series.

Dutch Creek Sandstone.—The Clear Creek chert is almost everywhere overlain by a sandstone which records an uplift either farther west in the Ozarkian region of Missouri or to the south in Llano or Appala-

Fig. 2.

Fig. 2.—View of Clear Creek chert in quarry near Tamms, in Alexander County. A vertical face, 180 feet high, is here exposed.

chia. This sandstone ranges from 10 to 12 feet to as much as 30 or more feet thick, and consists of iron-stained, reddish-brown or yellow, rather coarse grains of quartz sand cemented with iron oxide, in layers 10 to 24 inches thick. It outcrops in many places in Union and Alexander counties at the horizon immediately above the Clear Creek chert. It may be appropriately referred to as the Dutch Creek sandstone on account of the fact that good exposures occur along Dutch creek in the southwest part of Union County. In places this sandstone contains numerous moulds and casts of such fossils as *Pleurodictyon problematicum,* two or three species of *Zaphrentis, Leptostrophia perplana, Rhipidomella* cf. *penelope, Amphigenia curta, Spirifer duodenarius, Spirifer macrothyris,* and *Odontocephalus* sp., several of which also occur in the overlying Grand Tower limestone into which the sandstone grades through a transition zone of 8 or 10 feet without any interruption of deposition.

Grand Tower Limestone.—The limestone conformably overlying the Dutch Creek sandstone is rather thick-bedded, and coarsely crystalline, and has a total thickness of about 125 feet. It contains a large fauna, comprising species which clearly indicate the Onondaga age of the strata, of which the following are the most common: *Nucleocrinus verneuili, Stropheodonta patersoni, Chonetes koninckianus, Productella spinulicosta, Camarophoria gainesi, Pentamerella arata, Spirifer acuminatus, S. duodenarius, S. gregarius, S. segmentum, S. grieri, S. macrothyris,* and *Odontocephalus ægeria.*

The strata are well exposed in the north half of the Back-bone ridge north of Grand Tower, and in the Bake-oven mound a little farther north. They are also exposed in an old quarry a short distance east of Grand Tower, from which town the name Grand Tower[7] limestone has been applied to the formation.

Misenheimer Shale.—A sedimentary break appears to have occurred everywhere in this region at the top of the Grand Tower limestone. The succeeding strata correspond in age to the Marcellus and Hamilton of the New York section. They overlap the Grand Tower limestone in a few places, and in these the basal part is a dark shale which has a greatly disturbed appearance and contains numerous shells of *Leiorhynchus limitare,* and a few other fossils. This shale member has a thickness of 12 to 25 feet, and is well exposed in the banks of Misenheimer creek and its tributaries in the N.E.¼, sec. 34, and the N.W.¼, sec. 35, in Misenheimer township, Union County, where it rests unconformably upon the Clear Creek chert or the Dutch Creek sandstone. It may be appropriately referred to as the Misenheimer shale.

Lingle Limestone.—Resting conformably upon the Misenheimer shale where that is present, and unconformably upon the Grand Tower limestone or some older

[7] Savage, T. E.: Illinois State Acad. of Sci., Trans., 3, 116-132, 1910.

formation where the shale is absent, is a dark colored, somewhat shaly, hard, brittle limestone that contains such characteristic Hamilton fossils as *Microcyclus discus, Chonetes pusillus, C. coronatus, Tropidoleptus carinatus, Vitulina pustulosa, Athyris spiriferoides, Spirifer audaculus, S. fornacula, S. granulosus,* and *S. pennatus.* The lower part of this limestone outcrops near the top at the north end of the Devil's Back-bone ridge, north of Grand Tower, and the entire thickness of the formation is present along a branch of Clear creek in the N.E.¼, sec. 34, T.11S., R.2W., about one and one-fourth miles southwest of Mountain Glen. It is also exposed above the Misenheimer shale along a branch of Lingle creek in the S.W.¼, sec. 26, T.13S., R.2W., and it is proposed to refer to this formation as the Lingle limestone.

Upper Devonian.

Alto Formation.—Overlying the Lingle limestone southwest of Mountain Glen and in other places in sections 11, 23, 26 and 36, T.12S., R.2W., is a dark, siliceous shale and somewhat shaly limestone, 40 to 75 feet thick, which contains the fossils *Chonetes* sp., *Leiorhynchus globuliforme, L. mesacostale, Spirifer pennatus, Reticularia lævis,* and *Tentaculites* sp. From the exposure of this limestone along a creek in the N.E.¼, sec. 34, in Alto township (Union County), it will be designated the Alto formation. This formation is thought to represent about the time of deposition of the Portage or Chemung deposits of the New York section.

Mountain Glen Shale.—At the locality last mentioned, a hard, black, laminated shale having a band of iron pyrites in the basal part and containing numerous spores of *Sporangites huronensis,* and shells of a linguloid, *Barroisella spatulata,* unconformably overlies the Alto formation. This shale is present in several other places north of Jonesboro in Union County, where it rests unconformably on the Alto limestone. The thickness of the shale ranges from 25 to 45 feet, and it is probably to be correlated with the upper part of the New Albany black shale of Indiana, and the Chattanooga black shale of Tennessee. One of the best exposures may be seen along a stream about three and one-half miles N.W. of Jonesboro, in the S.W.¼, sec. 11, T.12S., R.2W. A good outcrop also occurs just below the dam at the State pond, in the S.E.¼, sec. 14, and at a few other places in the same township. This shale is usually considered of late Devonian age, but Ulrich is convinced that it represents early Mississippian rather than late Devonian time. From its occurrence near Mountain Glen it may be referred to as the "Mountain Glen shale."

Springville Shale.—Unconformably overlying the black Mountain Glen shale in the S.W.¼, sec. 11, and at the State pond in sec. 14, and near the east end of the ridge near the north border of sec. 23 in T.12S., R.2W., is a bed of greenish shale which on weathering becomes variegated and mottled in various shades of brown and red. This formation is also well exposed for several rods along the creek bank in the S.E.¼, sec. 1, T.13S., R.2W., and in many other places south of Jonesboro, in Union County. From the mottled color of the weathered portions of this deposit Worthen referred to it as the "Calico shale." In some places in the vicinity of Elco this shale has locally become strongly silicified, and the deposit has been worked as gannister, and used by the Western Firebrick Company in the manufacture of refractory brick. Worthen considered this shale the youngest of the Devonian deposits in southern Illinois. It is unfossiliferous in most of the exposures, *Leiorhynchus quadricostatum* being the only species found, except in more calcareous lenses in the lower part of the formation. Such lenses in the S.W.¼, sec. 11, and at the State pond, in T.12S. H.2W., furnished *Productella concentrica, Brachythyris semiplicata, B.* cf. *peculiaris, Ambocœlia unionensis,* and cf. *Cardiopsis radiata* which ally the formation with the early Mississippian (Rockford) limestone or southwestern Indiana. Good exposures of this shale occur in the ridge one and one-half miles northwest of Jonesboro, and along the wagon road in the lower part of the hill about the same distance south of Jonesboro, and in the hills about one mile west of this town. About five miles south of Jonesboro this shale is also well exposed in the bed and banks of a creek a short distance northwest of the village of Springville, in the S.E.¼, sec. 13, T.13S., R.1W., from which place it may be appropriately called the Springville shale.

UPPER DEVONIAN ROCKS OF THE NORTHERN OR INTERIOR CONTINENTAL PROVINCE.

The Devonian rocks of the northern or Interior Continental province are best exposed in Illinois in the vicinity of Rock Island, where their thickness reaches 150 feet. They are not known south of the latitude of Alton, Illinois, or east of the city of Springfield. These rocks are clearly an eastward extension of corresponding strata in Iowa and northern Missouri, and these Devonian formations in northwest Illinois are designated by the names by which they are known in Iowa, viz., Wapsipinicon limestone at the base, Cedar Valley limestone, and Sweetland Creek shale. All of these rocks should probably be considered of Upper Devonian age, as shown on a later page.

Wapsipinicon Limestone.—The Wapsipinicon limestone in Illinois consists for the most part of light gray, rather fine-grained, brecciated limestone, 60 to 75 feet thick. The basal layers which probably represent the Otis beds of Norton are well exposed on Campbells island, above Moline. They are only slightly brecciated, and contain numerous shells of *Spirifer subumbonus.* The middle, profoundly brecciated portion of the formation is well exposed in the railroad cut near Fayette, Iowa, and was called by McGee the Fayette breccia. It is also exposed in the old Cady quarry in Moline, Illinois. The rock fragments are fine grained, in places laminated, and range from a few inches to 2 or 3 feet in length. The smaller pieces are mostly shattered and displaced; but some of the larger masses have only been broken and tilted so that they are inclined at different angles with one another, but in some places the original beds can be traced for several feet. The upper layers, which are less brecciated than those in the middle portion, contain such fossils as *Productella subalata, Schizophoria iowensis, S. macfarlanei, Gypidula comis, Hypothyris intermedia* (=*H. cuboides*), *Spirifer iowensis,* and *Atrypa hystrix.*

In Iowa the lower strata of the Devonian are usually similar to those in Illinois, except possibly in Buchanan County where Calvin has described a dark shale member, the Independence shale, underlying the Wapsipinicon formation. The Independence shale contains many species of fossils all of which are similar to those present in the younger Lime Creek shale farther north in Floyd and Cerro Gordo counties, Iowa, and are not known at so low a horizon in any other locality. Several years ago this dark fossiliferous shale was thrown out in digging a well on the floor of a quarry near Independence, Iowa. It has not been seen in natural exposures, nor has it been certainly recognized in well records at this horizon in other places. It is believed by the writer, who had the privilege of visiting the locality with Professor Calvin and collecting some of the fossils from the old dump, that this shale came from a pocket of Lime Creek shale that at this place had sifted down through an open joint or fissure and filled a small cavern in the Wapsipinicon limestone, just as Pottsville sands and clays are often found filling fissures and caverns in the Devonian limestone in the vicinity of Rock Island. This would indicate that originally the Lime Creek shale extended southward at least as far as Independence, Iowa, but no rocks of this age are known in Illinois.

In Linn County, Iowa, Norton has described the Otis member of the Wapsipinicon limestone below the horizon of the Independence shale, which is thought to correspond with the limestone containing numerous shells of *Spirifer subumbonus* exposed on Campbells island in the Mississippi river north of Moline.

Cedar Valley Limestone.—The Cedar Valley limestone, which overlies the Wapsipinicon limestone in apparent conformity, consists of somewhat shaly, obliquely jointed limestone in the lower part, and contains the *Acervularia davidsoni* coral reef near the middle. In the upper part the strata consist of gray limestone which at certain levels is composed largely of spherical and flattened stromatoporoids. The total thickness of this limestone is about 100 feet. The characteristic fossils of the lower part of the Cedar Valley limestone are *Astræospongia hamiltonensis, Phillipsastræa billingsi, Acervularia profunda, Spirifer aspera, S. bimesialis, S. iowensis,* and *S. subundiferus.* The middle portion includes the coral reef horizon, and contains the fossils *Acervularia davidsoni, Favosites alpenensis, Cladopora iowensis, Striatopora rugosa* and *Spirifer parryanus.* In the upper layers occur *Pentamerella micula, Dielasma iowense,* and *Straparollus cyclostomus.* The writer has also collected *Hypothyris cuboides* from the limestone a few feet above the *Acervularia davidsoni* coral reef in Fayette County, Iowa.

Regarding the age of the Wapsipinicon and Cedar Valley limestones, it is significant that in Iowa and northwest Illinois *Spirifer subumbonus* occurs in abundance in the basal layers of the Wapsipinicon limestone, and *Hypothyris cuboides,* and *H. intermedia* which is

Fig. 3.

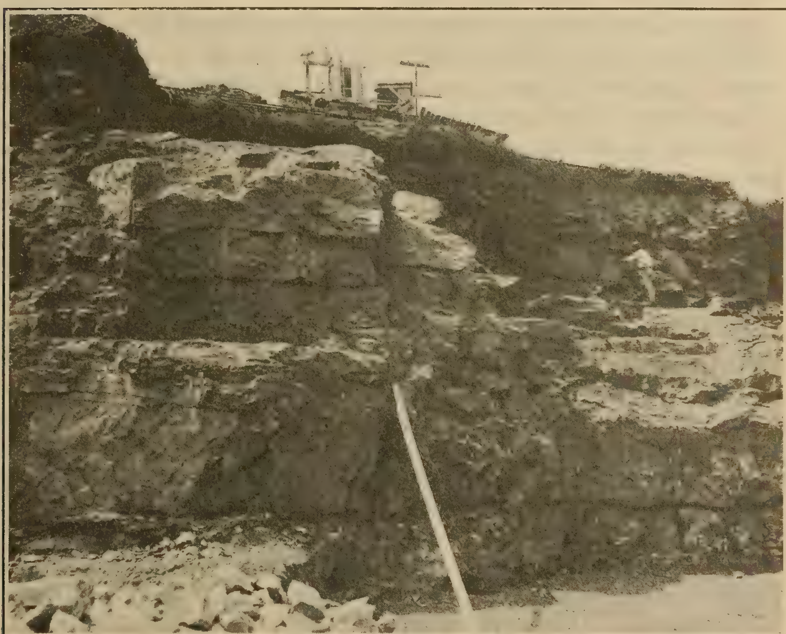


Fig. 3.—View of the lower part of the Cedar Valley limestone, near Milan, Rock Island County, Illinois.

regarded as a synonym for *H. cuboides,* are present in the lower part of this formation at Davenport and occur also in the Cedar Valley limestone above the coral reef. These species are characteristic of the early upper Devonian rocks (Tully limestone) in New York, and it is thought that the Wapsipinicon and the overlying Cedar Valley limestones in the Iowa, northwest Illinois, and northern Missouri region should be correlated with the early upper Devonian (Tully) limestone of the New York section.

The *Winnipegosan dolomite* in the Lake Winnipeg region, containing *Stringocephalus burtoni,* is probably the youngest Middle Devonian formation in the Interior Continental province. The overlying *Manitoban limestone* in that region, and the *Abitibi River limestone* in the James Bay region, are thought to about correspond in age to the Wapsipinicon and Cedar Valley limestones of Iowa and Illinois, and would thus also seem to be of early Upper Devonian age.

Sweetland Creek Shale.—The Sweetland Creek shale is a dark, rather thin-bedded shale, not so hard or black, or so distinctly laminated as the Mountain Glen shale in southern Illinois, or the New Albany shale in Indiana. It contains shells of a small linguloid, and great numbers of spores known as *Sporangites huronensis,* which appear to be identical with those occurring in the Mountain Glen shale in southern Illinois, with which formation it may nearly correspond in age. The Sweetland Creek shale represents a northern sea invasion. It unconformably overlies some horizon of the Cedar Valley limestone or older rocks, in places, as in the vicinity of Chicago, resting on strata as old as the Niagaran limestone. This shale ranges from 50 to 200 feet thick. It has usually been considered of Upper Devonian age, but may possibly, as Ulrich thinks, be as young as early Mississippian. It may be slightly younger than the Mountain Glen shale in the southern part of the state; and younger also than the State Quarry limestone and Lime Creek shale of Iowa. The two latter formations are younger than the Cedar Valley limestone but are not known to be represented by rocks in Illinois.

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Art. XIII.—*Type Section of the Morrison Formation;*[1] by Willis T. Lee.

The Morrison formation at its type locality at Morrison, Colorado, requires redefinition. The strata originally assigned to the Morrison include some that are equivalent in age to an older formation (Sundance of the Jurassic) and others at the top which contain fossil plants of Upper Cretaceous type.

In the summer of 1916, I visited Morrison in company with Prof. George L. Cannon, who assisted years ago in working out the geology of this region. He pointed out on the ground the formational boundaries used by him and his associates at the time the work was done which resulted in the Denver Monograph. Together we went to the old quarries where the dinosaurs were found. At this time he called my attention to fossil plants in the upper part of the original Morrison and also to the plant horizon in the overlying sandstone where he and Lieutenant Beckwith collected the plants described years ago by Lesquereux and placed in the Dakota flora.

The several lithologic units of the section at Morrison have not been carefully measured, but the estimated thicknesses are sufficiently accurate for present purposes. The classification which seems necessary because of the new information is indicated at the left in the following section. Explanatory notes and suggested changes are in parentheses.

Section at Morrison, Colorado.

		Estimated thickness in feet
Dakota group, 265 feet.		
1	Sandstone, massive, quartzose (the "upper Dakota" of some geologists)	75
2	Shale, sandy, dark colored. ("Dakota fire-clay")	5
3	Sandstone, massive, quartzose, plant-bearing near the base, lower 2 inches filled with carbonized wood, seemingly a fossil soil; horizon of plants collected	

[1] Published by permission of the Director of the U. S. Geological Survey. This paper is followed by one on the Flora of the Morrison Formation by F. H. Knowlton.

	by Beckwith and described by Lesquereux as Dakota flora. ("Lower Dakota" of some geologists; Purgatoire or Lower Cretaceous of others)	75
	Change in lithology and possible time break.	
4	Sandstone, friable, and shale; plant-bearing near the top, variegated in color in some places, particularly near the base (upper part of Morrison formation as originally described)	100
5	Sandstone, conglomeratic—the Saurian conglomerate—containing dinosaur bones and pebbles of quartz and jasper; sharply separated from the underlying shale	10
	Probable time break.	
Morrison formation, 160 feet.		
6	Shale, variegated, with layers of hard sandstone and limestone; contains Sauropod and other dinosaurs	150
7	Sandstone with dinosaur bones and quartz pebbles ½ inch in diameter, fills hollows in the underlying formation	10
	Erosional unconformity.	
Sundance formation, 17 feet (Upper Jurassic).		
8	Sandstone, friable, light colored	5
9	Limestone, impure, with pink concretions of chalcedony	2
10	Sandstone, massive, friable, pink to yellow; varies in short distances from 5 to 15 feet; rests with uneven contact on red sandstone and shale	10
Lykins formation (Permian ?)		
	Sandstone and shale—Red beds.	

According to Cannon's statement made on the ground, Nos. 1-3 of this section were regarded as the two sandstones of the Dakota and the shale as the "Dakota fireclay." Other geologists have followed this usage and when the "lower Dakota" and the shale above it a few miles farther south[2] were correlated with Purgatoire, No. 3 of the Morrison section naturally was regarded as Lower Cretaceous. There are numerous impressions of leaves about 15 feet above the base of this sandstone, and according to Cannon it was from this horizon that Lieutenant Beckwith collected most, if not all, of his so-called Dakota plants. The lithology of these specimens, which are now in the National Museum, confirms this statement.

[2] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, Castle Rock folio (No. 198), 1915.

In some places this "lower Dakota" or No. 3 rests on shale and its under surface is covered with worm-like bodies such as I have seen in many places associated with unconformities. In other places near Morrison the quartzose cliff-making "lower Dakota" is separated from the softer sandstone of No. 4 by a thin layer of porous rock full of small fragments of carbonized wood. These features suggest a time break but it may be one of slight significance.

No. 4 of the section is a part of the Morrison as originally defined. Yet it contains fossil plants which Knowlton describes as belonging in the Dakota flora. It should be noted here that the "Dakota flora" of this locality comes from "lower Dakota," a formation which some geologists place in the Lower Cretaceous series. No obvious break was found in the section between the plant horizon and the base of the Saurian conglomerate. If No. 4 is referred to Dakota on the basis of plant evidence, it will carry No. 5 with it, thereby putting into the Dakota group the dinosaurs of this conglomerate, provided they are of this time. The origin of these dinosaur remains, however, may have an important bearing on this question. If they are reworked material and derived from the older beds, then the conglomerate is seemingly the base of the proposed Dakota group.

It should also be noted that Nos. 1-5 have no marine fossils of any kind. This, along with the irregularity of deposition from place to place, the presence of fire-clay, and the further fact that when fossils are present they are the remains of land plants, apparently indicates that all of these deposits are of fresh-water origin.

No. 6 of the section is the well known dinosaur-bearing member of the Morrison and bones have been found in it at several horizons. No. 7 is a basal member of No. 6, is slightly conglomeratic, marks the lowest horizon at which dinosaur bones have been found, and lies unconformably on the older rocks. In the old quarry from which the bones were taken, I found pebbles one-half inch in diameter above the uneven line of erosion. Cannon assured me that the bones were taken from the pebble bed.

The rocks of Nos. 8-10 of the section between the pebble bed just mentioned and the typical Red Beds have been examined in many places north of Morrison. They vary in thickness, disappearing entirely in some places, while in others the thickness increases to more than 100 feet. In northern Colorado they contain *Ostrea* sp. and fragments of *Pentacrinus asteriscus*.[3] In brief, members 8-10 of the section must be referred to the Sundance formation of the Jurassic.

When the strata at Morrison were first described as Atlantosaurus Beds (later named Morrison), separating Red Beds below from Dakota above, the formational boundaries were based on conspicuous lithologic changes. Perhaps the quartzose nature of "lower Dakota" is not so important in determining formational boundaries as the conglomeratic nature of the Saurian conglomerate. Indeed, Eldridge seems to have considered this conglomerate as the possible base of Dakota, for in his description in the Denver Monograph (p. 61) he refers to the difficulty of distinguishing it from the lower Dakota of neighboring regions. However, this reference would necessitate distinguishing the dinosaurs of this conglomerate from those of the Morrison as here restricted or accounting for them as reworked material from the older beds. This question must be decided by the vertebrate paleontologists.

In order to compare the rocks at Morrison with those of neighboring localities, I followed the outcrop for several miles both north and south of that town. To the south for a distance of about 10 miles they are not so well exposed as I had hoped to find them. The Jurassic beds Nos. 8-10 of the section were not positively identified and no stratum was found within what is there called Morrison that could be correlated with the Saurian conglomerate. It is possible, however, that this conglomerate corresponds with the one which is there called "lower Dakota." Still farther south in the Castle Rock quadrangle the conglomeratic sandstone and the shale above it have been referred to the Lower Cretaceous.

The formations under study are better exposed north of Morrison. There I traced the several lithologic units of the Morrison section along the hogback as far as the town of Golden. About two miles south of that town the so-called Dakota fire-clay has been mined in several places, making excellent exposures. At the old work-

[3] Hayden, F. V., U. S. Geol. Survey of Colorado and New Mexico (Third Ann. Rept.), p. 19, 1869.

ings four sandstones are exposed. The lowest is continuous with the Saurian conglomerate, and above it are variegated shales similar to those in the lower part of No. 4 of the Morrison section. Above the shale is soft sandstone, the so-called "lower Dakota" of the region near Golden, and in it are many fossil plants. On this sandstone rests the lower shale of the fire-clay pits and above it is another plant-bearing sandstone. Next in order upward is the second shale used as fire-clay and above it the "upper Dakota" or No. 1 of the Morrison section.

The relations found may be summarized as follows: The "upper Dakota" is not a uniformly continuous layer of sandstone, but rather an intricate mass of overlapping lenses. The sandstone layers of "lower Dakota" and the fire-clay beds also are variable in number and in thickness. Although the shale is generally most abundant near the middle of what I suggest should be called the Dakota Group, it may occur between any two layers of the sandstone. The lower sandstone and the shale have been referred to the Lower Cretaceous on the assumption that they are continuous units. This assumption is not sustained by detailed examination. Furthermore, although the upper sandstone may contain fossil plants, I did not find them in this sandstone near Morrison, but did find many in the lower sandstones. If these plants are indicative of Upper Cretaceous age, the "lower Dakota" must be included in the Upper Cretaceous series. And not only so, but also the upper part of the type Morrison, which some geologists have maintained is Jurassic.

Although the facts here presented may seem trivial in themselves, they have far-reaching significance, for the boundary between Lower and Upper Cretaceous is involved. The Dakota flora as now understood includes not only plants from the "lower Dakota" and the upper Morrison, but as well plants from the Cheyenne sandstone of Kansas. This sandstone underlies the Kiowa shale, which, on the basis of marine invertebrates, has been referred by some geologists to Lower Cretaceous. Others, however, as pointed out by Knowlton in the accompanying paper, place the Kiowa and Cheyenne in the Upper Cretaceous series. This is done on the correlation that the Washita series is Cenomanian, strata that

European stratigraphers refer to the Upper Cretaceous. If the latter reference be conceded, the Purgatoire formation and "lower Dakota" of Rocky Mountain localities will fall at the base of the Upper Cretaceous. The abrupt change from the conglomeratic "lower Dakota" to the underlying Morrison (even at the town of Morrison, if the Saurian conglomerate is "lower Dakota") is in harmony with this suggestion. This disposition would make a thin but complex group of sandstones and shales in the lower part of the redefined Upper Cretaceous series.

Whatever may be the final reference of the group after revision of the Kiowa fauna and the Dakota flora, it now seems necessary to refer it wholly to one series or to the other rather than referring some of the members to Lower Cretaceous and others to Upper Cretaceous. It has been the custom of geologists, including myself, to postulate a withdrawal of the Lower Cretaceous sea from the Rocky Mountain region at the end of Lower Cretaceous time and a re-advance at the beginning of Upper Cretaceous. This interpretation depends almost wholly on the acceptance of the age relations as determined by the Kiowa invertebrates. From a consideration of all the localities known to me in Colorado and New Mexico, the stratigraphic relations seem best explained on the postulate that the Dakota group resulted from the halting and perhaps oscillating advance of the Cretaceous sea. As such it constitutes the basal part of the Upper Cretaceous series. This classification of the formations would restore the original usage of the term Dakota for Colorado localities and would leave the restricted Morrison unconformably below Dakota and unconformably above Jurassic, the only representative of the long epoch between Jurassic and Upper Cretaceous.

Art. XIV.—*A Dicotyledonous Flora in the Type Section of the Morrison Formation;** by F. H. Knowlton.

There has been renewed discussion within the past few years regarding the age of the Morrison formation, that is, as to whether it should be placed in the upper part of the Jurassic or in the overlying Cretaceous. The divergence of opinion on this point among stratigraphers and paleontologists was well brought out in a symposium on "The close of Jurassic and opening of Cretaceous time in North America," given before the Paleontological Society in 1914, though the majority opinion among those who participated in the discussion appeared to favor placing it in the Cretaceous. The object of the present paper is to present some recently acquired paleobotanical evidence, that, if correctly interpreted, seems to refer the upper part of the Morrison formation of the type locality definitely to the Cretaceous, and, further, to place it much higher in the Cretaceous than has been thought possible.

The dicotyledonous plants to be considered in this paper were collected in 1916 by W. T. Lee, of the United States Geological Survey. They came from the type section of the Morrison formation at Morrison, Colorado, occurring about 15 feet below the top of the formation in the north wall of the so-called gap at this place. The matrix bearing the plants is a hard, shaly, somewhat carbonaceous sandstone.

In view of the fact that the plants here described are of a type not before known to occur in the Morrison formation, it is naturally of the utmost importance to fix their position definitely with reference to the limits of the type section of this formation. Mr. Lee was fortunate in having with him on the occasion of his visit to Morrison, Mr. George L. Cannon, of Denver, who not only assisted in excavating many of the dinosaurs described by Marsh from these beds, but who also assisted in measuring the section and preparing the data on which the Morrison formation was established. He pointed out to Mr. Lee the top of the beds as originally included within the formation, and there can, therefore, be no doubt as to the position of the plant-bearing layer,

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which, as already stated, is about 15 feet below the upper limit of the formation. A fuller discussion of this type section of the Morrison, and a recommendation for redefinition, will be found in the paper by Mr. Lee which accompanies this paper.

The material studied consists of about 20 pieces of matrix and has afforded the following forms:

Salix sp., cf. *Salix proteæfolia* Lesquereux.
? *Ficus daphnogenoides* (Heer) Berry.
Ficus magnoliæfolia Lesquereux.
Cf. *Eucalyptus dakotensis* Lesquereux.
Phyllites sp.
Phyllites sp.

This small flora is thus seen to comprise six distinct forms, of which one species is positively, and three are provisionally identified.

Ficus magnoliæfolia, the form positively determined, was first described from the supposed Dakota at Morrison, Colorado, and was later reported by Lesquereux as present in the Dakota sandstone of Kansas.

Ficus daphnogenoides was established on material from the Dakota sandstone of Nebraska, and has since been found in the Woodbine formation at Arthur's Bluff, Texas, the Cheyenne formation at Chatman Creek, Kansas, the Magothy formation of New Jersey, Delaware, Maryland, and elsewhere, the Raritan formation of New Jersey, the Bladen formation of North Carolina, and the Tuscaloosa formation of Alabama.

Eucalyptus dakotensis has the Dakota sandstone of Kansas as the type and only previously known locality. It may be only a very narrow leaf of *Salix proteæfolia.*

The leaves described by Lesquereux under the name of *Salix proteæfolia* came originally from the Dakota sandstone of Nebraska, and were subsequently found at many localities in the Dakota of Kansas, and are present in the supposed "Dakota" of Colorado.

The above comparisons show very clearly that the affinity of this Morrison flora is undoubtedly with the flora of Dakota sandstone, or perhaps it would be better to say, with the plant-bearing beds possibly in the upper part of the Lower Cretaceous, or the lower part of the Upper Cretaceous which the term Dakota is now made to cover. It is perhaps safe to say that without the knowledge that this flora came from beds hitherto referred without question to the Morrison formation, it might have been identified as a Dakota flora, or rather with that from the so-called Colorado "Dakota." These plants have special significance because they came from the type Morrison; because they are biologically higher forms than have heretofore been found in this formation; and because practically only two localities were heretofore known to have afforded Morrison plant remains, these being the Freezeout Hills, Carbon County, Wyoming, and the eastern part of the Bighorn Basin, Wyoming.

The plants from the Freezeout Hills comprise 23 species, two of which are based on coniferous wood and the others on silicified trunks of cycads. To the latter Ward gave the name *Cycadella,* but according to Wieland this is not sufficiently distinct from the older genus *Cycadeoidea.*

The plants known from the Bighorn Basin embrace six forms, three of which are ferns, one an equisetum, and two are cycads based on foliage.

No dicotyledons have been found in either locality, and there is ordinarily no hesitation in referring both the Freezeout Hills and Bighorn Basin floras to the Lower Cretaceous. This matter will be referred to on a later page.

The type section of the original Morrison formation has a thickness of about 300 feet and is separated from the overlying beds by carbonaceous material which has the appearance of being a fossil soil. These overlying beds are about 75 feet thick and otherwise have been interpreted as identical with beds at Colorado Springs and Castle Rock, Colorado, that have been referred to the Purgatoire formation. Above the so-called Purgatoire formation is the Dakota sandstone of the region.

Lee made a small collection of plants in the presumed Purgatoire formation at Morrison about 25 feet above its base. The only species recognizable is *Sapindus morrisoni* Lesquereux, a form well known in the Dakota flora of the Denver Basin. The presence of plants in this so-called Purgatoire formation naturally suggests a review of what has long been known as the Dakota flora of the Denver Basin, especially since, according to Mr. Cannon, most if not all of the known "Dakota flora" of the Denver Basin came from the presumed Purgatoire formation and not from the Dakota as now recognized.

In the complete paper, of which the present is an abstract, I have given a revision of this "Dakota flora" of the Denver Basin. It includes 21 species, all but 3 of which came from the beds of Morrison. It further develops that only 6 of the 18 species are confined to the beds at Morrison, the others being widely distributed in the Dakota, Cheyenne, Woodbine, Raritan, Magothy, Bladen, Eutaw, Black Creek, Tuscaloosa, etc.

In attempting to interpret the relation of the "Dakota" of the Denver Basin to the Dakota in the type area as well as other areas where it has been identified, it appears that several views are possible. The type area for the Dakota is northeastern Nebraska. Here the Dakota has not been subdivided and is followed immediately by the Benton. In southern Kansas the leaf-bearing Dakota rests on the marine Kiowa shale, and this in turn on the Cheyenne sandstone, which contains a flora that certainly has much in common with the overlying Dakota. At Morrison the section appears to be similar to the Kansas section, that is, the Dakota as now delimited rests on the shale of the upper part of the Purgatoire formation, which in turn is underlain by the sandstone of the Purgatoire—the so-called lower Dakota which contains the "Dakota flora" of the Morrison region.

Are the strata at Morrison which contain similar plant forms to be referred to separate series? Are they to be correlated with the ordinary leaf-bearing Dakota of the Kansas section or with the Cheyenne, or are they to be considered as a group with the three units (Dakota, Kiowa, and Cheyenne) as formations? The data available are perhaps not sufficient to permit a definite answer to these questions, though it may be pointed out that certain observed facts of stratigraphy and physiography would be harmonized or rationalized by considering the Dakota as a group within the Upper Cretaceous and embracing the several units as formations. This, of course, involves the age assignment of the Cheyenne sandstone. As already pointed out, this forms a part of the Washita division of the Comanche series that has usually been placed by American geologists at the top of the Lower Cretaceous. But, as Berry[1] has recently pointed out, foreign paleontologists long ago indicated

[1] Berry, E. W., Maryland Geol. Survey, Upper Cretaceous, text, p. 222, 1916.

their belief that it is of Cenomanian age. Berry places it without qualification in the Upper Cretaceous. A very large Cheyenne flora is known, and although it has not been thoroughly studied, Berry and I have looked it over with some care and agree perfectly that its affinity is undoubtedly with the Upper Cretaceous. Whatever may be ultimately decided as to the relation between the Cheyenne and the type Dakota or with the so-called Dakota of the Denver Basin, I do not think there is any doubt about the "Morrison" plants being in the Upper Cretaceous flora.

A further word may be said on the interpretation to be given the stratigraphic position of the plant-bearing strata of the type Morrison. The floras previously known from beds regarded as of Morrison age, or in the approximate position of the Morrison, are without dicotyledons and there is no hesitation in referring them to the Lower Cretaceous. It is difficult to reconcile these floras with the dicotyledonous flora from the type sections of the Morrison. Is it not within the limits of possibility that certain beds that have been identified elsewhere as of Morrison age may not be the same age as the Morrison in its type section?

A hasty review of the Dinosaur fauna of the type Morrison, which includes some five or six species, shows that several of the species have been reported elsewhere, but according to C. W. Gilmore, of the U. S. National Museum, not a single one of these species has with certainty been identified outside the type area.

Conclusion.

The conclusion is reached that the dicotyledonous flora discussed in this paper from the type section of the Morrison formation, finds its closest affinity with the so-called Dakota flora of the Denver Basin, a flora that is known to come in whole or in part from what is classed as the Purgatoire formation, and not from the Dakota as at present delimited. Under the classification which places the Purgatoire formation,—the so-called lower Dakota at Morrison—in the Lower Cretaceous series, the "Morrison flora" occurs below the base of this series. The suggested classification makes Purgatoire include the plant-bearing part of the original Morrison, and makes it all basal Upper Cretaceous. Further, Lee's interpretation of the physiographic history of the region, indicating a relatively short time interval between the type Morrison and the sandstone formerly called lower Dakota, and making the main stratigraphic break at the base of the Saurian conglomerate the line of separation between Lower Cretaceous and Upper Cretaceous, undoubtedly finds support in this flora.

Art. XV.—*Studies in the Cyperaceæ;* by Theo. Holm. XXVIII. Notes on *Carex Franklinii* Boott, and *C. spectabilis* Dew. (With 15 figures drawn from nature by the author.)

Carex Franklinii Boott.

This beautiful species, named in honor of Sir John Franklin, was first found by Drummond in the Rocky Mountains, about lat. 59°, but since then, it has never been collected. It was, therefore, a great surprise when Mr. James M. Macoun wrote us about a year ago, that he had rediscovered the plant in Alberta, and evidently near the place where it was found by Drummond.—The species was found in abundance, and through the kindness of Mr. Macoun we have been in the position to examine quite a large material, upon which the following notes have been drawn. With respect to the habitat Mr. Macoun writes, that he found the species: ''at four stations along the Athabaska River at extreme distances of twenty miles apart, and in each case the habitat was the same. Here and there along the Athabaska River there are low, boggy areas bordering the river itself. These bogs are caused by seepage from the true bank of the river or by springs, and are characteristic of all mountain streams. There is generally a considerable trace of alkali in the soil, as is indicated by the occurrence of *Ranunculus Cymbalaria, Triglochin, Puccinellia, Dodecatheon,* etc. Between these bogs, which are often only a few yards in width, and the river there is always a narrow strip of higher ground formed of Alluvium, which although submerged at high water is generally a few feet above the river bed. It was always on this narrow strip that *Carex Franklinii* was found, and of the hundred or more specimens collected all but two or three were on the river edge of this bank associated with the usual plants of such localities. During parts of two seasons spent in Jasper Park a constant lookout was kept for this species, which had not been collected since Drummond's time, but it was seen nowhere else but in the localities indicated. As the old ''Athabaska Trail'' in many places follows the narrow strip referred to above and this was the trail followed by Drummond, it is reasonable to suppose that his specimens were collected not far from the localities at which *C. Franklinii* was collected in 1917 and 1918."—

According to Boott[1] the original diagnosis reads as follows:

"Spicis 6-9 apice masculis superioribus congestis sessilibus inæqualibus inferioribus alternis pedunculatis nutantibus, stigmatibus—3 vel 2, perigynüs oblongo-ovatis hispidis ore membranaceo oblique bifido squama hispida mucronulata longioribus (Tab. 218) *C. ovata* Dew.,—Torrey. Hab. Rocky Mountains, Drummond."

"Radix cæspitosa, fibris ferrugineis. Culmus bi-tripedalis, pars spicas gerens 3-5 pollicaris, strictus, nudus (rarissime folium vaginans infra spicas gerens), inferne obtusangulus glaber, superne angulis acutioribus hispidulus, reliquiis foliorum laceratis basi tectus. Folia radicalia culmo breviora, latitudine admodum varia, quædam setacea, alia lineam lata, scabra, margine hispida, superne attenuata. Spicæ 6-9 ferrugineæ, insigniter inæquales, 5-11 lineas longæ, 1-3 lineas latæ, ovatæ, quædam lineares, aliæ oblongo-ellipticæ. Spica terminalis ovata, apice conspicue mascula, ad ejus basin 1-3 arcte sessiles lineares tote masculæ vel flosculis foemineis paucis basi instructæ, ebracteatæ; intermediæ subsessiles approximatæ inferiores deorsum longius exserte pedunculatæ vel androgynæ vel tote fœmineæ; infima basi laxiflora et rarius composita (spicula unica basi aucta) subremota. Squamæ ferrugineæ nervo pallido margine albo-membranaceæ late ovatæ acuminatæ mucronulatæque dorso versus medium hispidæ. Pedunculi triquetri, hispidi, 2 lin. ad 2 poll. longi. Bracteæ foliaceæ angustæ sursum decrescentes, vaginatæ, inferior culmum paululum superans. Perigynium 2 1/3 lin. longum, lineam latum, ellipticum vel oblongo-ovatum, compressum, ore membranaceo oblique bifido, nervosum, superne ferrugineum hispidum, inferne pallidum glabrum, marginibus serrato-scabrum. Achenium oblongo-triquetrum, longe stipitatum, 7/9 lin. longum (cum stipite lineam longum) 4/9 lin. latum, pallide castaneum."—

To this, very excellent, diagnosis may be added, that the species is not cæspitose, but stoloniferous; nearly all the specimens, collected by Mr. Macoun, showed a cæspitose habit, but in some few plants there were long, horizontally creeping stolons, and Mr. Macoun informed us, that the soil in which the plants grew was so stiff, that it was almost impossible to lift them with the stolons attached. One of the most striking peculiarities in this

[1] In Hooker's Flora Bor. Am., vol. 2, p. 217. London, 1840.


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species is the manner in which the staminate and pistillate flowers are distributed, and in this respect *C. Franklinii* reminds very much of *C. petricosa* Dew.[2]

The number of spikes in Mr. Macoun's material did not exceed seven; the distribution of the flowers was as follows:

Terminal spike: mostly androgynous, very seldom purely staminate.
Uppermost lateral spike: staminate or androgynous, very seldom purely pistillate.
Second lateral spike: pistillate, seldom androgynous or staminate.
Third lateral spike: pistillate, very seldom androgynous.
Fourth lateral spike: pistillate, very seldom androgynous.
Fifth lateral spike: pistillate, in all the specimens.
Sixth lateral spike: pistillate, in all the specimens.

The squamæ of the staminate flowers show the same shape and color as those of the pistillate: broadly ovate with a short mucro; the color is light brown with purplish streaks, and the margins are hyaline; they are hispid on the dorsal face (fig. 2). The perigynium is elliptic with several thin veins, pale green at the base, purplish above, hispid, and scabrous along the margins; the beak is obliquely cut, hyaline (fig. 3), and the nut is distinctly stipitate (fig. 4).

The species resembles *C. petricosa* Dew., but is of a lighter color, and the squamæ are somewhat broader. A near ally of these species is *C. cruenta* Nees from the Himalayas, of which the superior spikes are frequently gynæcandrous, the inferior, on the other hand purely pistillate, and sometimes a little branched. The perigynium is narrowly lanceolate with a long beak, bilobed at maturity. In *C. fuliginosa* Schk. the terminal spike is always gynæcandrous, also in the var. *misandra* (R. Br.) O. F. Lang. It seems altogether characteristic of the *Stenocarpæ* to which these species belong, that the terminal as well as the lateral spikes are sometimes androgynous or gynæcandrous, and according to the distribution of the sexes and the structure of the inflorescence, the Stenocarpæ may be arranged as follows:

[2] The author: Remarks on the structure and affinities of some of Dewey's *Carices*. (This Journal, vol. 26, p. 488, November, 1908.)

Hebetatæ:

I. *Monostachyous*

a. dioecious: *C. lejocarpa* C. A. Mey.

b. monoecious: *C. circinata* C. A. Mey., *C. hakkodensis* Franch.

II. *Pliostachyous*

Spikes androgynous, sessile: *C. curvula* All.

Centrales:

III. Terminal spike staminate, the lateral pistillate: *C. mucronata* All., *C. sempervirens* Vill., *C. frigida* All., *C. ferruginea* Scop., *C. tristis* M. Bieb., *C. firma* Host, *C. hispidula* Gaud., *C. tenax* Reut., *C. setosa* Boott, *C. juncea* Willd., *C. stenantha* Franch. et Sav., *C. tenuis* Host, *C. hirtella* Drej., *C. luzulæfolia* W. Boott, *C. luzulina* Olney, *C. gynodynama* Olney, *C. Lemmonii* Boott, *C. albida* Bail., *C. macrolepis* D C.

IV. Terminal spike gynæcandrous: *C. fuliginosa* Schk., *C. psychrophila* Nees, *C. hæmatostoma* Nees, *C. cruenta* Nees.

V. Terminal spike, and some of the lateral androgynous: *C. petricosa* Dew., *C. Franklinii* Boott.

Desciscentes:

VI. All the spikes sometimes androgynous, single: *C. macrogyna* Turcz.

VII. All the spikes androgynous, fasciculate: *C. teinogyna* Boott, *C. longicruris* Nees, *C. insignis* Boott.

The grex is thus a very complete one, represented by dioecious and monoecious *hebetatæ,* passing through the singular *C. curvula* to the *centrales;* most of these show the ordinary habit with the terminal spike staminate, and the lateral pistillate; at the end of the *centrales* are some few species with the terminal spike gynæcandrous, passing into the peculiar species *C. petricosa* and *C. Franklinii.* Among the *desciscentes C. macrogyna* with the spikes androgynous, but single, passes into the most evolute types of the grex *C. teinogyna, C. longicruris,* and *C. insignis* with the androgynous spikes fasciculate; of these the two former are distigmatic with the beak of utriculus distinctly bidentate, while *C. insignis* is tristigmatic with the beak entire. A bidentate beak is also characteristic of several of the centrales, viz.: *C. frigida,* *C. tenuis, C. psychrophila* etc., but otherwise the orifice of the beak is mostly obliquely cut or emarginate; it is truncate in *C. juncea.*

The geographical distribution of the grex extends throughout the northern hemisphere. *C. fuliginosa β misandra* is circumpolar, and occurs beside on the mountains of northern and middle Europe, and on the Rocky Mountains as far south as middle Colorado. Many of the *centrales* are confined to the European Alps, several to the mountains of India and Japan, while only a few are indigenous to this continent, California, Nevada, the mountains of British Columbia, Alberta and Washington.—Of the monostachyous *hebetatæ C. hakkodensis* is a native of Japan, the two others of Alaska and adjacent islands. With regard to the *desciscentes,* these are natives of central and eastern Asia.

The *Stenocarpæ* occupy a position between *Athrochlænæ* and *Podogynæ;* of the former only monostachyous species are known: *C. pyrenaica* Wahlenb, and *C. nigricans* C. A. Mey, and they are distinct from the *hebetatæ* of the *Stenocarpæ* by the perigynium being divaricate or more or less reflexed at maturity, and prominently stipitate. Characteristic of the *Podogynæ* is the spreading perigynium borne on a very long, ciliate stipe.

Carex spectabilis Dew.

Although well defined by Dewey, in this Journal (vol. **29**, 1836), *Carex spectabilis* was lost for quite a number of years;[3] it was distributed by Olney under the name *C. podocarpa* R. Br. (Gray Herbarium); it was described by Professor L. H. Bailey as a new species: *C. invisa* (1886), and placed among the *Acutæ* Fries, all of which are distigmatic however; at the same time it was referred by Professor Bailey to *C. macrochæta* C. A. Mey. as a mere synonym; furthermore by G. Kükenthal (in litteris April, 1902) it was named *C. macrochæta* var. *pseudopodocarpa* and said to be identical with the distigmatic (!) *C. invisa* Bail., while finally in "Das Pflanzenreich" (1909) still another disposition was made by this same author, referring the plant to *C. Tolmiei* Boott. As late as 1895 the species was identified at the Her-

[3] The author: New or little known species of *Carex* (this Journal, vol. 17, p. 306, April, 1904), and: The *Cyperaceæ* of the Chilliwack Valley, British Columbia (l. c. vol. 18, p. 17, July, 1904).

barium of Harvard University as *C. atrata* L., the specimens having been collected by O. D. Allen in the Cascade Mountains, Washington. According to C. B. Clarke (in litteris December 9th, 1903): "Boott's *C. podocarpa* (minime R. Brown) is made up of *C. macrochæta* C. A. Mey., with *C. spectabilis* Dewey thrown in. I do not say this is wrong, i. e. I think *spectabilis* may be esteemed a var. of *macrochæta.* I think it is morally certain that the pieces named *C. spectabilis* Dew. by Boott's hand are Dewey's plant, and perhaps named by Dewey himself."—Now with respect to the more recent disposition by Kükenthal (l. c.) as var. *invisa* (Bail.) Kthl. of *C. Tolmiei* Boott, this cannot be accepted, since Dewey's name is much older, and especially not, because Kükenthal includes the plant, which Kjellman collected on the Vega Expedition (1882) and identified as *C. podocarpa,* but which proved to be *C. macrochæta* C. A. Mey.—

Concerning *C. Tolmiei* Boott, C. B. Clarke has given a very important account[4] of the material in herb. Boott, and of some of that in herb. Kew, which Boott probably saw, and we learn from this paper that the figure t. 299 in Illustr. *Carex* is taken wholly from the original specimens collected by Tolmie, while the diagnosis (l. c. p. 100) includes four other plants, and probably some others marked "*C. Tolmiei*" in herb. Kew—By Clarke a diagnosis is furnished of Tolmie's specimens, and by comparing this and the figures with *C. spectabilis* Dew. it is readily to be seen that these plants are specifically distinct. And so far as concerns *C. macrochæta* C. A. Mey., so excellently described and figured by C. A. Meyer,[5] this plant cannot be regarded as identical with Dewey's plant, nor as any near ally of this.—

However *C. spectabilis* Dew. is quite a variable plant, and the identification of the forms and varieties, when disconnected, is often a difficult task, especially when dealing with material from the subalpine and alpine regions. Typical *C. spectabilis,* moreover, deviates sometimes from the diagnosis, presented by Dewey. For instance the staminate spike is not always solitary; there are not infrequently two. The pistillate spikes are

[4] Clarke, C. B.: Note on *Carex Tolmiei* Boott (Jour. Linn. Soc., vol. 35, p. 403, 1902).

[5] Meyer, C. A.: Cyperaceæ novæ descriptionibus et iconibus illustratæ. (Mém. Savants Etrangers St. Petersbourg, Tome 1, p. 30, 1831.)

most frequently two, but three to four may also occur, and even five, though very seldom; the squamæ of the pistillate flowers vary from acute to aristate (fig. 5), and their color varies from reddish brown, the most common, to dark purplish. Also the perigynium exhibits some variation with respect to the orifice of the beak, slightly emarginate to distinctly bidentate (fig. 6), as well as the venation, the marginal veins being sometimes the only ones visible. The nut is always prominently stipitate. In the very copious material, which we have received from Mr. James M. Macoun, collected on Vancouver Island, British Columbia and Alberta, and from Mr. W. N. Suksdorf, collected in the mountains of Washington, we have been able to distinguish some forms and varieties as follows:

forma 1. *chrysantha* nob.—Squamæ utriculique flavescentes, cæterum ut forma typica. Washington: Mount Paddo at an elevation of 2000 m.

forma 2. *alpina* nob.—Spiculæ breviores ± remotæ sessiles vel ima pedunculata. Squamæ plerumque nigricantes. (Fig. 15.) Washington: Mount Paddo at an elevation of 2,300 m. British Columbia: Vancouver Island, Alberta.

Var. *β*. *superba* nob.—Rhizoma stoloniferum. Culmus 15-65 cm. altus apice cernuus. Spiculæ ♀ 2½-3 cm. longæ, graciles, inferiores longe-pedunculatæ, fere cernuæ, nigricantes. Squamæ atro-purpureæ e carina viridi longe scabro-aristatæ. Utriculi squamis latiores aristis breviores stramineo-virides atro-purpureo-maculati, in rostrum breve ore bidentato atro-purpureo contracti. (Figs. 10-12.) Alberta: Mount Edith Cavell, Fitzhugh Mt., on damp slopes, by brooks and springs.

Var. *γ* *elegantula* nob.—Culmus tenuis, apice cernuus. Spiculæ ♀ laxiores longe capillari-pedunculatæ, cernuæ. Squamæ ♀ emarginatæ aristatæ. Utriculi squamis latiores aristis breviores stramineo-virides parce atropurpureo-maculati in rostrum breve ore emarginato attenuati, cæterum ut var. *β*. (Figs. 13-14.) British Columbia: Selese Mt., Chilliwack Valley.

♀ Var. *δ* *gelida* nob.—Spiculæ 2-4 crassiores, contiguæ breviter pedunculatæ, nigricantes. Squamæ ♀ mucronatæ atro-purpureæ e carina viridi tenuissima breviter aristatæ. Utriculi squamis latiores aristis breviores dense atropurpureo-maculati in rostrum breve ore emarginato attenuati. (Figs. 7-9.) Alberta: above timber-line, Mt. Edith Cavell; British Columbia: Asulcan Glacier; Washington: Mount Paddo, about 2,000 m. alt.

Very conspicuous is the variation expressed by the two varieties *superba* and *elegantula,* in which the squamæ of the pistillate as well as the staminate flowers are aristate; in all the others, including the typical plant, the squamæ of the staminate flowers are obtuse with no indication of a mucro.

While the typical plant inhabits open, grassy slopes of the mountains below timber-line, the vars. *superba* and *elegantula* follow the water-courses, bordered with thickets; the var. *gelida* and the forma *alpina* occur at higher elevations, passing the timber-line; the forma *chrysantha* grows with the type.

And although these plants exhibit quite a different aspect with regard to habit, densely matted or stoloniferous, and color of spikes, they nevertheless may be readily referred to one species, *C. spectabilis* Dew. A corresponding variation is known from a number of other *Carices,* so excellently described by N. I. Andersson,[6] with reference to *C. vesicaria* L., *C. Buxbaumii* Wahlenb., *C. rigida* Good, etc.

Thus at middle elevations in the mountains we find the typical plant growing on open grassy, stony slopes; the rhizome is densely matted, the spikes pedunculate, remote, spreading; the staminate and pistillate spikes with reddish-brown squamæ, the former obtuse, the latter mucronate; the perigynium mostly pale green with the beak bidentate or, sometimes merely emarginate. In the thickets, that border the mountain-brooks, the var. *superba* occurs; a taller and more slender plant than the type; the rhizome bears long, ascending stolons, and the culm is slightly nodding at apex; the spikes are longer, and the pistillate almost nodding, borne on long, slender peduncles; all the spikes are of a dark, almost black color, and the squamæ are aristate; the perigynium is purplish spotted, and the beak distinctly bidentate. At similar situations in the Chilliwack Valley the var. *elegantula* occurs with the same habit and color, but even more slender in all respects, with the squamæ emarginate, aristate and with the slender perigynium merely emarginate. Just above timber-line the var.

[6] Andersson, N. I.: Skandinaviens Cyperaceer. Stockholm, 1849.

gelida appears; it is of lower stature than the type; the spikes are more or less contiguous, erect; the squamæ are mucronate, of a dark purplish color; the perigynium is also of a dark color, with the beak merely emarginate. At higher elevations we meet with the alpine form with the culms and leaves short, with the spikes, including the staminate, very short and thick; the squamæ are almost black, while the perigynium is pale green, and the orifice of the beak slightly emarginate. By comparing the habit and structure of these various plants, the varieties *elegantula* and *superba* may be defined as sciaphilous, the others as heliophilous types, and the correlation between environment and structure seems well marked in these.

If we compare now these various plants, representing *C. spectabilis* Dew., with *C. macrochæta* C. A. Mey., as suggested by Clarke (in litteris, l. c.), they certainly appear specifically distinct. In typical *C. macrochæta* as well as in the varieties *emarginata* nob., and *macrochlæna* nob.[7] the perigynium is pale green above, whitish below, distinctly several-nerved, and the beak is entire; the nut is not stipitate. The squamæ of the staminate and pistillate flowers are prominently aristate in the type and the var. *emarginata,* while simply mucronate in var. *macrochlæna.* In all the plants the rhizome is densely matted, the spikes drooping on long filiform peduncles, and the squamæ are black with the arista light green. A striking analogy exists between the two varieties *elegantula* (*C. spectabilis*) and *emarginata* (*C. macrochæta*), but the habit is quite distinct, beside the structure and color of the perigynia. With respect to the systematic position of these two species, we have placed *C. spectabilis* Dew.[8] as a desciscent type of the *Melananthæ,* allied to *C. Tolmiei* Boott and *C. Montanensis* Bail. *C. macrochæta,* on the other hand, we have placed in the grex *Æorastachyæ* on account of the drooping spikes, and the structure of utriculus. As defined by Drejer the *Æorastachyæ* comprise mostly distigmatic species, but pass gradually into some tristigmatic, the most evolute species of the grex, viz: *C. nesophila* nob., *C. macrochæta* C. A. Mey., *C. Magellanica* Lam. (with all the spikes gynæcandrous), etc.—

[7] The author: New or little known species of *Carex* (l. c.)
[8] The author: Greges Caricum (this Journal, vol. 16, p. 445, Dec., 1903)

The *Melananthæ* constitute a very interesting grex of which the "*formæ hebetatæ*" resemble certain *Vigneæ*, the terminal spike being gynæcandrous, and the lateral pistillate, all contiguous and forming a roundish head: *C. alpina* Sw., *C. melanantha* C. A. Mey., and *C. melanocephala* Turcz. (*C. nova* Bail.). The central types begin with *C. atrata* L. and its allies, culminating in *C. Mertensii* Presc. with all the spikes *gynæcandrous*. Through *C. Parryana* Dew. with the terminal spike varying from gynæcandrous to purely staminate, the *centrales* pass into *C. stylosa* C. A. Mey., *C. Raynoldsii* Dew. and *C. holostoma* Drej. with the terminal spike invariably staminate. As the most evolute of the centrales we have placed *C. Buxbaumii* Wahlenb. and its allies; characteristic of these is the terminal spike being gynæcandrous, the lateral pistillate and more or less remote. Some deviating types "*desciscentes*" we have placed at the end of the grex, among which are *C. ustulata* Wahlenb. with the terminal spike occasionally gynæcandrous, *C. venustula* nob., *C. Montanensis* Bail., *C. spectabilis* Dew. and a few others, of which the perigynia represent the structure characteristic of the grex.

While thus the "*hebetatæ*" remind of the *Vigneæ*, the central types agree very well with *Carices genuinæ*, and through some of these, notably *C. holostoma, C. stylosa* and *C. Raynoldsii*, the grex forms a transition to the *Microrhynchæ*; through *C. spectabilis* and *C. Montanensis* to the *Aeorastachyæ*, when we consider the two varieties, described in the preceding: *β superba*, and *γ elegantula*.

As may be seen from the preceding discussion of these greges, *Stenocarpæ* and *Melananthæ*, the morphological structure of the shoot, the subterranean as well as the aerial, constitutes no characters of importance for the classification of the species into greges. Thus in the *Stenocarpæ* the aphyllopodic *C. tenuis* Host. is of course, inseparable from the other members of the grex, most of which are phyllopodic. And with respect to the *Melananthæ* the phyllopodic *C. ustulata* Wahlenb. and *C. microchæta* nob. share the most essential characters with the aphyllopodic *C. Tolmiei* Boott and *C. spectabilis* Dew. Similar cases may be recorded from several of the other greges, notably the *Microrhynchæ*, where such deviation in shoot structure characterizes species so closely allied as *C. cæspitosa* L., *C. Hudsonii* A. Benn. (*C. stricta* Good.) on the one side, and *C. vulgaris* Fries, *C. turfosa* Fries on the other. Furthermore in the *Dactylostachyæ* both types of shoots are equally frequent, while the other structures are nearly the same. A monopodial ramification is relatively rare, but well marked in *C. digitata* L., *C. maxima* Scop., and indeed quite frequent in the *Lejochlænæ*. But neither the rare monopodium nor the very little frequent aphyllopodic culm play any rôle of importance to the establishment of the greges, although both constitute characters that are absolutely constant.—

EXPLANATION OF FIGURES.

FIG. 1. Carex Franklinii Boott, the inflorescence, natural size.
FIG. 2. Same species, scale of a pistillate flower; enlarged.
FIG. 3. Same species, perigynium, ventral face; enlarged.
FIG. 4. Same species, perigynium, longitud. section to show the stipitate ovary; enlarged.
FIG. 5. *Carex spectabilis* Dew., scale of pistillate flower; enlarged.
FIG. 6. Same species, perigynium; enlarged.
FIG. 7. Same species, var. *gelida* nob. from Alberta; the inflorescence; natural size.
FIG. 8. Same species, var. *gelida*, scale of pistillate flower, side view; enlarged.
FIG. 9. Same species, var. *gelida*, perigynium; enlarged.
FIG. 10. Same species, var. *superba* nob. from Alberta; the inflorescence; natural size.
FIG. 11. Same species, var. *superba*, scale of pistillate flower; enlarged.
FIG. 12. Same species, var. *superba*, perigynium; enlarged.
FIG. 13. Same species, var. *elegantula* nob. from British Columbia, scale of pistillate flower, side view; enlarged.
FIG. 14. Same species, var. *elegantula*, perigynium; enlarged.
FIG. 15. Same species, forma *alpina* nob. from Alberta, the inflorescence; natural size.

Clinton, Md., January, 1920.

ART. XVI.—*The Evolution of Flowering Plants and Warm-blooded Animals;* by EDWARD W. BERRY.

I do not recall that anyone has directed attention to the practically contemporaneous evolution of warm-blooded animals and the so-called flowering plants. As a simple matter of geologic record this has doubtless been done but no one has suggested the correlation of these striking events, which in each case represent the climacteric development of the respective kingdoms.

As regards the known geological records the first mammals antedate the first birds and both antedate the flowering plants, and the last group furnish evidence of their late Mesozoic differentiation which the mammals do not, except as this is inferred from the sudden appearance of mammals in previously unknown variety in the early Eocene.

The actual ancestry of the flowering plants is still shrouded in the mists of ignorance. Historically their earliest appearance in the geological record is in late Lower Cretaceous time where they are represented by leaf remains and petrified wood. These earliest known types do not appear to be primitive and the fact that they have been found in such widely separated regions as Europe, Greenland, North America, New Zealand and Australia justifies the assumption that they must have had an extended and as yet unknown antecedent history running back well into the older Mesozoic although they could not have become fully differentiated, abundant or varied in those earlier and more or less hypothetical days.

A characteristic feature of the flowering plants, not shared by the members of any other plant phylum, is that the ovary is closed and that after fertilization it, together with various accessory parts, develops into a fruit or pericarp. The production of fruit, using that term in the technical rather than in the popular sense, is a characteristic feature of the flowering plants, and the mere fact that fruit is a vernacular as well as a scientific term lends emphasis to the point that I wish to elaborate.

Plants, like all other organisms, are concerned chiefly with problems of nutrition and reproduction. The formation of seeds, an event which occurred during the Paleozoic, was an exceedingly great step in advance over the spore-forming habit of the earlier stocks—the present day dominance of the seed plants furnishing the proof of this statement, if proof be considered necessary. Fruit forming, which is of a different category from seed formation, is not only a protective device for the seeds with their concentrated food stuffs stored away for utilization by the germinating plantlet, it is also the great factor in distribution.

The methods by which this is effected are endless, including wings for flying, hooks and burrs for clinging, tension apparatuses for forcibly expelling the seeds, various floating devices, birdlime-like outer surfaces for sticking to birds or mammals, soft attractive pulps enclosing crustaceous seeds that pass uninjured through the alimentary canals of birds, and a thousand and one other methods.

The trends of floral evolution afford an analogous example of correlated modifications between the animal and plant kingdoms. The floral envelopes of primitive or anemophilous flowers are inconspicuous scales serving merely for protective purposes. In the specialized or entomophilous flowers these scales have been replaced by more or less conspicuous, often highly specialized and brightly colored floral parts, results of the advantages of cross fertilization through the agency of insect and bird visitors. Enthusiastic students have frequently insisted on the extent to which flower and insect structures have been influenced by these mutually beneficial adaptations.

A somewhat similar modification has taken place in the fruits of a large number of the flowering plants, and there is no reason to doubt that the bloom, odor, color and flavor of the pulpy fruits are adaptations for their distribution by animals—chiefly birds. There is a vast volume of literature relating to the distribution of plants by birds but the extent to which birds are factors in the distribution of perishable seeds like those of peas, beans or grains is not generally realized. In our latitudes these types of seeds are ripe at about the time that the Fall migration of birds commences. Migration is, however, not especially relevant since ordinary avian activities are quite sufficient except in such cases as involve the seeding of insular or remote regions. Digestion is suspended during flight, or largely so, and if a bird with a full crop meets an untimely end as is so often the case, the chances of uninjured seeds sprouting from the crop are not at all slim. Actual instances have been recorded and this must happen often enough to be of importance. The voiding or passing of uninjured seeds by active birds who overeat or are not healthy is also a factor of importance in distribution.

I do not wish, however, to dwell upon distribution, nor upon the evolution of fruits as influenced by mutual adaptations between them and birds or other animals. The two points that I wish to emphasize are (1) The approximate contemporaneity between the evolution of fruit and seed-bearing plants[1] and warm-blooded animals, and (2) The improbability of the evolution of the latter had not the former taken place.

Turning to the geologic record of the warm-blooded animals, it may be noted that the oldest known bird, *Archaeopteryx,* partly reptilian in character, comes from the upper Jurassic and was a carnivorous type, as were also the toothed birds of the Cretaceous. There are no records of frugivorous birds, or in fact any modern birds until a time subsequent to the differentiation of numerous families of flowering plants.

The geologic record of the primitive mammals is exceedingly imperfect. The earliest known are recorded from the upper Triassic of Europe, North America (Keuper of North Carolina) and South Africa (Stormberg beds). Essentially similar Prototherian or Metatherian types are present in the Stonesfield slates and Purbeck beds of England, in the supposed Jurassic of South Africa, and in the Cretaceous of North America, and possibly Patagonia. They survived as the archaic mammals of the earliest known Eocene (Paleocene of authors) terrestrial faunas.

Disregarding the obvious elements of unreliability in all estimates of the duration of geologic time, it is not without significance that most estimates of the length of time between the oldest known mammals of the Triassic and the great evolutionary deployment of their stock in the Eocene, are much longer than the interval between the first appearance of modern types and their culmination in the Pleistocene in all of the mammalian families including the pre-human and human races. Measured in results the differentiation of birds and mammals in the relatively short Cenozoic was far more profound than

[1] I refer, of course, to the angiosperm phylum.

anything that occurred during the long ages of the Mesozoic.

That the evolution of the higher plants was one of the important factors in this comparatively sudden efflorescence of the mammal and bird stocks cannot be doubted. The small Prototheria of the Triassic did not change greatly during the lapse of ages because the food supply did not change greatly and because of the competition for it of the reigning race of reptiles, and it may be suggested that the changing food supply due to the evolution of the flowering plants and which is suggested as one of the important factors in the evolution of the higher mammals, was also one of the factors that spelled the doom of the overgrown and specialized Reptilia of the Mesozoic.

The earliest mammals appear to have been insectivorous. The various orders of insects are old geologically and that they existed comfortably before the higher plants were evolved is obvious, but that the latter became an attractive source of food and were the stimulus for very many new genera and species cannot be doubted. Thus indirectly the flowering plants greatly increased the food supply of the insectivorous mammals. The Rodentia, Edentata and Primates depend almost entirely upon the flowering plants for food, as do the Ungulata, and indirectly the Carnivora, since the latter group is chiefly dependent on the aforementioned groups and to a less extent upon birds or cold blooded prey.

Upper Cretaceous floras furnish a large number of types of great food value, and among fruits—palm nuts, figs, walnuts, persimmons, etc. Very many fleshy fruits are found in the Eocene floras and these even include among their number such specialized fruits as dates and zapodillas (*Eoachras*). The *Ptilodus* skull described by Gidley (1909) from the Fort Union Eocene of Montana not only proved the marsupial character of that genus, but showed considerable dental specialization which its describer attributed to frugivorous habits.

The relatively sudden differentiation of flowering plants immediately antecedent to the equally sudden differentiation of the Eocene Mammalia was not fortuitous but the two series of events are to be correlated. Both were largely accomplished during a time when the sea had retreated for the most part from the continents and land surfaces were much extended. This also was possibly an evolutionary factor in both kingdoms as were any climatic changes that may have taken place. It is clear that the long period of land emergence that intervened between the time of deposition of the latest Cretaceous and the earliest Eocene marine sediments in most regions was the theater of evolution of the modernized plants and animals of the Eocene record.

There is considerable misapprehension of the known earlier records of the flowering plants and the statement is frequently made that the mid-Cretaceous marks the beginning of Cenozoic in so far as plants are concerned. Although it is true that they appeared in considerable numbers during the Upper Cretaceous the change in floras from Cretaceous to Eocene times was fully as great as among other groups of organisms and is similarly marked by the disappearance of the archaic types especially characteristic of the Mesozoic and a great modernization such as also occurred among the mammalia.

It requires but little argument to prove that human civilization could scarcely have been attained but for the presence of the flowering plants. Although the prehuman and eohuman races were largely carnivorous and supplemented a diet of flesh, fish and fowl (including shellfish) by such fruits and seeds as nature furnished them, and although certain existing races, such as the Esquimaux, maintain themselves without agriculture, the civilizations of history have all had their basis in an agricultural society, and as far as I recall all crop plants (except such unimportant foods as fungi, seaweed, etc.) of all races, ancient or modern, are angiosperms or flowering plants.

It is only by agriculture that large numbers in settled communities can be sustained and the flower of progress can bloom. Instances of the greatest production of concentrated energy are furnished by some of the grains, one third of the total weight of the whole plant being represented by the concentrated food stuffs of the seeds. Game, even as abundant and as stupid as was the bison of our western prairies, could not afford a basis for a civilization, and even in this instance it might be recalled that the basis of the abundance of the bison was the fodder furnished by members of the angiosperm alliance. Similarly the food of the camels, sheep, goats and horses of the nomadic races was this type of plant.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Mathematical Proof that the Atomic Weights are Integers when $O = 16$.*—This is an attempt to prove, on the ground of mathematical probability, the old hypothesis of Prout, which was advanced in 1815 and claimed that the atomic weights were exact multiples of that of hydrogen, and, consequently, when the latter was taken as unity were exact whole numbers. This old hypothesis has been conspicuous in the attention of chemists for more than a century and it has been one of the incentives for very accurate atomic weight determinations; for it has been always evident that many atomic weights were at least very near the hypothetical values. It may be stated, however, that our modern researches upon atomic weights, especially those of Richards and his co-workers, appear to have entirely disproved Prout's hypothesis as an exact and general statement.

The author of the article under consideration argues clearly and with evident accuracy that since 20 of the first 25 atomic weights (in the order of their magnitude) do not vary more than 0·1 from whole numbers there is only one chance in one billion that this is accidental. The fact must be admitted that there is an extensive approximation to Prout's hypothesis among the elements, and this is fully appreciated by chemists, but the author's deduction that the only possible interpretation of this fact is that all the atomic weights are integers cannot be granted because we have too much confidence in many of our atomic weights to admit that they are erroneous to such an extent; for instance, that sulphur, 32·06, and potassium, 39·10, are really 32·00 and 39·00, and it is even more difficult to believe that magnesium, 24·32, and chlorine 35·46 can be integers.

Fortunately we are gaining some insight into the structure of atoms with the knowledge that helium atoms are discharged in radioactive transformations, and from the study of electrons, while the recent discovery by Rutherford that hydrogen atoms are set free from nitrogen by the bombardment of the helium atoms from radium is very suggestive, and it is to be hoped that further knowledge as to the reasons for atomic weights will soon be obtained.—*Chem. News,* **119**, 247. H. L. W.

2. *The Activation of Carbon.*—In a paper presented before the American Electro-Chemical Society, N. K. Chaney has given a new viewpoint on the general nature of amorphous carbon, resulting from a study of defensive methods against toxic gases used in warfare. It appears that there are two kinds of amorphous carbon, one of them an active adsorbent of gases, the other possessing no adsorptive capacity. The active modifica-

tion is formed whenever carbon is deposited by chemical or thermal decomposition of carbon-bearing materials at relatively low temperatures, generally below 500 to 600° C., while the inactive form results from similar decompositions above this temperature. The active carbon may adsorb hydrocarbons immediately after its formation so that its power for combining with other substances is lessened, but it is possible to activate such a product by removing the hydrocarbons by distillation in presence of air, steam, or carbon dioxide at low temperatures, for instance in air at 300° C. It is interesting to know that anthracite and bituminous coal contain the active form of carbon, and that it may be prepared from these sources by the processes of activation just mentioned. The author says that the unique properties of this material, both as a catalyst and adsorbent suggest that it will find many industrial applications.—*Canadian Chem. Jour.*, **3**, No. 11. H. L. W.

3. *On the Sulphite Method for the Separation and Determination of Gallium when Associated with Zinc.*—LYMAN E. PORTER and PHILIP E. BROWNING have applied hydrogen sodium sulphite and hydrogen ammonium sulphite for the qualitative and quantitative separation of gallium from moderate amounts of zinc. For the qualitative tests about 5 cc. of the neutral or slightly acid solution was boiled for two minutes after the addition of sodium sulphite. The precipitate indicating gallium is filtered off after settling and hydrochloric acid is added to the filtrate, followed by potassium ferrocyanide, when a precipitate indicates zinc. Under these conditions as little as 0·0002 g. of gallium and 0·0003 g. of zinc could be detected, either when one was absent or both present. The method was found to be satisfactory for quantitative work on account of the granular nature of the precipitate. It is convenient to precipitate the gallium in a volume of about 200 cc. of neutral or slightly acid solution by adding 4 or 5 cc. of hydrogen ammonium sulphite (made by saturating 1:4 ammonia solution with SO_2) boiling for from 3 to 5 minutes, allowing the precipitate to settle, decanting the supernatant liquid through a filter, dissolving the precipitate left in the beaker with a few drops of hydrochloric acid, then, after adding about 200 cc. of water repeating the precipitation, and filtering off on the original paper. The method of washing is not described, but the precipitate is ignited and weighed as Ga_2O_3. The results of the test analyses, some of them made in the presence of 0·1 to 0·35 g. of zinc chloride, show remarkably close results on quantities of gallium oxide varying from 0·015 to 0·047 g.—*Jour. Amer. Chem. Soc.*, **41**, 1491. H. L. W.

4. *The Spectra of Isotropic Lead and Thallium.*—In a recent communication before the Royal Society it was stated by T. R. MERTON that interferometer measurements of the principal line in the spectra of ordinary lead and of lead from

pitchblende showed that in the latter case the line was less refrangible by 0·005A., while the line given by lead from Ceylon thorite was more refrangible by 0·0022A. Thallium, which occurs in pitchblende in very small quantity, was found to give a line more refrangible than ordinary thallium by 0·0055A. These facts are interesting in giving, in the case of lead, another physical property, besides atomic weight and specific gravity, in which the metal produced by radioactive transformations differs from the ordinary metal.—*Chem. News,* **119**, 281. H. L. W.

5. *The Petroleum Handbook;* by STEPHEN O. ANDROS. 16mo, pp. 206. Chicago, 1919 (The Shaw Publishing Company. Price $2.00).—This book is chiefly a compilation made from many sources with excellent judgment and covering all phases of the petroleum industry from the location of oil wells to the delivery of the refined products to consumers. It deals with the origin and occurrence of the substance, exploration and drilling, refining, natural gas, the shale-oil industry, the marketing of the products, and with special topics in connection with gasoline. The book is well illustrated by figures, and it contains many interesting tables of statistics. It is a very useful book for those who desire to obtain a knowledge of the scientific and technical aspects of this great industry. H. L. W.

6. *Secret Signalling by Light Rays.*—Of the numerous ingenious applications of scientific knowledge to the solution of problems which were emphasized by the world war, one at least is of sufficient general interest to merit attention in this place. More specifically, reference is here made to the investigations of R. W. WOOD on the sending and receiving of signals by means of light waves, both within and beyond the confines of the visible spectrum. Ordinary parabolic mirrors are not suitable for sending signals over long distances, from the rear to the front, because the field covered by the cross-section of the inaccurate beam is so large as to incur the risk of including a portion of the enemy's trenches simultaneously with the proper receiving station. This prohibitive characteristic is entirely avoided in Wood's "flash telescope."

This apparatus consisted primarily of a telescope having a tungsten lamp at the common focus of the objective and ocular. The objective was a non-cemented doublet, of three inch linear aperture, corrected to have the same focal length for the near infra-red and for a certain wave-length in the ultra-violet. The tungsten lamp was of the nitrogen filled type containing a very short spiral filament. With the low power ocular employed, the total magnification produced by the telescope was about fourteen fold. The focusing was effected by moving the objective along its optic axis, the position of the lamp being invariable relatively to the telescope tube, etc. The filter wheel was placed between the lamp and the objective. By rotating this wheel so as to interpose the proper ray-filter in the path of the beam of light, it was possible to flash signals either with white, or with infra-red, or with ultra-violet light. To use the telescope it was only necessary to point the tube in such a direction as to cause the image of the lamp filament to be accurately superposed upon the inverted image of the receiving station. As regards efficiency, the following comparative data may be mentioned. A parabolic reflecting lamp of 35 cm. aperture carries less than 10 km. The flash-telescope, when used in broad daylight, carries 30 km., while using less than one-half the power consumed by the search light.

Some additional advantages of Wood's telescope are: (a) the beam of light is a very narrow cone (cross-section about 6 ft. at a distance of 1 mile) so that secrecy is assured, (b) the telescope can be aimed with great precision, (c) the instrument can be used as a receiver of signals sent out by a very distant station, and (d) ordinary displacements of the lamp with respect to the tube, arising from shocks incident upon transportation, have no deleterious influence on the accuracy of pointing. Case (d) does not hold true for parabolic reflecting lamps.

When conditions were such as to preclude the use of white signals in full daylight, the difficulty was overcome by employing radiations between $\lambda 6900$ and $\lambda 7500$. The ray filters were made, in the well-known way, by staining gelatin with appropriate aniline dyes. In general, the filter was compound, one gelatin sheet being stained with cyanin and the superposed plate with almost any deep orange coloring matter. The flash-telescope was always provided with two infra-red screens, the brighter and darker filters being best suited for signalling over distances from two to six miles, and under two miles, respectively. By using spectacles or field glasses, etc., in conjunction with color screens of the same kind as in the sending apparatus, the dazzling daylight was decreased in intensity to a very much greater degree than the infra-red radiations, thus causing the distant signal lamp to assume the appearance of a brilliant star on an approximately black landscape.

Secret signalling at night was accomplished by using ultra-violet rays. The filters consisted of circular discs of black glass having an oxide of nickel as the coloring base. The receiving apparatus was essentially a short focus telescope, of very wide aperture, provided with a screen coated with barium platino-cyanide and coinciding with a focal plane of the condensing objective. This screen was viewed through a small ocular. The ultra-violet light was not transmitted by the screen, of course, but the focal spot was made visible by the bright green phosphorescence of the barium compound. With the less dense filters signals were received at a distance of 5·5 miles, and with the deeper filters at 2·5 miles.

To establish large beacons or reference points for naval and aeronautical purposes the best results were obtained by using a quartz mercury arc covered with a screen of nickel glass. The small amount of red light which would be transmitted by this kind of glass is not emitted by the mercury arc so that, beyond very short distances, the screened lamp is not visible to the unaided eye. On the other hand, the powerful mercury line at λ3650 falls exactly at the center of the transmission band of nickel glass. By employing an appropriate phosphorescent detecting apparatus, a lamp arranged in the manner just suggested has been seen by an observer in an aeroplane flying at an elevation of 3,000 meters.

In addition to the practical applications of the ultra-violet lamp, the original paper contains an interesting account of certain striking phenomena which occur when various objects are illuminated with ultra-violet light of practically a single wave-length. For example, the lens of the human eye becomes phosphorescent. The skin assumes a peculiar hue, natural teeth phosphoresce brilliantly, false teeth appear black, etc. By using a very dilute solution of potassium chromate, the author has taken photographs (reproduced in the paper) of his face and of one hand. This filter transmits the radiations that excite the phosphorescent screen, but it completely absorbs the ultra-violet rays reflected and scattered by the skin. Old cicatrices, ordinarily invisible, come out with great distinctness. In this connection, the author suggests the possibility of taking advantage of these phenomena in physiological researches.—*Jour. de Phys.*, **9**, 77, 1919. H. S. U.

7. *The Air Propeller;* by FREDERICK BEDELL. Pp. 96, 22 figures. New York, 1919 (D. Van Nostrand Co.).—This book deals primarily with the working characteristics and theory of the air propeller, but it also contains a brief discussion of the airplane engine and the power available for airplane propulsion. The author's style is lucid and the text is profusely illustrated by clear-cut diagrams each of which occupies a full page. The appendix comprises a glossary of technical terms, alphabetically arranged, and a few supplementary diagrams relating to "power required." It is the intention of the author and publishers to form six chapters of a new volume by combining the present text with the book entitled "Airplane Characteristics" (see **46**, 691, 1918). H. S. U.

8. *Smithsonian Meteorological Tables. Fourth Revised Edition.* (Publication 2493.) Pp. lxxii, 261, with 107 tables and an index. Washington, 1918. Smithsonian Misc. Collections, vol. 69, No. 1.—This edition has been corrected to January, 1918. Many of the tables have been subjected to extensive revision based upon the new vapor pressure tables, the recomputed table of the relative acceleration of gravity at different latitudes, and

the recent more accurate determination of the density of mercury.

Among the new tables added may be mentioned those for converting barometric inches and millimeters into millibars, for determining heights from pressures expressed in dynamic units, tables of gradient winds, and tables giving the duration of astronomical and civil twilight, and the transmission percentages of radiation through moist air. Certain tables, chiefly mathematical, have been omitted from the latest edition. It is thus evident that the value of this useful book has been greatly enhanced by the thorough revision which it has recently received.

H. S. U.

9. *Accounts Rendered of Work Done and Things Seen;* by J. Y. BUCHANAN. Pp. lvii, 435. Cambridge, 1919 (University Press).—This volume is essentially a collection of thirty-three papers written by the author at different times and dealing with a variety of subjects. In general, however, the field of observation is restricted to oceanography, and to such allied lines of research as would interest the chief physical-chemist of the Challenger expedition. The papers are reproduced in their original form, and all notes or comments on the articles themselves, as well as reminiscences regarding the circumstances in which they appeared, are embodied in the Contents (pages vii to lvii), and occasionally in postscripts to the papers.

Many of the topics are of a sufficiently non-technical nature to afford very interesting and instructive material for the general reader. As examples of this type may be mentioned: "The Sperm Whale and its Food, The Oceanographical Museum at Monaco, The Wreck of the 'Santos Dumont No. 6' at Monaco, . . ., and The Daintiness of the Rat." The text is profusely illustrated with excellent figures and plates, and it forms a valuable companion volume to the earlier collection of papers by the same author entitled "Comptes Rendus of Observation and Reasoning" (see **47**, 139, 1919). H. S. U.

10. *La Tension de Vapeur des Mélanges de Liquides. L'Azéotropisme. Part I;* by MAURICE LECAT. Pp. xii, 319. Brussels, 1918 (H. Lamertin).—The primary object of the entire work is to present the results already obtained and to facilitate the future study of the remarkable physical property called "azeotropism," that is, the phenomenon exhibited by certain homogeneous mixtures of two or more liquids which maintain a constant boiling point at constant pressure quite independently of the percentages of the constituents present in the mixture. In general, therefore, azeotropic mixtures are the analogues of eutectic solid solutions or alloys. The author characterizes the first part (or volume) as a "Handbuch" and the second as a "Lehrbuch."

The first quarto volume begins with an elementary review and outline of the laws derived both empirically and theoretically. These laws are stated in words and expressed in mathematical form, but the proofs are to be given in the second volume, as yet unpublished. The second and principal division of the present volume consists of tables of data pertaining to the distillation of mixtures of liquids. The individual tables of this division refer respectively to binary mixtures and azeotropism of the first kind, to azeotropic binary mixtures of the second species, to ternary systems, and to quaternary systems. The third division is devoted to the bibliography of the special field of research. The author lists are given both in the alphabetical and in the chronological order. The first volume is undoubtedly a thesaurus of information and it should be of great practical value to experimental physical chemists. H. S. U.

11. *Pensées sur la Science, la Guerre et sur des sujets très variés;* by MAURICE LECAT. Pp. vii, 478. Brussels, 1919 (Maurice Lamertin).—During the past twenty years the author usually devoted one hour every evening to recreative reading and to jotting down quotations which struck him as valuable or remarkable. At the suggestion of an eminent scientist (not named) the author was induced to publish the present voluminous collection of choice "Pensées." The material has been classified as far as its great diversity permits, and the key words for each general division are given in alphabetical order at the tops of the pages. The quotations have been gleaned from many languages and they are occasionally presented in their original (untranslated) form. The entire domain of human thought has been searched as with a fine-toothed comb, and the endeavor has been made to eliminate all personal bias, so that some quotations are given which express thoughts of which the author does not approve. The main list of 11,000 pensées is followed by a subject index, an author index, and a supplementary collection of "important" pensées. Whenever possible, each quotation is followed by the name of its author, and the dates of the author's birth and death. The collection is unique and,—for purposes of reference, inspiration, and education,—of inestimable value. This notice may be appropriately concluded by giving two typical examples of the pensées:

7085. *"Un trésor de belles pensées vaut mieux qu'un amas de richesses."*

Isocrate (—436/—334).

2750a. *"Patriotes, ne soyons pas chauvins. Respectons, au-dessus de tout, la vérité."*

Env. 1, VI, 1919. Card. Mercier (1851/...).

H. S. U.

II. Geology and Natural History.

1. *The Geology of Kentucky;* by Arthur M. Miller. Dept. Geol. and Forestry Kentucky, Ser. 5, Bull. 2, 392 pp., 114 photographs, maps, and diagrams, 1919.—As a result of twenty-five years of local endeavor, Professor Miller of the University of Kentucky here describes the essential geology of his state. Seven chapters are devoted to a more or less detailed description of the stratigraphy, two to the physiography, two to the geologic structure, seven to the economic products, and the last part gives the literature referring to the whole subject. The geographic distribution of most of the formations is illustrated on maps, one for each period, and there are many plates picturing the more typical fossils of the formations beneath the Coal Measures. This book will do much good in spreading a correct knowledge of geology throughout Kentucky, and at the same time serving as a reference work for American geologists. We congratulate the author upon the successful conclusion of this his favorite study and his long labor of love for his fellow citizens. C. S.

2. *The Geography of the Ozark Highland of Missouri;* by Carl O. Sauer. Geog. Soc. Chicago, Bull. 7, 245 pp., 26 pls., 44 text figs., 1920 (Univ. Chicago Press, $3.00 net).—This study in regional geography of an area as large as Ireland is written by a native of the region, who is deeply interested in its welfare though he does not now live there. It is a collection of facts relating to the environment, such as the rock formations, erosion cycles, climate, and material resources; to the settlement and development of the area by the French, Americans, and Germans; and to the recent economic conditions. He says in conclusion:

"By developing along the lines sketched [in this book] the Ozark Highland will offer homes to a much larger number of people under much better conditions than at present. Few of them will accumulate large wealth, but, engaged in useful pursuits, they will be strangers to poverty, and they may participate equitably in the progress of the state. By thus becoming the seat of an enlightened and contented population, preserving still the democratic spirit which it now possesses, this region in the future may make its appropriate and sufficient contribution to our national life." C. S.

3. *Geology of India;* by D. N. Wadia. Pp. 398, 20 pls., 37 text figs. London, 1919 (Macmillan & Co.).—The attention of geologists and stratigraphers is called to this valuable manual setting forth clearly the geology of India as brought up to date. The book is intended for college students, but is in reality one for geologists. It deals with the physical features, the stratigraphy and historical geology from the Archean to the Pleistocene, the Deccan trap, and the economic geology of India.

C. S.

4. *Secrets of Animal Life;* by J. ARTHUR THOMSON; pp. vi, 325. New York, 1919 (Henry Holt & Co.).—"The aim of this book of short studies is to interest thoughtful readers in the multitudinous problems of animal life as they present themselves to the modern biologist. Some of them deal with old problems which have reasserted themselves in new guise; others deal with new problems which recent research has brought into prominence. Most of them are confessedly appreciations of, and reflections on, the investigations of other naturalists." "The first ten studies deal with individual animals; the next six have to do with the web of life; the ten that follow raise problems of development and behavior—two subjects more intimately related than appears at first sight; the remaining fourteen studies may be grouped round the concept of evolution."

These forty brief essays show great literary skill and present in most attractive manner much that is well worth knowing about the lives of animals and biological phenomena in general. It is seldom that nature's secrets are revealed in so charming a guise. W. R. C.

5. *The Unity of the Organism, or The Organismal Conception of Life;* by WILLIAM EMERSON RITTER. Two vols.; vol. 1, pp. xxix, 398; vol. 2, xv, 408. Boston, 1919 (Richard G. Badger).—The most fundamental discoveries in biology in recent years have been made by the experimental methods of research, but the majority of such advances have been limited to certain narrow fields in which only a single one of the innumerable attributes of the organism has been the subject of study. Too often the investigator fails to realize that the results of his laboratory experiments may not hold good in nature itself and is even more likely to lose sight of the bearing of his subject on the organism as a whole.

The author's basic proposition is that the living organism "in its totality is as essential to an explanation of its elements as its elements are to an explanation of the organism." With this idea in mind he reviews the most recent advances in all fields of biology and shows that most of the modern biological conceptions are inadequate for a full understanding of nature in that they mainly deal only with the constituent parts or elements of the organisms. He criticizes the so-called elementalist school of biology for assuming that the whole organism results from the sum of its parts, whereas in his view the parts are explained only by the consideration of the organism as a whole.

Part I consists of a critical survey of the elementalist conception of the organism and deals with the chemical and physical composition of the living individual and the production of individuals by other individuals.

Part II sets forth the constructive side of the organismal conception, dealing with growth integration, chemico-functional integration, the organismal significance of the internal secretory system, neural integration and implications of the tropistic and segmental theories of nerve action, psychical integration, organic connection between physical and psychical, and a sketch of an organismal theory of consciousness.

The author accepts neither the materialistic doctrine that the material elements as known to us in inorganic nature are the sufficient casual explanation of organic phenomena, nor that of supernaturalism. He says (vol. II, p. 149): "The essence of my contention is that the natural substitute for these imponderable things are the *living, individual organisms themselves,* and not the particles of which they are composed. Each and every individual organism is a natural reality by exactly the same criteria that the atoms, molecules, cells and tissues of which it is composed are natural realities. And since each individual is to some extent different from every other, and maintains its individuality in full possession of these differences, by its power of transforming foreign substance into its own substance, it is ultimate both as to structure and as to causal power in as deep and literal a sense as the material particles of which it is composed are ultimate."

Whatever difference of opinion may exist as to the importance of the general conception of organismalism, the author has rendered a conspicuous service to the philosophy of biology in bringing under critical and impartial examination the whole field of modern biology. W. R. C.

6. *The Life of Matter; an Inquiry and Adventure;* edited by Arthur Turnbull; pp. xviii, 324, with 322 illustrations and 4 colored plates. Philadelphia (J. B. Lippincott Co.) and London (Williams and Norgate), 1919.—The preface states that "the work purports to supply—in illustrative, though sketchy form—a reliable guide and insight into observational methods and experiments . . . and to provide a stimulus to any ordinary individual desirous of understanding the widespread applications of modern science to the necessities of real life."

A well illustrated but disconnected and rambling account of many topics in physical and natural science. W. R. C.

7. *Psychology from the Standpoint of a Behaviorist;* by John B. Watson; pp. xiii, 429, with 63 text figures. Philadelphia and London, 1919 (J. B. Lippincott Co.).—In this book, designed as an elementary text, the subject is treated from a strictly biological standpoint, with the entire elimination of those metaphysical discussions of consciousness, sensation, perception, attention, will, image, and the like, which form so large a part of many textbooks of psychology. The author follows the same scientific methods for studying human activity and conduct that have given such excellent results in work on animal behavior, of which behavioristic psychology is the outgrowth. The first half of the book consists of a general description of

psychological methods, receptors and their stimuli, neuro-physiological basis of action, and the responses of muscles and glands. Then follow chapters on the hereditary modes of response, emotions, instinct, genesis and retention of explicit and implicit language habits. The last 80 pages treat of the organism at work and of the personality and its disturbance. The book can hardly fail to appeal to the interest and imagination of the student, for the greater part of the abstract reasoning characteristic of so many of its predecessors is replaced by the experimental evidence on which the conclusions are based. In place of a multitude of technical definitions to be memorized (and later forgotten) the reader finds common sense explanations of mental phenomena applicable to his daily life, appreciation of which will give him a better understanding both of himself and of his associates. W. R. C.

8. *A Laboratory Outline of Embryology; with Special Reference to the Chick and the Pig;* by Frank R. Lillie and Carl R. Moore; pp. ix, 66. Chicago, 1919 (University of Chicago Press).—Concise laboratory directions for the comparative study of the separate organ systems of these two animals; particularly suitable for the embryological courses in medical schools. W. R. C.

9. *The Cactaceæ: Descriptions and Illustrations of Plants of the Cactus Family.* Volume I; by N. L. Britton and J. N. Rose. Pp. vii, 236; 36 plates (27 colored) and 301 text figures. Washington, 1919 (The Carnegie Institution, Publication No. 248, Vol. I). Our knowledge of an exceedingly difficult group of plants is materially increased by this careful and exhaustive contribution. The Cactaceæ, with but few exceptions, are natives of America, attaining their best development in the more arid portions of the tropics. A few, however, extend into higher latitudes, both northern and southern, and the well-known Indian fig has become widely naturalized in southern Europe and other parts of the world. The present work is based on a study of more than fifteen years, and the authors or their agents have visited all the more important cactus areas in both North and South America. They have also examined, wherever possible, the type specimens of described species and have brought together large collections of greenhouse and herbarium material. They divide the family into the following three tribes: the Pereskiæ, characterized by stalked flowers, broad flat leaves, and a lack of glochids or barbed hairs; the Opuntieæ, having sessile flowers, an abundance of glochids, and usually minute fugacious leaves; and the Cereeæ, in which sessile flowers are present but neither glochids nor leaves. In the present volume only the first two tribes are treated, leaving the extensive Cereeæ for the succeeding volumes (of which three are promised). The Pereskieæ includes the single genus *Pereskia,* of which 19 spe-

cies are recognized. The Opuntieæ comprise the very large genus *Opuntia* with 254 species, and the much smaller genera *Pereskiopsis, Pterocactus, Nopalea, Tacinga, Maihuenia* and *Grusonia,* the largest of which has only 10 species. Each species is described at length and full data are given regarding type localities and geographical distribution. In many cases interesting notes are added, especially in the case of cultivated species and those with a long and involved synonymy. In the course of the volume, 41 new species are described, 32 belonging to the genus *Opuntia* and the others distributed among the genera *Pereskia, Pterocactus, Nopalea* and *Tacinga,* the last being the only new genus proposed. A noteworthy feature of the work is the full series of colored illustrations, mostly from the brush of Miss M. A. Eaton of the New York Botanical Garden. These are supplemented by line drawings and by reproductions of photographs showing plants in their natural surroundings. A. W. E.

10. *Fossil Plants: A text-book for students of Botany and Geology;* by A. C. Seward. Vol. IV, small 8vo, pp. xvi, 543, with figures 630-818 in text. Cambridge, 1919 (Cambridge University Press).—Notice of the first volume of this work was given by Goodale in this Journal, June, 1898 (**5**, 472). The second and third volumes were reviewed by Wieland, November, 1910 (**30**, 356), and August, 1918 (**46**, 475). The Ginkgoales, Coniferales, and Gnetales are the subjects of this, the concluding volume of Professor Seward's great text. It is in completed form, primarily an outline of the knowledge of fossil plants, excepting the angiosperms, which will be permanently useful and usable to the student of structure as well as investigators of fossil floras.

As a whole, these volumes have gained from a course of annotation extending through more than twenty years. In this time the subject matter of Paleobotany has at least trebled in bulk, and methods have reached a precision not exceeded in either branch of Paleozoology. There is observable a distinct advance over the texts of Schimper, Solms, and perhaps Zeiller, both in amount of detail, and in illustration, along with much of that clear discussion which makes the studies of Scott so readable. Yet it is in no sense a criticism to say that this new text belongs with its prototypes to the formative period of Paleobotany. Could any faults or lacks be fairly named, they would only be those inherent to all paleobotanic studies thus far. Uneven treatment and illustration, with much speculation, have admittedly characterized much of the work on fossil plants.

But those broader points of view to which Professor Seward's text signally contributes, are rapidly clearing. Pitting theory against theory is far less in evidence, and determination of the time of appearance and range of structures in geologic time is now recognized as more profitable than the older purely genealogic speculations. All this contributes to far sounder interpretations of ecologic factors and the course of climatic change in the past, as certainly indicated by fossil plants, once understood. It should be possible to bring the animal and plant record into essential agreement.

Generally speaking, the workers in Paleobotany have been too few, and this is only another way of saying that large parts of the plant domain have not been explored by men trained in the cognate subjects of botany and geology. Thus the immense series of petrified gymnosperm stems abundant from the Devonian to now, has not been determinedly sectioned by anatomists. And similarly the purely phytologic record has reached a point of congestion, rather than analysis. In the angiosperms, the necessary basis of exactly illustrated existent species has even remained just where Ettingshausen left it quite sixty years ago with a list of some 3,000 species figured by the so-called ''nature print'' method. This work needs to be extended, especially to all tropic species, and there needs to be accumulated a new series for the determination of leaf species directly from photographs of characteristic areas enlarged to ten diameters. The hand lens and camera lucida alone are scarcely sufficient aids in detecting and comparing the finer and ultimate features of venation. In the case of carbonized tissues freshly treated for study before checking sets in, remarkable results have already been brought out. G. R. W.

III. Miscellaneous Scientific Intelligence.

1. *Publications of the Carnegie Institution of Washington.*—The following publications of the Carnegie Institution have been recently received. (See earlier, vol. **48**, pp. 401, 402.)

No. 85. Index of economic material in Documents of the States of the United States. Pennsylvania, 1790-1904. Prepared for the Department of Economics and Sociology of the Carnegie Institution of Washington; by Adelaide R. Hasse. Part I—A to E, 4to, pp. 1-810.

No. 185. Index to United States Documents relating to Foreign Affairs, 1828-1861. In three parts. Part II—I to Q; by Adelaide R. Hasse. 4to, pp. 795-1331.

No. 249. Displacement interferometry by the aid of the achromatic fringes, Part IV; by Carl Barus. Pp. 122, 119 text figures.

No. 270. A Biochemic Basis for the study of problems of Taxonomy, Heredity, Evolution, etc., with especial reference to the starches and tissues of parent-stocks and hybrid-stocks and the starches and hemoglobins of varieties, species and genera; by Edward Tyson Reichert. In two parts. Part I. 4to. Pp. xi, 376, 34 pls. Part II, pp. vii, 377-834.

No. 278. Contributions to the genetics of *Drosophila melanogaster.* I. The origin of gynandromorphs; by T. H. Morgan and C. B. Bridges. II. The second chromosome group of mutant characters; by C. B. Bridges and T. H. Morgan. III. Inherited linkage variations in the second chromosome; by A. H. Sturtevant. IV. A demonstration of genes modifying the character "Notch;" by T. H. Morgan. Pp. 388, 11 pls., 105 text figures.

No. 281. Department of Marine Biology; Alfred G. Mayor, Director. Papers from the Department of Marine Biology of the Carnegie Institution of Washington. Volume XIII. Pp. 128, 19 pls., 4 text figures.—Five papers are here included.

No. 283. The environment of Vertebrate life in the late Paleozoic in North America; a paleogeographic study; by E. C. Case. 4to, pp. 273, 8 figs.—To be noticed later.

No. 289. Climatic cycles and tree-growth; A study of the annual rings of trees in relation to climate and solar activity; by A. E. Douglass. Pp. 127, 12 pls., 40 text figures.

No. 291. Contributions to the geology and paleontology of the West Indies; prepared under the direction of Thomas Wayland Vaughan. Pp. 184, 53 pls., 8 text figures.—This volume opens with brief introduction by Dr. Vaughan. The body of the work consists of 5 West Indian papers on the following subjects: Tertiary calcareous Algæ, by Marshall A. Howe (6 plates); Fossil Foraminifera, by Joseph A. Cushman (15 plates, 8 text figures); Fossil Bryozoa, by Ferdinand Canu and R. S. Bassler (7 plates); Tertiary Mollusks, by Charles W. Cooke (16 plates); Tertiary decapod Crustaceans, by Mary J. Rathbun (9 plates).

No. 295. A new type of hereditary brachyphalangy in man; by Otto L. Mohr and Chr. Wriedt. Pp. 64, 7 pls.

Classified list of Publications of the Carnegie Institution of Washington. Pp. 192.—A very valuable catalogue (pp. 1-23) of the many volumes published by the Carnegie Institution (to Dec. 1, 1919) with descriptive notices (pp. 25-184) of a large number of the memoirs. The prices (postpaid) of the publications are given, the books having strong paper covers; in some cases volumes in cloth are to be had at an advance of 50 cents.

2. *Publications of the Yerkes Observatory.* Volume IV, Part II. *Photographic Investigations of Faint Nebulae;* by Edwin P. Hubble. (University of Chicago Press) 4to, pp. 17, 15 tables and plates III and IV and 2 text figures.—This memoir is a dissertation submitted to the Ogden Graduate School of Science of the University of Chicago in candidacy for the degree of doctor of philosophy. It is general in character as exhibited in the data given in the tables and in the interesting plate (III) showing Wolf's classes of nebulæ, copied from the Königstuhl (Heidelberg) Publications.

3. *Catálogo de 7412 Estrellas de Declinaciones comprendidas*

entre-52° Y-57° (1875) para el Equinoccio 1925, by PABLO T. DELAVAN. Volume V. Pp. xxii, 149. La Plata, Observatorio Astronómico, 1919.—Catalogues of the stars of the southern heavens are not too numerous nor complete; hence this volume will be especially valuable. It connects on the north with the catalogue planned by the Argentine National Observatory of Córdoba which is to extend from the *Durchmusterung* of Argelander (including all stars to the ninth magnitude from 80N. to —23S.) to —52°S. Ing. Felix Aguilar is to observe the zone from —57° to —62°.

4. *Technical Book Review Index. Issued by the Technology Department of the Carnegie Library of Pittsburgh.*—This Index, printed from part of a card-index maintained by the Carnegie Library of Pittsburgh, is a record of book reviews in scientific, technical and trade journals currently received by the Technology Department. It is concerned mainly with books on pure and applied science but includes a few on allied subjects. The arrangement is by authors. The price of the Index is fifty cents a year.

OBITUARY.

REAR ADMIRAL ROBERT EDWIN PEARY, the indefatigable Arctic explorer, died at his home in Washington on February 20. He was born at Cresson, Penn. in 1856 and was graduated from Bowdoin College in 1877. In 1881 he entered the U. S. Navy as civil engineer and was early connected with the surveys for the proposed Nicaragua Ship Canal. His Arctic explorations commenced in 1886, and his 8th Arctic expedition, begun in July, 1908, was crowned with success when he reached the North Pole on April 6, 1909. The scientific results of his Arctic work were of the first importance and he well merited the promotion to the rank of rear admiral given him in 1911.

PROFESSOR FRANK PERKINS WHITMAN, whose death was announced recently, had held the chair of physics in Western Reserve University since 1886. He was born at Troy, N. Y. in 1853 and was graduated from Brown University in 1874. He made a number of important contributions to his special department of study; his place among scientific men is well stated by his associates in Cleveland: "he was not a research scholar and never wished to be considered one, but he did have a profound knowledge of the great problems of physics and astronomy and he kept up with the research work done in these branches."[1]

[1] Science, Jan. 30, p. 106.

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[FOURTH SERIES.]

ART. XVII.—*The Piedmont Terraces of the Northern Appalachians;* by JOSEPH BARRELL.

Edited by H. H. ROBINSON.

CONTENTS.*

* This article is published in three sections but the entire Contents are given here. The second part, beginning with the discussion of "Indications from the Coastal Plain of many baselevels," will appear in the May number, and the concluding part, beginning with "Criteria for the recognition of fluvial and marine baselevels," will appear in the June number.

Editorial Preface.

The physiographic problems of the Appalachian Province, especially of its seaward side, had interested Professor Barrell for many years, in fact from the beginning of his career as a geologist. His interest in them, however, did not become acute until he discovered the evidence, in 1911, which led him to recognize the existence of many planes of erosion in western Connecticut and to conclude from their stair-like character, their linear plan, and because they had always faced the sea, that they were probably of marine origin.

During the following year (1912) he devoted much time to the study of the Connecticut terraces from the point of view of their marine origin and he further extended his field of study so as to include the entire seaward slope of the Appalachian region as far south as Maryland. The results of this study were presented in two papers—"Piedmont Terraces of the Northern Appalachians and Their Mode of Origin" and "Post-Jurassic History of the Northern Appalachians"[1]—at the December meeting of the Geological Society of America in New Haven in 1912.

The work on which these two papers were based, and which Professor Barrell was carrying on, may be summarized under the following headings:

1. Study of the topographic maps on a scale of 1:62,500 covering New England, eastern New York, New Jersey, eastern Pennsylvania, and Maryland. The purpose was to gain a general idea of the extent of the terraces and their modes of expression in different regions. Certain critical features were looked for, such as wind gaps, spurs, and composite slopes. The limitations imposed by the imperfect representation of much of the topography and the necessity of checking up details in the field were clearly kept in mind.

2. The preparation of a map of the region mentioned above on a scale of 10 miles to the inch showing the geographic extent of the marine terraces. Also a map covering the same region and on the same scale showing wind gaps and accordant valley terraces.

[1] Abstracts in Bull. Geol. Soc. Amer., vol. 24, pp. 688-696, 1913.

I am under great obligation to Dr. Isaiah Bowman for advice and for information bearing on the early stages of Professor Barrell's work. My own knowledge, gained through random talks with Professor Barrell and as a result much too incomplete to do justice to his ideas, covered only the late stages.

3. Construction of projected profiles covering a belt of country 90 miles long and about 20 wide in western Connecticut and Massachusetts on a scale 1: 62,500 showing the broad stair-like terraces and the assumed positions of shore-lines. Also a similar profile of an area 40 by 55 miles in Maryland, besides others covering the Harvey Lake-Pittston-Scranton region of Pennsylvania and part of the Catskills. In addition a large number of maps and profiles of special areas were drawn to show clearly the character of the terraces and shore-lines.

4. Tentative correlation of the terraces of different regions.

5. Preliminary profile sketches showing (*a*) present relations of principal peneplanes in New England, (*b*) relations of peneplanes and contemporaneous sediments, and extent of overlaps, (*c*) time relations of the Connecticut marine terraces.

6. Projection inland of the planes of unconformity between the sedimentary formations of the Coastal Plain in order to fix the age of the Piedmont and Appalachian erosion surfaces.

7. Restoration of former river grades based on data, such as wind gaps and rock benches, obtained from the study of the topographic maps.

8. A study of marine benches and their associated deposits on different types of coast. This study was begun some years before the terrace problem was taken up primarily for the purpose of developing criteria for the recognition of marine and terrestrial conglomerates. Some phases of it, however, were seen to have so intimate a bearing on the latter problem as to call for further investigation. This applied particularly to marine conglomerates and to fluvial conglomerates that had been reworked by the sea.

9. Preliminary outline and notes for a paper on the "Evolution of the New England Drainage."

The foregoing is largely a record of laboratory work. The study in its broader aspects was based, in fact had to be based, on topographic maps, but this study in turn was founded on and controlled by field work. Professor Barrell's note books record such work in New England during the summers of 1911, 1912, and 1913; in Pennsylvania in 1912 and 1913; and in Maryland in 1912. He adopted the method of map study partly from necessity and partly, no doubt, because it enabled him to accomplish his purpose in the shortest time. That he was able to present the subject in so comprehensive a manner by the end of 1912 must have been due in a large degree to the fact that it had been in mind for many years. He had accumulated so many relevant facts that when he discovered the terraces in western Connecticut and recognized their probable marine origin he was able to reach general conclusions, which he was convinced were correct, with a minimum of systematic field work. He was thus led to publish his conclusions in preliminary form in 1912 and to postpone systematic field study until the opportunity should arise for giving it his uninterrupted attention. He fully realized that the evidence he had gathered was only sufficient, so far as others were concerned, to give his main conclusion—as to the marine origin of the terraces—the status of a working hypothesis and that much additional field work was required to confirm or deny it.

The opportunity to take up the work again in earnest did not present itself until 1918 when a sabbatical year gave him the additional time which he had long desired.[2] In the latter part of that year he put a considerable number of maps and profiles in form for publication and began a first draft of discussions of the principles involved in the analysis of the relief of the seaward slope of the Appalachians. He had planned field work for the summer of 1919 which embraced a study of (*a*) composite valley slopes in Connecticut and Pennsylvania, (*b*) wind gaps especially in Pennsylvania, (*c*) baselevels on the Delaware beginning with the Somerville, (*d*) the slate belt between the Susquehanna and the Delaware in relation to the Harrisburg peneplain. He had also planned to devote the summer of 1920 to field work. It should be noted that he also spent a short time in the field in 1915 studying the uplands in Sullivan County, N. Y., where they are developed on nearly horizontal strata. The early months of 1919 were spent on the preparation of his manuscript, interrupted temporarily by the writing of a paper on isostasy, and he had planned to con-

[2] During the interval 1913-1918 the problem was, however, much in his mind and various points are treated in articles he was then publishing, namely, ''Upper Devonian Delta of the Appalachian Geosyncline'' (1913-1914), ''Rhythms and the Measurement of Geologic Time'' (1917), and ''Factors in the Movement of the Strand-line and their results in the Pleistocene and Post-Pleistocene.

tinue the drafting of the manuscript until he went into the field. The completion of the manuscript, to the misfortune of all, was cut short by Professor Barrell's untimely death in May.

I have compared this manuscript with the outline notes on which he based his talks in 1912 and find that so far as it goes it covers much the same ground but in a more systematic manner. In addition there are outlines of several important topics on marine denudation—its competency, the way it works, and a discussion of typical cases. From other notes it appears that the important topics which remained to be written embraced the detailed discussion of (*a*) the terraces of western Connecticut and Massachusetts [note—"terraces marine in Connecticut, subaerial in Massachusetts"]; (*b*) the terraces of eastern Connecticut and Massachusetts [note—"some terraces dropped out on east; more subaerial erosion, softer beds"]; (*c*) marine and subaerial phases of erosion in New England, [In part, presumably a summary of the two preceding sections]; (*d*) History [note—"Pliocene age of Piedmont terraces"]. In view of Professor Barrell's plans for further field work it is to be presumed that these topics would not have been written nor the manuscript put in final form for some time to come.

Many of the topics in the manuscript are plainly unfinished—are in effect more or less brief outlines of what Professor Barrell intended to do or for guidance when he took up the final drafting of the paper. In this respect it must remain as it was written. Some minor changes in subject matter have been made where they were obviously called for, and some explanatory paragraphs have been added by the editor where it seemed they might be helpful, but the great majority of changes have fallen under the general head of style. In this phase of the work the editor has tried to follow Professor Barrell's own habit of thorough and painstaking revision. It seems proper to suggest that the reader should keep in mind the unfinished condition of the manuscript on which this printed article is based.

It will presumably assist the reader to better understand the manuscript and the various figures if the main points of Professor Barrell's interpretation of the problem are given here, especially as he had not reached the stage where he had organized or perhaps could organize the work as a whole. Further, it will assist those who are approaching the general problem for the first time if there is also presented a summary outline of the older interpretation up to 1911, when Professor Barrell began his work. For a comprehensive summary of Appalachian research up to the same year the reader may refer to Dr. Bowman's Forest Physiography, Part II, Physiography of the United States, Chapters XXV and XXVIII-XXXII.

The scientific interpretation of the later physiographic history of the Appalachian Province, based on the conception of a normal, or pluvial, erosion cycle, began with the classic work of W. M. Davis presented in three papers, the first of which appeared in 1889.[3] And it is a tribute to Prof. Davis' keenness of thought and ability in exposition that his underlying conception of the problem quickly gained acceptance and has been the foundation, it may be said almost without qualification, of all later research.

In general, then, the interpretation of the physiographic history of the Appalachian region has rested on the recognition of a topographic plane of reference, commonly known as the Cretaceous peneplain, above which rose older residual masses, below which were locally cut secondary topographic levels of Tertiary age representing temporary stillstands of the land following periods of uplift, and on the outer margin of which rested the great unlithified series of Mesozoic and Neozoic sediments. The underlying assumption was that all peneplaned surfaces were the result of fluvial denudation and that remnants of all remain so little reduced as to permit the former surfaces to be restored with assurance.[4]

In most parts of the province three cycles of peneplanation were recognized and correlated in a general way, as the Cretaceous, the early Tertiary, and the late Tertiary. In some localities an older erosion surface, the Jurassic peneplain, was recognized. Keith went

[3] The Rivers and Valleys of Pennsylvania, Nat. Geogr. Mag., vol. 1, 183-253, 1889.

The Rivers of Northern New Jersey with Notes on the Classification of Rivers in General, *ibid.*, vol. 2, 81-110, 1890.

The Geologic Dates of Origin of Certain Topographic Forms on the Atlantic Slope of the United States, Bull. Geol. Soc. Am., vol. 2, 545-586, 1891.

[4] See sections on back of Delaware Watergap topographic map.

further than other workers in recognizing a much larger number of erosion surfaces. From his published work it would appear, however, that he did not consider these surfaces as representing an equal number of erosion cycles but rather as due to the individual conditions under which different rivers eroded.

Professor Barrell's conclusions were at variance with the older views on many points, especially as to the number of erosion cycles, the origin of the erosion surfaces, and the age of those surfaces. His work in Connecticut had convinced him that the number of erosion cycles was considerably greater than had been supposed, a view that was supported by the Mesozoic and Neozoic sedimentary record. The complexity of this record is strikingly at variance with the simplicity of the accepted physiographic record for that same period. He differed fundamentally in considering the terraces, at least in New England, as initially the result of marine denudation and in assigning to the majority of them a post-Miocene age. The only point in common with the older view was the recognition of a "Cretaceous" topographic plane of reference whose surface had been shaped by fluvial denudation. It was over this surface that the sea made its first advance. He considered that the terraces could be restored from their existing remnants; on the other hand, he believed that the pre-Cretaceous erosion surfaces in all probability had been so far destroyed as to be unrecognizable except in isolated residual masses.

The process of marine erosion was intimately connected with the conception of a rhythmic oscillation of the land which he described in the first two parts of "Rhythms and the Measurement of Geologic Time." During an emergent stage the land would be subaerially eroded and in time the resistant rock formations would tend to become interfluvial ridges. Upon submergence these ridges would become peninsulas, islands, and reefs which would be planed off, though not completely, by the sea and it would only be after submergence had ceased that wave planation would be at all profound. Such a process would give beveled ridges grading into a more or less continuous rock terrace which would terminate in a seacliff. Professor Barrell emphasized the importance of an antecedent fluvial denudation of the land to a stage of advanced maturity or old age; there was "not whole-sale marine erosion of a mountain region,'' as he tersely put it in a marginal note for guidance on this point.

It is quite evident that Professor Barrell was led, by his conclusion as to the marine origin of the terraces, into investigations along several much neglected lines. The absence of a generally accepted body of criteria for distinguishing between the effects of marine and fluvial denudation caused him to take up the study of marine action on present coasts of different character. Emphasis was naturally placed on the effects of marine planation on surfaces characterized by a post-maturity of form developed in a normal erosion cycle and on the determination of those features which should be expected to endure through later cycles of fluvial erosion. He was extending an earlier study on marine and terrestrial conglomerates in order to develop criteria for the determination of fluvial conglomerates that had been reworked by the sea. He was carefully studying the Cretaceous and Tertiary sedimentary deposits, for it was evident, as was long ago pointed out by McGee, that a correct interpretation of their physical history would go far toward solving the physiographic history of the contemporaneous land areas. Professor Barrell had convincingly demonstrated his ability to handle such a method of attack in his paper on the ''Upper Devonian Delta of the Appalachian Geosyncline'' and I have no doubt that in the present instance he would have been able to apply it with much greater refinement because the problem contained fewer unknown quantities.

It is clear, then, that he was developing several groups of ideas side by side and had presumably not reached the point where he could exactly judge to what extent any conclusions reached along these lines might modify his early views. Thus, such inconsistencies of thought as may exist in the manuscript he left, point to a healthy state of mind. Moreover, the fact that he was following out logically each principle and its deduced consequences as he developed them shows that he was not wedded to any one fixed theory as to the origin of the Piedmont terraces. He was holding the balance, indeed, with rare judgment between apparently contradictory facts and at all times keeping his mind open to conviction.

As bearing on this matter it will be interesting, perhaps, to sketch very briefly the development of the problem which ended in the recognition of the numerous terraces and the assignment to them of a marine origin. Professor Barrell became interested in the physiography of New England in 1909-1910 while engaged in field work in southwestern Massachusetts (Housatonic folio). In the latter year he made a preliminary map study of the general physiographic problem on the basis of several selected sections in an east-west direction across Vermont and Massachusetts and in a north-south direction along the Green Mountains and Taconic Range. And it is to be noted that the topography was interpreted on the basis of a subaerial origin and three cycles of erosion—Jurassic, Cretaceous, and Tertiary—except that the Cretaceous peneplane in part was considered of marine origin. The results of this study are recorded in a dictated but unchecked manuscript of 24 typewritten pages dated December, 1910. This map study was followed by a field study of selected areas in the latter part of the summer of 1911. These areas covered most of northwestern Connecticut, western Massachusetts, and the extreme southwestern part of Vermont. The interpretation of the topography followed the same lines as the preliminary study and Professor Barrell was on the look-out for evidence of a Cretaceous shore-line in Connecticut. His notes on the topographic details of several localities contain the question "Is this a sea-cliff?", and it may be noted that the features so questioned were later taken to mark either the Goshen or Litchfield shore-line. Remnants of three erosion planes were distinguished which were called Jurassic, Cretaceous (Schooley), and Tertiary (Harrisburg) and in addition some evidence was found of a fourth which lay between the Schooley and Harrisburg. In order to determine what the attitude of these surfaces was nearer sea-level, a projected profile was drawn covering the southern half of western Connecticut. The picture which this presented must have been quite unexpected, for it showed that the hills forming the sky-line, instead of descending as though they were part of a single dissected surface, resolved themselves into a number of apparently horizontal benches differing in elevation from 100 to 200 feet. Further study showed the presence of these benches at other localities and because of their attitude and nearness to the sea and certain erosional details, Professor

Barrell came to the conclusion that they were of marine origin. This conclusion led Professor Barrell to make a detailed re-examination of the topography of western Connecticut and Massachusetts, based largely on maps and projected profiles, and as a result he decided that it was possible to distinguish eleven benches, all of marine origin, of which the eight lower and better preserved ones were assigned a Pliocene and Pleistocene age. That Professor Barrell reached this general conclusion after a conscientious effort to solve the problem on the basis of the fluvial origin of the erosion surfaces seems to me particularly interesting and as reason for confidence in the general correctness of it.

Professor Barrell's deep attention to the problem of the Piedmont terraces and the long range plans he had made for its completion when coupled with his reputation for soundness and originality of thought make it most desirable to publish the manuscript he has left, even though it be fragmentary and incomplete, so that the line of thought may be carried forward by others. The problem still remains to be worked out in a systematic way and it should appeal especially to the younger geologists whose minds are in a receptive mood toward new ideas. But it is also evident that the work will have to be carried on by mature students, trained to rigorous thinking, who will not accept the ideas here presented as final but rather as suggestions to be tested in the field, for as Professor Barrell's notes show, this had been his own attitude toward them.—Editor.

Introduction: *Difficulties of the fluvial peneplane hypothesis.*

The attention of the writer was first drawn to the subject of Appalachian baselevels in 1894 by Davis' inspiring article on "The geologic dates of origin of certain topographic forms on the Atlantic slope of the United States." Employed at the time in eastern Pennsylvania, opportunity was found in the next two years for studying the subject in a fertile field. Certain conclusions which bear on the present problem were reached in 1896 in a thesis on the "Geological history of the Archean highlands of New Jersey," presented at Lehigh University in part fulfillment for the degree of Master of Science. The most significant conclusion in the present connection was that derived from a study of the wind and water gaps across Kittatinny mountain. From New York to Maryland, and even farther south, this resistant quartzite ridge rises boldly above the valleys on either side, its summit maintaining a remarkably uniform elevation of 1,500 to 1,700 feet through most of the distance. In a few places, however, it rises distinctly above this level and at others, more especially near stream channels, it falls below it. Ridges of the same general elevation lie farther to the northwest and all clearly represent eroded remnants of a former peneplane.

The Kittatinny ridge is cut by the major streams and by some of lesser volume, such as the Swatara. Wind gaps spaced between the water gaps[5] show that in the first cycle of uplift after the formation of the peneplane many minor streams flowed across this ridge. The drainage at the time of uplift, therefore, was not adjusted to structure but was superposed across a most resistant formation.

In the time that has elapsed since the uplift of the Kittatinny peneplain broad lowlands have been developed while the resistant quartzite has been but slightly touched by erosion and still shows nearly original levels. Such loss as it has suffered has been through the development of steep slopes by the erosion of adjacent soft formations. Let ten times the period pass away which has elapsed since the uplift of the Kittatinny peneplain and, if only subaerial denudation were concerned, the ridge would still stand up with flattened slopes rising several hundred feet above the adjacent lowlands. That is to say, the notable persistence of Kittatinny Ridge through at least two later cycles of erosion raises the very strong presumption that the rock which forms it would have stood as a well-defined ridge above the more perfectly baseleveled lowlands at the close of the Cretaceous period of peneplanation. Therefore, during the prolonged erosion cycles leading up to the Kittatinny peneplain, the streams should have become thoroughly adjusted to structure and only at wide intervals should master streams have crossed the resistant ridges in long-inherited courses. How, then, did such a degree of

[5] [Presumably the depressions along the summit of the ridge rather than the well marked wind gaps, like Pen Argyl, at lower elevations.—Editor.]

superposition come to exist as is shown by the presence of many wind gaps in Pennsylvania?

It is not conceivable that tilting of the peneplain could have brought about general superposition of the drainage. The angle of tilt necessary for this purpose would have had to be steeper than the slopes of the ridges. Such a tilt, before it reached the elevation implied on the landward side of the axis, would have caused entrenchment of the drainage in soft formations rather than deflection across the most resistant ones.

Davis has suggested that the discordance to structure shown by the tributaries of the Susquehanna north of Harrisburg is due to alluvial upbuilding and superposition during the latest stages of development of the peneplane. This supposition, however, can not account for the numerous wind gaps unless the whole region were mantled with sediments. Such a mantling, indeed, is equivalent to a landward extension of the Coastal Plain deposits across the Kittatinny ridge, an extension of from 60 to 70 miles and more beyond the present limits of the Coastal Plain. The conclusion was reached by the writer in 1896 that after the completion of the Kittatinny peneplain, a movement of submergence took place which caused the sea to advance far inland beyond the present position of the Coastal Plain, cutting into and burying the low Kittatinny ridge under sediments. This conclusion, it should be said, was not published, but served with later observations to raise questions in regard to the validity of current interpretations.[6]

Geological work in western Massachusetts in 1911 showed remnants of four baseleveled surfaces at elevations of 2,250, 1,840, 1,400, and 1,100 feet. In Vermont traces of one or more still higher levels were observed. Which of these should be regarded as the southern New England peneplain, supposed to be of Cretaceous age, and which the Harrisburg peneplain of early Tertiary age? If two of these represented Cretaceous and early Tertiary levels, what were the other two levels?

In a preliminary attempt to answer these questions the various erosion surfaces were traced toward the sea and along the Appalachians to the southwest in order to obtain a broader correlation. But instead of simplify-

[6] [It was not printed. It is stated in the Master of Science thesis referred to in an earlier paragraph and is here given in the following section.—EDITOR.]

ing the problem this study appeared to make it more complex, for the highest surface to the north did not warp down to coincide with the highest one to the south. On the contrary, it disappeared by passing out above the latter and the second surface to the north became coincident with the highest to the south. Furthermore, the slopes of none of these could be correlated with the slopes of the Cretaceous formations or the older peneplaned surfaces of the crystalline rocks on which these beds rested. It was clear, then, that the entire problem of the post-Jurassic history of the northern Appalachians needed re-examination.

Citation from the Master of Science thesis, with editorial note.

The full title of the thesis referred to in the previous section is as follows "The Geological History of the Archean Highlands of New Jersey, including their extension in New York and Pennsylvania, 1896, Joseph Barrell." The thesis is divided into two parts, namely, "Part I, The geological description of the Highlands" and "Part II, The geological history of the Highland province." The extracts here given are from Chap. VIII, Part II, which is entitled "History of the Later Mesozoic and Tertiary drainage." These extracts, and much more so the thesis as a whole, give clear evidence of the penetration of thought and breadth of vision which were so characteristic of Professor Barrell's work in later years.

After reviewing numerous facts in regard to the drainage, Barrell concluded that "The drainage indicates a Mesozoic burial of the Blue Ridge" and he went on to "investigate the causes which could have led to the inconsequent, discordant drainage of the minor streams across the Blue Ridge" under the following headings: "(*a*) Hypothesis of streams consequent upon the original structure, (Not adequate)"; "(*b*) Hypothesis of flow across Blue Ridge being due to crustal tilting after peneplanation, (Not probable)"; "(*c*) Flow across Blue Ridge indicates burial beneath Mesozoic sediments, (Probable)."

Under (*c*) he wrote: "The only remaining hypothesis which occurs to the writer to account for this anomalous drainage at the opening of the Tertiary is to assume that previously a layer of waste had been laid down over the country by a shallow sea, burying the previously base-leveled Blue Ridge. Following uplift of the region above sea level, the streams would flow in general courses along the dip [of the deposits] and only later in eroding their beds would discover that their courses lay across the Blue Ridge. Even after every trace of the cover had been removed the streams by their discordance with the structural features would still betray the fact of its previous existence.''

This hypothesis is developed under a number of headings, as follows: (1) The epoch of submergence; (2) Details of discordance as shown by wind gaps at numerous localities in Pennsylvania and New Jersey; (3) Discussion of the details of the discordance illustrated by the previous examples, in which the generally accordant level of the wind gap bottoms is considered; (4) The age of the cover; (5) Argument for a Cretaceous cover, and (6) Conclusion as to age and extent of cover.

Under the last topic he wrote: ''From the preceding discussion we find that during the late Cretaceous a slight submergence caused the sea to move far inland; its shallow waters spreading a littoral deposit over [the region of] the Great Valley and the Blue Ridge. The submergence did not extend over the whole Coast; the Highlands [of New Jersey] formed an axis which was not submerged, but ran far southward forming a flat peninsula like the present eastern shore of Maryland.

''The bay on the inside of this peninsula did not extend very far over the Appalachians, being restricted by the limits of the submergence. It covered the Blue Ridge at least from Culver's Gap in New Jersey to Perry County, Penna., but did not extend over any part of the mountain in New York. The depth of the material was at least thick enough to bury from sight the Blue Ridge, requiring probably a depth between one hundred and four hundred feet.

''Upon uplift at the beginning of the Tertiary the streams flowed at random over the nearly level coastal plain, as do now the streams east of the 'fall line.' It was only later that they discovered the hidden barrier to their courses and began to toil for their existence.

''Thus, the wind gaps of eastern Penna. have been taken as circumstantial evidence of a once wide reaching mantle of late Cretaceous sediments. The observations made thus far are incomplete and further study is needed to confirm this hypothesis or to supplant it by another which shall better fulfill the requirements of all the facts. The writer believes, however, that the conclusion regarding the burial of the Blue Ridge is well founded.''

Methods for map study.

Introduction.—The re-examination of the problem was undertaken in 1912 and was based on several methods of attack which were planned to be free from subjective bias. The fact that nearly the whole of the seaward slope of the Appalachian Province and Coastal Plain from southern Vermont to northern Virginia is covered by the topographic maps of the U. S. Geological Survey on a scale of 1: 62,500 was particularly favorable to the investigation. Map study rightly pursued not only supplements field study but also suggests new details and even problems for field study, although as Davis has pertinently remarked ''it seems to lead different investigators to different results.''[7]

Emphasizing of contours.—In order to follow the remnants of an ancient topography from one topograpic sheet to another it was found desirable to emphasize significant contours with colored crayon or ink. But if contours are selected at random, because they bring out a few features in one quadrangle, local physiographic forms may come to assume an undue importance and may obscure other features of regional significance. Such a haphazard treatment of a map is subjective rather than objective and tends to fix in the mind and on the map merely tentative hypotheses. To avoid this tendency certain definite contour intervals only were emphasized and as a matter of convenience those marking the even hundreds of feet were chosen. Thus for a north-south belt of a quadrangle extending through western Connecticut the appropriate contours to be emphasized are as follows:

Winsted	1,200,	1,400,	1,600
Waterbury	800,	1,000,	1,200
Derby	400,	600,	800
Bridgeport	200,	400,	——

[7] W. M. Davis: The Peneplain, Geographical Essays, 1909, p. 353.

After the maps have been treated in this manner, care being taken that each elevation is represented by the same color on different sheets, the eye at a glance can note the general accordance or discordance of summit elevations and can more easily pick out significant details.

Method of projected profiles.—An ancient peneplane may have been uplifted so long ago and become so thoroughly dissected that only far-scattered remnants remain. Even the remnants will have been cut down to some extent below the original surface. From the valleys below no suggestion of the former plane is seen, but from a few favorable positions slightly above the ancient surface the eye, by projecting the remnants into one view, may be able to perceive the original level character.

The range of vision, however, is limited; photographs fail to bring out faint details of distant landscapes: neither eye nor camera can record the exact levels or elevations or angular slope of the line of sight. Some method, therefore, is needed for this study which shall be founded on topographic maps and which shall be in the nature of a vertical profile, yet project from any desired direction the scattered remnants into one section. A belt of country three, ten, or twenty miles wide may be needed, depending on the distance between remnants, to give the best results. The projection of such a belt of country upon one plane gives what the writer has called a "projected profile."

In constructing a projected profile the horizontal scale must be large enough to bring out essential details, and generally the vertical scale must be exaggerated. Whatever vertical scale is adopted it should be used for all the profiles so that they may be directly comparable. The width of the belt of country to be projected depends upon the degree of dissection and should be great enough to give, if possible, a well integrated sky-line, especially when the problem, as in the present instance, deals with thoroughly eroded surfaces. The direction of view must be chosen so as to bring out to best advantage the features sought. It is not always possible beforehand to determine the best direction of view from the topographic maps so that it may be necessary, and in any case it is generally advisable, to make several projected profiles of a region in order to determine which direction is the best.

For the present problem the topographic maps on a scale of 1: 62,500 are of a suitable horizontal scale. After a number of trials the vertical scale chosen was one inch equal to two hundred feet, or 1: 2,400. This scale is convenient, also, because it permits the use of cross-section paper ruled to tenths of an inch; each division thus equals 20 feet, which is the usual contour interval of the topographic maps of the eastern United States. This vertical scale, twenty-six times the horizontal, grossly exaggerates the relief; it is necessary, however, in order to clearly distinguish the erosion planes on the Piedmont slope which differ in elevation only by one to two hundred feet.

The writer has found this method of projected profiles of so much use in the present study that a detailed illustration of the method will be given, both for the purpose of showing the basis on which the projected profiles have been made and to illustrate the adaptability of the method for similar problems.

The method is essentially as follows. A strip of cross-section paper is fastened parallel to the lower edge of the drawing board and the topographic sheet is fastened above so that the direction of view is at right-angles to the length of the section and thus parallel to a T-square placed against the lower edge of the drawing board. The area to be projected is outlined on the map and the contours which cut the front edge of the block are projected first to give the foreground. Then the topography, beginning at the front and working toward the back of the block, is systematically projected onto the cross-section paper with the aid of the T-square. As each hill is outlined on the section a line is drawn through it on the map to show that it has been projected and this also gives a record of the progress of the work. Each successive belt of topography shuts out all behind it except the higher elevations, thus indicating what features are to be projected as the work progresses. At the outset it is advisable to study the topography of a region first from the map in order to become thoroughly familiar with it. When, however, this familiarity has been gained, as well as experience in the method of projection, profiles of this character can be built up quite rapidly and with little mental labor.

[It should be said in regard to projected profiles that they are objective with respect to summit elevations but that slopes may or not be truly shown. A rather limited experience suggests that there is room to exercise considerable judgment in the selection of slopes. The case may arise, also, where it is advisable to omit a prominent object in the foreground because it hides too much of the country beyond; or, if it seems desirable to retain it, the topography hidden by it may be indicated by dotted lines. In effect a projected profile is a skeletonized block diagram and consequently calls for the exercise, in some degree, of the pictorial sense.—EDITOR.]

There are a number of reasons why this system of projected profiles is preferred to the more simple profiles in common use. Single vertical-plane profiles generally are of limited use in demonstrating the former existence of a surface now nearly destroyed by erosion. The direction of a single vertical section must be specially chosen if it is to pass through more than one or two remnants. The greater part of such a profile will show only the surfaces of later erosion and the choosing of the position of the vertical plane is open to the danger of selecting facts which support a favored hypothesis.

Miss Hatch has published profiles of a section of southeastern Connecticut which show excellently the character of the upland as a succession of terraces facing the sea and stepping down from 500 feet through 400, 300, 200, and 100 feet.[8] Projected profiles were constructed of the ridges between the principal stream valleys; five strips each averaging about two and one-half miles wide were used. Where, as in this case, the terraces are fairly well preserved such narrow strips will give a satisfactory profile. Where no one interfluvial ridge, however, has the terrace system well preserved, a projection of several ridges upon the same plane will become necessary in order to piece out the evidence.

Lobeck has used a somewhat similar system of projection in his study on "The position of the New England peneplane in the White Mountain region,"[9] except that the foreground is omitted. He divided a belt of country fifteen miles wide into five strips and projected each separately, each profile showing only the sky-line for a belt three miles wide. Putting in the foreground, however, has a certain advantage in construction, even if

[8] Laura Hatch: Marine terraces in southeastern Connecticut, this Journal, 44, 319-330, 1917.
[9] The Geogr. Review, vol. 3, pp. 53-60, 1917.

afterward it is omitted, as it offers a systematic way of building up to the sky-line with less danger of omitting some of the lower culminating points. It also gives an impression of the degree of dissection and may bring out the position of erosion planes below the one which determines the sky-line.

The method of projected profiles which shows all visible summits was adopted chiefly, however, because it is a method more free than others from the subjective defect of picking and choosing the facts. Belts of country are selected which stand up highest. That line of sight is taken across this belt which is at right angles to the general slope of the topography and which gives, therefore, the least concealment of the background by the foreground. It is the direction of sight which is best adapted to show the character of the culminating upland surface, as to whether it was a plane or a series of planes.

Complexity of the physiographic record.

Physiographic Divisions of Connecticut.

The physiography of Connecticut has been so well described by Davis[10] that it will only be necessary to record here certain new facts which have been determined since his descriptions, as well as that in the "Geology of Connecticut,"[11] were published, and to restate certain general features bearing on the problem under discussion.

The upland attains its greatest altitude in the extreme northwestern part of the state and slopes gently down toward Long Island Sound, the slope becoming steeper in the last 5 to 10 miles. It is divided into two parts by the central lowland and these are commonly known as the eastern and western uplands. The upland surface has had a physiographic history corresponding in general to that of the Piedmont Plateau of the Middle and South Atlantic States and to the Coastal Plain, although the later record is left in different form. South of Connecticut the Coastal Plain proper is mostly submerged, bringing the waters of Long Island Sound against the ancient metamorphic rocks.

[10] The Triassic Formation of Connecticut, Part III, U. S. G. S., 18th Ann. Rept., vol. 2, 1896-97.

[11] State Geological and Natural History Survey, Bull. No. 6, Chap. 1, by Wm. North Rice.

Although in most general views in the field, the upland has the appearance of being a single peneplaned surface, detailed study of the topographic maps shows it is divided into a number of benches or terraces of variant width which differ in elevation from 200 to 400 feet. The extent of the eight pre-Pleistocene terraces is shown by fig. 1.

In the northwestern part of the state the upland surface lies mostly between 1,200 and 1,400 feet above the sea. The highest hills rise 200 to 300 feet above this level and the valleys are cut several hundred feet below it, those of the larger streams having their floors from 500 to 700 feet above sea-level. In a general way the hilltops broaden and the relief somewhat diminishes as the upland descends toward the Sound.

The highest elevations are in the extreme northwestern corner of the state where the surface is a plateau 1,700 to 1,800 feet above the sea. Above this general level low, dome-shaped hills rise, their culminating point being Bear Mountain 2,355 feet in elevation. This belt of high country is the southern end of the Taconic Range and represents an erosion surface distinct from those of the western upland at lower elevations.

The rocks of the western upland are dominantly granites, gneisses, and schists. The latter are commonly highly metamorphic feldspathic and siliceous mica-schists and over considerable areas are so intimately injected with granite as to make them a very resistant gneiss. On the whole, the rock formations of the western upland are somewhat more massive and resistant than those of the eastern upland.

The main drainage exhibits a marked indifference to geologic structure. In places, best seen in the Housatonic valley, a river will flow for a few miles along the outcrop of a weak formation and then break across resistant rock masses in a steep-walled gorge. The regional trend of the rock formations is slightly east of north, but broad sweeping belts occur convex to the northwest. The structure planes dip for the most part to the east and southeast. The relative indifference of the larger drainage pattern to the structure is to be explained as the result of a number of factors. The broad areas of resistant rocks and frequent flat dips have permitted a digitate pattern to persist from earlier erosion cycles. The initial drainage appears to have been to the southeast, diagonal to the structure; the Housatonic still

FIG. 1.

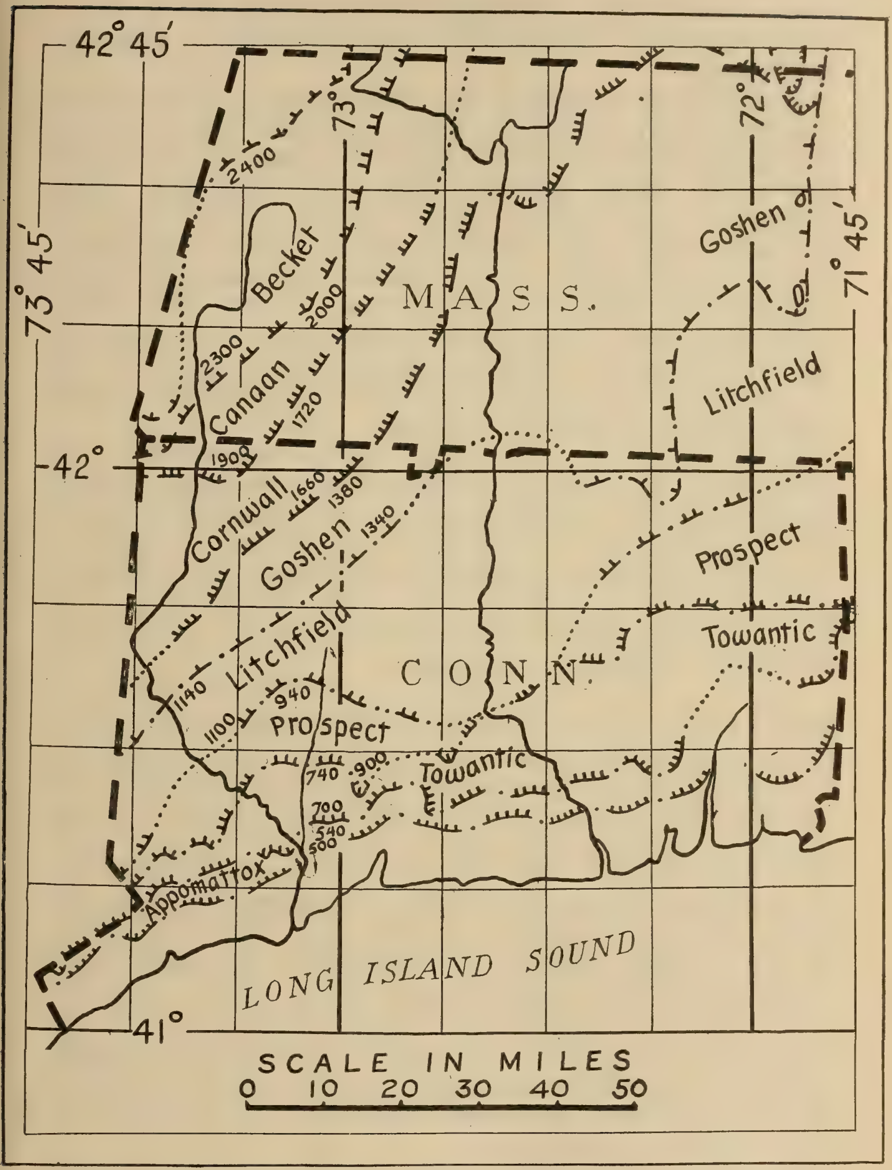


FIG. 1.—Extent of the Pre-Pleistocene Piedmont Terraces in Connecticut and western Massachusetts. Preliminary survey made in 1912 from topographic maps.

flows on a general course S 40° E for a distance of 30 miles above its junction with the Naugatuck. A secondary drainage pattern has tended to develop, however, in a north and south direction, giving shorter courses to the

Sound and taking advantage of the directions of foliation, though not located for long distances on any one set of beds.

The eastern upland, in the northern part of the state, has broad areas slightly above 800 feet in elevation, widely isolated hills rise to 1,000 feet, and the culminating points range between 1,200 and 1,300 feet. The principal valleys have elevations between 500 and 700 feet above the sea. The elevations of these three elements of the upland surface descend toward the south and to some degree approach each other. For some miles back from the shore the river valleys are drowned, the higher hilltops are flatter and occupy a larger area; the region as a whole has less relief than farther north and is physiographically younger.

In the northern half of the eastern upland the rock formations, in part, lie in distinct belts striking slightly east of north and the drainage is well adjusted to structure. In the southern half there is a greater proportion of granite in large irregular masses and the drainage shows little relation to structure. The Connecticut flows south-east diagonal to resistant formations, pointing to an origin through superposition.

The central lowland is from 15 to 20 miles wide over most of its area but narrows at its southern end. It is determined by the weak Triassic shales and sandstones. Over broad areas it is a gently hilly country between 100 and 200 feet above sea-level, although away from the principal rivers the average elevation will range a hundred feet higher. The rivers are trenched below the general level in youthful valleys, indicating a moderate uplift since the lowland was developed. The continuity of the lowland surface is interrupted by many trap ridges which rise to elevations of 200 to 400 feet near the shore and of 700 to 1,000 feet over the greater part of the lowland. Views from the crests of the higher ridges show that they lie at about the elevations of the adjacent uplands and must represent with them the remnants of older baselevels of erosion.

Thus from the point of view of origin, the distinction between the central lowland and the upland largely breaks down. The higher parts of the lowland are an integral part of the upland and the lower parts of the upland, especially near the shore, are part of the lowland.

The whole of Connecticut (southern New England) has experienced broad uplifts of the crust recent enough so that the belts of resistant formations have not been removed to any great extent by erosion, yet long enough ago to permit narrow valleys to be cut deep into the harder rocks while the softer rocks, in the central lowland, have been worn down to a peneplane of a lower level. It is clear, then, that the resistance of the various kinds of rocks to erosion has been very unlike. It is an understatement rather than an overstatement to say that the interval needed to reduce the resistant formations of the upland to a peneplane would have to be more than ten times greater than that which has witnessed the development of a peneplane in the central lowland.

The physiographic history of the upland is complex, but involves three major problems. These are (1) the causes which have determined the height and distribution of the highest hills which integrate into the sky-line as seen in a broad view from the highest points, (2) the history of the broad rolling surfaces and higher open valleys of the upland, the agricultural portions of the plateaus, and (3) the history of the deeper and narrower river valleys showing steep rocky slopes, rock benches, and drift filled floors.

For the treatment of the first and second of these problems the western upland of Connecticut appears to be the most favorable region of any part of the Piedmont Plateau, of which it is a separated member. There are several reasons for this. It is in closer relation to the sea than is the Piedmont Plateau southwest of the Delaware; the area is underlain by broad resistant formations which have preserved to a greater degree the initial topographic outlines. Chiefly, however, the region is valuable for study because the structure strikes toward the sea instead of parallel with it, as is the case from New Jersey to Georgia. The result is that, as the plateau surface is traced inland along the interfluvial ridges, the changes are those due mainly to differences in physiographic history and only in minor degree to changes in rock formation. From New Jersey south, on the contrary, in following the sloping Piedmont Plateau inland along the interfluvial belts, the rock formations repeatedly change and are the major factor in determining the surface forms.

The Complexity of the Connecticut Record.

An inspection of projected profiles of western Connecticut, [see pl. V and figs. in the following section], brings out the fact that from the shore northward the hilltops do not slope upward as remnants of a single warped peneplane tangent to the upland surface. On the contrary, they fall into a series of benches each member of which is higher than the preceding one. Likewise the hills below the sky-line and the rock benches and spurs on valley sides show a similar habit.

Each set of locally accordant hilltops does not necessarily represent a regional baselevel, for the distance above baselevel is a product of many factors and it is possible that certain older or temporary baselevels may have had the evidence of their existence completely masked by the effects of later erosion with respect to other baselevels. Nevertheless it is clear that the topography of the western upland is not the result of the erosion of a simple warped surface, nor is it the product of even two partial erosion cycles. Its history is much more complex.

Irregular warping or faulting cannot account for the step-like character of the sky-line, for the margins of the steps are sinuous lines, best seen on the maps, but well seen on the profiles where a lower baselevel passes in between the outposts of a higher level. Furthermore, inspection of separated regions, such as the eastern and western uplands, shows similar series of benches at almost the same elevations, indicating that the movements of uplift have been broad and regular. Some warping should be expected, some faulting to a minor degree is possible, but the study shows that such factors cannot be invoked to explain the general features of either the western or the eastern upland. There must be postulated many long halts in regional uplift, permitting partial peneplanation with respect to many baselevels. The western upland is a region, as already noted, that has been peculiarly sensitive to changes of baselevel, and the resistant nature of the rocks has preserved the evidence of these changes for a long period of time.

Let the conditions for recording baselevels on the Connecticut upland be contrasted with those of interior regions far removed from the sea. In the latter, the rivers would keep on at their old grade even after renewed uplift until headward erosion proceeding from the sea had had time to reach the interior region. If the movement of uplift were 200 feet the steepening of the river grade during downward and headward cutting would cause, at a certain distance inland, the new grade to be only 100 feet below the old, and near the headwaters the influence of the new movement would completely disappear. Thus the stages of crustal movement are undifferentiated and become additive in a continental interior. Phases of depression of the crust may pass without record in that region whereas on the seaward margin embayment gives a sinuous shore and sedimentation takes place below the new baselevel. The outer slopes of the continent, therefore, are much better adapted than the interior for a study of detailed changes in baselevel.

In this section attention has been called to the indications of complexity in the physiographic history of the Connecticut upland. The detailed analysis of the numerous baselevels which have left a record will be postponed, however, until after the presentation of the criteria bearing upon their interpretation.

Editorial Note on Projected Profiles of the Terraces of Western Connecticut.

The step-like character of the profile of the western upland, referred to in the preceding section by Professor Barrell, is best seen in pl. V which shows the entire series of terraces.[12] It is also seen in the following projected profiles which have been selected from a much larger number drawn by Professor Barrell. Most of them show the topography of localities where the "steps" are well marked. It should be kept in mind that the vertical scale of all the profiles is greatly exaggerated, i. e., is twenty-six times the horizontal. It should also be remembered that all the terraces, however perfect may have been their initial development, have been dissected by later subaerial erosion so that they are to be recognized at the present time only from their remnants. If the planation were complete in all cases, it would be expected that the remnants of the younger terraces would integrate into a more even and continuous sky-line than the older ones.

Figure 2 shows several of the younger terraces projected from an area 6 by 8 miles in extent on the Stam-

[12] This is in the third part of the paper which will be published in the June number of this Journal.

ford and Norwalk quadrangles. The stair-like character of these benches is evident. These benches are not so strongly developed as the older ones; in fact the Pitcher Mountain terrace (280-320 feet) is entirely re-entrant in character in this area and the New Canaan terrace (340-380 feet) also shows this feature. The elongated flat-topped form of many of the hills is a characteristic feature of the topography of southern Connecticut the significance of which, from the point of view of the marine origin of the terraces, is referred to by Professor Barrell in later sections of the article. The relative steepness of the slopes which connect the successive level benches should be noted.

Fig. 2.

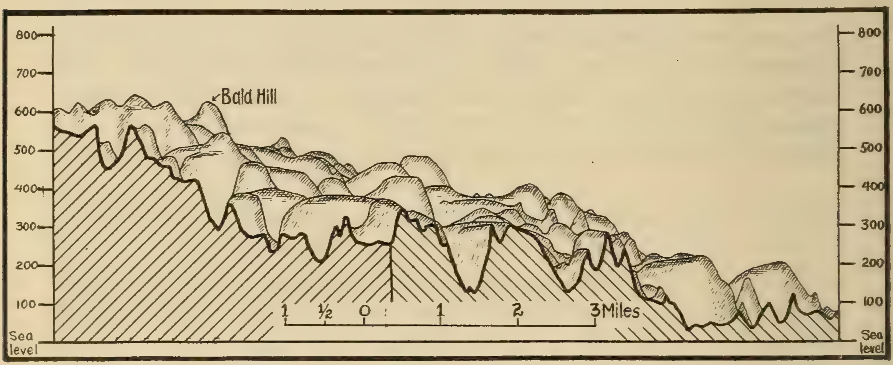


Fig. 2.—Projected profile of parts of the Stamford and Norwalk quadrangles showing the Sunderland (200-240 feet), Pitcher Mt. (280-320), New Canaan (340-380), and Appomattox (480-520) terraces. View looking N 45° E.

Figure 3 shows the adjacent parts of the Towantic (700-740 feet) and Prospect (840-880 feet) terraces projected from an area 6½ by 8½ miles in extent on the Derby and New Haven quadrangles. The integration of elongated flat-topped hills into an even sky-line is well shown and also the relative steepness of the slope joining the two levels. As will appear, this latter feature is taken to indicate an old shore-line.

Figure 4 shows the adjacent parts of the Litchfield (1,100-1,140 feet) and Goshen (1,340-1,380 feet) terraces projected from an area 6½ by 9½ miles in extent on the New Milford and Waterbury quadrangles. These terraces are older than those shown on the preceding profiles and the hilltops do not give so continuously a level sky-line although they are quite accordant in elevation.

FIG. 3.

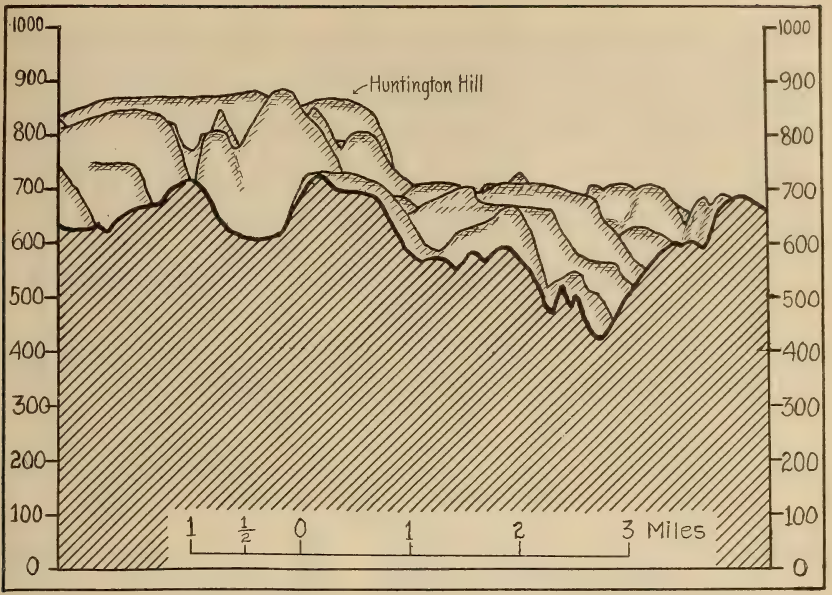


FIG. 3.—Projected profile of parts of the Derby and New Haven quadrangles showing the Towantic (700-740 feet) and Prospect (840-880) terraces. View looking east.

FIG. 4.

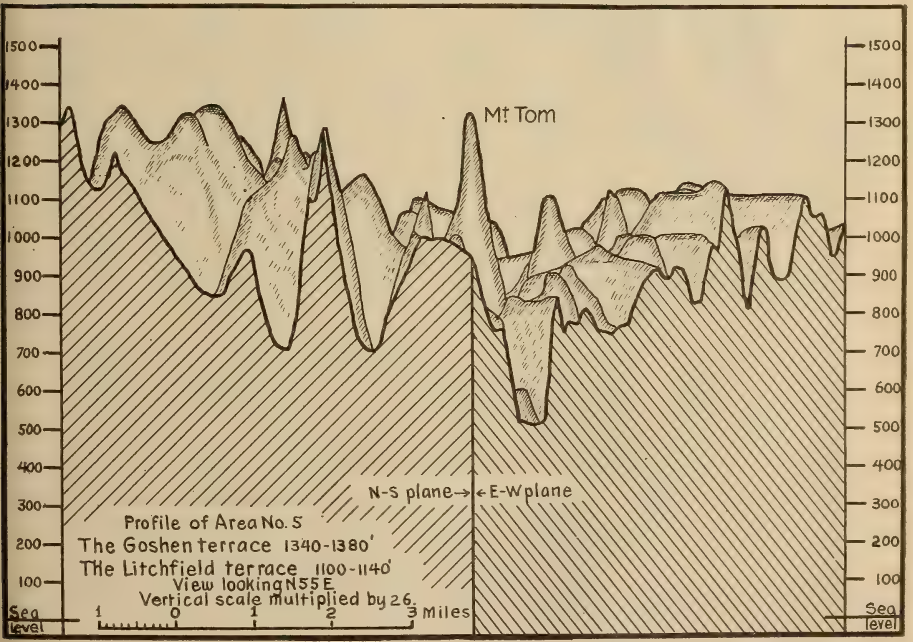


FIG. 4.—Projected profile of parts of the New Milford and Waterbury quadrangles.

The transition slope from the lower to the higher level may be recognized, about 1½ miles to the left of Mt. Tom, but is less evident than on the preceding profiles owing to the greater complexity of the geologic formations in this area. Mt. Tom, formed of resistant amphibolite, was interpreted by Professor Barrell as a rock stack now so eroded, however, that no definite evidence of wave work on its slopes can be detected.

Figure 5 shows the adjacent parts of the Goshen (1,340-1,380 feet) and Cornwall (1,640-1,680 feet) terraces projected from an area 6½ by 9½ miles in extent on the Cornwall and Winsted quadrangles. The Goshen terrace is well shown and also the transition slope, *i. e.*,

FIG. 5.

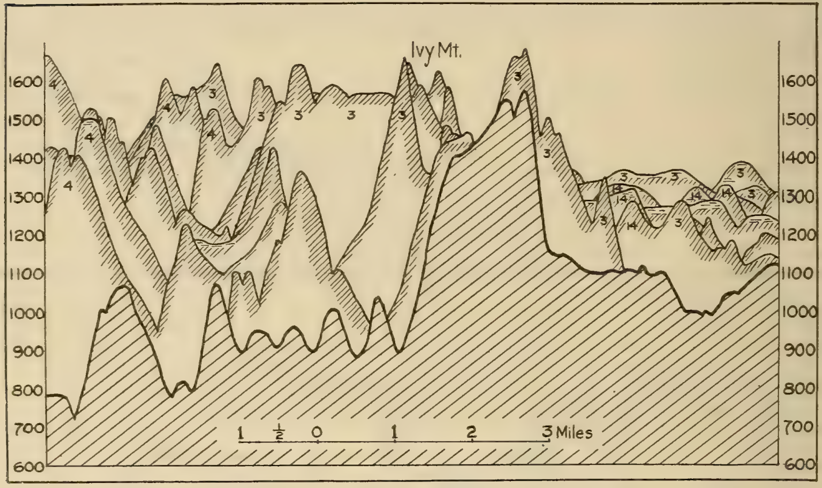


FIG. 5.—Projected profile of parts of the Cornwall and Winsted quadrangles showing the Goshen (1,340-1,380 feet) and Cornwall (1,640-1,680) terraces. View looking N 55° E. (3) Berkshire schist, (4) Becket gneiss, and (14) Thomastown granite.

the Goshen "shore-line"; on the other hand, the remnants of the Cornwall terrace show a much more irregular sky-line. The numerals correspond to those of the geologic formations as given on the preliminary geologic map of Connecticut.[13] It is seen that the difference in elevation of the two terraces does not depend on differences in rock formations and moreover the Goshen plain, referred to in the next paragraph, is developed on granite and schist. The general lack of dependence of the

[13] Conn. Geol. and Nat. Hist. Survey, Bull. No. 7, 1906.

terraces on differences in the rock formations is one of the reasons for considering that the terraces could not have been formed in the first place by subaerial erosion even though the evidence of such erosion may now be predominant.

Figure 6 shows the relative extent of remnants of the Cornwall terrace between the elevations of 1,600 and 1,680 feet (solid black) and of the Goshen terrace between 1,300 and 1,380 feet (diagonal ruled) in practi-

FIG. 6.

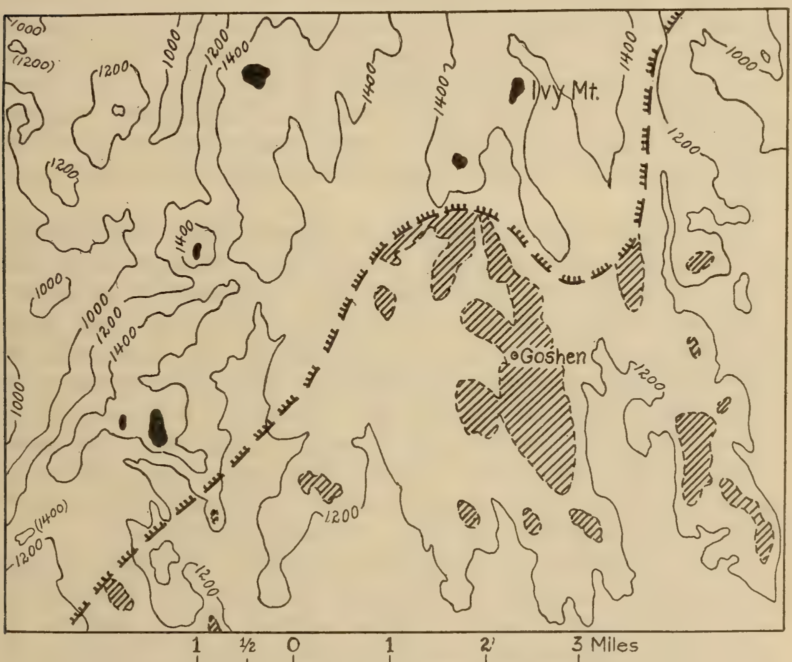


FIG. 6.—Map showing remnants of the Cornwall terrace between 1,600 and 1,680 feet (solid black) and remnants of the Goshen terrace between 1,300 and 1,380 feet (diagonal ruled).

cally the same area covered by the preceding profile. The sinuous line which crosses the map marks the position of the Goshen shore-line. When it is considered that the remnants of each terrace embrace an equal range in elevation, namely, 80 feet, it is seen that the Goshen terrace is very much better preserved than the Cornwall. After viewing the country from the summit of Ivy Mountain Professor Barrell noted that "The regions to the north and south look entirely different. To the south the Goshen plain lies 300 feet below and extends southward for four or five miles. It consists of broad flat hills—rolling dissection—deep till—good farming land. To the north the hilltops slope from 1,640 up to 1,700 feet. Very much less land at this approximate level because this is the outer margin of the 1,650-1,700 foot plain—also shows greater age. Thinner soil—poorer farming land. The glacier felt the decline in elevation from the Cornwall to the Goshen plain and dropped till over the northern end of the latter.'' The difference in the topography here noted strongly impressed itself on Professor Barrell and was an important factor in determining the probable ages of the terraces. Expressed in terms of topography it may be said that broad flat-topped and elongated hills are not so characteristic of the region northwest of the Goshen ''shoreline'' as they are of the region southeast of it. The explanation of this difference is brought out in later sections.

The Connecticut terraces are widest in the eastern part of the state and gradually narrow in a southwesterly direction until they attain their least extension in the western part of the state, as shown by fig. 1. It has been thought that it would be interesting for comparative purposes to give profiles embracing the lower terraces of these two localities. Both are represented among Professor Barrell's profiles, but those here shown have been redrawn to cover larger areas from somewhat different points of view. The large profile, pl. V, and fig. 2 show the terraces at intermediately situated localities.

Figure 7 shows the projected profile of the Stonington, southern quarter of the Moosup, and western quarter of the Charlestown (R. I.) quadrangles, the direction of view—N 25° E—being parallel to the shore. Profiles of five interfluvial ridges in the Stonington quadrangle have been published by Miss Laura Hatch and for descriptions one may refer to her article ''Marine Terraces in Southeastern Connecticut.''[14] The 200 and 500 foot levels are well marked and are interpreted as representing stillstands of the land through considerable intervals of time. Levels at 300 and 400 feet may be recognized but are not so strongly developed. The integration into an even sky-line of the summits which mark the 500 foot level is very noticeable. It is largely due to the presence of elongated flat-topped hills or ridges, and such ridges are quite characteristic of the entire region.

[14] This Journal, 44, 319-320, 1917.

FIG. 7.

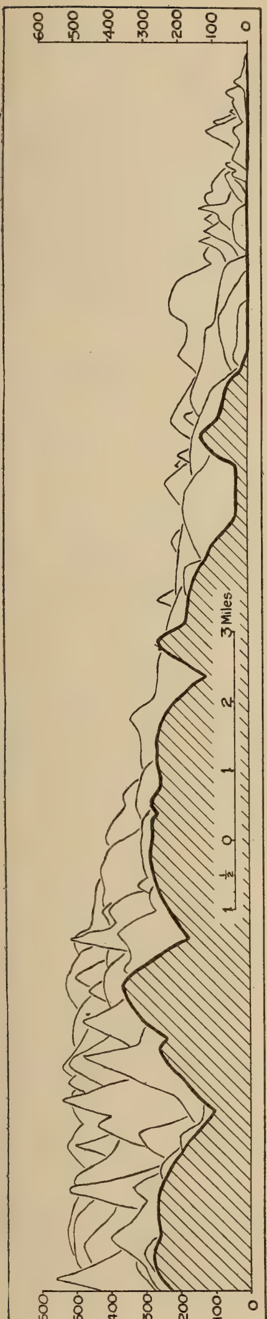


FIG. 7.—Projected profile of the Stonington and parts of Moosup and Charlestown (R. I.) quadrangles. View looking N 25° E.

FIG. 8.

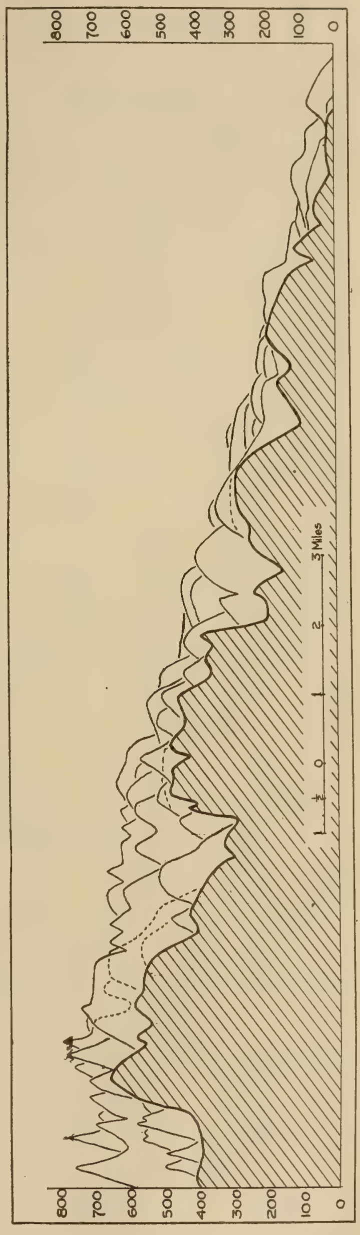


FIG. 8.—Projected profile of the Stamford and part of the Oyster Bay (N. Y.) quadrangles. View looking N 30° E.

Figure 8 gives the projected profile of the Stamford (Conn.) and northwestern portion of the Oyster Bay (N. Y.) quadrangles where the terraces are narrowest, the direction of view being N 30° E or nearly parallel to the shore. A comparison of this profile with the preceding one appears to indicate that the terraces there seen are present but much less strongly developed. The problem of this weaker expression may be left for future solution. It may be said that the explanation does not seem to be found in the seaward protection afforded by Long Island, for the high level terraces show a corresponding narrowness as compared with their eastern portions, and it can not well be supposed that a permanent barrier has existed since the latter part of the Cretaceous at which time the two highest terraces are assumed to have been cut. The main factors appear to be a somewhat greater resistance of the rock formations to erosion and a steeper general surface slope than in the eastern part of the state. There was also an initial difference in the topography of the two localities though not sufficiently marked, perhaps, to have had much effect on the rate at which the benches may have been cut.

It should not be inferred that the recognition of the terraces was based only on the accordance of hilltops because the profiles give that impression. There is always the possibility of a chance accordance of hilltops and mere accordance no doubt has been too loosely used as a criterion for the recognition of peneplanes. Professor Barrell had this possibility clearly in mind and in his earliest note-book certain criteria are given for the recognition of true coincidences of level in a partly reduced upland. They are: "(1) There must be some 'special' feature (or features) in the level observed, not a mere hilltop; (2) similar features elsewhere must be accordant and lie in the same plane, (3) the baselevel is as low as the lowest features correctly determined as belonging to the stage, and (4) levels should be regionally independent of structure, and rocks of similar resistance, when in similar relation to baselevel, should have a corresponding topographic development." An idea of what these special features were is gained from this article and an inspection of maps and notebooks shows that Professor Barrell was constantly on the lookout for them.

[To be continued]

ART. XVIII.—*A Model for Demonstrating Crystal Structure;* by HERBERT P. WHITLOCK.

The interest, both scientific and popular, in atomic groupings in relation to crystal structure which has been created by the recent work of W. H. and W. L. Bragg and others has caused a demand for some means of presenting to an audience, either in the class room or from the lecture table, the essential facts of these group movements. The difficulty encountered in representing complex particle combinations in any series of diagrams involving their projection upon a flat surface has led the writer to resort to three dimensional models of various constructions, the latest and most effective of which is the subject of the present paper. The principle involved, that of supporting a series of inconspicuous rods carrying beads spaced at appropriate intervals by means of two perforated diaphrams, is not new. Models of this general type were described by Bowman in 1910,[1] and somewhat similar models were suggested by Sohncke in 1879.[2] The writer in constructing the present model has endeavored to produce a demonstrating device which may be readily put together and taken apart while the demonstrator is speaking, which is plainly visible to a fairly large group of auditors, and which, by using interchangeable rods, may be employed to demonstrate and study any point system of atomic spacing.

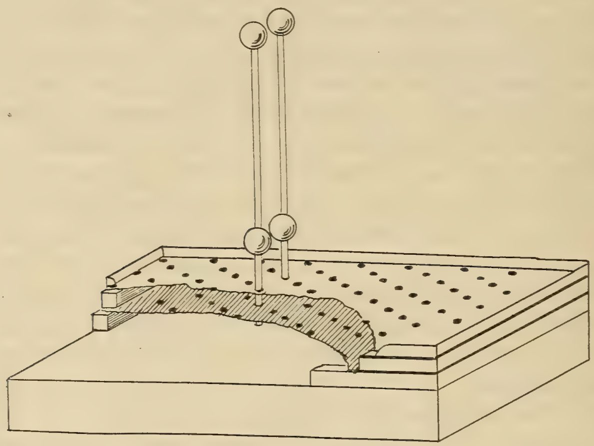
The frame work of the model, which is illustrated, partly cut away to show the construction, in fig. 1, consists essentially of a wooden block 9 inches square surmounted by two narrow frames, each 3/8 inch deep, and finished with a narrow moulding. Between the two frames and between the top frame and the moulding are inserted two sheets of tin, which previous to their assembling have been clamped together and punched with holes laid out by means of a carefully constructed pattern. The holes should be of such a diameter that they will readily take a glass rod of 3 mm. diameter, and in clamping the sheets of tin together with the pattern the punched holes are made to register accurately.

Two such frameworks or stands are necessary, one

[1] H. L. Bowman, Min. Mag., 16, 51, 1910.
[2] L. Sohncke, Entwickelung einer Theorie der Krystallstructur, Leipzig, 1879.

laid out in centered squares spaced to about 25 mm., or one inch, for groupings in the isometric and tetragonal systems; this may also be used for orthorhombic, monoclinic and triclinic groupings. The second stand is laid out in equilateral triangles of similar spacing, for hexagonal and rhombohedral groupings, and may also be used for orthorhombic, monoclinic and triclinic lattices. The atoms are represented by spherical wooden beads, one half inch in diameter, which may be obtained in six colors from dealers in kindergarten supplies.[3] The supporting rods are cut from ordinary glass rod stock of a diameter which will fit the holes in the wooden beads.

Fig. 1.



The rods are cut accurately to the desired length and the beads are spaced accurately on them and fastened with a drop of glue. It was found convenient to adopt for isometric groupings a cube of 10 cm. (4 inches), which takes four spacings between holes of the frame and permits the construction of all the simple isometric crystal structures.

A few illustrations will serve to show the method of using the model, which has been tried out before several audiences. Fig. 2 shows the model arranged to illustrate the space lattice of a centered cube. The dodecahedral planes of particle crowding are here accentuated. Removing the outer rods and substituting one of them

[3] The beads used in the model illustrated were obtained from Milton Bradley Co.

for the central rod, the model presents the aspect of a centered cube, fig. 3.

Introducing rods appropriately spaced with beads of a different color the atomic grouping of cuprite may be produced as in fig. 4 where the introduced beads represent the copper atoms. This structure may be carried further by replacing the white beads of fig. 2 and adding more copper atoms, as in fig. 5. It now becomes apparent that the spacing of the colored beads representing copper atoms are arranged in a face-centered cubic lattice. This may be demonstrated by removing the white beads of the cube centered lattice which represented the oxygen atoms.

Retaining the rods carrying the colored beads of the face-centered lattice and introducing rods carrying another face-centered cubic lattice, the atomic grouping of sphalerite may be reproduced as in fig. 6 in which the white beads represent sulphur atoms and the colored beads zinc atoms or vice versa.

The point system of calcium fluoride (fluorite) may be demonstrated by retaining the white, face-centered cubic lattice of fig. 6, and substituting for the colored face-centered cubic lattice rods which carry a closer-spaced cubic lattice or colored beads which center every tetrahedral group of the white beads as in fig. 7. Here the white beads represent calcium atoms and the colored ones fluorine.

An atomic structure which is somewhat difficult to visualize is that of the diamond. It may be demonstrated on the model by setting up two face-centered cubic lattices of the white beads, one shifted along the cubic diagonal of the other one quarter of its length, as in fig. 8. It will be noted that this network presents the same aspect as that of sphalerite fig. 6, with the exception that the atoms represented are of one kind.

The atomic structure of calcium chloride (halite) is another example of the shifting of the position of one face-centered cubic lattice with respect to another similar lattice. This may be demonstrated with rods upon which two sets of colored beads are spaced so that they occupy the relative positions shown in fig. 9, in which one lattice is shifted along the cubic edge of the other one half its length. The beads of two lattices represent respectively atoms of calcium and of chloride.

Fig. 2.

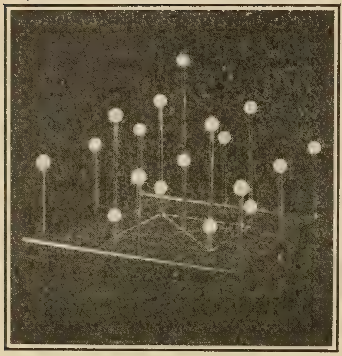


Fig. 3.

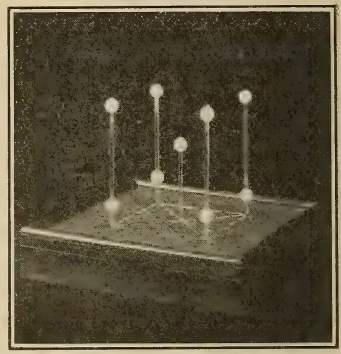


Fig. 4.

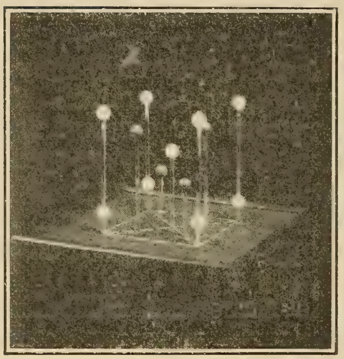


Fig. 5.

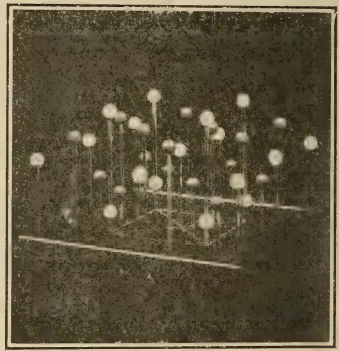


Fig 6.

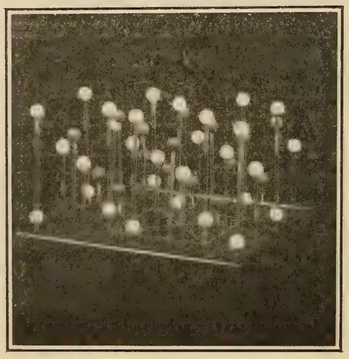


Fig. 7.

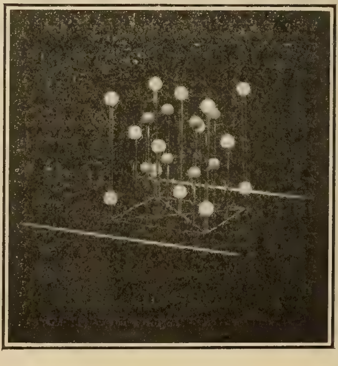


Fig. 8.

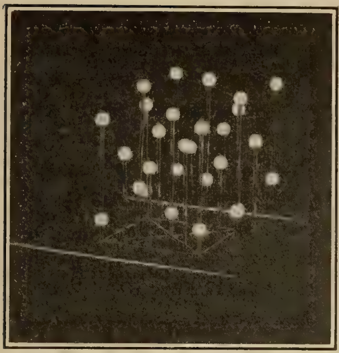


Fig. 9.

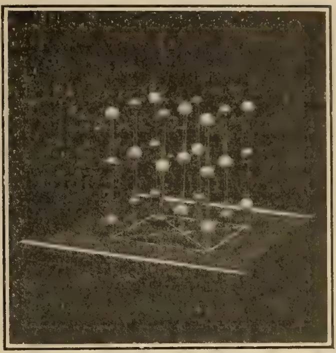


Fig. 10.

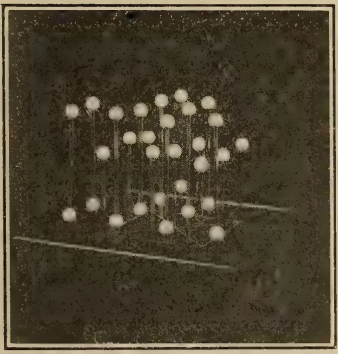


Fig. 11.

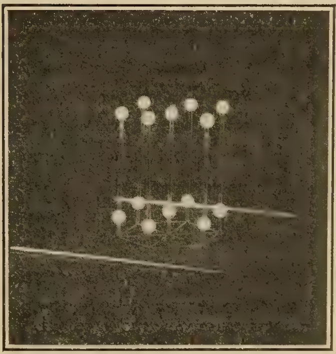


Fig. 12.

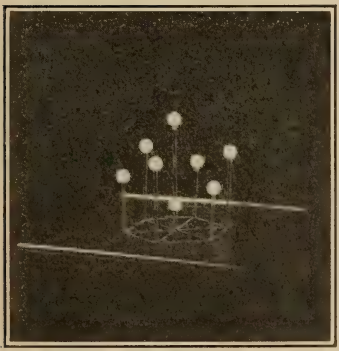


Fig. 13.

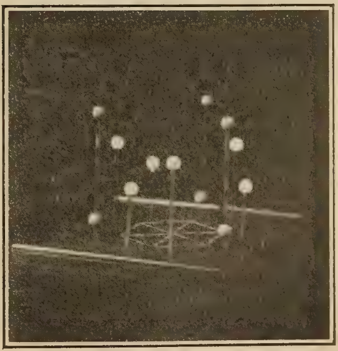


Fig. 10 shows a centered square prismatic lattice constructed from the same rod and bead elements used in fig. 2 and capable of being "taken down" to show a single centered square prism of the tetragonal system. Similarly the principal lattices of the orthorhombic system may be demonstrated with the same rod and bead elements by varying the spacing of the holes used. By also varying the length of the rods lattices of the monoclinic and triclinic systems may be demonstrated.

The triangular spaced stand is shown in fig. 11 arranged to show a hexagonal space lattice which of course may be varied both by using a system of holes closer or further apart or by varying the bead spacing on the rods.

A rhombohedral space lattice is illustrated in fig. 12. This again may be varied as in the preceding instance, and by removing appropriate sets of rods the relation of this lattice to interpenetrated triagonal lattices may be demonstrated.

Fig. 13 shows the triangular frame arranged to show Bragg's suggestion as to the atomic structure of quartz, the colored beads representing silicon atoms and the white ones oxygen atoms.

All of the foregoing concrete examples are constructed from diagrams and data given by W. H. and W. L. Bragg.[4] They have been chosen more or less at random and by no means exhaust the possibilities of the device. Rod and bead elements may be added to the accessories of the model *ad libitum,* and a little practise will render possible the construction and demonstration of a very extended series of group movements including all but the most complex groups. With a framework constructed with a closer system of perforations even these latter may be reproduced.

The simplicity of this model, its low cost of construction and its ease of manipulation should render it possible of adoption as a lecture accessory by many teachers of crystallography.

Department of Mineralogy,
American Museum of Natural History,
New York.

[4] X-Rays and Crystal Structure, London, 1916.

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

In the type locality of the Craghead Creek shale, section 17, township 46, range 9 west, Callaway county, the youngest member of the section is a light-colored, sandy shale, carrying an abundant series of pelecypods, few corals and bryozoa, with an association of brachiopods, never abundant, of the following species: *Productella callawayensis, Schizophoria striatula* (a large variety), *Spirifer iowensis, Cyrtina triquetra, Atrypa reticularis* (with coarse ribs and extravagantly developed growth varices). The pelecypods, which for the most part are undescribed forms, comprise the following genera: *Palæoneilo, Edmondia, Actinopteria, Grammysia, Schizodus, Pterinopecten, Paracyclas,* and *Goniophora.*

The Cow Creek Section of the Craghead Creek Shale.

About fifteen miles northeast of this former locality, in section 25, township 47, range 8 west, on the divide between Auxvasse and Loutre rivers, a small, sharp anticline, cut almost at right angles by Cow Creek, gives a fine exposure of Craghead Creek shale, which for the most part is made up of beds younger than those exposed in the type locality. The thickness of the Devonian exposed in this locality is somewhat over twenty feet; the section, measured from the top to the creek bed, is as follows:

Zone No. 1. A fine-grained, chocolate-colored, paper shale, never abundantly fossiliferous and frequently quite ferruginous; the known fossils from this zone are species common to the shales below and comprise the following forms: *Athyris minima* Swallow, *Spirifer amarus* Swallow, *Lioclema occidens* H. & W., *Cladopora prolifica* H. & W., and large masses of *Stromatopora.*

Thickness 0-36 inches.

Zone No. 2. Hard limy shale, gray in color, fossils frequently silicified, crushed and water-worn; *Stropheodonta callawayensis* Swallow (common), *Productella callawayensis* Swallow (common), *Spirifer euruteines* Owen (rare), *Cyrtina triquetra* Hall (rare), *Schizophoria striatula iowensis* (rare), *Zaphrentis* sp. (common), two species of *Aulopora* (rare).

Thickness 12 inches.

Zone No. 3. Yellow-brown, sandy shale, almost barren of fossils; pelecypods, two species (rare), gastropods, casts of three species (rare), *Spirifer euruteines* Owen (rare).

Thickness 48 inches.

Zone No. 4. Yellow, soft, limy shale, very fossiliferous; *Zaphrentis* sp. (common), *Spirifer euruteines* Owen (exceedingly abundant), *Camarotœchia* sp. (rare), *Atrypa reticularis* (rare), *Schizophoria striatula iowensis* (rare), *Cyrtina triquetra* (rare).

Thickness 20 inches.

Zone No. 5. Iron-stained, gray, shaly limestone, made up almost entirely of fragmentary *Schizophoria striatula iowensis*. This layer is harder and breaks down in large blocks which do not weather nearly so rapidly as the beds above and below; *Schizophoria striatula iowensis* (quite abundant), *Stropheodonta callawayensis* Swallow (common), *Camarotœchia* sp. (rare), *Orbiculoidea* sp. (rare), *Aulopora* sp. (rare), *Zaphrentis* sp. (rare).

Thickness 10 inches.

Zone No. 6. Fine-grained, bluish, limy shale, fossils abundant; pelecypods, 14 species, mostly undescribed forms, *Orthoceras* sp. (rare), *Spirifer iowensis* Owen (rare), *Atrypa reticularis,* large form (rare).

Thickness 10 feet to creek bed.

Of the abundant pelecypods from zone No. 6, the following genera are identified, those most abundant being given first: *Paracyclas, Palæoneilo, Schizodus, Edmondia, Grammysia, Actinopteria, Pterinopecten, Goniophora.* Brachiopods are quite rare in this zone, but the two species recorded are forms that occur only in the uppermost layers of the shale, in the type locality. However, with the evidence offered by the pelecypods alone, the correlation of this zone with the top of the Craghead Creek exposure can scarcely be questioned, especially when the very similar lithologic character of the beds is taken into consideration.

It is interesting to note in this connection that ten species from the upper beds of the Craghead Creek shale are seemingly identical with forms described by Doctor Cleland in Bulletin No. 21 of the Wisconsin Geological and Natural History Survey, as follows: *Orbiculoidea telleri* Cleland, *Liorhynchus greeni* Cleland, *Camarotœchia scitulus* Cleland, *Cranæna iowensis* (Calvin) (figs. 8 and 9 only), *Edmondia fragilis* Cleland, *Goniophora obtusiloba* Cleland, *Pterinopecten telleri* Cleland, *Grammysia nodocostata* Hall, *Ptyctodus calceolus* N. & W., and *Ptyctodus ferox* Eastman.

Fulton, Mo.

ART. XX.—*A Geologic Section from 40 Miles West of St. Louis County to Jackson County, Missouri;* by E. B. BRANSON.

Sections of the geology of St. Louis County[1] and Jackson County,[2] Missouri have been published recently and it will help those not familiar with the geology of the state to have a section connecting these eastern and western counties. The sections shown in the accompanying figures were prepared from data obtained as described in the following paragraphs.

The writer has mapped in detail the geology through which the section passes from eastern Warren County to eastern Moniteau County, a distance of about 90 miles, and has examined large numbers of outcrops and made less detailed maps on the west end of the section through Moniteau, Cooper, and Pettis counties. Complete mapping in these counties will doubtless bring to light details not shown in the section. Between Charette Creek in Warren County and the west line of St. Louis County, a distance of about 20 miles, no mapping or sectioning has been done.

The extreme western end of the section, which involves Pennsylvanian strata, is taken mainly from the reports of Marbut[3] and Hinds[4] and is included merely to connect the western end, involving Mississippian and older strata, with the Jackson County section. The writer has made no investigations along the line of the section west of Sedalia, in Pettis County.

Maps showing details of Devonian distribution will appear in a bulletin of the Missouri State Bureau of Geology and Mines, and the stratigraphy of the Sylamore and related formations will be treated at length in a report soon to be published.

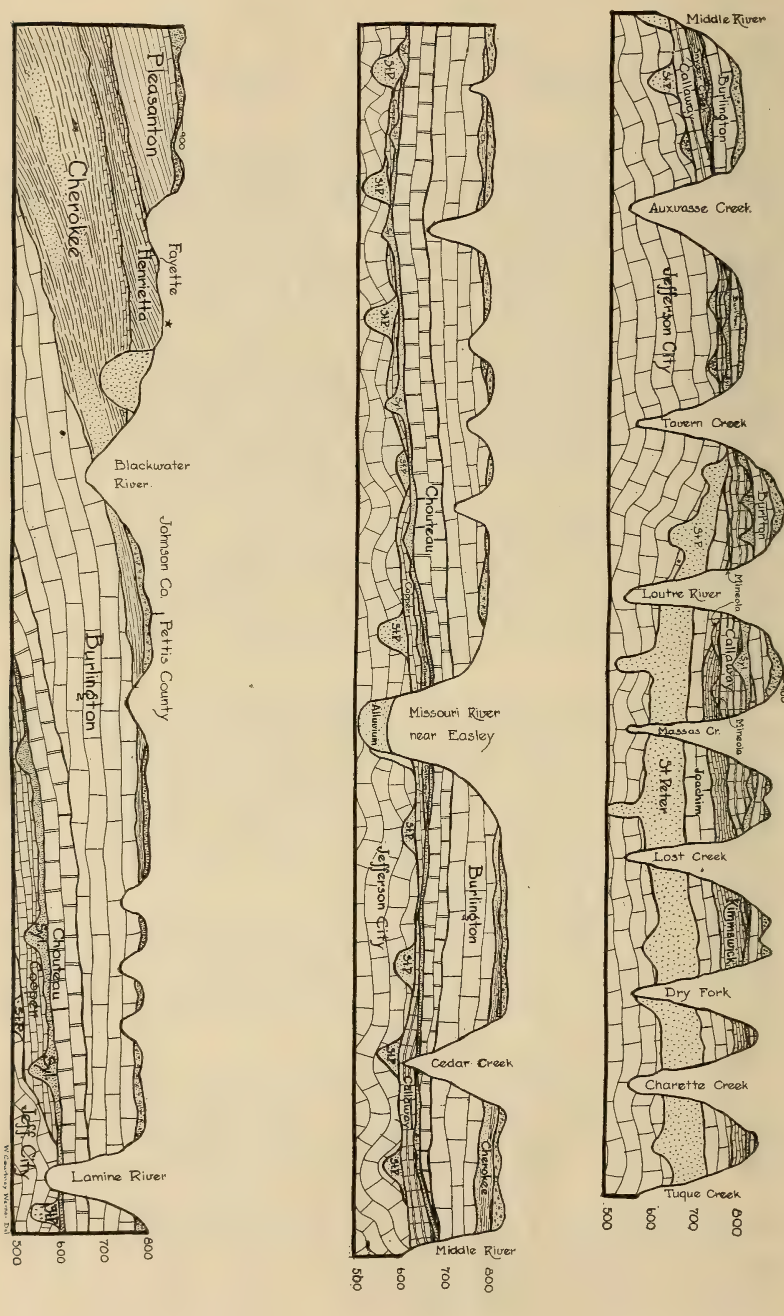
The strata shown are nearly horizontal along the line of the section if minor folds are neglected. The top of the Jefferson City dolomite lies at an elevation of about 650 feet in eastern Warren County and has about the

[1] Fenneman, N. M.: Geology and mineral resources of the St. Louis quadrangle, Missouri-Illinois, U. S. Geol. Survey, Bulletin 438.

[2] McCourt, Albertson and Bennett: The Geology of Jackson County, Missouri Bureau Geol. Mines, 2d Series, vol. 14.

[3] Missouri Geol. Survey, vol. 12.

[4] Missouri Bureau Geol. Mines, 2d Series, vol. 13.


Pleasanton
Cherokee
Henrietta
Fayette
Blackwater River.
Johnson Co.
Pettis County
Burlington
Chouteau
Cooper
Jeff. City
Lamine River
500
600
700
800
Chouteau
Missouri River
near Easley
Alluvium
Jefferson City
Burlington
Cedar Creek
Callaway
Cherokee
Middle River
500
600
700
800
Middle River
Burlington
Callaway
Auxvasse Creek
Jefferson City
Tavern Creek
Burlington
St. P.
Loutre River
Mineola
Callaway
Massas Cr.
Mineola
St Peter
Joachim
Lost Creek
Kimmswick
Dry Fork
Charette Creek
Tuque Creek
500
600
700
800

same elevation on the Missouri River, 100 miles west. Westward from western Cooper County, 160 miles from St. Louis the dip is steeper, and eastward from the eastern edge of Warren County, 40 miles from St. Louis, the dip is great enough to bring Pennsylvanian strata to the 650-foot level within a few miles.

There are many minor folds along the line of the section, the most pronounced of which is at Mineola, in Montgomery County, about 85 miles west of St. Louis. Here the top of the Jefferson City arises 200 feet in about four miles from southeast to northwest and dips again to the westward several feet per mile. The structure is a sort of dome which the section does not cut at the summit. Numerous minor folds that rise 20 feet or more are not uncommon but in working along the section one is struck by the general horizontality of the strata.

Rocks from Lower Ordovician to Pennsylvanian are exposed in the section but no Silurian is present. The following are the formations present in a belt 10 miles wide, with about average and maximum thicknesses in that belt. The minimum thickness of all excepting the Jefferson City dolomite is zero.

Pennsylvanian:	Pleasanton formation	175 feet	
	Henrietta formation	100 feet	
	Cherokee shale	250 feet	
Mississippian:	Salem limestone	Usually absent	50 feet
	Burlington limestone	80 to 100 feet	190 feet
	Chouteau limestone	30 to 50 feet	70 feet
	Sylamore sandstone	8 inches to 2 feet	70 feet
Devonian:	Snider Creek shale	20 feet	50 feet
	Callaway limestone	20 to 30 feet	60 feet
	Mineola limestone	10 to 20 feet	40 feet
	Cooper limestone	10 to 20 feet	30 feet
	The Cooper and Mineola never occur in the same section.		
Ordovician:	Kimmswick limestone	40 feet	80 feet
	Joachim dolomite	40 feet	70 feet
	St. Peter sandstone	70 feet	200 feet
	Jefferson City dolomite		More than 200 feet exposed and the bottom not reached.

The Jefferson City Dolomite (*Lower Ordovician*).—The Jefferson City is continuous from one end of the section to the other though it is not exposed west of central Pettis County, about 165 miles west of St. Louis. It is very sparsely fossiliferous and the writer has never collected an identifiable fossil from it in this region. It was uplifted, folded into a great many small folds and deeply eroded before the seas advanced over it to deposit another formation.

The St. Peter Sandstone (*Lower Ordovician*).—The lands were deeply covered with wind-blown sand, derived from unknown sources, when the seas readvanced over the Jefferson City, and this sand was used to form a marine formation that filled the valleys and spread widely over the uplands. The maximum thickness that still remains is about 200 feet and this is in old valleys. Over the uplands the maximum is little more than 100 feet. The irregularities in thickness in the eastern part of the section are due almost entirely to the irregularity of the surface on which the sand was deposited. Westward the formation thins, either on account of original deposition or subsequent erosion of the top, and west of eastern Callaway County, about 75 miles from St. Louis, becomes discontinuous. The sand between the old valleys has been removed by erosion and the St. Peter is left as isolated, linear masses, usually only a few hundred feet wide, and ranging up to more than 100 feet in thickness. This condition continues to eastern Pettis County, about 150 miles from St. Louis where the formation dips under. In a linear section one of these sandstone masses would be crossed every three or four miles on the eastern end and every five or six miles on the western.

In many places the Jefferson City and St. Peter were folded into sharp, narrow synclines and after erosion the St. Peter remained in the bottoms of the synclines. The contact between the St. Peter and Jefferson City is one of nonconformity, the latter presenting a surface of truncated, minor folds to the former.

The Joachim Dolomite (*Lower Ordovician*).—In eastern Callaway County, about 75 miles from St. Louis, appears a thin edge of dolomite, representing Broadhead's First Magnesian limestone, the Joachim of later writers. The formation gradually thickens to 40 feet and ranges from 40 to 70 feet thick to the eastern edge of the section. It rests nonconformably on both St. Peter and Jefferson City, but mainly on the former. In the west it appears at about the same place that the St. Peter becomes discontinuous. Imperfect fossils occur in the dolomite in a few places but the writer has not found any well enough preserved to be identified.

The Kimmswick Limestone (*Middle Ordovician*).—In eastern Callaway County at the place where the St. Peter becomes patchy and the Joachim begins, the Kimmswick limestone enters as a thin wedge. It is patchy and though it occurs farther north does not occur again in the section until 15 miles farther east. From here it maintains a thickness of 40 to 70 feet to the eastern end of the section.

The Kimmswick is a limestone of middle Ordovician age and is abundantly fossiliferous. It has been divided into two distinct formations by Broadhead, and Ulrich considers that the bottom in the eastern end of the section is Plattin. The faunas have not been collected and studied thoroughly enough to warrant drawing positive conclusions, and the writer's study of the rock in the field leads him to class all of it as Kimmswick.

Along the line of this section the writer has never seen the Kimmswick resting on any formation but the Joachim and there is no positive evidence of unconformity between them. An unconformity is to be expected and as the writer has not studied this contact as he has most of the others, the evidence may have been overlooked.

The Silurian.—The writer has seen no evidence of the presence of Silurian rocks in the section.

The Devonian.—Devonian rocks in Missouri are thin and patchy, but in this section the Middle Devonian is represented by the Cooper limestone and the Mineola limestone and the Upper Devonian is represented by the Callaway limestone and Snider Creek shale. Their maximum thickness in any section is less than 100 feet.

The Mineola Limestone (*Middle Devonian*).—Near the eastern edge of Callaway County occur the westernmost outcrops of the Mineola limestone. For 40 to 50 miles along the section this formation occurs in patches and rarely has a thickness of more than 10 feet though southwest of Montgomery City it is 40 feet thick over an area of a few acres. It is extremely irregular in composition, ranging from limestone of high purity to sandstone, though the commonest phase is a porous, sandy limestone. In many places it is highly fossiliferous, and the faunas are closely related to those of the Onondaga of Indiana and Ohio, though not to the Grand Tower of southeastern Missouri. It was deposited on an erosion surface of low relief and rests on various formations. Most commonly it lies disconformably on Kimmswick or Joachim, but in some places it lies on St. Peter and Jefferson City. It seems to have formed in a narrow bay extending westward from Indiana.

The Cooper Limestone (*Middle Devonian*).—The Cooper limestone, which was forming at the same time as the Mineola, extends westward from western Boone County and a barrier less than 20 miles in width separated the Cooper and Mineola seas. The formation is a very compact, fine-grained limestone, which ranges up to 30 feet in thickness though its average thickness is less than 15 feet. Like the Mineola it is not continuous but occurs in patches. It outcrops as far west as central Pettis County where it dips under westward. It rests nonconformably on Jefferson City dolomite in most places, but in a few places on St. Peter sandstone. The Kimmswick and Joachim do not extend into its territory and the St. Peter occurs there only in patches. It is usually nonfossiliferous, but in some places bears a fauna of a few species most of which are related to those of the lowest Devonian in Iowa. The lithologic characteristics of the Cooper have led to its identification as Louisiana limestone, though its position in the geologic column and its fauna place it far below that formation.

The Callaway Limestone (*Upper Devonian*).—From the Missouri River on the west to central Warren County in the east, a distance of about 90 miles, the Callaway limestone, of the upper Devonian, succeeds the Mineola and Cooper. Though it becomes patchy on the east and west, it is almost continuous for the entire distance. Where best developed, in Callaway County, it is commonly 50 feet thick, but near the eastern edge it is rarely more than 20 feet thick and the same is true for the western 30 miles of its extent. The Callaway is extremely limited in its north-south extent, not having been observed beyond one tier of counties, save for a few patches in Cole County south of the Missouri River. It is unconformable on Mineola, Cooper, Kimmswick, Joachim, St. Peter, and Jefferson City. As the formation becomes mainly sandstone at the west its western margin of outcrop, along the west bluff of the Missouri River in Moniteau County, is probably near the western margin of the sea in which it was deposited.

The Snider Creek Shale (*Upper Devonian*).—In Montgomery and Warren counties the Callaway limestone is succeeded by the Snider Creek shale, which is mainly shale and subordinately limestone. It appears to be conformable on the Callaway limestone and at no place rests on other formations. Its thickness ranges up to 50 feet but is ordinarily less than 20 feet. Its present extent is formed of erosion remnants and as a consequence is patchy. It can not be traced for more than a few miles at any place and its total extent is confined to a small part of two counties. It is the highest Devonian formation in Missouri and the sea in which it formed evidently came from the north. Greger[5] has pointed out the similarity of its fauna with the faunas of the upper Devonian of Iowa.

Interval between Devonian and Mississippian.—A period of erosion of considerable length followed the deposition of the Snider Creek. In many places Devonian strata were tilted a few degrees and the folds eroded to an even surface before Mississippian rocks were deposited and at no place has the writer found Mississippian conformable on Devonian. The evidences of unconformity are: old valleys in the Devonian; joints in the Devonian rocks filled with Mississippian sediments; caves in Devonian rocks partially filled with Mississippian sediments; overlap of earliest Mississippian sediments over various Devonian formations; a complete break in the faunas.

Mississippian.

The Sylamore Sandstone (*Basal Mississippian*).—The Mississippian seas advanced over a surface of gentle relief, with occasional valleys 30 to 60 feet deep, and deposited the Sylamore sandstone, which varies in thickness up to 70 feet. This averages little more than a foot in thickness and the greater thicknesses occur mainly in

[5] This Journal, vol. 27, pp. 375-378.

old valleys. The Sylamore is almost continuous from the eastern part of the section to the western. In most places it underlies the Chouteau limestone but it lies on Snider Creek, Callaway, Mineola, Cooper, Kimmswick, Joachim, St. Peter, and Jefferson City. Its relationships to the underlying rocks include all of those discussed in the last paragraph. The Sylamore bears a basal Mississippian fauna which is illustrated and discussed in a paper soon to appear.

The Sylamore varies in color from light gray through grayish green to dark brown. In Warren County it has been mistaken for the Ferruginous sandstone of the Pennsylvanian. The greenish phase is peculiar and recurs in places from southwestern to northeastern Missouri. In a few places shales are associated with the sandstone and may occur above or below it.

The Sylamore has been considered as part of the Chouteau or part of the Devonian by most investigators of this region.

The Chouteau Limestone (*Kinderhookian*).—Through much of the section the Chouteau limestone rests on the Sylamore. The transition from the Sylamore to the Chouteau is usually brought about by the presence of shale, two or three inches thick, which bears a typical Chouteau fauna. The Chouteau consists of dark-colored argillaceous limestone below, and light-colored, sandy dolomite above, but the dolomite occurs only where the formation is thick. In Cooper and Pettis counties the upper half contains a great deal of sandstone. In the eastern 60 miles of the section the formation has been observed in only one place, and is absent through most of the distance. Near Fulton it is one foot to two feet thick and thickens to 60 feet in the bluffs of the Missouri, 25 miles west of Fulton. West of the Missouri River it averages 50 to 60 feet thick to Pettis County where it dips under.

The Chouteau seas were patchy along the middle part of the section and had withdrawn slightly from their Sylamore boundaries. The Sylamore keeps its thickness in areas where no Chouteau is present though that thickness is only one or two feet. On the other hand, the Chouteau remains limestone to the edge of the various patches showing that little or no erosion took place on the exposed Sylamore flats.

The Chouteau was rather extensively eroded before the Burlington seas advanced. This is shown by the thickening and thinning of the formation, and by the top part always being absent where the formation is thin. Also it is not uncommon to find Burlington resting on Devonian or older formations with no Chouteau or Sylamore present. Only rarely is there evidence of unconformity where contacts of Chouteau and Burlington are exposed.

The Burlington Limestone (*Osagian*).—The Burlington limestone is continuous from St. Louis County to Jackson County, the counties of St. Louis and Kansas City. Its nearest outcrop to Jackson County is about 40 miles east. It ranges from 20 feet thick to 190 feet thick and is much the same lithologically everywhere, save that the lower 10 to 30 feet are brown in the eastern end of the section. For more than half of its extent it rests on the Chouteau, for perhaps one-fourth of its extent on the Sylamore, and over small areas on Snider Creek, Callaway, Kimmswick, and Joachim. The irregularity in thickness is due to erosion of the top, and well sections seem to show that it thickens westward from the place where it dips under in Pettis County.

The Salem Limestone (*Meramecian*).—The Salem limestone outcrops only rarely but occurs over wide areas in small patches. At Boonville, in Cooper County, its outcrops are well known and in Boone County Broadhead[6] found it outcropping 15 to 20 feet thick in one place. *Archimedes,* in cherts, occur in hundreds of places, scattered along the section, but the writer has not seen outcrops of rock bearing *Archimedes,* excepting at Boonville and Broadheads' locality. Only a short distance east of the section several other Mississippian formations occur but they were either eroded away or were not deposited west of St. Louis County.

The Pennsylvanian.—At the eastern end of the section patches of Pennsylvanian fire-clay and sandstone occur rarely at the tops of the hills, a little shale comes in a few places at the tops of the hills where the section crosses Boone County, and from western Pettis County westward nothing below Pennsylvanian outcrops. The Pennsylvanian is represented by the Cherokee, Henrietta, and Pleasonton formations and by the Warrensburg sandstone which was deposited in a valley in the Cherokee and on Henrietta shales.

[6] Geol. Survey of Missouri, vol. 12, p. 383.

Younger Deposits.—East of the Missouri River along the section glacial drift occurs, undisturbed here and there in protected places, but much more commonly glacial materials are mingled with residual and wind-blown materials to make up the mantle rock. Loess caps most of the hills near the Missouri River and laps down over the sidehills in many places to meet the alluvium of the valleys. The loess reaches a thickness of 50 feet or more but is ordinarily less than 20 feet in thickness. On the hilltops a few miles from the river finer, wind-blown materials make up most of the mantle rock and under it are residual and glacial materials. Most of the residual deposits are composed of chert derived from the cherty limestones and dolomites.

Keyes Sections.[7]—Dr. Charles Keyes recently published sections that differ so widely from the writer's observations that it seems worthwhile pointing out the differences.

Keyes' sections show the Chouteau resting on the Hannibal shales, which, he says, "decline in thickness westward until by the time Cooper County is reached they disappear by attenuation." The writer does not know of a place where the Chouteau rests on the Hannibal excepting within about 20 miles of Hannibal. At the western end of his section Keyes shows the Chouteau resting on the Louisiana limestone but the Louisiana does not outcrop within 100 miles of this western end and probably does not occur within 90 miles of it. Keyes' section shows the Saverton shales extending nearly to the western end, but these shales are not known within 100 miles of that place. His section shows the Snider shales extending from Hannibal to Cooper County. The writer has mapped these shales in what appears to be their total extent, and that is entirely in Callaway and Montgomery counties. The Callaway limestone appears in Keyes' section from its western end to near Hannibal; some 30 miles too far west and at least that distance too far northeast.

Keyes' section shows Silurian all the way from Sedalia to Hannibal. The writer has not found Silurian outcropping at any place along the Missouri River or its tributaries. It probably does not come within 100 miles of Sedalia. His section shows no Cooper or Sylamore,

[7] Proceedings of the Iowa Academy of Sciences, vol. 23, p. 113.

and shows the Ordovician limestone (in the main Kimmswick but including some Joachim) extending from Hannibal to Sedalia. The western edge of both the Ordovician formations is in eastern Callaway County about 90 miles from Sedalia. His section also shows the St. Peter sandstone as a continuous formation from Hannibal to Sedalia, whereas it is discontinuous for about 90 miles from Sedalia.

It is true that the main object of Keyes' article is to show the relationships of the Chouteau, but even these are erroneous west of the outcrops of the Mississippi River and its tributaries.

These late sections of Keyes practically repeat those of an earlier article in a Bulletin of the Geological Society of America.[8] Both articles mislead in verifying, by seemingly later investigations, errors of the reports of Swallow,[9] Meek,[10] and Broadhead.[11] None of these reports were detailed and many identifications of strata were left provisional awaiting further investigations. Some studies on the areas considered in this discussion were made by Keyes and his helpers on the Missouri Survey but they were in the nature of reconnaisance work. It is hard to understand how even a few days work on the geology of Pettis and Cooper counties could leave any warrant for the sections given by Keyes.

While mapping the Cooper limestone in Pettis and Cooper counties, the writer visited all the localities for Vermicular sandstone, Louisiana limestone, and Cooper marble mentioned by Swallow in Reports I and II of the Geological Survey of Missouri, and no Vermicular nor Louisiana was found. A sandy phase near the middle of the Chouteau seems to have been identified as Vermicular though it shows only rarely any Vermicular markings and contains a typical Chouteau fauna. The Chouteau limestone below the sandstone was identified as Louisiana by Swallow, though from bottom to top it contains the most typical of Chouteau species in abundance. The Sylamore is so thin and inconspicuous that it was not recognized as a formation by Swallow. Swal-

[8] Bull. Geol. Soc. Am., vol. 13, pl. 44.

[9] Geol. Survey of Missouri, First and Second Annual Reports, Part I, pp. 186-203.

[10] *Ibid.*, Part II, pp. 95-119.

[11] Geol. Survey of Missouri, 1855-1871, pp. 37-64.

low mentions the great irregularities in thickness of the St. Peter but does not tell of the patchiness of its remnants.

Acknowledgments.—My first work in Callaway County was made easy by Mr. D. K. Greger who knew practically every outcrop of Devonian of importance in that county. Mr. Greger and several of my advanced students have worked with me on various parts of the section here discussed and many of the details and larger features were first brought to my attention by them.

University of Missouri,
Columbia, Mo.

Art. XXI.—*On the Occurrence of Dyscrasite in Australia;* by George Smith.

The only discovery of dyscrasite in Australia was made in the Consols Mine at Broken Hill. The lode in this mine is a true fissure vein having no known connection with the main lode of the district and whose ores were dissimilar in almost every respect.

The Consols lode passed through alternate bands of amphibolite and crystalline schists, but was only ore-bearing in the former. The fissure, however, continued through the schist, but though driven on in this rock for many hundred feet was never found to contain more than a thin seam of flucan assaying traces of silver. Where the lode entered the amphibolite it opened out immediately, the gangue being limonite in the oxydised zone and siderite with calcite below; this change was found at a vertical depth of about 130 feet.

The principal ores were stromeyerite (by far the most important in point of productiveness), fahlerz, dyscrasite, chloro-antimoniate of silver, cerargyrite, iodyrite and some galena, with small quantities of stephanite and pyrargyrite. Sternbergite and proustite were also met with. The stromeyerite averaged between 9,000 and 10,000 ounces of silver per ton, and the fahlerz 6,000 to 7,000 ounces, but it is proposed to refer herein only to the dyscrasite and the chloro-antimoniate, as these ores were closely associated, the latter being the result of the alteration of the former and was confined to the upper levels. The chloro-antimoniate occurred in lumps more or less detached, sometimes containing a core of unaltered dyscrasite; perfect pseudomorphs were occasionally seen. Several tons were found including two pieces weighing 475 and over 700 lbs. respectively. Analyses showed that it varied from about 45% to 75% of silver, the average being 70%.

Some of the lumps of dyscrasite were large, possibly up to 30 cwts. when *in situ*. Being generally "frozen" to the footwall it had to be blasted out, which fractured the larger pieces. The largest lump shipped weighed 16 cwts. after it had been broken as small as possible for shipment; it was known as the "Turtle Slug" and was originally portion of a larger mass. It was crystalline and quite free from any foreign mineral. Its assay value was about 80%. When smelted it realized £4,375. Many other lumps ranging from 10 cwts. downwards—some of which had been parts of larger masses—were found.

The largest deposit of ore was confined to a small area, and included 127 cwts. of dyscrasite which, including a little ore and gangue, averaged as smelted nearly 70% of silver. This accounted for about 30% of the total silver contents of that particular deposit. Later discoveries in calcite yielded higher values and the general average was thereby raised considerably. One interesting deposit of the dyscrasite showed that vughs in crystallised siderite had been filled and the crystallisation was beautifully reproduced. The largest piece of this kind weighed 87 lbs., the assay value being about 83% of silver. Many careful tests were made and the dyscrasite was always found to be pure. The commonest types were 72% and 84% (Ag_3Sb & Ag_6Sb) followed by Ag_4Sb, Ag_5Sb, Ag_9Sb, $Ag_{12}Sb$, $Ag_{18}Sb$.

The total quantity of dyscrasite found would be in excess of 10 tons. Very fine arborescent crystallizations were met with besides beautiful crystalline masses which were readily shattered into innumerable crystalline grains which possessed a brilliant tin white lustre; unfortunately these unique specimens were all dispatched to London where the rich ore was smelted.

The crystallizations in calcite were exceptionally beautiful and were the richest kinds met with.

My friend Dr. C. A. Anderson, mineralogist to the Australian Museum, Sydney, has kindly made an examination of some of the few crystals which are now available and has supplied me with the following notes:

"The dyscrasite is sometimes in the form of flattened unterminated prismatic crystals embedded in calcite or siderite, strongly striated vertically, and irregularly aggregated into parallel and subparallel groups, or it may be in cylindrical crystals, the faces in the prism zone merging into one another, and terminated by the basal plane or by a globular enlargement on the apex. Occasionally the crystals are pseudo-hexagonal plates tabular on the base, which is marked with striæ running parallel to its outlines. One such crystal, about 7 mm. in diameter, was mounted on the goniometer and approximate measurements were obtained; probably the forms *c* (001), *e* (011), *z* (112), *s* (133) are present, but the angles obtained vary considerably and the forms can not be identified with certainty. Another habit is represented by a granular mass of very small, closely aggregated, equi-dimensional crystals, which somewhat resemble rhombic dodecahedra in shape, but all the faces are concave and quite unsuitable for goniometric determination."

The discoveries referred to were made during 1890-1900. The mine has now been closed down for several years. Up to the time of my retirement from its management there was no reason to doubt that rich ores such as dyscrasite and fahlerz, which were then being found in the deepest levels, would not continue downwards. The other ores referred to, however, did not extend to the deeper levels.

Sydney, New South Wales,
Oct. 11, 1919.

Art. XXII.—*The Comanchean and Dakota Strata of Kansas;*[1] by W. H. Twenhofel.

Table of Contents.

Introduction.

The formations in Kansas which in this article are referred to the Comanchean are those which in the southern part of the state are known as the Cheyenne sandstone, Kiowa shale and Medicine beds and those which in central and northern Kansas have been called the Mentor beds and Dakota sandstone. The writer has spent parts of several field seasons in the study of these formations and has arrived at the conclusion that the marine beds of the southern and central portions of the state are the stratigraphic equivalents of the Dakota sandstone of the central and northern portions, the chief evidence being that the former dove-tail into the latter on at least three horizons—perhaps five—which are disturbed from near the base to well up toward the summit. Much of the evidence for this conclusion has previously been published in separate articles by other students. Because this evidence is as yet not widely known, however, it and such new data as the writer has collected are brought together in this article and afford the basis for the conclusion noted above.

Since the marine beds belong to the Comanchean or Lower Cretaceous as defined by American authors, it follows from this conclusion that the Kansas Dakota, generally assumed to be the base of the Upper Cretaceous in that state, is of Comanchean age. In the final topic of the article there is considered the lower boundary of the Upper Cretaceous. The fact that the base of the Upper Cretaceous of Europe appears to have its correlate beneath, or somewhere within, the lower half of the

[1] Published by permission of the State Geologist of Kansas.

Washita—the uppermost division of the Comanchean or Lower Cretaceous as defined in the United States—affords the basis for an inquiry into the validity of intercontinental limitation of periods.

Previous Views.

It has been generally assumed that the Dakota is the initial formation of the Upper Cretaceous. This view has been repeatedly challenged by stratigraphers, among whom Professor L. F. Ward appears to have been the pioneer as shown in his statement that "It would seem probable that a considerable portion of the deposits underlying the marine Cretaceous of the Rocky Mountain region which have heretofore been referred to the Dakota Group on purely stratigraphical evidence may really be much older."[2] In his article on "Types of Sedimentary Overlap," Grabau strongly insisted on the Comanchean age of at least a part of the Dakota and also maintained that the formation is probably of different ages in different parts of its distribution.[3] In Scott's "Introduction to Geology," the Dakota is placed in the Lower Cretaceous. In this assignment he stands alone among authors of American text-books.[4] A summary of the conclusions of American students on this subject has been made by Todd and as a result of his examination of the literature he concluded that the Dakota is Lower Cretaceous.[5]

The Cheyenne-Kiowa-Medicine Sequence.

The strata belonging to this sequence occur near the southern border of the state, extending as a narrow irregular band from near the town of Medicine Lodge in Barber Co. to just south of the town of Meade in Meade Co. South of about the middle of the distribution there is an outlier on the Oklahoma line. The orientation of the band is conditioned by the topography, and as a consequence is extremely irregular. Northward the Comanchean strata are overlain by the terrestrial deposits of the Plains Tertiary, which on the eastern and

[2] L. F. Ward, Jour. Geol., 2, 265, 1894.
[3] A. Grabau, Bull. Geol. Soc. Am., 17, 620-627, 1906.
[4] W. B. Scott, Introduction to Geology, 2d edition, p. 702, 1907.
[5] J. E. Todd, Trans. Kansas Acad. Sci., 23 and 24, 65-69, 1917.

western limits of the band cross the Comanchean strata to rest upon the Permian; the latter in this portion of the state constitutes the base on which the Comanchean sediments were deposited. Southward of the Comanchean band, with the exception of the outlier noted and others in Oklahoma, the Comanchean strata have been removed by erosion, a great deal of which appears to have been accomplished in post-Cretaceous time and antecedent to Tertiary deposition in this region.

The sequence in the southern portion of the state is as follows:

Medicine beds[6]	
Reeder sandstone, terrestrial, "Dakota" flora...	20 ± feet
Kirby clays,[7] terrestrial, "Dakota" flora.......	50 ± "
Greenleaf sandstone,[7] marine, Washita fauna....	50 ± "
Spring Creek clays,[7] marine, Washita fauna.....	50 ± "
Kiowa shales and limestones, marine, Washita fauna	140 ± "
Cheyenne sandstone, terrestrial, "Dakota" flora.	100 ± "

The Cheyenne sandstone consists of light gray to yellow quartz sandstone with subordinate interbedded shale. The bedding is extremely irregular and discontinuous. Lateral gradation from one to another texture of sand or to shale is very abundant. Cross-lamination is present in nearly every horizon, the foresets tending to have southern inclinations, being quite steep, and averaging around 3 to 4 feet, although some are very much longer. Interbedded shales are most commonly of dark colors. The sand grains vary from extremely fine to coarse, in some horizons being almost flour-like, while in others there are streaks of quartz and chert pebbles. The materials are poorly cemented and are thus easily eroded. Badland features are rather characteristic of the exposures.

Fossil leaves of dicotyledons and other plant matter are locally quite common in some horizons, particularly in the upper part. The credit for the discovery of the dicotyledonous flora belongs to R. T. Hill and members of his party.[8] Vegetable remains in the form of silicified logs had previously been discovered in this formation by Cragin[9] and he had described a cycad therefrom as

[6] F. W. Cragin, Am. Geol. **16**, 381, 1895.
[7] C. N. Gould, this Journal, **5**, 169-175, 1898.
[8] R. T. Hill, this Journal, **49**, 473, 1895.
[9] F. W. Cragin, Bull. Washburn Coll. Lab. Nat. Hist., vol. 2, No. 10, pp. 65-66, 71, 1889.

Cycadeoidea munita and identified foliage as belonging to *Glyptostrobus gracillimus* Lx.[10]

The Cheyenne sandstones are of terrestrial origin and were deposited on relatively flat lands near the sea. They contain gypsum crystals which, were they contemporaneous in deposition with the sands, would indicate that marine waters were concerned in their deposition and that the climatic conditions were those of aridity. The writer is of the opinion that such were the climatic conditions, but that the gypsum was brought in either by sea water at the time of the Kiowa submergence or from the Kiowa by ground water after the uplift of the latter.

The Kiowa shales and limestones are near-shore deposits, consisting of alternations of shell limestones filled with pelecypods and gastropods, and calcareous and bituminous clay shales. The bituminous shales contain few fossils and those present are not of large size. Shales of this character are most common in the lower half of the formation and are probably not typically marine, but deposits of enclosed bays similar to those in which the black muds of the east Baltic are now depositing.[11] One of the limestones contains small quartz and chert pebbles and on several levels in the formation there are thin beds of gray sandstone. Gypsum crystals and amorphous gypsum are more or less abundant throughout and places have been found where the shells lie in a matrix which is partially composed of gypsum. This points to enclosed seas and arid conditions. At the base of the formation there is a 6 to 18 inch bed which has been called the Champion shell bed; it consists almost wholly of small *Gryphæas*. About fifty species of marine invertebrates, thirteen species of vertebrates, and a few insect remains have been collected from this formation. Some of the common invertebrates are: *Cardium kansasense* Meek, *Cyprimeria kiowana* Cragin, *Exogyra texana* Roemer, *Gryphæa corrugata* Say and varieties, *G. navia* Hall, *Ostrea quadriplicata* Shumard, *Pecten texanus* Roemer, *Protocardia texana* Conrad, *Schlœnbachia belknappi* (Marcou), *Schlœnbachia peruviana* (Von Buch) (Marcou), *Trigonia emoryi* Conrad, *Turritella* near *T. seriatim-granulata* Roemer.

[10] F. W. Cragin, Am. Geol., 16, 263, 1895.
[11] W. H. Twenhofel, this Journal, 40, 272-280, 1915.

The Spring Creek beds consist of bluish, greenish and yellowish clays containing nodules of clayey limonite. They contain about half a dozen species of invertebrates of which all that have been identified are also present below in the Kiowa shales. The thickness of the beds varies up to about 50 feet and in some places they are not present at all because of subsequent erosion, the Tertiary resting directly on the Kiowa. The member is of shallow-water marine origin.[12]

The Greenleaf member is composed of light gray to light brown massive-bedded and occasionally cross-laminated sandstone. Less than half a dozen species of marine invertebrates have been identified from this member and all of these are present in the Kiowa shales. The member carries the record of a retreat of the Comanchean sea, but whether this was the final retreat or an intermediate one can not be stated. The thickness varies from nothing up to about 50 feet.

The Kirby clays consist of reddish sandy clays interbedded with yellow sandstones. They rest conformably on the Greenleaf sandstones and are the coastal plain terrestrial deposits laid down by streams which pushed their channels and spread their burdens over the territory uncovered by the retreating sea. Possibly the streams played a part in repelling the marine waters. The only fossils which have been seen in this formation are fragments of leaves of dicotyledons. The thickness varies from nothing up to about 50 feet.

The Reeder member consists of dark brown massive sandstones which are greatly cross-laminated more or less throughout and contain many small pebbles of quartz and chert and large nodular concretions. The sandstones contain fossil leaves of dicotyledons belonging to species which are characteristic of the "Dakota." This member is of terrestrial origin. The thickness varies from nothing to more than 20 feet.

The sequence of events occurring in the deposition of these southern deposits was as follows. At first the region was part of a coastal plain over which streams of low gradient deposited sands and clays. The climate was probably not greatly dissimilar from the present

[12] This and the two succeeding members were differentiated by Gould (op. cit.) and the descriptions, except where modified, are based on those given by him.

one, with perhaps a greater tendency toward aridity. The invading Comanchean sea covered this plain and great banks of *Gryphæas* flourished in the shallow waters. The advance appears to have been oscillatory, as from time to time there were conditions giving rise to deposits of black mud, perhaps laid down in lagoons developed by rivers on the borders of the sea. In these black muds, decomposition of organic matter, probably through the agency of sulphur bacteria, gave rise to sulphur gases—now shown in the abundant nodules of pyrite in some of the beds—bringing about the elimination of the bottom life which had existed in the clearer waters. As the sea advanced farther northward, black mud deposition decreased on this portion of the bottom and calcareous sediments attained a greater importance. As the sea retired, the Spring Creek clays and Greenleaf sandstones were deposited, while, on the succeeding land, streams extended their channels across the late sea-bottom to the receding waters and laid down the Kirby clays and Reeder sandstones. A complete cycle of sedimentation had taken place, beginning with terrestrial deposits, running through the gamut of marine sediments, and ending with those of terrestrial origin.

The Mentor-Dakota Sequence.

This sequence makes its first appearance north of the great tongue of overlapping Tertiary which extends across the southern portion of the western half of Kansas, and its uppermost portion extends northward into Dakota. In the southern limits there are several levels of marine deposits carrying marine fossils. With distance northward these gradually drop out, but at least one marine horizon extends as far north as southeastern South Dakota. The origin and sequence of strata in this portion of the state are as follows, the data relating to the uppermost portions being almost wholly compiled from the work of other students to whom citations will be made on succeeding pages.

Base of Benton, marine.
Upper Dakota
  Gypsiferous shales, salt lake or arm of sea and terrestrial deposits, ''Dakota'' flora(?) ....10-20 feet
  Saliferous shales, partly and perhaps entirely marine, Washita fauna ....15-30 feet

Shell bed, marine, Washita fauna	6	inches
Lignite zone, coastal plain terrestrial	6-26	inches
Shales, terrestrial?	5 ±	feet
Lower Dakota, terrestrial, ''Dakota'' flora	250 ±	feet
Mentor sandstone bed, marine, Washita fauna	8	feet
Sandstones and shales, terrestrial, ''Dakota'' flora	52	feet
Shell bed, marine, Washita fauna	2-3	feet
Shales, terrestrial?	30	feet

The gypsiferous shales consist of gray to dark shales interbedded with gray and red sandstones. Gypsum crystals and impregnations exist pretty generally throughout. There are also thin beds of gypsum. So far as the writer has information, no fossils have been identified from the member, but logs have been found in the basal Benton which Logan considers to have ''undoubtedly belonged to the upper Dakota horizon.''[13] The sediments which formed this member probably developed in relic lakes left by the retiring Washita sea. The climate was probably of such a character that the concentration increased and the lakes ultimately disappeared through drying up or filling up with mud. The thickness varies from 10 to 20 feet.

The saliferous shales are of gray to dark colors and highly impregnated with salt. Interbedded are sandstone layers from two of which marine fossils have been collected. Those definitely identified by Logan are:[14] *Arcopagella macrodonta* Meek, *Cardium kansasense* Meek, *Corbicula subtrigonalis* Meek, *Crassatellina oblonga* Meek, *Cyrena dakotensis* Meek, *Màctra siouxensis* Meek, *Margaritana nebraskensis* Meek, *Protocardia salinaensis* Meek, *Tellina modesta* Meek, *T. subscitula* Meek, *Trigonarca salinaensis* Meek, *Yoldia microdonta* Meek. Nearly every one of these species is represented by identical or closely related forms in the Mentor beds so that there is little doubt but that they were inhabitants of the same sea. The thickness of this member varies from 15 to 30 feet.

From the shell bed which is only about 6 inches thick, Logan lists:[14] *Cardium kansasense* Meek, *Leptosolen conradi* Meek, *Pharella dakotaensis* Meek. It is preceded by shales similar to those of the saliferous zone, and related to them in origin.

[13] W. N. Logan, Kansas Univ., Geol. Surv., 2, 212, 1897.
[14] W. N. Logan, op. cit., pp. 207-212.

The strata from the shale bed to the top of the saliferous zone contain deposits which were probably made by minor backward and forward movements of the strand-line. The beds containing marine fossils record northward or forward movements. The unfossiliferous sands and muds record southward or outgoing movements of the strand-line. The waters, at times, were evidently strongly concentrated.

The lignite zone, where present, varies in thickness from about 6 to 26 inches. In some localities it is wanting, and it is not certain that it is at the same level in every one of its occurrences. The deposit is evidently of terrestrial paludal origin.

The lower Dakota consists of red, brown, yellow and gray quartz sandstones and gray, dark and brown shales. The former dominate above, the latter below. The sandstones are rough-bedded, and quite commonly cross-laminated, with foresets of variable steepness, length and direction of inclination. Some levels are characterized by the abundant presence of limonite concretions of all sorts of shapes. At different localities and in different horizons occur splendidly preserved fossil leaves of dicotyledons. The sequence varies greatly from place to place and the writer has found it impossible to recognize any horizon beyond the limits of an exposure. Gradation from shales to sandstones is extremely common in parts of the division. If a section be measured north of the limits of the lower marine strata described below, it is certain that the equivalents of some of the latter beds will be included in the Lower Dakota. There is great variation in thickness and the figure given is merely approximate.

The character of the Mentor beds is best shown by the section exposed in the Natural Corral in McPherson County. This is as follows:

5. Sandstone, red to brown, coarse to medium-grained, locally contains many of the concretions which are characteristic of the ''Dakota.'' Where these are greatly developed, the fossils are absent; but where concretions are few, fossils are abundant. Those most diagnostic are: *Cardium kansasense* Meek, *Trigonia emoryi* Conrad, *Turritella salinaensis* Meek (near *T. seriatim-granulata*). These serve to fix the Washita age of the stratum 8 feet
4. Sandstones, yellow, well-assorted, highly cross-laminated, probably of terrestrial origin .... 26 feet

3. Blue paper shale with 2 feet of pale yellow sandstone. Fossil leaves of dicotyledons are present in both shale and sandstone. The zone is probably of terrestrial origin .... 26 feet
2. Shell limestone with fossils identical to those in the Kiowa, the zone correlating best with a zone about 30 feet from the base of the latter as exposed near Belvidere, Comanche County. Common fossils are: *Cardium kansasense* Meek, *Cyprimeria kiowana* Cragin, *Turritella* near *T. seriatim-granulata* Roemer ....2-3 feet
1. Dark blue gypsiferous shales, either of terrestrial origin or of a lagoon adjacent to the sea .... 30 feet

The Mentor beds were deposited over an area on which the sea and the land contended for supremacy and over which the strand-line advanced and retreated several times. The terrestrial deposits are in part the alluvial deposits of wandering rivers, in part delta deposits, and possibly in part deposits by wind.

Summary of the Conditions of Origin of the Comanchean of Kansas.

It is obvious that the strata of the southern and central areas were once connected, and it may be that connection beneath the Tertiary cover still exists. The strata were deposited under conditions which permitted the sea and the land to contend with each other for the places of deposition; that is, in the border zone between the two realms of sedimentation, held alternately by the land and the sea. At least three times, perhaps five, the sea advanced, and as many times retreated. These to-and-fro migrations could have been produced by oscillation of sea-level, due to cyclic upward and downward movement of varying extent; or to intermittent and differential downward movement. During the times of stability, there would have been a building outward of the shore-line by terrestrial sediments, and during the times of rapid downward movement, a northward invasion by the sea, the thickness and character of the deposits of each realm being consequent upon the extent of movement. Which type of movement prevailed, the writer does not know, but the more simple theory has the greater appeal; that is, that the major movement was downwarping rather than of an oscillatory nature, with uplift toward the close of marine deposition and consequent extension of terrestrial deposition to the limit of marine retirement. This was at least as far southward as northern Texas, as shown by the Woodbine formation which is the equivalent of a part of the "Dakota." However the depositions were accomplished, there resulted a dovetailing of marine and terrestrial sediments, the former everywhere containing a Washita fauna, the latter in most cases a "Dakota" flora. Figure 1 shows this in ideal cross-section.

The generalized cross-section shows that the "Dakota" sandstone of Kansas, with its contained dicotyledonous flora, and the marine strata known as the Kiowa, Mentor, etc., are of one age and were deposited during the same period of time, the former being the terrestrial equivalents of the latter. This conclusion can be maintained to the top of the last stratum containing marine fossils. It is possible that a disconformity and a stratigraphic break may occur in the upper member of the "Dakota," but on this point the writer has no information. On the other hand, it may actually be that terrestrial deposition continued somewhere between Kansas and Texas without serious break from the close of the retirement of the Washita sea to the appearance of the Benton sea. This is, however, considered unlikely. That a considerable period of time is involved between the retirement of the Washita sea and the invasion of the Benton sea is suggested by the decided differences between the two faunas.

Correlates of the Kansas Comanchean.

In the preceding discussion it has been tacitly assumed that the marine beds of the Kansas sequence are the equivalent of the Washita of the Texas sequence. This appears to be the most reasonable conclusion in the light of the facts known at present. It is true that there are some things in the fauna which are of Fredericksburg aspect; but for the greater part, the species are more like those of the Washita. This correlation makes the Dakota—certainly the "Dakota" of Kansas—of Washita age, taking it from the Upper and placing it in the Lower Cretaceous, as these two divisions have been defined in the United States.

About the mouth of the Big Sioux River in south-

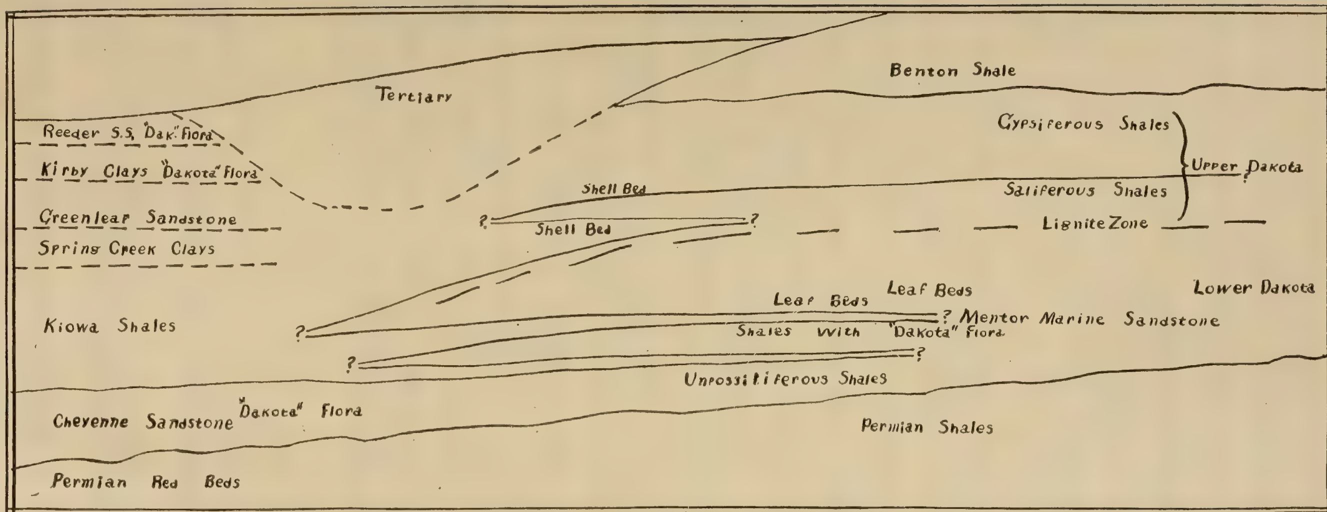


FIG. 1.—Ideal cross-section from the Kiowa shales of southern Kansas to the "Dakota" of Nebraska. One shell bed is indicated in the Saliferous Shales. There may be two. No line of separation is shown between the Lower "Dakota" and the unfossiliferous shales beneath the basal marine horizon, and it is believed that none exists. The contact between the Tertiary and lower horizons is one of erosion.

eastern South Dakota and the adjacent parts of Nebraska Meek states that the Dakota has a thickness of 400 feet and consists of sandstones and shales. From some horizon or horizons of this sequence have been collected the following invertebrates:[15] *Arcopagella? macrodonta* Meek, *Cyrena dakotensis* Meek, *Mactra siouxensis* Meek, *Margaritana nebraskensis* Meek, *Pharella dakotaensis* Meek, *Trigonarca siouxensis* Meek. The zone containing the fossils correlates best with the thin sand layers in the upper Dakota of Kansas. The shells may have been inhabitants of brackish water, but not of fresh water, as nearly related forms occur in the marine Mentor.

In the Black Hills of South Dakota Darton found[16] that the lower portion of what had previously been known as the Dakota in reality consisted of four formations or members, to which, from the base upwards, he gave the names of Lakota, Minnewaste, Fuson and Dakota, the last being limited to those strata containing the leaves of dicotyledons which have generally been considered as constituting the "Dakota" flora. The Minnewaste formation is of limestone. No marine fossils were discovered in any of the formations, so it is assumed that none is present. That the uppermost unit correlates with the "Dakota" of Kansas is considered very probable. The three lower formations are regarded as of Comanchean age; it is not known, however, whether they have a time equivalence with the Washita.

Strata which are the equivalent of the Washita were identified about fifteen years ago in Colorado near the base of the sandstones which had previously been referred to the "Dakota."[17] The discovery was made by Stanton and Lee in a section on the Purgatoire River, the section being divided and correlated as follows:

5. Benton shale
4. Dakota sandstone ....100 feet
3. Dark shale and shaly sandstone, with a Washita fauna ....50-100 feet
2. Coarse, cross-laminated, gray sandstone ......15-60 feet.
1. Morrison shale

[15] F. B. Meek, U. S. Geol. Surv., Terr., 9, p. XXV, 1876. In the absence of definite information it is assumed that there is but one shell zone in this northern occurrence. This assumption may be in error and there may be more than one.

[16] N. H. Darton, U. S. Geol. Surv., 21st Ann. Rept., pt. IV, pp. 526-532, 1900.

[17] T. W. Stanton, Jour. Geol., 13, 661-668, 1905.

It is possible that zone 2 is the equivalent of the Cheyenne sandstone, but a correlation on the basis of lithology and stratigraphical position is so hazardous that it is not attempted. Zone 3 contains species which are present in the Kiowa, and no doubt whatever can be entertained that the zone is contemporaneous with some portion of the Kiowa. Nothing equivalent to the upper marine zones of the Kansas sequence has been discovered and it is assumed that the Washita sea existed in Colorado for a much shorter time than it did in Kansas.

In his description of the geology of the Apishapa quadrangle Stose[18] differentiated the strata containing marine fossils, together with the sandstones below, as the Purgatoire formation and showed that in some of the sections there is much lateral variation of lithology in some horizons. The upper portion of the Purgatoire is certainly of Kiowa age and the lower portion may be the equivalent of the Cheyenne.

In the Colorado Springs quadrangle Findlay[19] differentiated the Purgatoire formation into the Lytle sandstone member at the base and the Glencairn shale above. The shales contain a few fossils; there are none in the Lytle sandstone.

The important consideration for this portion of the country is the age of the ''Dakota.'' In the folios to which reference has been made it was separated from the strata below on the basis of its dicotyledonous flora, but that evidence can be given no validity since, as we have seen, such also occurs below the Washita fauna. It is possible that the Colorado ''Dakota'' may belong to the Upper Cretaceous and be younger than the leaf-bearing beds of Kansas, but such a conclusion, or, in fact, any conclusion, must wait for further evidence.

Sequence of Events for the Plains Comanchean.

The sequence of events for Kansas and adjacent states from the time of the first appearance of the Comanchean sea to the time of the invasion of the Eagle Ford-Benton sea was something as follows:

1. Terrestrial deposition of the Cheyenne sandstone, by streams and winds on a coastal plain in a semi-arid climate.

[18] G. W. Stose, U. S. Geol. Surv., Folio 186, pp. 3-5, 1912.
[19] G. I. Findlay, U. S. Geol. Surv., Folio 203, pp. 7-8, 1916.

2. Kiowa invasion of the sea, and deposition of the Kiowa-Medicine formations.

a. Advance of the sea to a little north of the city of Salina, Kansas.

b. Retreat of the shore-line toward southern Kansas with terrestrial deposition over the central part of the state.

c. Readvance of the shore-line to beyond Salina, Kansas.

d. Retreat of the shore-line toward southern Kansas, with renewed terrestrial deposition over the central part of the state.

e. Advance of the shore-line to central Kansas, forming the marine shell bed of the Upper Dakota.

f. Retreat southward, with renewed terrestrial deposition over the central portion of the state.

g. Two rapid advances of the sea (perhaps only one), separated by a short retreat, one of the advances progressing as far north as southern South Dakota.

3. Retreat of the Comanchean sea as far south as Texas, possibly followed by erosion of the plain of construction.

4. Invasion of the Eagle Ford-Benton sea, and deposition of the initial beds of the Cretaceous.

The Base of the Cretaceous.

Some have insisted that the Lower Cretaceous or Comanchean of this continent has the value of one system and that the Upper Cretaceous represents another. If so, where shall the base of the Upper Cretaceous be drawn? There was most certainly an extensive retirement of the sea at the close of the Washita and there are considerable differences between the faunas of the Washita and those of the Benton. It therefore would appear that the place to draw the plane between the Lower and Upper Cretaceous should be in the 10 to 20 feet of strata which separate the last appearance of the Washita fauna from the first appearance of the Benton. So far as Kansas, Nebraska and Oklahoma are concerned, the plane indicated appears to be the only place where such a line of separation can be drawn. Many European students have correlated the Washita with the Cenomanian of the Upper or Neo-Cretaceous of Europe,[20] of which the Dakota has long been considered the equivalent.[21] The general drift of American opinion, so far as the writer has been able to learn it, also appears to have been toward correlation of the Washita, at least the upper part, with the Cenomanian.[22] In Europe the time of the Cenomanian witnessed a great transgression which extended beyond the limits of the Lower Cretaceous sea, so that the strata of this European division now hold the same position with respect to invasion that is held by the Benton of the Plains.[23]

This raises the question as to what should constitute the boundary of a larger time unit. On the basis of diastrophism, the plane of separation between the Upper and Lower Cretaceous in Kansas and adjacent states should be placed at the top of the Washita and its equivalents. In Europe it apparently should be placed at the base of the Cenomanian—considered by many European students the equivalent of the Washita. Thus the diastrophic principle places the break on one continent at one level and on another continent at a different level. There ought to be nothing strange about this—it seems that such should be normal rather than otherwise—and the writer is inclined to the opinion that it will ultimately be found to be true for several of the larger time units, especially when we get away from the present conception that the order of historic events on this continent was the same as in the Old World. He would go still further and insist that such is quite likely to be the case for some of the larger time units even on opposite sides of the same continent, thus agreeing with Willis that "Each region has experienced an individual history of diastrophism, in which the law of periodicity is expressed in cycles of movement peculiar to the region" and "The periods of diastrophic activity" have been "as regards the whole surface of the earth in general not contemporaneous."[24]

[20] A. de Lapparent, Traité de Géologie, vol. 3, p. 1408, 1906.
E. Haug, Traité de Géologie, pt. 2, p. 1293, 1907.

[21] E. Kayser, Lehrbuch der Geologie, pt. 2, p. 513, 1908.

[22] C. Schuchert, Bull. Geol. Soc. Am., 20, 584-585, 1910. Stanton also quoted to that effect.

[23] De Lapparent, op. cit. p. 1384.
J. Parks, A Text-Book of Geology, p. 412, London, 1914.
T. C. Chamberlin and R. D. Salisbury, Geology, vol. 3, p. 168, 1907.

[24] Bailey Willis, Science, new ser., 31, 247, 249, 1910.

The theory of universal unconformities grew up during the past century on the assumption that either all the continents or all the oceans move as a whole, and it received tremendous support from the postulate of Suess that the lowering of the strand-line and the rising of the land came about through earth shrinkage and greater depression of the ocean basins. Chamberlin and Salisbury gave it further support when they stated their view that the "deformative movements begin . . . . with a depression of the bottom of the ocean basins by which their capacity is increased" and "The epicontinental waters are correspondingly withdrawn into them."[25] The writer wishes that the theory of universal depression or elevation of the strand-line could be established, as the problems of intercontinental correlation and those of the opposite sides of the same continent would thus be immensely simplified. That some withdrawals of the sea may have been of this general character is quite probable, and if such could be determined they might be made to constitute the high places of the geologic time-scale—perhaps the divisions between eras. That most of the movements were in the nature of local regional elevation and depression, taking place irrespective of what the oceans and the other continents were doing, seems to the writer to be far more probable and to rest on a firmer basis of fact; and that the separation of the geologic time-scale into periods is based on the planes of division thus created seems far more probable than that they are due to general withdrawals of the sea.

If the bounding planes between period divisions of the geologic column are determined by local regional withdrawals of the sea, how is it to be decided for each continent what constitutes a period? For nomenclature relating to the geologic time-scale to be of real value to geologists and students in general, the larger time units should have, so far as possible, the same limitations on one continent as another. If the postulates considered above are valid, it would mean that after the boundaries of a period or system have been determined on one continent, they will have to be determined for other continents on a basis of paleontologic criteria irrespective of where the diastrophic breaks may be. Otherwise a term given

[25] Chamberlin and Salisbury, Geology, vol. 3, p. 192, 1907.

to a period will mean one thing on one continent and something else on another continent.

The writer would compare the divisions of geologic history in their relations to the geologic history of the continents to the divisions which have been made in the history of man. The great divisions of American and European history have been based on great events in the history of these peoples, and ultimately these high points may become the basis for the division of the histories of all peoples, the histories of other peoples being made to conform to that of Europeans and Americans. In Chinese history, for instance, the high points would be at times which might coincide in some instances with the high points in our history and in others not. It may come to pass that ultimately another civilization with different antecedents will supplant the existing one. In this civilization, the high points in the present one may have no significance. So the high points in European geologic history may or may not have any relation to the high points of American geologic history. In lands other than those in which the periods were first defined, fossils would be the final arbiters of period delimitation.

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SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Potassium Nitrate from the Chilean Nitrate Industry.*—P. F. Holstein, of the du Pont Nitrate Co., Tantal, Chile, gives an account of an important source of potash in the sodium nitrate of Chile, which is beginning to be utilized and promises to be of much importance in the future.

During the year ending June 30, 1918, over 6½ billion pounds of nitrate were produced in Chile, and the average potassium nitrate content of all the sodium nitrate shipped is probably 2%, so that there were contained in this nitrate about 130,000,000 lbs. of potassium nitrate, the potash of which could not be utilized in the mixture and was, consequently, of no value. This large amount of wasted potash corresponds to about 21% of the total consumption of the United States.

That this potash may be separated successfully at the producing plants and sold as a distinct product there is not the least doubt, for this has been done since 1914 by a number of the "oficinas," and there are probably 100 other plants in the country where the same thing could be done with but slight modifications of the usual processes and small additional equipment. Even if the price of potash should drop to the pre-war level there would still remain a substantial profit to the manufacturers, a fact of importance in meeting the competition of artificial nitrate in the future. For many purposes there is an advantage in producing potash in the form of nitrate rather than as chloride or sulphate, for it may be refined readily to produce the pure salt, and the crude product consisting of sodium nitrate containing from 20 to 80% of potassium nitrate is particularly useful as a fertilizer, since both the nitrogen and the potassium are valuable for that purpose.

The methods employed for separating products more or less rich in potassium nitrate consist in fractional crystallization, carried out by drawing off the liquid before crystallization is complete and obtaining from it a crop richer in potassium, or in evaporating or refrigerating the usual mother liquors.—*Jour. Ind. Eng. Chem.*, **12**, 290. H. L. W.

2. *A Hydride of Tin.*—Although the formation of a gaseous tin hydride was supposed to have been shown nearly 100 years ago by Kastner when the metal was dissolved in hydrochloric acid, many subsequent investigations have failed to confirm this observation, and it has been supposed for a long time that no such compound exists. Recently, however, Peneth and Furth of Prag have succeeded in showing that a hydride of tin can be prepared. Their method consists in making an alloy usually

corresponding nearly to the composition required by the formula Mg_2Sn, then pulverizing it and treating it with hydrochloric or sulphuric acid, usually of about 4-normal strength in an apparatus similar to that used in the Marsh test for arsenic. The hydrogen thus produced gave metallic mirrors of tin in the heated tube. The yield was exceedingly small in proportion to the amount of alloy employed, but there appears to be no doubt, from the account of the tests made upon the mirrors, that a gaseous tin hydride has at last been prepared. Experiments showed that the substance could be condensed by passing the hydrogen containing it through a U-tube cooled with liquid air, but no sufficient quantity of it had as yet been prepared for the determination of its physical properties or its chemical formula. It may be observed that the same authors have recently shown in a similar way the existence of hydrides of bismuth and its radioactive isotope polonium, and that they have announced the probable existence of a gaseous hydride of lead.—*Berichte,* **52,** 2020. H. L. W.

3. *A New Indicator for Bases and Acids.*—It is stated by M. CHAUVIERRE that the coloring matter of red beets is an exceedingly delicate reagent for the detection of bases and acids. To prepare the indicator some pieces of beet are boiled with water and the solution is filtered. A very opalescent liquid of a beautiful violet-red color is thus obtained to which a drop of potassium hydroxide solution gives a bright yellow color. This yellow liquid is a reagent of great delicacy for acids, and not only mineral acids but also the weakest organic acids, such as tartaric acid and oxalic acid, produces the original violet-red color. It is stated that the reagent is much more sensitive than litmus or even phenolphthalein, but it cannot be used in the form of a test-paper, since the coloring matter is not fixed by paper. It appears that this coloring matter does not form a true solution, but is colloidal in its nature, as is indicated by its opalescent character. It is stated that the reagent is sensitive to dilute boric acid solution, but no statement is made in regard to its behavior with carbon dioxide, a matter of much importance in connection with its practical application.—*Bull. Soc. Chem.,* **25,** 118. H. L. W.

4. *Chemically Reactive Alloys.*—E. A. ASHCROFT calls attention to certain alloys that are oxidized with remarkable rapidity by cold, moist air. Alloys of calcium and lead show this behavior to a considerable degree, but they are not so rapidly oxidized as magnesium-lead alloys. This behavior was observed when from 5 to 50 per cent. of magnesium was present, but it appears that a mixture of 15% magnesium and 85% lead produces one of the most active alloys. Moisture is essential to the reaction, the crushed alloy is most rapidly attacked, but large pieces are quickly oxidized and fall to powder. The prod-

uct is black and is said to consist of a mixture of magnesium hydroxide and the hydroxide of lead suboxide. When treated with boiling water the alloy evolves hydrogen and the same solid compounds are formed.—*Trans. Faraday Soc.*, **14**, 271.

H. L. W.

5. *The Preparation of Organic Compounds;* by E. De Barry Barnett. 8vo, pp. 273. Philadelphia, 1920 (P. Blakiston's Son & Co. Price $3.25 net).—This is the second edition of a very useful laboratory manual of British origin. No very extensive changes have been made in the present edition, but some descriptions of larger-scale apparatus are among the noteworthy additions, and it has been the author's aim to give the student an insight into industrial operations in connection with the theoretical principles of the subject.

The list of preparations presented is unusually extensive and well classified, covering very satisfactorily the various fields of organic synthesis, while copious references to the literature are given, which should be of much assistance, both to students and instructors, in courses of organic preparations. H. L. W.

6. *The Value of the Rydberg Series Constant.*—In the year 1914 an attempt was made by W. E. Curtis to derive the best value for the Rydberg constant N from the most reliable data on the wave-lengths of the series lines of hydrogen. The result then obtained was $109679.22 = N$. In obtaining this important constant the author failed to realize that the tertiary iron standards refer to 15° C. By using 20° C. in the reduction of the hydrogen wave-lengths to *vacuo* he introduced a slight error in the final result. Since the first paper of Curtis was published, very accurate determinations of the indices of refraction of air, for an unusually wide range of wave-lengths, have been made by Meggers at the National Bureau of Standards in Washington, D. C.

A second paper on the same subject by Curtis has recently appeared, and in it he takes advantage both of the latest data for the refractive indices of air and of the experience gained in his earlier calculations. In this paper six series formulae are compared and it is found that a Rydberg expression involving two constants is not only capable of representing the hydrogen series satisfactorily but that it is appreciably superior, in this respect, to the theoretical formulae of Bohr and Allen. The probable effect upon the determination of N arising from the fact that each of the lines $H\alpha$ and $H\beta$ is a doublet is investigated, and shown to be inappreciable. The author suggests the provisional adoption of the value 109678.3 for N. By way of comparison, it is desirable to state that, in 1918, R. T. Birge discussed the same question and arrived at the value 109678.705 for N. It seems clear, therefore, that the *seventh* digit cannot be finally established until more accurate values for the wave-lengths of the separate components of the hydrogen lines are available.—*Proc. Roy. Soc.*, **96**A, 147, 1919. H. S. U.

7. *Experiments with Perforated Electrodes on the Nature of the Discharge in Gases at Low Pressures.*—Certain more or less preliminary experiments on the passage of electricity through rarefied gases have been performed by F. W. ASTON in a manner which promises to appreciably increase our knowledge of the complex phenomena involved.

A brief description of the discharge vessel will now be given. A cylindrical glass shade, with a plane lower edge and a hemispherical top (axis of revolution vertical), was closed at the bottom by a disc of stout plate glass. The electrodes were circular discs of zinc having a diameter (11·8 cm.) slightly less than that of the inside of the glass cylinder. When used as cathode material, zinc was found to have several advantages over aluminium and other base metals; for example,—it gave off but little gas, it sputtered inappreciably, and it was readily worked into shape. The lower disc was fixed relative to the containing vessel, while the upper electrode could be raised or lowered by means of a vacuum-tight winch. The lower electrode was cut through by a diametral slit 10·0 cm. long and 0·0182 cm. wide. To the underside of this electrode a Faraday cylinder was fastened. The vertical cross-section of this cylinder was similar in outline to that of a sector of a circle, having an obtuse angle at the vertex. The upper chamfered edges of the Faraday cylinder were separated from each other just enough to produce a slightly wider slit than the opposing one in the lower electrode. The distances between the corresponding edges of the two parallel slits could be reduced to less than 0·01 cm. The Faraday cylinder was protected by an appropriately shaped guard cylinder. A description of the auxiliary apparatus and an account of the manner of making observations would be superfluous in this place.

The most important results obtained may be summarized as follows: (a) When the lower disc was made the cathode, and was maintained at the same potential as the Faraday cylinder, the experiments showed that about one half of the total current in the discharge is brought up to the cathode by positive ions. (b) Owing to the intense ionization in the neighborhood of the slit (and to other possible causes discussed in the paper) all attempts to determine the distribution of velocities in this stream failed to give unambiguous results. (c) When the perforated disc and the upper electrode were made respectively the anode and the cathode, while the total current was kept constant, it was found that the current carried into the Faraday chamber by the cathode rays decreased in geometrical proportion as the cathode receded in arithmetical progression. (d) The effect both of the distance apart of the electrodes and of the total current, on the vanishing of the last trace of the positive column or anode glow was found to be remarkably definite (cathode settings reproducible to within one per cent.).—*Proc. Roy. Soc.*, **96**A, 200, 1919.

H. S. U.

8. *The Line Spectrum of Sodium as Excited by Fluorescence.*—This was the subject of the Bakerian lecture delivered by R. J. Strutt in June, 1919 and quite recently published in the "Proceedings" (*vide infra*). The paper contains a very clear general account of the author's earlier work in this field as well as a more detailed discussion of some new experiments and results. The success of the latest work was due primarily to the improved form of sodium vacuum-arc lamp devised and perfected by Strutt. Without a diagram it is not feasible to describe the lamp in this place. Suffice it to say, that this piece of apparatus fulfilled the following conditions: (a) it radiated very fine lines with extremely narrow reversals, (b) the intensity of the lines was unusually great, and (c) the lamp could be run continuously and unattended for 24 hours or more before prohibitive opacity of the silica walls set in.

Of the seven reproductions of excellent photographs presented in the plate, the first illustrates the extreme sensitiveness of the *D* lines to reversal. The interference fringes were obtained by using a Fabry and Perot *étalon* of 5 mm. thickness. When, by the aid of a weak electromagnet, the luminous vapor was thrown against the wall of the lamp nearest to the interferometer the reversals were very much narrower than when the radiating column was deflected against the more remote wall of the tube. "With the sodium lamp as described, focussed upon the wall of an exhausted bulb containing sodium vapour, very brilliant resonance is obtained, bright enough to be readily shown in the largest lecture room. This brightness makes possible various experiments which would be very difficult to carry out with the salted flame as source."

An estimate of the breadth of the resonance *D* lines was made with the aid of a Lummer plate and accessory apparatus. On the assumption of a probability distribution of radiation in one *D* line, the true breadth of the line was calculated as 0·017 Angström. The value obtained by using Fabry and Buisson's formula,—which refers to the Doppler effect,—was 0·020 Angström. The latter datum involves the hypotheses that the radiator was the sodium *atom* and that the temperature of the vapor was 250° C. Under the circumstances, the two values for the breadth of a *D* line may be considered as quite concordant.

The favorable conditions produced by the new lamp enabled Strutt to succeed in an experiment which he had been unable to realize on previous occasions. It was the excitation of the second doublet of the principal series by using the same line alone as the stimulator. Not only was the doublet at λ3303 excited by λ3303 but also the *D* lines, at λ5893. This observation is very important because it clearly establishes the existence of some mechanical coupling between the system which absorbs λ3303 and that which emits λ5893. Furthermore this phenomenon seems to have no analogy in the behavior of the vibrating systems dealt with in classical mechanics. On the other hand, the radiations of higher frequency at λ3303 were not detected when the radiations of lower frequency at λ5893 were caused to pass through the vapor in the resonance bulb. The lines of the subordinate series gave no re-emission.

When *D* light falls on sodium vapor of appropriate density, it is known that an intense surface emission occurs from the front layer, and a weak one from succeeding layers. Analysis by absorption in an independent layer of sodium vapor showed that the superficial emission is more absorbable, and therefore nearer the center of the *D* lines.

Polarization could not be detected in the ultra-violet resonance radiation, though in accordance with previous observers it was readily perceived in *D* resonance.—*Proc. Roy. Soc.*, **96**A, 272, 1919. H. S. U.

9. *Electric Oscillations and Electric Waves;* by George W. Pierce. Pp. ix, 517, 136 figures. New York, 1920 (McGraw-Hill Book Co.).—This book is designed to present a mathematical treatment of some of the fundamentals of the theory of electric oscillations and electric waves. The material is conveniently divided into two Books, of which the first (17 chapters, 345 pages) relates to electric oscillations and the second (9 chapters) to electric waves. Book I deals with circuits containing capacity, resistance, and self-inductance, with the free oscillations of variously coupled circuits, with resonance relations, etc. Book II is devoted to Maxwell's equations, to wave equations, to electrical doublets, and to theoretical investigations of the radiation characteristics of an antenna. The author says: "Although the selection of material particularly applicable to radiotelegraphy has been the first consideration, yet, because the electromagnetic theory, which is fundamental to radiotelegraphy, is fundamental also to optics, wire telephony and power transmission, it is hoped that the volume may be useful in these fields also."

As regards the manner of presentation and attention to practical details nothing is left to be desired. In many places where the student's previous mathematical attainments may be inadequate, the author has incorporated clear concise proofs of the relations and theorems required. This is especially true of the complex quantity, of vector algebra, and of ordinary differential equations. The judicious use of italic and Clarendon type, the employment of Gibbs' notation for dot and cross products, the inclusion of illuminating foot-notes throughout and of useful tables in the appendix, and the care with which the line diagrams have been constructed, all redound to the credit of the author and publishers. In short, the book seems to be a valuable and efficient contribution to the important field to which it pertains. H. S. U.

10. *The Book of the Damned;* by CHARLES FORT. Pp. 298. New York, 1919 (Boni and Liveright).—The gilded illustration of a fictitious planet and of ten suns or stars on the bright red cover, taken in conjunction with the striking title, would generally cause the casual observer to suppose that the book is a novel and that it might contain some very entertaining, perhaps even highly exciting, reading matter. Such expectations are immediately dashed as soon as attention is given to the actual contents of the volume. It will be found that by "the damned' the author means the alleged facts and observations which may be found recorded in reputable scientific journals and which have been "excluded" from the heaven of accepted phenomena either on account of their lack of importance or of their doubtful authenticity. He has undoubtedly devoted a large amount of time and energy to the compilation of the material presented, but the object in so doing is left in doubt by the absence both of a preface and of an introduction.

The author's style is at first confusing or bewildering, then amusing, but soon very tiring. Two fairly chosen typical quotations will suffice to illustrate this adverse criticism. (P. 8.) "But by the excluded I mean that which will some day be the excluding. Or everything that is, won't be. And everything that isn't, will be—But, of course, will be that which won't be —." (P. 207.) "It may be that the Milky Way is a composition of stiff, frozen, finally-static, absolute angels. We shall have data of little Milky Ways, moving swiftly; or data of hosts of angels, not absolute, or still dynamic. I suspect, myself, that the fixed stars are really fixed, and that the minute motions said to have been detected in them are illusions. I think that the fixed stars are absolutes. Their twinkling is only the interpretation by an intermediatist state of them." H. S. U.

11. *Mesures Pratiques en Radioactivité;* by W. MAKOWER and H. GEIGER. Translated by E. PHILIPPI. Pp. vii, 181. Paris, 1919 (Gauthier-Villars et Cie.).—A page by page comparison of the present volume with the original English edition,—which appeared as long ago as the year 1912,—shows that absolutely the only change effected by the translation is one of language. The translator gives neither a preface of his own nor any clue to the reason for making the translation. He has not brought the text or appendixes up to date in any respect whatever. On the contrary, he has retained the typographical slips of the original volume [for example, the one in equation (39)] and added some new errors. Consequently the French edition has nothing to recommend it to English readers.

H. S. U.

II. Geology

1. *Factors of Climatic Control;* by W. J. Humphreys. Jour. Franklin Inst., **188**, 775-810, 1919; **189**, 63-98, 1920.—This very important paper on the factors that control climates of the present and past should be read by all geologists and paleontologists. The factors discussed number fourteen, and of these the following are the most important: (7) Extent and composition of the atmosphere, (8) Vulcanism, (10) Land elevation, (11) Land and water distribution, (12) Atmospheric circulation, (13) Oceanic circulation, and (14) Surface covering. The factors mentioned, when most significant, are thought to bring on the glacial climates. Volcanic ash floating high above the zone of clouds is believed to be a contributing cause of much significance in glacial climates, and its absence the reason for the warmer interglacial conditions. C. S.

2. *Ueber fragliche Tunicaten aus dem Perm Siciliens;* Palæont. Zeits., **2**, 66-74, 1 pl., 2 text figs., 1915. *Ueber die Organization der Anthozoen;* Ibid., **2**, 232-250, 14 text figs., 1918. *Phylogenie und System der Pelmatozoen;* Ibid., **3**, 1-128, 114 text figs., 1918. By Otto Jaekel.—In the first paper cited, Jaekel describes some small fossils that occur in the limestones of Sosio, Sicily, as natural molds. These he compares with living tunicates of the genus *Rhodosoma,* to which they have considerable likeness. However, no pyramids closing the two openings into the sack, as in living forms, have as yet been found in these fossils. For this reason the form *Permosoma tunicatum,* n. gen. et sp., is doubtfully referred to the solitary tunicates.

In the second paper, which is of a highly theoretic nature, the author takes up an ontogenetic study of the septal introduction in the Tetracoralla and Hexacoralla, and concludes from this and other evidence that the Anthozoa had their origin in a bilaterally symmetrical, errant and metameric, worm-like animal, with a mouth at one end and an anus at the other end of a digestive tract. This form adapted itself through fixation to a sessile mode of life, which caused it to bend and double on itself, bringing the polar ends into close association. A new mouth was eventually developed in what was originally the posterior end, and the original mouth, gut, and anus transformed into the simplified gastral cavity of these sack-like animals. Accordingly, the Anthozoa arose in a stock higher in development than the assumed planula.

The third paper is by far the most important of the three here noticed. It is twenty years since Jaekel published his great work on the history of the Pelmatozoa, and as he does not now see his way to a completion of it in the detailed manner of the first volume, he here gives an extended sketch of his ideas as to the interrelations of the Echinoderma, and especially the stalked forms. There are 114 pen and ink drawings made by the author, and some of them show striking plated objects of great beauty. The work mentions or defines more or less briefly 456 genera (many of which are new), and all in all no student of the Pelmatozoa can be without it. The classification in its broader outlines follows the one of twenty years ago and in many ways is unlike any other.

Jaekel says the Echinoderma are naturally divisible into three subphyla: (1) Pelmatozoa (including the four classes Crinoidea, Cystoidea, Carpoidea, and Thecoidea), (2) Asterozoa (Stelleroidea and Ophiuroidea), and (3) Echinozoa (Holothurioidea and Echinoidea). It is from the Crinoidea that he derives the other three classes, while the Asterozoa he holds to have developed out of the Thecoidea. The class Crinoidea is divided into three subclasses: Eocrinoidea (which most students classify as Cystoidea), Cladocrinoidea (including the camerate crinoids), and Pentacrinoidea (embracing the greater number of crinoids). The class Cystoidea has three subclasses, the Dichoporita, Diploporita, and Blastoidea. C. S.

4. *The Environment of Vertebrate Life in the Late Paleozoic in North America; a Paleogeographic Study;* by E. C. CASE. Carnegie Institution of Washington, Publ. No. 283, 273 pp., 8 figs., 1919.—In this detailed paleogeographic work the author first develops the principles that underlie the discerning of the ancient geographies, and then takes up a comprehensive study of the very varied physical environment of the seas and lands of Pennsylvanian and Permian times in North America. He seeks in this way to learn the conditions of environment that gave rise to the peculiar and varied amphibian and reptile development in late Paleozoic time. The phenomena of aridity appear earliest in eastern North America, and here also occur some of the reptiles. Finally red beds and the vanishing of epeiric seas become far more prevalent, and with these are associated the extraordinary rise of the early Permian vertebrates of Texas, New Mexico, and Oklahoma. The study "emphasizes the changes from a long period of slow evolution in a singularly monotonous environment through a period of rapid expansion in a diversified environment to final extinction." C. S.

5. *Die Trilobiten der Zone D-d_1 von Prag und Umgebung;* by O. NOVAK. Palæontographica Bohemiæ, No. 9, Ceská Akad. Císare Františka Josefa, Trída II, 51 pp., 4 pls., 1918.—It appears that the late Otomar Novak intended to publish a work on the trilobites of this zone. His work, however, was left unfinished in 1890, and is now completed by J. Perner, who, according to the rules of nomenclature, must be regarded as the author of five forms described by him, even though he accepts the names proposed by Novak and cites him as author. In the paper are noted or described thirty-two species and varieties, and of these sixteen are new. The material is well illustrated.

C. S.

6. *Kritische Studien ueber die Terebratula-Arten der schwedischen Kreideformation;* by Assar Hadding. Palæontographica, vol. **63,** 25 pp., 9 pls., 5 text figs., 1919.—This is a revision of the Swedish species of Danian and Senonian Terebratulas, based on the external characters, internal ones not being accessible. There are nineteen forms, and of these four are new varieties. It is to be regretted that nothing is attempted in the way of a generic revision, since it appears that more than one genus is present. C. S.

7. *A Catalogue of the Mesozoic and Cenozoic Plants of North America;* by F. H. Knowlton. U. S. Geol. Survey, Bull. **696,** 815 pp., 1919.—In this catalogue Knowlton gives the bibliographic references to about 735 genera and about 4150 named species and varieties of plants found in the Mesozoic and Cenozoic of the United States and Canada. The starting point for the recognition of names is the Linnæan "Species Plantarum" of 1753. In 1878 Lesquereux listed 706 forms. In the Triassic, Knowlton now lists about 130 named forms, in the Jurassic about 125, and the remainder, about 3895, appear to be almost equally divided between the Cretaceous (including the Comanchean) and the Cenozoic. The genera, species, and varieties, and their synonyms are arranged in alphabetic order, being preceded by the bibliography (about 474 titles) arranged according to authors (about 70). Following the catalogue there are given (1) a biologic classification of genera, (2) an index of genera and families, and (3) floral lists arranged geologically and geographically (pages 697-815). There is also a large geologic table giving the approximate stratigraphic position of North American Mesozoic and Cenozoic plant-bearing formations as interpreted by the author.

We congratulate Doctor Knowlton upon the completion of this indispensable work—a great labor of love—for which he has the silent thanks not only of all paleobotanists and botanists, but of stratigraphers as well. C. S.

8. *Stratigraphy and Correlation of the Devonian of Western Tennessee,* Tennessee Geol. Survey, Bull. **21,** 127 pp., 4 pls., 11 text figs., 1919. *New Species of Devonian Fossils from Western Tennessee,* Trans. Connecticut Acad. Arts and Sci., **23,** pp. 109-158, pls. 1-5, 1920. By Carl O. Dunbar.—The Tennessee bulletin describes in great detail the history, structure, and stratigraphy of the Devonian—largely the Lower Devonian—of the Western Valley of the Tennessee River, aggregating nearly 500 feet in thickness, although at no place do the strata exceed about 150 feet. A striking discovery is the presence here of upper Oriskany of the New York type, and the transference of the Camden formation from the Lower to the Middle Devonian. It is a very careful and detailed stratigraphic report, and a fit associate for the Lower Devonian work of the states of New York and Maryland. The author and the State Geological Survey of Tennessee are to be congratulated upon the production of this

highly scientific work, which also has its practical bearings on the economic products of the area studied.

In general, the strata lie in nearly horizontal attitude, but locally they rise into low open folds with the dips rising to as much as 10°. At Clifton one of these arches rises fully 250 feet, and at Grandview another is 100 feet high. In addition to the gentle folds, the southern half of the valley is considerably faulted and the vertical throws range from a few feet to perhaps 150 feet. On the other hand, the Harriman and Camden cherts, due to their hard and brittle nature, are thoroughly fractured and crumpled, so that locally the strata may have dips of 80° or more. Gentle warping went on during the Devonian, but the major folding and faulting is thought to have been an interior consequence of the Appalachian orogeny of Permian time.

The Devonian sequence is as follows: At the top is the thin Chattanooga shale and its basal Hardin sandstone, which seemingly are better placed in the Mississippian period. There are here no Upper Devonian nor any Hamilton equivalents. The Middle Devonian begins with the thin Pegram (= Onondaga) limestone that lies disconformably upon the Camden chert. The Camden, with a thickness up to 200 feet, has 42 species, many of which occur also in the Clear Creek of Illinois, and both formations appear to correlate with the Esopus and Schoharie of New York. The Lower Devonian of Oriskanian time has at the top the Harriman chert, with a fauna of 25 species, followed below by the Quall limestone, having 10 species; both correlate with the typical New York Oriskany fauna. Then follows a long series of Helderbergian formations. The uppermost one is the very thin and patchy Decaturville chert, with a fauna of 20 species relating it to the Becraft of New York, followed below by the Birdsong shale, 35 to 65 feet thick, bearing a Helderbergian (= New Scotland) fauna of 99 determined species. Then comes the Olive Hill formation, consisting of about 160 feet of limestones, with local beds of oolitic iron-ores, and a fauna of 58 species, best comparable with that of the late Coeymans of New York. The base of the Helderbergian consists of the Rockhouse shale (up to 26 feet thick), yielding a fauna of 35 species, with several Silurian hold-overs, correlating best with the basal member of the Lower Devonian of the Arbuckle Mountains and less clearly with some part of the Keyser formation of Maryland. The Rockhouse rests disconformably upon the higher formations of the Middle Silurian, there being here no Upper Silurian strata.

The work closes with detailed descriptions of forty local sections, with the faunas listed for each zone.

In the second paper, Doctor Dunbar describes and illustrates 37 new species found by him in connection with the work above reviewed, and proposes 3 new gastropod genera, *Saffordella, Aulopea,* and *Distemnostoma.* C. S.

9. *Paleogeography and Diastrophism in the Atlantic-Arctic Region during Paleozoic Time,* by O. Holtedahl.—Correc-

TIONS: Figures 9 and 11 on pp. 13 and 14 should be reversed; fig. 11 (p. 14) gives the *Upper Devonian map* and fig. 9 (p. 13) the *Pennsylvanian map.* Also on page 10, in the explanation, second line from top, "in early Silurian time" should read "in Silurian time."

Page 12, line 21 from top should read as follows: "Norwegian Sea, the Skandik of De Geer, which sediments tell of enor—."

Page 23, line 8 from bottom for "Amferer" read "Ampferer."

The slowness of the present mail service between the United States and Norway prevented the author from reading the proof.—EDITORS.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Report of the Librarian of Congress,* HERBERT PUTNAM, pp. 1-105; also *Report of the Superintendent of the Library Building and Grounds,* F. L. AVERILL, pp. 169-179, *for the fiscal year ending June 30, 1919.*—The additions to the Library of Congress during 1919 amounted to about 96,000 volumes with upwards of 36,000 copies of maps, music, and prints. In addition there are a large number of manuscripts not separately enumerated. Among the important additions of printed material are the Orientalia from the Far East to which Mr. W. T. Swingle has devoted himself. In the division of manuscripts, many important papers have been obtained, in part by gift, in part by purchase. These include the Tyler Papers; those of James Buchanan written to his niece Mrs. H. L. Johnston; those of Theodore Roosevelt; of William H. Taft and numerous others. These are individually enumerated and it is remarked that the division of manuscript has now become the gathering place for the materials which students of history are using daily in their work. The musical division now includes more than 853,000 volumes, pamphlets and pieces, of which 31,000 have been added in the past year. There have also been acquired numerous war posters, photographs and general literature, the interest of which will greatly increase in the future. The Library has played an active part in the war efforts of the country and a considerable part of its normal staff was thus engaged. The two appeals to the public of the American Library Association have yielded an aggregate amount of five million dollars. The chief need of the Library mentioned is the one felt in so many directions, of an adjustment of the salary schedule, to adapt it to the present cost of living.

2. *Annual Report of the Superintendent of U. S. Coast and Geodetic Survey,* E. LESTER JONES, *for the year ending June 30, 1919.*—The work of this Department has also been much influenced by the progress of the war which closed during the period now included. Of particular interest is chapter III showing the many needs of the Hydrographic and Geodetic Surveys in this country and its possessions, called for especially by the improved modern methods now in use. This chapter is accom-

panied by numerous illustrations dealing not only with the Atlantic Coast but that of the Pacific including Alaska, as well as Porto Rico, the Virgin Islands and the Philippines. The part played by the Bureau during the war is made manifest by the fact that 272 men from the field and office took an active part; a list of these is enumerated. The Bureau also contributed five of its vessels to the fleets operated by the Navy and rendered valuable aid both through the field and office force, its charts and otherwise. The charts accompanying the volume show the progress of field operations as regards topographic surveys, triangulation, levelling, magnetic observations, etc. It is regrettable that the Superintendent is compelled to acknowledge that lack of funds has led to a steady disintegration in the personnel, so that only prompt relief can prevent this important branch of the Federal Government from, at least in a measure, "being stripped of its best brains."

3. *Commonwealth of Australia: Institute of Science and Industry.*—Bulletin No. 14 gives the results of an investigation by John Read and H. G. Smith of the Australian "Marine Fibre." This is the fibrous portion of the leaf sheath of *Posidonia australis*, a plant which grows abundantly in the shallow waters of the Australian coast, particularly those of South Australia. The physical and chemical properties of the Fibre are described in detail with a view to determining the uses for which it is most suitable. The pamphlet is accompanied by 20 half-tone plates.

4. *Special Library Census.*—A circular letter, dated February 28 and signed by Wm. F. Jacob, librarian of the General Electric Co., Schenectady, has as its object the gaining of general information as to the "special libraries" in the country. A special library has been defined as: "A good working collection of information either upon a specific subject or field of activity; it may consist of general or even limited material serving the interests of a special clientele; and preferably in charge of a specialist trained in the use and application of the particular material."

Particular information is desired as to the following points: The name of the institution or company and that by which the library is known with that of the librarian or custodian. Further, the library can be classified as any of the following: financial, business, legal, engineering or technical, institutional, municipal, reference, agricultural; if not, how can it be classified? Also, does it serve a special clientele? Finally, would the librarian be willing to assist other special libraries to a reasonable extent?

The data as to the above points may be sent to Wm. F. Jacob, Chairman Library Census Committee, care of the General Electric Company, Schenectady, N. Y., who will be glad to answer any questions relating thereto.

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[FOURTH SERIES.]

Art. XXIII.—*The Mathematics of Isostasy.* I; by T. C. Chamberlin.

In the October number of this Journal there appeared a posthumous paper by the deeply lamented Dr. Joseph Barrell,[1] on "The Status of the Theory of Isostasy," in which he criticized with great severity a paper by Dr. William D. MacMillan on the mathematical aspects of isostasy.[2] The terms of the criticism and the importance of the subject are such as to make a supplementary statement seem imperative, notwithstanding the embarrassment of doing this under the circumstances of the case. It is a first duty, however, to note that Dr. Barrell was not permitted to give his paper a last revision. Quite likely some modification of phraseology in the line of his usual urbanity of statement might have been made had the paper passed under his hand again. Passing the matter of form and many minor points as negligible, there remain two reflections that call for comment. The first relates to the preparation and purpose of Dr. MacMillan's article, the second to some of the essential points in the article itself. The first falls to me, as the really responsible party; the second, to Dr. MacMillan.

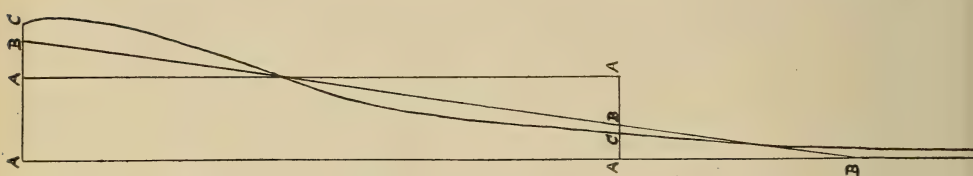
It seems clear from the tone of his paper that Dr. Barrell, in the absence of any knowledge of the circumstances that called forth the paper of Dr. MacMillan, and impressed by its shortness and limitation to one phase of the subject merely, drew the inference that its author had given little serious study to the subject and that the

[1] Joseph Barrell: The Status of the Theory of Isostasy, this Journal, vol. 48, pp. 291-338, Oct., 1919.

[2] Wm. D. MacMillan: On the Hypothesis of Isostasy, Jour. Geol., pp. 105-111, Feb.-Mar., 1917.

paper was an ill-considered intrusion into the discussion of a complicated subject to which others had given long and laborious study. It is obligatory upon me, for reasons that will at once appear, to show that, quite on the contrary, Dr. MacMillan's paper was the outcome of protracted consideration and that it was regardful of other workers in quite an exceptional way. It was particularly considerate of our great leader in modern isostatic work. The whole story is worth telling merely as a matter of method.

To reach the real origin of MacMillan's paper, it is necessary to go back almost to the beginning of Dr. Hayford's monumental work on isostasy. It sprang remotely from my review of one of Dr. Hayford's earliest contributions a dozen years ago.[3] By reference to



this review, it will be seen that, at that early stage of the inquiry, Dr. Hayford was feeling about, by the use of trial hypotheses tested by the method of the least squares, to find the depth of compensation that would best satisfy the data at his command. In these trials he made three assumptions as to the distribution of density. While he did not hold either of these as excluding the others, he regarded a uniform distribution to a depth of 113·7 kms.[4] below the surface as most satisfactory, because it gave the least residuals.

My review urged that it was important (1) to discriminate between what was really determined and what was only interpretation, and (2) to adhere as closely as practicable to the natural distribution of density. I recognized, of course, the propriety of using arbitrary distributions of density to save mathematical labor, especially where the labor was, as in this case, scarcely less than heroic. To make my point tangible, I intro-

[3] Jour. of Geol., vol. 15, pp. 73-81, 1907.

[4] Later he found 122 kms., 76 miles, more satisfactory and as this figure appears most widely in the literature of the subject, it will be used in the rest of this article.

duced the accompanying figure in which a generalized curve of what I thought might be a natural distribution of density was superposed on two of the distributions used by Hayford. Later, Hayford was good enough to make the curve I had suggested the basis of trial and published his results under the name "Chamberlin compensation."[5] The residuals in this case seemed quite as favorable as in the best of the distributions previously tested, but there was this notable difference: the latter, uniform distribution, gave a compensation depth of 76 miles, while my supposedly naturalistic curve gave a depth of 178 miles. From the geological point of view this much greater depth seemed a vital matter, for some geologists, who had previously tried to form the best concepts they could of the thickness of the crust from considerations of "the level of no strain" and other criteria then thought trustworthy, felt that even 76 miles was surprisingly deep. Major Dutton, the father of the formal doctrine of isostasy, so expressed himself to me personally.

But, strangely enough, as it seemed to me, notwithstanding the fact that the first trial of a supposedly natural distribution of densities gave quite as favorable residuals as the best of the artificial distributions previously tried—and in the face of the obvious probability that more carefully studied naturalistic distributions would give even better results—nearly every quotation of Hayford's results cited the depth of 76 miles as though it were the essential outcome of his laborious studies, and usually in such a way as to imply that it was a *demonstration* of the real depth of compensation, though Hayford had made no such claim. This was so general that it led me to suspect that there must be something in the technical treatment of the case, whose meaning I had failed to detect, that distinctly favored the outcome 76 miles, though based on a uniform distribution that seemed geologically improbable, rather than the outcome 178 miles, based on a graded distribution that seemed more probable. And so, after having myself recurred to the published treatment repeatedly without finding any clue to such hidden evidence, I raised the question, as opportunity offered, with my mathematical colleagues.

[5] J. F. Hayford: The Figure of the Earth and Isostasy from Measurements in the United States, Publ. of the U. S. Coast and Geodetic Survey, p. 159, 1909.

At different times and independently, Dr. F. R. Moulton, Dr. A. C. Lunn and Dr. Wm. D. MacMillan were good enough to inspect the published treatment and to assure me they could see nothing in it that favored the result 76 miles as against the result 178 miles.

These recurring inspections were scattered through several years and had naturally awakened certain other questions as to the specific trustworthiness of the mathematical methods adopted in handling the geodetic data. And so at length I ventured to ask Dr. MacMillan to make a study of them purely from the mathematical point of view. This Dr. MacMillan was good enough to do. There was placed at his command the whole history of the inquiry and its literature, as well as such suggestions as several of us who had been interested in the subject for years could give. At the close of his study he prepared an abstract of his results. This was discussed freely by various associates interested in the matter, mathematicians, astronomers, physicists, and geologists. As a result it came to be our common judgment that MacMillan's critique should be laid before Hayford in a friendly, informal way, and that later perhaps we should invite him to unite with us in a quiet discussion of the matter. The result was that after such submission and some correspondence, a conference was arranged. Dr. Hayford came over to the Quadrangle Club and lunched with us, after which we adjourned to my lecture room and spent the afternoon in an ideally frank and friendly discussion. It so happened that President Woodward, of the Carnegie Institution, on his way to Mt. Wilson, lunched with us and joined in the discussion. There were present mathematicians, astronomers, physicists, and geologists to the number of a dozen or more. Besides Hayford and MacMillan there were present Moore and some of his colleagues of the Mathematical Department, Michelson and some of his colleagues of the Physical Department, Moulton of the Division of Mathematical Astronomy, and those of our geological staff interested in the problem.

The conference opened with an elaborate statement by MacMillan supported by ample citations from Hayford's printed reports to show the care and caution with which he had avoided untenable claims. Hayford replied elaborately, ably setting forth his methods and results and his points of view. The subject was then thrown open for discussion in which Moulton and Woodward were the chief participants. As nearly as I recall, essentially all the points referred to by Dr. Barrell in his criticism were included in the discussion, and much besides. Hayford made no attempt to overthrow MacMillan's statement as to the inadequacy of the geodetic data to demonstrate the depth of compensation; he did not go beyond the claim that the chief compensation took place in the upper levels, to which no dissent was expressed.

The most far-reaching feature of the discussion, so far as mathematical competency is concerned, was a challenge by Moulton of a concession incidentally made by MacMillan to the effect that geodesists could prove a specified thing named. Moulton insisted that they could not prove this mathematically in the strict sense of the term. He asserted that he could specify a distribution of density that would satisfy the geodetic data perfectly and yet would be quite different from the distribution thought to be demonstrated. He admitted that his assigned distribution might be open to physical or naturalistic criticism—might indeed be absurd from these points of view—but mathematically it would perfectly satisfy the data. Woodward supported Moulton on this point, and quoted Poincaré, one of the most brilliant and penetrating of modern mathematicians, as having said in effect that for every set of physical data assembled by observation or otherwise, an indefinite number of mathematical solutions could be offered, each one of which would perfectly satisfy the data.

I was so much impressed by the far-reaching import of these statements, coming from mathematicians of such standing, that later, as occasion offered, I followed up the matter with concrete tests, framing specific cases made as favorable as possible for demonstration, made indeed more favorable than any actual case realized in geodetic practice. But in all cases where these were submitted to Moulton or MacMillan, they affirmed unhesitatingly that other solutions than the one purposely made the basis of the case could be offered that would satisfy the data of the case equally well in a mathematical sense. MacMillan added that, if, in my constructive cases, I were to make further observations and add new data, these new data would probably knock out some or all the solutions previously offered except the true one, which of course would still stand, but that it would be possible for the mathematician to present new solutions that would fit the new data as well as the old. And this might be repeated until a moral conviction would be established that the one solution that held good through all additions of data was the true one, but such moral conviction would be as near to a strictly mathematical proof as it would be possible to attain.

Some time after this memorable discussion, on due deliberation it seemed best to give to a wider audience the benefit of MacMillan's studies on the mathematical aspects of the isostatic inquiry, and so a summary was published in the Journal of Geology.[6] There was no thought that it had any special bearing on any particular discussion of isostasy, except that of course it related to the fundamental work of Hayford, and was a tribute to its monumental character. My thought was that MacMillan's studies were a contribution to sound methods and wholesome interpretations rather than an adverse criticism of the work which any of the great students of the subject had done. In the main his discriminations related to necessary and altogether unavoidable limitations, a knowledge of which it is wholesome for everyone to possess. I still think they are wholesome, and I recommend that they be re-read and kept in mind.

For myself, I believe the subject of isostasy has an importance to geology that none of us have yet come adequately to realize; but isostasy can only come into its place of real importance—which of course is precisely its true place—through critical scrutiny of every aspect of the subject and by circumspection in basing interpretations on it. The more appreciative and friendly our attitude, the more searching the scrutiny of its processes may well be made, and the more circumspect the interpretations based on the results.

I have recited this little history as the best way of dismissing the impression which Dr. Barrell seems unfortunately to have entertained, that MacMillan's paper sprang from hasty consideration, or shallow work, or was given to print as a disturbing challenge of the work of any of those who were diligently studying the problem from their own points of view.

I may perhaps be permitted to add here that at the

[6] Jour. of Geol., Feb.-Mar., pp. 105-111, 1917.

conference named, I briefly expressed my personal view that isostasy is accomplished by segmental action in the form of wedging, rotation, sliding and like adjustments, including internal deformations, consistent with a solid earth, rather than by undertow and similar methods suitable to a crust floating on a mobile substratum. This view of mine stands quite apart from that commonly entertained and will require much study in concrete detail before it can become a deployed working hypothesis. Still the very suggestion that such a mode of isostatic adjustment is possible, helps to loosen the restraint laid on inquiry by the assumption that there is only one method of such adjustment. It should help to give inquiry a wholesome freedom.

Note by Charles Schuchert.

As Professor Barrell's literary legatee, it is my duty to say, in connection with this discussion, that in Professor MacMillan's original article there was not the slightest hint as to the long preparation behind the paper, now made so clear by Professor Chamberlin. On the other hand, it was MacMillan's first paper on isostasy—in fact, the title is "On the Hypothesis of Isostasy," whereas it is in reality on the use of mathematics in isostasy. It should be borne in mind that Barrell was looking upon isostasy from the geological side, and that to him mathematics was but a help in explaining certain features of the hypothesis. I doubt very much if he could have taken MacMillan's view of 1917, now made clearer, that is, that "from a purely mathematical point of view, any set of a finite number of observations of the intensity and direction of gravity can be satisfied, not approximately, but exactly, in infinitely many ways by a proper distribution of density in the earth." Barrell undoubtedly believed that isostasy is primarily a geodetic and geologic hypothesis and that it could not be looked upon "from a purely mathematical point of view." His viewpoint was that of the geologist, and, therefore, very different from that of MacMillan. On the other hand, if he had known all that Professor Chamberlin now states of that "memorable discussion," and that in the MacMillan article "there was no thought that it had any special bearing on any particular discussion of isostasy," and the further fact that Chamberlin does not believe in a deep-seated zone of special isostatic compensation, undoubtedly Barrell would have treated MacMillan's paper very differently. I still feel, however, that even in that event he would have taken issue with Chamberlin. The crux of the whole affair is that there have come to be two explanations of isostasy, one (the newer one of Chamberlin) regarding it as brought about "by segmental action in the form of wedging, rotation, sliding and like adjustments, including internal deformations, consistent with a solid earth"; the other (of geologists in general and Barrell) holding it to be effected "by undertow and similar methods suitable to a crust floating on a mobile substratum."

The Mathematics of Isostasy. II; by William D. MacMillan.

My attention has been called to a severe attack in this Journal for last October by the late Professor Barrell on my paper on Isostasy which was printed in volume 25 of the Journal of Geology.[1] A somewhat lengthy absence from the city and from my usual duties has delayed my reply.

A careful reading of Barrell's paper seems to reveal a feeling of irritation which I am sure grew out of a misinterpretation of the real purpose and nature of my paper. To set the matter right, the first step is to discover just where the error of interpretation entered and what its correction requires.

As a first point, it is to be noted that my paper was written by a mathematician for geologists, but there was no misunderstanding about this, for Dr. Barrell himself recognizes it on page 314. This fact is to be kept in mind.

The key to Barrell's misreading of my paper may be found, I think, in his opening statement respecting it (p. 316). In this he says: "Its attitude is that of skepticism toward any specific form of isostatic theory and of destructive criticism toward the one employed by Hayford."[2] The real attitude of the paper can be judged from the quotations that follow:

My own opening statement is this:

> The splendid papers by Hayford and jointly by Hayford and Bowie have brought the subject of isostasy into the foreground for discussion by geologists and others who may be interested. These papers have taken the subject out of a field of more or less vague conjecture, and by subjecting it to a very careful quantitative examination have shown very clearly that isostasy in some form can be accepted as a reality (p. 105).

[1] Jour. Geol., vol. 25, Feb.-Mar., p. 105, 1917.
[2] This Journal, 48, p. 316, Oct., 1919.

After some details I say:

This is a very notable reduction and it places the hypothesis of isostasy on a solid foundation of credibility (p. 106).

And a little farther on I say:

Hayford's success, which must be considered a notable one, consists in showing, by very complete computations which extend over a large mass of data, that assumptions of very moderate differences of density are sufficient to bring the observations and theory into fairly close accord. Whether or not any other hypothesis will or can be equally successful must of course be left for the future. Until some such hypothesis makes its appearance we are fairly entitled to put our faith in the broader outlines of isostasy and leave it to further observations and discussions to make the details of the theory more precise (p. 106).

It is certainly hard to find anything offensively skeptical or destructive in this. The key to the trouble, I think, lies in the paragraphs that follow:

To be sure, they have not *proved* the reality of isostasy, for in the mathematical sense no physical hypothesis can be proven. But they have formulated precise hypotheses of isostasy and have shown that a vast mass of observational data covering the United States is very much better satisfied by theories which include their hypotheses than by the usual gravitational theory which excludes the hypothesis of isostasy (p. 105).

From a purely mathematical point of view, any set of a finite number of observations of the intensity and direction of gravity can be satisfied, not approximately, but exactly, in infinitely many ways by a proper distribution of density in the earth. The virtue of the theory of isostasy, therefore, lies, not in the mere fact that the observations are more nearly satisfied by the theory than without it, but in the fact that a definite principle is laid down for the variations of density, and that this principle brings theory and observations into a satisfactory accord. As Hayford's four distinct hypotheses show, any smoothly uniform hypothesis of isostasy can be regarded only as a first approximation to the actual situation, and Hayford has been successful in showing that any one of these four hypotheses is a good first approximation (p. 111).

And in my final paragraph:

While the theory of isostasy has made a very successful approach to the solution of the problem of bringing the anomalies of observation into accord with the theory of gravity, it must be admitted that there is no evidence to show that the solution of the problem is necessarily isostatic (p. 111).

I think the discriminating reader will see that there is nothing whatever in these passages that is either objectionably skeptical or destructive respecting the *truth* of isostasy. They do involve, however, not merely skepticism but a firm conviction that the isostasy is not mathematically proved. My offense then is that, as a mathematician, speaking to geologists I have affirmed that certain things were *not mathematically proved,* not that they are not true.

Now the main purpose of my paper was to point out just what mathematics had done or could do in the isostatic inquiry and just what it could not do. I very naturally assumed that such a discrimination would be welcomed by all students of the subject controlled by the scientific spirit, as I understand this to be precisely what the scientific spirit demands. I did not dream that it would be offensive to any scientific student. I supposed it to be a prerequisite of safe procedure to employ mathematics just so far as it really may be employed and to be very careful to distinguish clearly those conclusions which the mathematics warrant and those conclusions which they do not warrant. It is in this latter respect, mainly, that a mathematician can be of service.

Now mathematics has wonderful resources in setting forth the relations of things. When it is employed in a physical field this extraordinary power is naturally matched by a complete inability to discriminate, so far as objective reality is concerned, between the many possible solutions which satisfy the given data. From a mathematical point of view they are all true, so that it is necessary to go outside of its field to find a basis of discrimination.

Now these wonderful capacities of mathematics set over against its necessary limitations are matters of common knowledge among mathematicians. It did not seem to me more than necessary to state that particular phase of them that related to the subject in hand. Dr. Barrell, however, thinks I should have been more specific and demonstrative. To show that the geodetic observations can be satisfied mathematically by a non-isostatic solution as well as an isostatic solution, let us suppose that there are n geodetic observations. At each observation three things are determined, two deflections and one intensity. In n observations there are, therefore, $3n$ quantities determined. In order to satisfy these n observations it is sufficient to pick out $3n$ points in the interior of the earth and at these points place masses of the proper numerical value. The equations which determine these numerical values are linear, and the only condition upon them is that the determinant be not zero, which is a very mild condition since its value depends only upon the three n points which were chosen. Negative masses will mean deficiency of density and positive masses will mean excess of density. By this means the n observations can be satisfied exactly. The solution is non-isostatic. Without doubt it may also be non-geologic. It has no virtue that I can see except to show that non-isostatic solutions are conceivable.

A telling illustration of the capacity of mathematics to develop or to deal with relations of almost any sort is to be found in the reduction of geodetic observations to a datum surface, on which I made some suggestions, and to the criticism of which Dr. Barrell devotes six pages. The issues he discusses, however, are not just those that I raised or at least supposed I had raised. The matter is really quite simple. There is an ideal geoid that was often pictured by teachers of the old geological school, and easily retained by those of us who forgot most of what little else we learned about geology, namely, the form they said was taken by the earth in its primitive molten state, a perfectly symmetrical spheroid, each layer homogeneous, the whole covered by an ocean of uniform depth. This was really an ideal picture of isostasy. We were taught that all later deformations took their departures from this. Now I did not intrude this familiar old picture on the readers of my paper. As a mathematician I had no right to. Besides, it might be out of date. I did, however, specify the mechanical qualities of just such a body as forming the true base of reference in the interpretation of isostatic data. I did not mention the fact that Dr. Barrell had used the same base. For this I am sorry, not because it was obligatory as a matter of priority, but because he seems to have been aggrieved by my neglect to do so. I do not think, however, that there was anything new in recognizing this as the ideal base, except our own special ways of discussing it. If there was anything in common between us, *that* much at least ought to be right and I don't see why I should have been brought to bar for it. At any rate we were anticipated in the basal idea.[3]

[3] Jour. Geol., vol. 21, p. 528; also pp. 578-580, 1913.

Now the resources of mathematics are such that geodetic observations can be reduced in perfect mathematical consistency to any other datum surface than this ideal one, either above it at any selected horizon up to the top of the highest mountain or beyond, or below it down to the deepest "deep" of the ocean or beyond. My suggestions did not relate to the consistency or correctness of such reduction but to the use of such reductions in deriving results that involved natural factors. If the value derived from reduction to artificial datum surfaces are used as though they represent natural values actually involved in isostatic readjustments, they are liable to lead to error. This I endeavored to illustrate concretely. There ought to be no difficulty in distinguishing between the legitimacy of using a convenient base like the sea-level in reducing observations in a strictly consistent way, and the danger of using the numerical results of such reduction in applications that have natural relations to the true base of isostatic adjustment in the earth. It should be obvious on the mere statement that the reduction of observations to the horizon that would become a real surface, if perfect isostasy were attained, is safest and best.

Dr. Barrell devotes seven pages to my statement that the geodetic data are insufficient to demonstrate mathematically the depth of compensation. This was not elaborately discussed in my paper and I do not think it needs elaborate discussion here after what has already been said about the capabilities and the limitations of mathematics. The *truth* about the depth of compensation was not under discussion but *the mathematical proof or lack of proof*. The very fact that Hayford, after having used four hypotheses by way of trial, and having found results running 37, 76, 109, and 178 miles respectively, explicitly declared that the data were insufficient to decide which of these was the true depth, is sufficient evidence that nothing like a conclusive depth of compensation has yet been reached, even with mathematics supplemented by other resources. It is idle to hope that mathematical manipulation of geodetic observations alone can ever *demonstrate* such depth. It may greatly aid in bringing out the full meaning of data and in the precise application of interpretations and hypotheses. It may thus give a force not otherwise attained to those concrete physical or natural criteria to which appeal must be made to distinguish the solution that actually applies to the real case from the solutions that merely fit the terms of the data mathematically.

I pass by many minor points of criticism because they are of little moment in themselves and I desire to limit my reply to such fundamental matters as are too vital to the wholesome progress of science to be passed in silence, much as I regret the necessity of any reply at all. In my judgment there are few things more prejudicial to the progress of science than the unwarranted assumption that a far-reaching doctrine is proved, while yet real proof is far from having been reached and may be quite unattainable in any strict sense. I think that an intelligent belief or even a favorable impression, entertained in full consciousness that demonstration is still lacking, is a better support for a doctrine than stronger claims on a less secure basis.

ART. XXIV.—*Notes on the Manzano Group, New Mexico;* by WILLIS T. LEE.[1]

These notes are in the nature of a review of two papers published recently in this Journal as follows: "Contributions to the Stratigraphy of Eastern New Mexico," by Charles Lawrence Baker (Feb., 1920, pp. 99-126), and, "On the Ammonoids from the Abo Sandstone of New Mexico and the Age of the Beds which contain them," by Dr. Emil Böse (Jan., 1920, pp. 51-60).

The two papers deal with the same questions, hence should be considered together. The contribution by Böse deals with the validity of the previously accepted grouping of the formations and with the establishment of the Pennsylvanian-Permian boundary in New Mexico; that by Baker deals with these and several other problems of interest to those concerned with the stratigraphy of this state.

Many geologists have been working in New Mexico in recent years and, although much of the available information is not yet published, several short papers have appeared bearing on one or another of the problems.

[1] Published by permission of the Director of the United States Geological Survey.

As none of these are mentioned in either of the papers reviewed it would be difficult for one not familiar with the formations described to compare the results of the several observers. As there are many who will desire to use all the results obtainable in this interesting region it seems desirable to call attention to observations made by other men on the formations described in the papers reviewed. Baker's paper touches several unsettled questions but I shall review only those which I am personally somewhat familiar with. These are: The Pennsylvanian-Permian boundary; the age of the Manzano group; the nature of the Upper Triassic deposits and the correlation of Shinarump conglomerate with the Glorieta sandstone of Baker; the Triassic-Jurassic boundary; and, the age of certain sedimentary rocks which are described by Baker as Upper Triassic.

These papers emphasize the separation of the Manzano group from the underlying rocks by an unconformity, the significance of which has been steadily increasing since it was first described in 1909.[2] During the years immediately following this description the unconformity was observed in many places and came soon to be generally regarded as an unconformity of wide extent, which appropriately marks the separation of the Pennsylvanian from the Permian series.[3] But in the press of other matters the details were not published.

Baker refers to the pre-Abo disturbance as causing "gentle folding in the regions of all present mountain uplifts" but states that east of the front range near Mora the Abo formation contains "several thousand feet of arkoses." It was this movement that produced the highlands which I have called the Ancestral Rocky Mountains[4] and which furnished not only the thousands of feet of arkoses observed near Mora but the coarse red conglomerates of Permian and perhaps in part of Triassic age many thousands of feet thick in northern New Mexico and southern Colorado.[5] No close correlation of

[2] Lee, Willis T., and Girty, George H.: The Manzano group of the Rio Grand Valley, New Mexico, U. S. Geol. Survey, Bull. 389, 1909.

[3] Lee, Willis T.: General stratigraphic break between Pennsylvanian and Permian in western America, Bull. Geol. Soc. America, vol. 28, pp. 169-170, 1917.

[4] Lee, Willis T.: Early Mesozoic physiography of the southern Rocky Mountains, Smithsonian Misc. Collection, vol. 69, No. 4, 1918.

[5] Lee, Willis T., and Knowlton, F. H.: Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico, U. S. Geol. Survey, Prof. Paper 101, p. 41, 1917.

these conglomerates with those farther south has been made but the occurrence of fossiliferous marine limestone of Pennsylvanian age in the vicinity of these thick conglomerates of post-Pennsylvanian age implies that the uplift raised mountains out of the Pennsylvanian sea which were comparable in bulk to the present Rocky Mountains.

Closely connected with the significance of the unconformity is the second question, viz., the age of the Manzano group. As early as 1909 when the group was named it was pointed out (p. 33 of the Manzano Bulletin) that certain fossil plants, from beds now known to be Manzano, suggested Permian or Triassic age. However, the invertebrate evidence as interpreted at that time seemed in favor of the Pennsylvanian age of the group. Soon after this original publication by Lee and Girty the growing evidence, both from plants and invertebrates, was such that the Permian age of the Manzano group was generally accepted and this attitude was reflected in the abstract by Lee just referred to. Nothing, however, came forward to bring the question to a definite decision on the Geological Survey until July, 1919, when N. H. Darton's reference of the Manzano group to the Permian was approved for a comprehensive paper on the geology of New Mexico now in a final stage of preparation.

In this connection it may be mentioned that the opinion that this unconformity "appropriately constitutes the division between Pennsylvanian and Permian time" finds sanction on the U. S. Geological Survey, whereas Böse concludes that the ammonoides found at Tularosa, New Mexico, 200 feet above the base of the Abo, the basal formation of the Manzano group, throw this formation into the Pennsylvanian series. If this relationship were established a major unconformity would be included within the Pennsylvanian series and the Pennsylvanian-Permian boundary would fall at some undetermined horizon within a group of conformable strata. This raises a serious problem in classification which is too involved to be discussed here.

The illuminating observations relative to the Triassic sedimentaries are of great interest. The sandstone, which caps Glorieta Mesa and is widely distributed farther to the south and east, is correlated by Baker with the Shinarump conglomerate, a formation now known to extend from western New Mexico to Wyoming. Those interested in this subject must regret that details upon which proof must rest are wanting.

Of even greater consequence is the author's treatment of beds which, although admitting that they "may not be Triassic" he describes as the upper member of the Upper Triassic. He describes two of these beds in such a manner that they are plainly recognizable. They are the "conspicuous bed of white much cross-bedded sandstone which was traced from the southern Sangre de Cristo Mountains eastward to beyond Tucumcari," and "a bed of gypsum about 50 feet in thickness, underlain by thin dark brown flaggy and very bituminous limestone." Without doubt the cross-bedded sandstone is the Wingate, which has been correlated[6] with lower La Plata and Vermilion Cliff to the west and with Exeter to the east, and which is now classed as Jurassic.[7] These and the gypsum beds have been described at some length in the Smithsonian publication just referred to where the gypsum is explained as a deposit from the interior sea of Upper Jurassic time. This brief note is not the place for extended discussion as to whether the beds of gypsum are of Triassic or Jurassic age, but it is appropriate to raise the question whether the author is justified in including a gypsum formation of the thickness, character and extent of those mentioned, in beds which he describes as "entirely of terrestrial origin, in the main river and stream deposits." It is equally appropriate to call attention to the fact that reasons have been presented for connecting the beds of gypsum with the Jurassic marine invasion. If the gypsum was derived from sea water it can not be included in rocks of non-marine origin.

[6] Lee, Willis T.: Early Mesozoic physiography of the southern Rocky Mountains, Smithsonian Misc. Collection, vol. 69, pp. 1-41, figs. 5 and 6, 1918.

[7] Emery, Wilson B.: The Green River desert section, Utah, this Journal, (4), vol. 46, pp. 551-577, 1918.

Art. XXV.—*The Piedmont Terraces of the Northern Appalachians;* by Joseph Barrell.

Edited by H. H. Robinson.

[Continued from p. 258]

Indications from the Coastal Plain of Many Baselevels.

The view that there are frequent oscillations of the earth's crust rather than age-long stability is based on several lines of evidence developed in recent years. The numerous baselevels of the western upland of Connecticut, of the Piedmont Plateau, and the Coastal Plain constitute one line of this evidence.

The shore-line at any time may be taken as the axis of no elevation. It separates the region of erosion from that of deposition. During emergence the shore-line migrates seaward and the deposits on the landward side suffer erosion. During submergence it migrates landward and new sediments are laid down on an erosion surface. An unconformity results. Over the continuously submerged portion no unconformity separates the two formations, but the change in the depth of water and in the kind and quantity of sediment furnish evidence of crustal movement.

In general, unconformities, changes in slope, and changes in formation in a marine series correspond to a migration of the shore-line and a change of baselevel over the adjacent regions of erosion. It should be noted, however, that changes in the nature of the sediments may not furnish decisive evidence, for they may be due to other causes such as climate or bottom scour.

In the development of the Coastal Plain the pre-Comanche surface has been warped on an axis parallel to the landward margin. The region of the Coastal Plain has gone down, the Piedmont Plateau and mountains beyond have gone up. The thickness of the Coastal Plain deposits increases southeastward from the margin of the plateau, whereas the elevation of the plateau increases toward the northwest. But the motion of tilting which has gone forward since the Jurassic has been highly variable although never reversed. Each younger formation of the Coastal Plain has a lesser slope than the preceding formation. Most of the warping was accomplished in the Comanche period. The base of the oldest Comanche formation at Washington has the relatively steep slope of 115 feet per mile; at Baltimore the slope is 94 feet per mile. The base of the Cretaceous has a much flatter slope at both places, namely, 33 feet per mile.

Recent study of the Coastal Plain formations has revealed what to older geologists would have seemed a surprising number of unconformities. In the Patuxent quadrangle just west of Washington, for instance, thirteen unconformities have been detected between the crystalline rocks of pre-Comanche age and the present surface.[15] In fact, there are only two surfaces between formations that are not mapped as unconformities. Some of these unconformities represent very long periods of time, as shown by marked change in tilt between formations, the great volume of formations, and marked change in character of sediments; most important, however, by marked changes in faunas. Some of the time intervals are represented in other parts of the Coastal Plain by formations which are absent here, but even these additions do not begin to make a complete record. In the opinion of the writer much less than half of post-Jurassic time is represented by actual sediments in the Patuxent quadrangle. An especially long interval at the close of the Cretaceous appears to be unrepresented, the entire Oligocene is missing, and there is another long gap between the Miocene and the late Pliocene formations.

Each of these unconformities marks a change of baselevel that must have affected the Piedmont Plateau as well as the Coastal Plain. Some of the erosion intervals were so prolonged that the Plateau must have become peneplaned with respect to the new baselevel. In view of this evidence in the Coastal Plain of intermittent tilting and uplift of the Piedmont and Appalachian region, how can the post-Jurassic erosion history of that region be interpreted in terms of one Jurassic, one Cretaceous, one early Tertiary, and one late Tertiary baselevel? Even if four dominant baselevels have been determined, the ages assigned to them are, in the nature of things, hardly more than mere guesses.

[15] Columnar section, Patuxent folio, U. S. G. S. 1907.

GENERAL INDICATIONS OF WIDE OSCILLATIONS OF THE STRAND-LINE.

The views respecting oscillations of the strand-lines, entertained by leading geologists up to the close of the nineteenth century, are expressed in Dana's Manual of Geology of which the first edition was published in 1863, the fourth and thoroughly revised edition in 1895. And various other text books in this country express the same ideas. From these volumes it is learned that at the opening of the Paleozoic era a sea covered the greater part of North America, the principal land area being a large V-shaped mass surrounding Hudson Bay. During the Paleozoic successive belts of land were added, representing roughly the present outcrops of rocks of the successive periods. The Paleozoic interior sea was thus regarded as continuously in existence, but as periodically diminishing in area. Occasional marginal expansions were granted on the evidence of younger strata overlapping beyond immediately older strata, but such expansions were regarded as minor features not affecting the general progress of continental growth.

On the Atlantic border the Coastal Plain deposits begin with the Potomac group of the Comanchian period, fresh water in origin and regarded as deposited in estuaries. The shore-line was drawn as following the present landward boundary of the Potomac. With the opening of the Upper Cretaceous the sea advanced inland but the shore-line is not shown as extending beyond the previous limit fixed by the Potomac. This marked the maximum submergence. During the Tertiary a progressive emergence of the Atlantic Coastal Plain was held to have taken place, the parts under water being limited by the present outcrops.[16]

During the fifteen years following the last edition of Dana's Manual the general progress of geologic thought may be measured by the "Outlines of Geologic History with special reference to North America," a volume written by many contributors and presenting a series of paleogeographic maps constructed by Willis. In this volume the character of the interior Paleozoic sea shows a marked change. Wide advances and retreats are shown. Large areas are indicated as doubtfully land or sea. Grabau, writing on Ordovic, Siluric, and early

[16] J. D. Dana, Manual of Geology, 1895, pp. 813 and 881.

Devonic times, shows especially a complete revolution of ideas based on the recognition of many unconformities and disconformities. On the maps by Willis, however, the transgressions of the sea are still limited to their present outcrops.

For the upper Mesozoic and Tertiary of the Atlantic Coastal Plain the shore-lines are restricted to the landward limits of the present outcrops. In fact, the Potomac deposits are not represented at all; the area of their occurrence is covered by the general symbol indicating "Land or sea, more likely land."

In the same year that the foregoing volume appeared (1910) Schuchert published his important paper on "The Paleogeography of North America," dealing with the subject of the former distributions of land and sea much more critically than had any previous writer. From lower Cambrian to Pliocene, inclusive, fifty-seven maps are given for successive periods. As former maps had fallen into error by showing the epeiric seas much more continuous and broad than the evidence really warranted, Schuchert considered the seas as extending only so far as the evidence warranted, recognizing that future detailed study would extend many of the transgressions beyond the limits given by him. His maps are most notable for bringing out the recurrent emergencies of the continent and draining of the shallow seas. They express a far-reaching idea which was not existent in American geology twenty years before. Time and time again the seas expanded many hundreds of miles across the interior of the continent and again withdrew.

On the maps, however, the seas are shown as not extending many miles beyond present outcrops except where faunal resemblances necessitated oceanic connections across areas where the former deposits had been later buried or eroded. This limitation, as noted, was due in part to the adoption of the definite and scientific procedure of requiring proof, but in greater part it marked the general persistence among paleontologists of an idea which physiographers had shown to be unfounded. This was the idea that rock formations were able to maintain themselves as land through all geologic time notwithstanding the effects of subaerial denudation. Thus the Adirondacks were spoken of as the relics of Archean mountains and the Cambrian strata about them were regarded as forming land, an emerged ancient coastal plain, since the close of the Cambrian.

At the present time it is well recognized that even in a single geologic period subaerial denudation will go far toward baseleveling a land mass, that superficial deposits may be removed no matter how wide their extent, and that a slight submergence may cause a wide advance of the sea. There is no reason, therefore, for restricting shore-lines to the limits of outcrops as has previously been done. The position of the shore for every period is a problem open to special investigation and to be decided by a variety of evidence.

Suess had early called attention to the feature of positive and negative movements of the strand-line, but the earliest expression of these views in American geology appears to have been by Gilbert. Over twenty years ago he gave a presidential address before the Geological Society of America on "Continental problems." Under the topic *Do continents grow?*[17] he ventured to doubt if the lands had progressively extended through geologic time. He said that possibly there should be no dissent, but the evidence on which the doctrine was founded appeared to him so far from conclusive that he ventured to doubt. He then called attention to the fact that the farthest transgressions of the sea must have left thin overlapping deposits which were subject to erosion through later time and that the progress of denudation was chiefly dependent upon elevation above baselevel. On the other hand, unconformities are difficult to detect and impossible to follow seaward under overlying formations. It was pointed out that as a consequence we are unaware of the maximum limits of the oscillations of land and sea in both directions and consequently inclined to ignore their existence. His remarks were in the nature of keen philosophical analysis, but as they were not strongly backed by his own convictions nor by illustrative demonstrations, they did not impress geologists as much as their vital importance warranted. The rapid change of view during the opening decade of the twentieth century was in reality due to the intensive study of faunal horizons in the field and laboratory, a method largely due to H. S. Williams, and to the recognition of

[17] Bull. Geol. Soc. Am., vol. 4, pp. 187-190, 1893.

the great importance of disconformities, for which much credit should be given to Ulrich, Schuchert, and Grabau.

The first suggestion of a notable extension of the shore-line northwest of the present limits of the Atlantic Coastal Plain came, strangely enough, not from a stratigrapher who might be logically credited with a desire to extend the former domain of Neptune, but from a physiographer, and one who has urged the inadequacy of marine denudation to produce extensive baseleveled surfaces.

In 1890, W. M. Davis published his paper on "The rivers of northern New Jersey, with notes on the classification of rivers in general."[18] In this he discussed the significance of revived and superposed rivers. In brief, the drainage of northern New Jersey is superposed across the Watchung trap ridges of the Triassic area and across the margin of the adjacent lobe of the Archean Highlands. The latter preserve on their flat summits remnants of the Schooley peneplain. Davis argued that the superposed drainage showed that the Cretaceous cover once overlapped the Triassic area, the shore-line resting on the margin of the crystalline rocks, and the subaerially baseleveled land surface extending beyond. This involved an extension of the Cretaceous cover only about twenty miles beyond the present outcrop of strata, but it was based on definite evidence, that of drainage, and was farther than any stratigrapher had ever suggested extending the Cretaceous sea in this region. In a later paper[19] Davis suggested the existence of a former Coastal Plain cover in Connecticut extending inland twenty miles from Long Island Sound, his reasoning being similar to that applied to the problem in New Jersey, and Schuchert has adopted these limits as fixing the shore of the maximum mid-Cretacic marine invasion.

At the present time, then, the accumulated evidence clearly shows that there have been many wide transgressions and regressions of the sea over the land throughout geologic time. An oscillating strand-line, rather than a progressively retreating one, represents the closest approximation to actual conditions. It is clear, also, that many of the transgressions extended much

[18] Nat. Geogr. Mag., vol. 2, pp. 81-110, 1890.

[19] The Triassic Formation of Connecticut, U. S. G. S., 18th Ann. Rept., vol. 2, 1896-97, p. 162.

farther than is indicated by the present outcrops of formations. How far they may have extended can not be said because erosion has removed the plainest and most commonly accepted evidence, namely, the deposited sediments. When this situation exists the problem of determining the position of a former shore-line becomes a physiographic one. For a proper solution it is necessary to recognize that the sea is as competent as subaerial agencies to produce extensive peneplanes, that marine denudation, like fluvial denudation, has its characteristic features, and that some of these features may endure for long periods even though the peneplaned surface be modified by later subaerial erosion.

Fluvial peneplanes.

Editorial Note.

It should be understood that the following three sections, namely, "Re-examination of the Harrisburg peneplain," "Significance of present valley forms," and "Evidence of baselevels given by wind gaps" are based in part on map study and although Professor Barrell was well acquainted with region, he had planned to further test his conclusions in the field. The results as they stand, therefore, should be considered tentative in character; they illustrate the complexity introduced into the problem by many rather than few baselevels of erosion.

Re-examination of the Harrisburg Peneplain.

In a study of the later Appalachian history, as revealed by the land forms, a re-examination of previous work should be made beginning with the basal postulates. The criteria for tracing a warped and elevated erosion surface must be reviewed and ultimately those for distinguishing fluvial and marine peneplanes must be taken up. In this section a fluvial peneplane will be examined and in doing this the methods employed will be made clear.

It has been seen that Davis in 1889 recognized the presence of an old baseleveled surface, represented by uplands, which he named the Schooley peneplain and a younger one, represented by broad valley lowlands, which he called the Somerville. In 1903 Campbell presented evidence of an intermediate erosion surface which he named the Harrisburg peneplain.[20] In the vicinity of Harrisburg, where this peneplain is well developed and preserved on the upper Ordovician slates, it has an elevation slightly over 500 feet. Farther up the Susquehanna valley in the vicinity of Sunbury, Campbell considered that the Harrisburg peneplain had an elevation of 800 feet, near Pittston of 1,200 to 1,300 feet, and in northwestern Pennsylvania of about 2,200 feet. His conclusions as to the warping of the peneplain rested on the fact that everywhere he was able to recognize at least two erosion surfaces. The upper and more complete of these he correlated with the Schooley peneplain of ''Jura-Cretaceous'' age; the second was regarded as the Harrisburg, formed in early Tertiary. In addition, the Somerville was recognized as developed only on the softest rocks. The recognition by Campbell of three baselevels in Pennsylvania represented an advance in the physiographic interpretation of this part of the Appalachians similar to that by Keith south of the Potomac.

To show a well developed and well preserved peneplain the nature of the rock formations must be closely adjusted to the time elapsing during peneplanation and that elapsing after uplift of the peneplaned surface. Thus the remarkable meanders of Conedoguinet Creek lie partly in limestone and partly in slate which indicates that when they were assumed the surface must have been a very perfect plain. In fact, the breadth of the meanders suggests that some aggradation had taken place at the junction of the creek with the Susquehanna. At the present time the slate outcrop has many hills rising to 520-540 feet, whereas the limestone has relatively few and in general is eroded to a distinctly lower level than the slate. On the other hand, the resistant quartzite of the Kittatinny ridge was not notably eroded during the Harrisburg cycle nor later except by undermining through the removal of the slate at its base. The Newark shales, sandstones, and traps, which cover most of the New Cumberland quadrangle and lie immediately south of the limestone area, must have been peneplaned in large part during the Harrisburg cycle, but considerable areas of sandstone and trap still rise above 600 feet and other large portions have been reduced to below 520

[20] M. R. Campbell. Geographic development of northern Pennsylvania and southern New York. Bull. Geol. Soc. Am., vol. 14, 277-296, 1903.

feet. The result of these inequalities of resistance shown by the Newark formations is that the Harrisburg peneplain, although rather broadly developed over the Triassic on the Susquehanna, is not so clearly evident as it is on the more uniformly resistant Ordovician slate. If rock formations were all equally resistant the problem of tracing peneplains, which are now in an eroded condition, would be greatly simplified. In nature, however, rock formations differ much in their resistance to erosion and generally the same formation will differ from place to place, consequently it is of first importance to evaluate these differences and allow for them in tracing a peneplain, or series of peneplains, from one region to another.

With this idea in mind the Harrisburg peneplain may be examined more carefully. The Mauch Chunk shale outcrops north of Cove Mountain (Harrisburg and New Bloomfield quadrangles) and shows the Harrisburg surface at about 520 feet as well as does the Martinsburg shale south of Blue Mountain. The same formation outcrops farther up the river in the vicinity of Millersburg where it is seen to have been smoothly peneplaned with respect to a baselevel at the Susquehanna of about 540 feet. Between these two localities Devonian shales and sandstones outcrop. They are more resistant than the Mauch Chunk and evidently were not baseleveled in the Harrisburg cycle, as lines of hills rise from 650 to 730 feet even near the river. The surface at this locality was reduced, perhaps, to a mature form during that cycle and the valleys since cut in the Devonian formations are still in a state of youth even near such a large river as the Susquehanna. The Devonian strata outcrop again farther north (northwestern part of Millersburg and central parts of the Millerstown and Sunbury quadrangles) where the country is hilly and shows no trace of the valley flats belonging to the Harrisburg baselevel. The accordance of flat hilltops at a level of 800 to 860 feet suggests that this region of Devonian formations was peneplaned in an earlier cycle than the Harrisburg with respect to a river level of about 750 feet. This peneplain was then dissected during the Harrisburg cycle but not so extensively as to prevent its recognition at the present day.

In the southern part of the Sunbury quadrangle the

Clinton shales outcrop west of Selinsgrove and show a very thorough leveling at 600 to 630 feet. The relation of this level to that of the localities of Devonian outcrops is the same as for the Mauch Chunk shale. This surface therefore represents the Harrisburg peneplain. Farther northwest the Clinton shales again outcrop and show broad hilltops at 620 to 640 feet which are the last clear expression of the Harrisburg peneplain, although it may be present on the North Fork of the Susquehanna at an elevation of about 700 feet (Bloomsburg quadrangle). Throughout a straight-line distance of about sixty miles from Harrisburg to Sunbury the Harrisburg peneplain maintains itself 200 feet above the present river level, rising two feet per mile. A part of this grade may be assigned to warping as the Susquehanna presumably has a considerably steeper grade now than it had when the Harrisburg peneplain marked its level.

Campbell correlated the Harrisburg with a baselevel in the vicinity of Sunbury at about 800 feet embracing the localities where the Devonian formations outcrop. The writer has come to the conclusion, however, that the plane at this level is not equivalent to the Harrisburg and he has called it, therefore, the Sunbury peneplain. This newly recognized peneplain is not an entirely satisfactory surface to trace because the valley flats have been destroyed and it is possible that its surface has been lowered by later erosion. It is not impossible that it may have been as much as 100 feet higher than the elevation assigned to it and thus more widely separated from the Harrisburg peneplain.

The following tabulation gives in descending order the elevations of the Susquehanna and North Branch which appear to account best for the remnants of an upland—the Sunbury peneplain—above the gentle slopes developed in the later Harrisburg cycle.

Estimated elevations of the Sunbury baselevel on the Susquehanna and North Branch, and present river levels.

			Sunbury.	Present.
Pittston	quadrangle,	about	1,200	560
Shickshinny	"	"	1,000	500
Shamokin	"	"	900	450
Sunbury	"	"	850	425
Millersburg	"	"	750	400
Harrisburg	"	"	650	340

The Susquehanna would reach a low grade after uplift more quickly, because of its size, than would a smaller stream, and consequently peneplains would be best developed along its course. On minor streams peneplains comparable with those along master streams would be developed only during periods of prolonged crustal rest and widespread planation. Other factors which must be taken into account, however, are the attitude of the rocks and the amount of uplift separating successive baselevels. Sedimentary rocks with steep dips offer less resistance to erosion than when horizontal so that a pronounced uplift leads to a deeper dissection and more rapid destruction of a peneplain developed on them. The Devonian strata in the Pittston quadrangle, for example, are nearly horizontal whereas in the Harrisburg quadrangle they are nearly vertical. The amount of uplift at Pittston was the greater but the river took appreciably longer after uplift to reach stable grade.

Let the Harrisburg peneplain now be followed northeast on the belt of slate from the Susquehanna to the Delaware. Near the Schuylkill Campbell assigned it a level of about 500 feet and on the Delaware 700 feet and he noted that near both streams monadnocks rise above the general level, as they do also in the intervening region.

To the writer there appears to be considerable doubt as to whether the significance of these monadnocks has been correctly interpreted. Near the Schuylkill the monadnocks are both higher and more numerous than near the Susquehanna. The slopes above the 500 foot level look like post-mature valley sides eroded with respect to a lower baselevel. In order that the surface might reach the degree of planation shown near Harrisburg an elevation of 550 to 600 feet would have to be taken and on the Lehigh and Delaware the corresponding elevation would be, respectively, 650 and 700 feet. In this connection it should be noted that although in general near the Susquehanna the Harrisburg (520-540 feet) is well marked, isolated hills rise to 640 feet four miles from the river and 350 feet above it (southwest corner of Harrisburg quadrangle). Near the Schuylkill hills rise to 740 feet one mile from the river and 500 feet above it; near the Lehigh 940 feet one to two miles from the river and 600 feet above it; near the Delaware 840 feet one-half mile from the river and 600 feet above it. These differences may be partly accounted for by assuming that uplift has been greater in the vicinity of the Delaware than near the Susquehanna thus permitting later erosion to more completely and deeply dissect the peneplain at the former locality. On the other hand, it is probable that the Harrisburg peneplain was never as well developed on the slate in the region between the Schuylkill and Delaware as it was in the vicinity of the Susquehanna.

Campbell ascribed large importance to the Harrisburg peneplain as indicating a stillstand of the land through the early part of Tertiary time. The difficulty in clearly identifying it in the region from the Schuylkill to the Delaware suggests that its importance has been exaggerated. Several equally important cycles of erosion may have elapsed between the level marked by the Kittatinny ridge and that of the Harrisburg peneplain as developed on the Ordovician slates near the Susquehanna.

Evidence of Baselevels given by Wind Gaps.

Kittatinny Ridge, or North Mountain, the outcrop of resistant Silurian quartzite, forms a prominent and persistent ridge extending from southern New York to Alabama, as already described. It is cut at intervals by what are obviously old stream valleys, many of which have long been recognized as such, whose floors are now high above the adjacent country. The significance of these as indicative of an originally superposed drainage across the ridge has been discussed in a preceding section. Similar gaps cross the Blue Ridge in Virginia and have been long regarded as indicators of river piracy. It seems that they may be used also as records of baselevels of which no other clear evidence remains. As wind gaps have not been used before in a comprehensive manner for this purpose, the argument should be amplified. It should be said that the term as here used is restricted to what are clearly ancient river valleys crossing a resistant formation through which no river now flows because of capture of the headwaters by a stream more favorably situated.

The most obvious thing about a wind gap is that it definitely fixes the position of a point on an ancient stream course. But in relation to baseleveling it is more important to recognize that the gap fixes relatively an old stream level and that the form of a gap may give valuable evidence as to the nature of at least one and perhaps several erosion cycles. The last point is further treated in the following section.

In this connection it is necessary to determine as closely as possible the elevation of the original bottom of the wind gaps. It is evident, on account of the age of the gaps, that the present bottom in most cases does not coincide with the original one. Glaciation may have filled in or scoured out a gap according to the direction of ice motion; creep from the sides tends to fill in the bottom. More important, however, brooks may flow both ways from a gap and notch it below the original level. These features do not show well on the topographic maps but usually can be evaluated on the ground. In general, south of the glacial limit the cols of the gaps appear to be not more than fifty feet below the level they possessed when occupied by streams.

As may be most readily determined from the topographic maps more than one system of gaps cuts through the Kittatinny ridge. The gaps of a higher system lying between 1,300 and 1,400 feet are relatively shallow, their cols reaching about 200 feet below the mountain crest. Most of these gaps are now so eroded that in themselves they do not furnish reliable evidence of a former superposed drainage. They acquire significance, however, from their general accordance with a baselevel otherwise determined, as described in the next section. The conspicuous system lies at elevations between 900 and 1,100 feet. In this group are included all the well-known gaps in New Jersey and Pennsylvania, such as Culver's and Pen Argyl.

In addition to the gaps on Kittatinny Ridge it should be noted that on minor ridges gaps of a still lower set are found. Two such wind gaps are found on Rattlesnake Ridge at an elevation of 750 feet (New Bloomfield quadrangle). These appear to mark the Sunbury baselevel. In general, for the lower baselevels, the gaps show a greater range of altitude and in nearly all cases represent minor stream adjustments due to strong uplift and rapid erosion.

The sides of the wind gaps when compared with the precipitous slopes of the present water gaps indicate the advanced maturity or old age of the streams which once flowed through the gaps. The cliffs of the Delaware Water Gap are well known. The Lehigh Gap below the level of the wind gaps shows two facets, an upper at about the angle of repose, a lower marked by a rock cliff. The Pen Argyl wind gap shows two facets, as illustrated with exaggerated vertical scale in fig. 9. The slope of the lower two-thirds of the gap is about 18 degrees, whereas for the upper one-third it is about 8 degrees. The upper and flatter slope does not appear to be a mere rounding off of the lower one, instead it belongs to the older and higher series of gaps and denotes a baselevel in an erosion cycle which reached a far more advanced stage than did the cycle marked by the lower slopes of

Fig. 9.

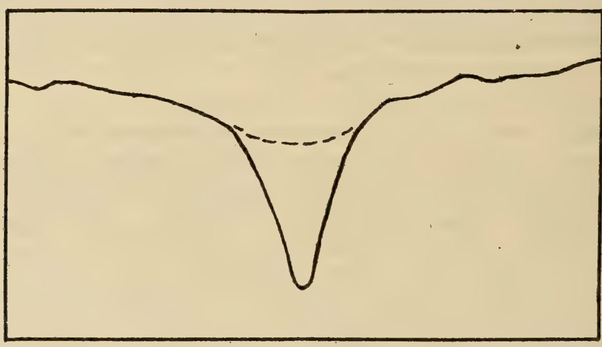


Fig. 9.—Pen Argyl Wind Gap showing composite slopes.

the gap. The restored elevation of this old baselevel, indicated by the dotted line in fig. 9, about 1,350 feet, which agrees with the upper set of wind gaps on the Kittatinny ridge and also with the baselevel of about 1,400 found farther north.

It is clear on comparing both the upper and lower slopes of the Pen Argyl gap with those of the gorges cut by the present through-flowing rivers that all moderately resistant formations must have been very thoroughly peneplaned during the cycles represented by those slopes. Especially in the older cycle even the massif of the Kittatinny ridge must have been reduced to a chain of hills whose slopes were not over ten degrees. All subsequent time has been so brief in comparison that the upper slopes belonging to this older cycle have been flattened but little further through weathering and creep.

It may be questioned why any of the stream adjustment was left to later cycles when the first cycle was so prolonged. The answer would appear to turn on the amount of uplift. The uplift which inaugurated the second cycle of erosion was greater than that of the first cycle and consequently a tributary did not have to develop so flat a grade before it could appropriate, at a given distance, the headwaters of a neighboring stream. The drainage became adjusted to structure early in the cycle, whereas in the first cycle, because of the smaller uplift, it most probably became adjusted late in the cycle. The wind gaps of the second cycle, as represented by the lower slopes of the Pen Argyl gap, are much less numerous than are those of the first cycle, although they are much clearer in origin.

There is seen to be evidence, therefore, of fluvial baselevels at about 400 feet (Somerville), 520 (Harrisburg), 750 (Sunbury), 940 (?),[21] 1,350 (Schooley?), and 1,600 feet (Kittatinny), the higher levels being only approximate. And most of these are present within a rather limited area in the vicinity of the Susquehanna water gap. The 750 (Sunbury) level is made more definite by the evidence from wind gaps. The 940 level is disclosed in the foregoing locality only by them and the 1,350 level is less definitely registered.

It will be shown later that the granite-gneisses of northern New Jersey and southern New York are of a breadth and resistance which permitted the 1,350 level to be developed upon them and also to be preserved, forming, in part, the Schooley peneplain determined by Davis. Remnants of the 940 level may be identified in the same region but they are so fragmentary that they could hardly be used by themselves as evidence of a former erosion surface, for they might also be explained as residuals from an older cycle partly reduced toward one of the lower baselevels.

It is evident that a fluvial peneplane might be so completely destroyed by the formation of a younger and lower one that the only evidence of its existence would be preserved in wind gaps. The reason is that with the completion (the old age) of a cycle, stream channeling

[21] See following section.

ceases where wind gaps occur and can not be renewed at these places in the next cycle because of the diversion of the channeling stream. A competent stream will sink its gorge through a resistant formation in a small fraction of the time that surface wash requires to lower the same formation an equal amount. The gorge may thus be the only mark of a baselevel on a resistant ridge and it will endure while the whole surface of adjacent soft formations is repeatedly baseleveled in succeeding cycles. In this respect, therefore, the cutting of wind gaps is a fluvial process which corresponds to wave planation against residuals of resistant rock during a submergent phase at the close of a cycle of marine peneplanation.

Significance of Present Valley Forms.

Let the geologist travel up a river which is entrenched to a depth of five hundred to one thousand feet in resistant rock, as are the Housatonic, the Hudson through the Highlands, or the upper courses of the Delaware and Susquehanna. From the railroad or highway he will be most impressed by the precipitous slopes which rise some hundreds of feet above him. Let him climb some hill from which he may gain a commanding view along the main valley or up those of tributary streams. He will commonly see the outlines of an upper and wider valley with gentle slopes below which the present stream is entrenched. From especially favorable situations he may obtain an impression of a still higher and flatter valley outline. He will put together the scattered bits of evidence and reach a convincing conclusion because he can see that the tops of various spurs and outlying hills fall into the same level plane.

The significance of such valley slopes is now well recognized by physiographers; the upper and flatter slopes indicate a stillstand of the land long enough for a valley in hard rock to reach old age, followed by uplift so recent that the river has had time only to carve a young valley in the old valley floor. There are certain aspects of these valley forms, however, which are not so thoroughly appreciated by geologists in general and these need discussion in this section of the paper dealing with the development of principles and criteria.

These valley facets are seldom well shown on topographic maps; their representation requires a point of view and refinement in drawing that is rarely attempted on maps on a scale of 1: 62,500. On the older maps spurs may be smoothed over, or if located by the topographer from the valley below, may be shown with errors in elevation of 100 to 200 feet. One locality, however, where the uplifted valley floor is so wide and well pre-

FIG. 10.

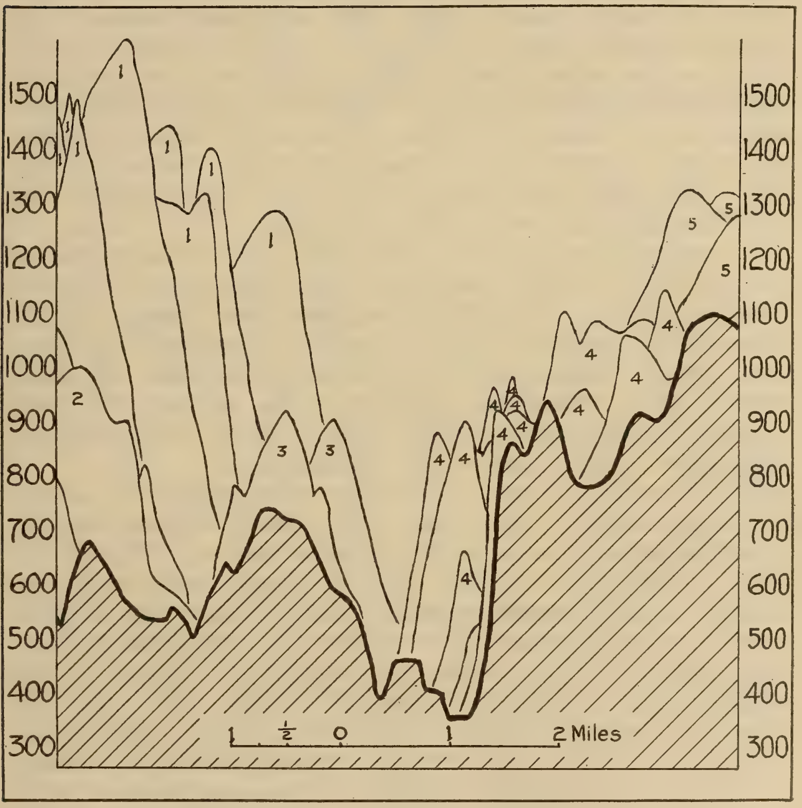


FIG. 10.—Projected profile of valley of Delaware River from one mile north of Dingman's Ferry to Smith's Ferry. (1) Medina and Oneida sandstone, (2) Salina shale, (3) Oriskany sandstone, (4) Hamilton sandstone, and (5) Catskill sandstone and shale.

served that it does show clearly on the topographic map is found on the Delaware River in the Wallpack (Pa.) quadrangle. The projected profile of this locality, looking southwest (down the valley) from one mile north of Dingman's Ferry to Smith's Ferry, is shown in fig. 10.

This section of the Delaware is adjusted to structure and flows on the soft beds between the Oriskany and the Hamilton sandstones. The northwest dip of the strata is flatter here than elsewhere and consequently the outcrops are wider. The Catskill beds of hard sandstones and shales stand up on the northwestern wall to 1,330 feet. The Hamilton sandstone, a hard siliceous silt, rises to 900 feet and except where cut by ravines is all above 600 feet. East of the river is the Oriskany sandstone, a coarse quartz rock with calcareous cement. It is less resistant than the Hamilton and only at two localities in seven miles does it rise to 900 feet; on the other hand the outcrops of this formation do not fall below an elevation of about 550 feet. The hard Oneida-Medina quartzite, forming the Kittatinny ridge, rises to 1,600 feet. The Delaware has an elevation of 325 to 355 feet and Flat Brook flows at 345 to 500 feet.

In explanation of these differences in the elevations of the belts of different rocks an older generation of geologists would have said that they were due merely to differences in resistance of the rocks to erosion. In fact, that would doubtless be the offhand comment of most present day geologists. However, the subject will bear a closer examination and it will be seen that differing resistance is only part of the explanation.

The Hamilton forms a shelf a mile broad cut across the basset edges of the beds. This shelf, although somewhat dissected, shows many summits between 900 and 950 feet, as illustrated in fig. 10. It clearly represents an ancient erosion surface, and lying so near the present river it must represent very closely the actual valley floor over which the river once meandered in a stage of advanced local baselevel. This old valley, then, may be given an elevation of about 950 feet and in confirmation it should be noted that this level corresponds very closely to those of the original bottoms of the conspicuous wind gaps which cut Kittatinny ridge. The slightly lower elevation of Culver's Gap, just east of the northern end of the projected area, is probably due to later glacial scouring.

The Hamilton sandstone still shows this level because it has been resistant enough to withstand erosion during the time which has elapsed since it was thoroughly leveled by the Delaware during the 950 foot cycle of erosion. It also appears to have been eroded to a state of early maturity during a later cycle [the Harrisburg?] and is now in a stage of earliest youth with respect to the present river level. On the other hand, the Oriskany sandstone is weaker than the Hamilton; it is sapped from two sides and eroded to an average level 200 feet lower than the latter, yet two residual masses (see profile) rise to the same height as the many hilltops on the Hamilton outcrop west of the river. This is additional evidence of the reality of the 900-950 erosion surface.

FIG. 11.

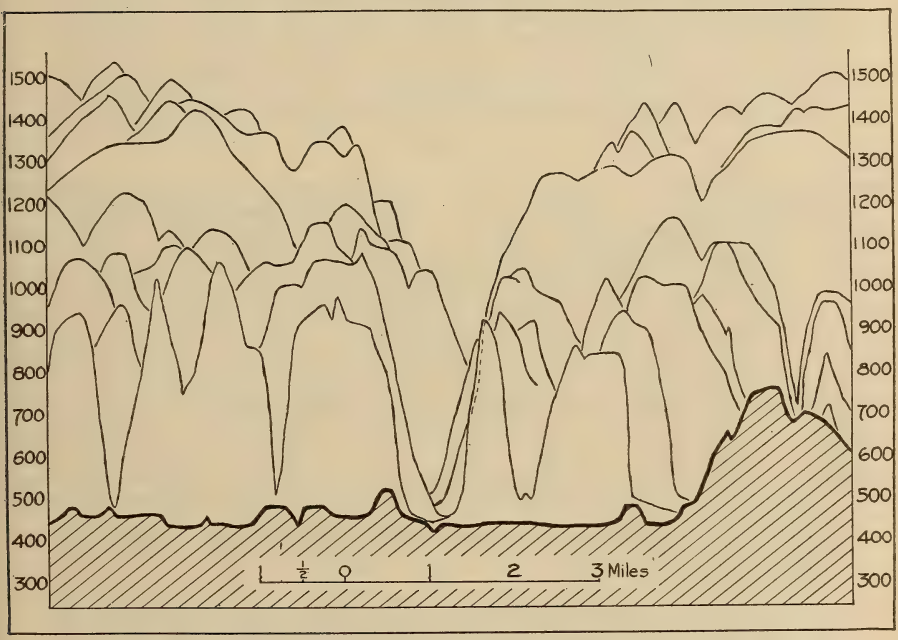


FIG. 11.—Projected profile of valley of Delaware River for 15 miles up stream from Port Jervis, N. J.

Another interesting locality is shown on the Milford (Pa.) and Port Jervis (N. J.) quadrangles where the Delaware River flows southeastward in a deep and narrow gorge across a plateau 1,300 to 1,600 feet in elevation the surface of which is characterized by low hills and swamps. The dissected edge of this plateau forms the northwest margin of the projected profile of the Wallpack locality shown in fig. 10. The projected profile of the Delaware through this plateau in the Milford-Port Jervis region is shown in fig. 11; it extends 15 miles up the river from Port Jervis. The plateau here has summit elevations of about 1,500 feet and has clearly been dissected by an ancient river with respect to a baselevel at a present elevation of about 1,400 feet. This oldest valley is seen to have been about six miles wide and 200 feet deep. The river presumably developed a set of meanders in this wide flat valley and there would have been very flat spurs advancing out to the margins of the meander belt. There appear to be traces of such spurs close to the 1,400± baselevel, but most of them, in any case, would have been sapped by erosion with respect to lower baselevels.

Fig. 12.

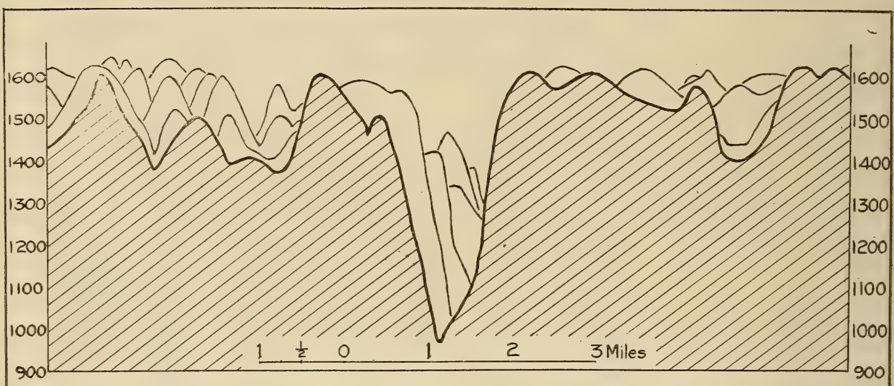


Fig. 12.—Projected profile of part of the Monticello (Pa.) quadrangle. View looking north.

A section of the oldest erosion surface as it appears on the Monticello quadrangle is shown in fig. 12. It embraces an area about 9 by 6 miles, with Monticello in the northeast corner, the direction of view being north. The plateau is here slightly higher than at the localities just described and is trenched by the valley of the Neversink River. It is underlaid by the Catskill sandstones and shales dipping gently to the northwest. The surface thus bevels across the formation and the higher hills mark outcrops of the harder beds. This beveling of the ancient structure shows that the upland is a peneplaned surface which originally had a high degree of perfection. The topography of the part covered by the Monticello quadrangle indicates that this plane, which is assigned an elevation of about 1,650 feet, was dissected to an advanced degree with respect to a baselevel at a present elevation of about 1,400 feet. This corresponds to the relation just described in the Milford—Port Jervis locality.

The crest of the Kittatinny ridge throughout the greater part of its length is part of the peneplain which forms the surface of the Monticello plateau. The latter, indeed, displays a much better development of the Kittatinny peneplain than does the ridge from which it was named. The clear evidence both north and south of the Delaware that the Kittatinny peneplain was dissected through a long cycle of erosion with respect to a baselevel at about 1,400 feet is to be correlated with that derived from the considerable number of apparent wind

Fig. 13.

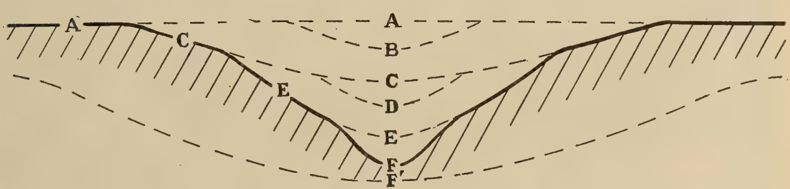


Fig. 13.—Composite valley slopes resulting from a series of quickening uplifts.

gaps which cross Kittatinny Ridge at about this same elevation. The evidence from the plateau supports the idea that these low passes are true wind gaps and that they indicate a higher degree of superposed drainage during the 1,400 foot cycle than during the following cycles. A large part of the adjustment to structure took place during the closing stages of the 1,400 foot erosion cycle.

The evidence of successive baselevels presented in the last three sections is convincing in regard to their relative duration. They represent successive uplifts in a quickening series and the general character of the valley slopes is shown in fig. 13. These latter, it should be said, pertain to the Pleistocene-Pliocene series; for the upper and outer parts of a river system showing older stages the slopes are in general proportionately flatter.[22] In

[22] J. Barrell. Rhythms and the Measurements of Geologic Time. Bull. Geol. Soc. Am., vol. 28, p. 762, 1917.

order that the successive profiles should be cut, the younger within the older, the oldest cycle, C, must have been the longest, E the next longest, and F the most brief. This kind of a record implies an increasing rapidity of recurrence in diastrophism. As this is a conclusion with far-reaching implication let us examine some other points of view.

If the present baselevel should endure for a sufficient time the streams would sink to a flatter grade, the valley slopes would become more gentle, and the profile F change to F′, destroying the previous record. But as we can not look into the future, the nature of the series must be decided on the basis of the record of the past. That record is shown by the relations of A, C, and E, and these indicate an increasing rapidity in the recurrence of uplifts. These uplifts, however, need not have been simple and free from short period minor oscillations. As shown by the broken lines in fig. 13, a short pause, B, may have occurred and yet had the evidence of its existence totally destroyed by a longer pause C, and another, D, by a longer pause E. Even the development of peneplains does not require an age-long freedom from movements in baselevel. Minor oscillations may continue, but they need not lead to a progressive rise of the land. In the lower portions of the river systems alternate fill and scour of the valley would take place, but in the upper parts or on the interfluvial slopes erosion would still continue and increase the perfection of the peneplain.

The significance of such a quickening series of uplifts in relation to the increase in the rate of fluvial erosion in recent geologic time and the vast stretching out which it implies for the earlier stages of erosion has been discussed by the writer elsewhere,[23] the argument resting especially upon the Pleistocene series of uplifts as recorded on the soft deposits of the Coastal Plain. The same argument is seen to apply to the series of higher baselevels recorded upon more resistant formations and reaching back of the Pleistocene into the Tertiary.

The evidence of the valley forms shows that we live in an age of quickening earth unrest and that geologic time is long, to a degree which even now is but little appreciated.

[23] Loc. cit., pp. 761-767.

Marine Peneplanes.

Competence of Marine Denudation.

The competence of heavy waves to trim off headlands, to fill up bayheads, to transport sand and mud, and to build up a profile of equilibrium may be accepted without discussion. On the other hand, the ability of waves both offshore and on the shore to plane across hard rocks for miles, or tens of miles, is not so generally recognized. In the past twenty years, however, important examples of marine denudation have been described. The literature has been recently reviewed by D. W. Johnson who is inclined, from the field evidence as well as on theoretical grounds, to assign a place of consequence to marine peneplanation.[24]

The fact that waves and wave-generated currents can transport sand for long distances and build up sea bottoms to a profile of equilibrium implies that the same forces, acting over a long period, can erode rock to nearly the same profile. But the question is the practical one whether the land is ever stationary long enough for this to be accomplished and whether fluvial denudation would not so far outstrip marine denudation that the work left for the latter would be inconsequential.

The actuality of marine planation of greater or less extent on many coasts is proved by old sea cliffs with an uplifted platform at their bases. On the other hand, it is ordinarily difficult, if not impossible, to determine how much the submerged continental margin is due to marine denudation and how much to aggradation. It appears probable that deposition of sediment and outbuilding are more important at the present time. The evidence of marine planation of the shores bordering the North Atlantic is summarized by Johnson as follows:

> "The great wave-cut platform ("strandfladen" of the Norwegians) fringing the west coast of Norway, best known through the studies of Reusch, Richter, Vogt, and Nansen, has an average breadth of nearly 30 miles, and a maximum breadth of nearer 40 according to Vogt and Nansen, if we include the portion still submerged. Notwithstanding the doubt implied by Reusch, and clearly expressed by Nansen and Nussbaum, regarding the essential marine origin of this feature, it is generally considered, and

[24] D. W. Johnson. Shore Processes and Shoreline Development, chap. V, Development of the shore profile, 1919.

probably correctly so, one of the best examples of marine abrasion on a large scale yet discovered along our present coasts. Nansen describes similar platforms of marine abrasion fringing the coasts of Siberia, Greenland, and other land areas, none of which are so broad as the Norwegian case, although a breadth of nearly 20 miles is not unknown.[25]

In his excellent paper on the physiography of the east coast of India, Cushing has described the old elevated peneplane, the marine denudation plain with an extreme breadth of over 40 miles, and the remarkable sea cliff which separates them.[26] In regard to the sea cliff he says:

"The ancient sea wall which forms the eastern slope of the Ghats is shown to be such by its relation to the plain of marine denudation, both being carved out of the same structure already referred to in considering the peneplain, and by the lack of those characteristics which indicate a fault scarp. . . . The sea wall is boldest in the south near Kodaikanal, . . . where it rises from the inner margin of the Carnatic to an altitude of over 7,200 feet with an average slope of 32°. In many places it approaches the 'sheer precipice' so much recorded in general literature, and so little found in nature. It is so formidable that a bridle path is the only means of ascent. It would seem that the weaker members here underlying the resistant structures permitted the sea to develop a steep sea wall and the drainage of the peneplain to the west helped to preserve it in that condition. In the northern sections where the peneplain has a lower altitude the sea wall is less striking in height, and those conditions which gave the peneplain a mature dissection permitted the adjoining sea wall to develop a gentle slope. The sea through its long continued action at the base of the wall searched out the less resistant structures, and with the help of the other denuding agents, made it retreat most where weakest and most exposed, so that the sea wall to-day is irregular and fragmentary."

Sea cliffs with wide platforms at their bases in both hard and soft rocks show that marine planation can be rapid enough to cut tens of miles inland before fluvial denudation can peneplane the adjacent land. With lower cliffs the shore erosion would cut farther inland in a given period of time though not in direct proportion to the lesser volume of cliff material to be removed, for erosion of the cliff can doubtless be carried forward by

[25] Op. cit., pp. 230-231.
[26] S. W. Cushing: The East Coast of India, Bull. Am. Geog. Soc., vol. 45, pp. 81-92, 1913.

undercutting much more rapidly than the abrasion of the offshore bottom.

The effective deterrents to marine planation are an abundance of land waste, especially coarse waste, delivered by rivers. Even if the waves are powerful enough to prevent the extensive growth of deltas, their energy may be almost entirely absorbed in grinding up and removing the waste. Also, a decreased depth of water due to emergence of the land has a deterrent effect because the energy of the waves is then absorbed offshore. This condition, however, is but temporary and the supply of coarse river waste must also come to an end.

As will be shown, even a small rise of sea-level is effective in promoting marine denudation. It seems clear, therefore, that marine denudation becomes relatively more effective when the cycle of fluvial denudation has passed its maturity. During the late stages of the erosion cycle low sea cliffs instead of high ones would be characteristic. The development of the marine peneplane would be chiefly by subaqueous erosion and to transform the broad outer margin of a fluvial peneplane into a marine peneplane would not require the removal, on the average, of over 100 to 200 feet of rock.

There would seem to be no room to doubt the probability of the existence of marine peneplanes many tens of miles or more in breadth. In studying a seaward-facing peneplane, therefore, the possibility of its origin, either in part or in whole, through marine agencies should be thoroughly considered.

The Process of Marine Denudation.

Ancient peneplanes become either erosion surfaces covered by later deposits and constituting unconformities or erosion surfaces without protecting covers now uplifted and undergoing destruction. And whereas these surfaces were formerly considered as made only by marine action, in recent years they have been conceived of almost exclusively as having been formed by fluvial denudation. The truth is that they may be formed not only by marine and by fluvial denudation but also, even if less commonly, by eolian erosion.

It was natural that fluvial denudation should supplant marine denudation as the explanation of the origin of extensive erosion planes, for the forces of subaerial erosion could be observed at work over the broad surfaces of the continents, in marked contrast to the narrow zone over which the sea worked, thus making it possible to formulate concisely and graphically a normal cycle of fluvial denudation. Nevertheless, marine planation has been an important process in the past and in favorably situated regions is still notably effective in producing plane surfaces. Consequently, in order to determine the expectability of ancient peneplanes of marine or fluvial origin it is necessary to examine the way in which submarine and subaerial forces carry on their own work and also coöperate.

It has been held by some geologists that marine denu-

Fig. 14.

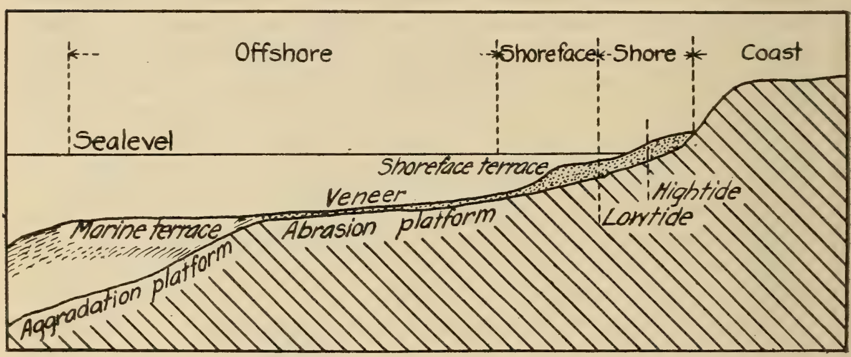


Fig. 14.—The chief divisions of the marine profile. After D. W. Johnson.

dation is effective only at the shore. The shore, however, is simply the zone of visible and impressive action; erosion is there dominant only on a young and bold coastline. Marine erosion passes quickly to a stage of maturity when bottom erosion, to a depth approaching wave base, has to remove as much or more material as does the breaking surf.

Marine erosion, in fact, works to a graded profile comparable to that of a stream. This is evident both from observation and theory. The profile, as shown in fig. 14, becomes horizontal at the depth of wave base, namely, the depth at which the wave action of the heavier storms just ceases to stir the bottom material. Moving toward the shore the waves lose some of their power through bottom friction and can only stir the material at a lesser depth. The result is that nearer shore the wave work is in equilibrium on a shallower bottom. Farther inshore the water shallows until the waves break and surf results. The remaining energy is there concentrated; beach material is thrown up, a distinct bench may be cut, and the base of a sea cliff undermined. The main divisions of the marine profile are shown diagrammatically in fig. 14 and are in conformity with those adopted by Dr. D. W. Johnson.[27]

In so far as wave action and the currents generated by waves move a veneer of material back and forth over the abrasion platform there must be wear both of the veneer and the rock below. In times of gentle wave action the profile tends to become shallower because aggradation instead of erosion tends to occur over the abrasion platform; consequently erosion is mainly the result of the higher intensity of action during storms, as it is on the land surface. The direction of storm winds, as well as their intensity, affects the character of work done over the sea bottom. The latter can never be in perfect equilibrium but adapts itself to ever changing conditions, oscillating about a mean. At one time a shore may be stripped temporarily of its beach material, at another time an unusual amount may be piled up. The profile, however, remains the same in character for shores exposed to different intensity of wave action but differs in scale; it reaches equilibrium soonest and displays the typical form on shores of weak resistance and on bottoms of alluvial material.

From an inspection of the bathymetric charts of the margins of many water bodies, the following data have been derived and previously published.[28]

Generalized Profile of Equilibrium for Shelf Sea.

Distance from shore in miles.....	1	2	3	5	10	20	100
Depth of water in fathoms	7·5	11	13·5	15·5	18	23	50

The symmetry of this profile is greatly disturbed by a number of factors which are always present to some degree. The profile is flatter on a shore toward which sediment is driven, undertow sweeps the bottom material

[27] Shore Processes and Shoreline Development, pp. 159-163, 1919.
[28] Joseph Barrell: Rhythms and the Measurement of Geologic Time, Bull. Geol. Soc. Am., vol. 28, pp. 779-780, 1917.

in certain directions giving current effects, and variations in storms and in depth of water modify it from one scale to another.

A study of the relation of depth to distance from shore for specific types of water bodies gives the following results:

Bottom Profiles established by Wave Action.
Depths of water in feet.

Type of water body	Distances from shore in miles. 5	10	20	80	100
Stormy shelf seas	95	110	140	300	300
Stormy epeiric seas	55	70	90	110	110
Quiet epeiric seas	35	50	70	90	90
Wide lagoons	15	15	...	...	...
Playa seas	0 to 5	...	...	...	...

Fig. 15.

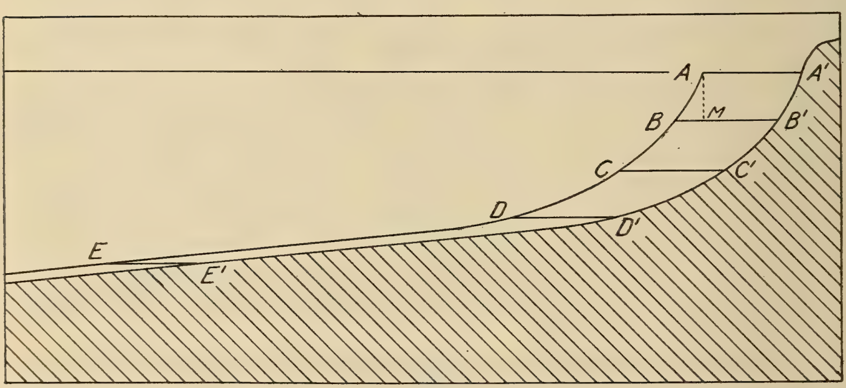


Fig. 15.—Profile to show that, with a stationary land, erosion occurs on all parts of the profile of equilibrium.

That erosion must take place on all parts of the profile of equilibrium, under stationary conditions of land and sea, may be shown in the following manner. In fig. 15 let ABCDE and A′B′C′D′E′ be two consecutive positions of the profile of equilibrium. As the curve remains the same in form for both positions, the distances AA′, BB′, etc. must be equal. The area of ABB′A′ is equal to that of a rectangle with the base BB′ and height AM, and the same relation is true for the other areas. Therefore in this case, the quantity of material eroded for equal vertical distances is the same. But the erosion surface is very much greater for the deeper offshore part of the profile (DE) than it is for the shallower nearshore part (AB), which corresponds to the very much weaker forces of erosion on the deeper parts. The profile of equilibrium, then, for stationary conditions of land and sea is such that its slope becomes flatter in proportion to the progressive weakness of erosion with depth. This is not the same as the curve of decreasing amplitude of wave motion with depth, for rapidity of erosion is a function of several factors of which wave motion, however, is the most important.

The depth to which rock platforms can be cut must be distinctly less than the depth at which wave motion prevents the settling of the finest silts. Current action, coöperating with waves, is important in moving sands over the abrasion platform at depths where wave motion alone has but little influence. As to the depths at which silt can be moved we may quote from D. W. Johnson's recent book:[29]

"Thomas Stevenson has made a very interesting comparison between the depths at which mud reposes on the floor of different parts of the North Sea, and the vigor of wave action in those places. He finds that there is a direct relation between these two phenomena, the depth of the level at which mud accumulates increasing in much the same proportion as the violence of the waves. From this we may infer that the upper limit of mud accumulation is a measure of the maximum depth of wave disturbance in any given locality. Applying this rule to the North Sea, we find that in protected areas, as the inner parts of Moray Firth and the Firth of Forth, and along the Holland coast in the narrow southern part of the sea, wave action reaches to a depth of from 25, 50, or 100 feet, while in exposed places the disturbance is appreciable to a depth of from 300 to 500 feet or more. According to J. N. Douglas, the fishermen off Land's End bring up stones one pound in weight, which have been washed into their lobster pots at a depth of 180 feet by the action of the ground-swell, while coarse sand is often washed from a depth of 150 feet by storm waves and hurled to the lantern gallery of the Bishop Rock lighthouse, 120 feet above low-water."

Johnson concludes that there is no theoretical reason why appreciable oscillatory wave action should not extend

[29] Shore Processes and Shoreline Development, p. 79.

to a depth of 600 feet and disturb clay, mud, and probably the very finest sands. Oscillatory waves, however, would have practically no erosive power at that depth, but waves of translation would appear to be capable of producing noteworthy erosion and transportation.[30] On the other hand, the actual forms of the profiles of the shelf seas seem to show that bottom transportation becomes ineffective at somewhat lesser depths. The rise of sea-level since late Glacial times, which is estimated at as much as 20 fathoms, has overdeepened the ocean profiles and they have been adjusted to the present higher water-level only where there is a great abundance of unconsolidated bottom material. The lack of recognition of this condition has created the impression that wave action in

Fig. 16.

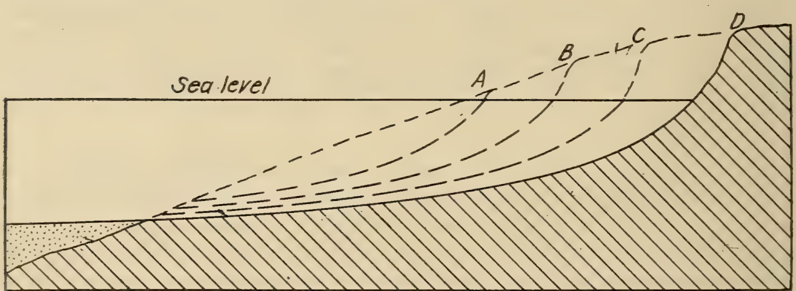


Fig. 16.—Successive stages of marine erosion on a stationary coast.

general is effective to a greater depth than is actually the case. A depth of 50 fathoms seems more probable than the limit of 100 fathoms, for coast charts commonly show a downward curvature of the bottom profile at about the former depth, indicating the cessation of effective wave action.

Various Cases of Marine Denudation.

In an analysis of the features of marine denudation, when acting on a surface previously shaped by fluvial denudation, there are several cases to be considered.

Case I. Let submergence bring the sea against moderate hill slopes, as illustrated by fig. 16. Successive stages of erosion are shown by A, B, C, and D. During the youth of the shore-line, erosion will be concentrated

[30] Loc. cit., pp. 81-83.

upon headlands. A mature profile of equilibrium will be established while the strand-line is still young. As the shore retreats, the sea operates against a larger and larger proportion of higher land and brings about a notable change in the character of the coast. The character of the sea-bottom profile, however, changes much less.

Increase in the depth of erosion for equal distances inland, due to increasing height of sea cliff, must tend to slow down the rate of advance, but the slowing down is probably much less than a simple inverse proportion to the volume of material to be removed. The reasons are (1) that not all the wave energy is expended in the erosion of headlands, for much is wasted in bays without proportionate effect, (2) for equal stages of advance the depth of bottom erosion increases very slowly, and (3) although the sea cliff increases in height and more material must be removed, yet the process of undercutting maintains a very rapid rate because the greater quantity of coarse angular debris is competent to erode the abrasion platform much faster than would a lesser amount of material. It is by the oscillation of the veneer of waste that the platform is worn down. A superabundance of waste would temporarily protect the rock below, but when the whole amount can be moved by storms, increase of moving debris presumably increases the corrasion of the rock below. The maximum volume of denudation for equal time intervals is reached when the shore-line has attained maturity.

Case II. Another case which needs discussion is that of marine denudation against a sinking land with a hilly topography. Such a surface is commonly regarded as favoring marine planation; it permits the waves to act more strongly against the shore because less of their energy is spent on the offshore bottom.

The work of marine planation is shallower in this case than in the preceding one, as shown in fig. 17. Let AM be the initial profile of equilibrium. As submergence and planation are going forward together the shore-line will retreat from A to C and the profile of equilibrium will advance from AM to CO. Instead of erosion on the offshore bottom, as in Case I, there is aggradation. Let the slope of the rising strand-line be AC. Draw TT′ parallel to AC and tangent to the profile AM. It will be tangent to CO at T′ and to BN midway between T and T′. Then when the strand-line is at C, for example, there will be erosion on the landward side from T′, whereas offshore from that point there will be aggradation.

In long continued planation this offshore aggradation very greatly reduces the work of the sea in cutting inland, for the depth of bottom erosion is reduced from AX, the ultimate depth of effective wave action, to AT′. For example, take the profile given in the preceding topic for a stormy shelf sea. If submergence to a depth of three fathoms should go forward while the sea were cutting

Fig. 17.

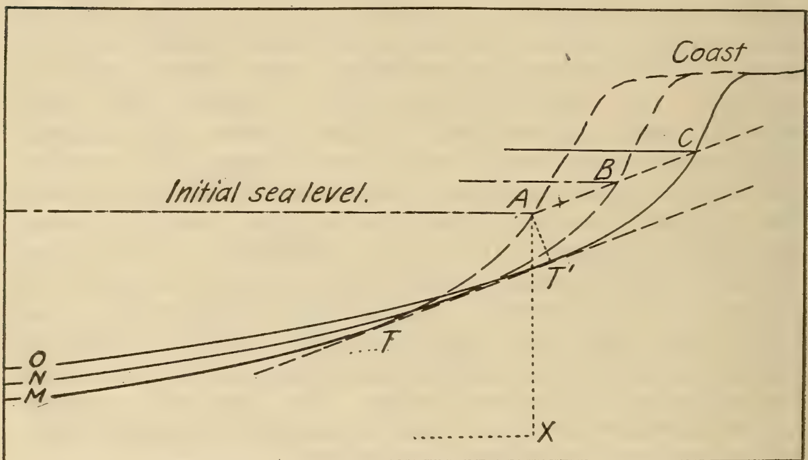


Fig. 17.—Successive stages of marine erosion on a sinking coast.

inland one mile, the slope would be tangent to the profile of equilibrium two miles from the shore at a depth of eleven fathoms. To maintain this profile marine denudation would need to go forward to a depth of only eleven fathoms instead of an ultimate depth of about fifty, as in the case of a static sea-level. Thus the work of marine denudation would be reduced about four-fifths. A very slight rate of submergence, therefore, will bring about a retreat of the shore inland several times faster than under stationary conditions of land and sea.

Case III. The more usual case is that of rapid submergence after which the sea cuts inland and establishes a normal profile. This condition exists at present in many regions. The best studied example is that of the east and south coasts of England where the rapid advance of the sea has raised the very practical and important problem of control. The shore formations consist chiefly of unconsolidated deposits on the east coast and of chalk on the south, both of which are very soft and unresistant. The cobbles and flints from the chalk are ideal material for grinding up the associated debris. The present rapid rate of erosion and the spectacular appearance of these shores thus illustrate a case where the normal profile of submarine denudation has not yet become established.

Marine denudation working against a land already dissected by fluvial erosion will attack islands and headlands from two or three sides, giving rise to rock stacks, reefs, and shoals. When an island is reduced to a shoal below strong surf action it should endure for a long time because the supply of coarse veneer is lacking; erosion would be at the base and tend to maintain steep slopes. Shoals will persist while the shore-line is pushed inland, as is shown by the charts of many regions of active marine denudation. The general result is that marine peneplanes should exhibit a notable irregularity of elevation even in an advanced stage of development.

To the islands of a marine peneplane, remaining after elevation, D. W. Johnson suggests the advisability of applying the name monadnock. The hummocks here discussed, however, are of a different nature, they represent fairly normal departures from the uniformity of the peneplaned surface. They are not relics from a previous cycle of erosion, but correspond to the low interfluvial ridges normal to a fluvial peneplane. Their rounded summits may have been some fathoms below sea-level and their bases may have been at depths of 20 to 40 fathoms depending upon circumstances. Thus they may have a relief of 100 or more feet, and their summits should be accordant, even more so than their bases. They may be expected to develop along the outcrops of very resistant formations and may be a direct inheritence from an interfluvial land ridge. Cross currents between them may scour out deeper channels than the normal, permitting a cross drainage to become established upon emergence without the necessity for complete burial of the whole ridge.

The critical study of the stratigraphic series indicates with increased certainty that oscillations of sea-level have been characteristic of all geologic time and that, on the average, they have been of shorter period and of larger amplitude during the culminations of diastrophism. In the later parts of this paper the field evidence from Connecticut will be given for extending the character of the Pleistocene oscillations there recognized, as well as in the Coastal Plain, backward into the Tertiary, but with longer stillstands between periods of movement. This raises the question as to the character of marine denudation following submergences of post-maturely dissected lands to an extent of from 50 to 200 feet.

For a submergence of fifty feet or less the valley floors would be flooded to so small a depth that wave action would be slight. The chief line of marine attack would be upon the more prominent parts of the coast; vigorous wave erosion of headlands would be stimulated and a mature coast would be made young.

For a submergence of 200 feet, which is about the average interval between the terraces in Connecticut, the conditions would be quite different, for the depth of wave action in epeiric seas would be approached. Lowlands would be broadly flooded and under favorable conditions transformed into such bodies of water as the North Sea, the Baltic, or Hudson Bay. An entirely new coast line would result, exposed to notable wave action at and near the shore. The waves from the ocean, encountering no offshore bottom, would roll with undiminished force against the coast and a new facet of marine denudation would be planed inland in a short time. On the shore of each embayment wave action would also proceed, but with less intensity than on the outer shore and varying with the depth and width of the water body.

For several reasons the submergence of a coast to the extent of about 200 feet and the consequent erosion phenomena furnish important evidence for the recognition of marine planation. First, wave attack is not only against the outer coast line but is repeated on various minor scales along all embayments, especially on their windward sides. Second, wave action attacks a surface shaped by fluvial denudation. The result at first would be a fluvial surface modified by wave action. In the end, however, there would result a true marine peneplane, and it would be generated the more rapidly because the bulk of the erosion had been previously accomplished by subaerial agencies and the surface left in a condition favorable to marine attack. Upon emergence the old valley lines in part would be re-established and the flat-topped interfluves would be on the kinds of rocks and in the situations favorable to the preservation, for a long time, of the surfaces of marine denudation.

From the geologic standpoint the strand-line is ever shifting and neither the land nor sea maintains a stability of level between the periods of marked and rapid change. Minor oscillations and halts occur at all stages. The mind tends to dwell on the more conspicuous features and to over-simplify nature. In formulating the criteria for the recognition of marine denudation regard must be had for this inconstancy of baselevel.

The situation is illustrated by the shores of the extinct Lake Bonneville. The highest and most conspicuous shore-line is the Bonneville, on the average 1,000 feet above the level of Great Salt Lake. On the other hand, the one which represents the longest stand of the water and the greatest volume of shore work is the Provo, which has an elevation about 600 feet below the Bonneville strand. The entire slope, however, from the Bonneville level to that of Great Salt Lake is modified by wave action and under the proper slant of sunlight the many horizontal scorings from temporary water levels may be observed. The causes of the changing water level of Lake Bonneville were the cutting down of the outlet and variations in climate, but the results in shore action are comparable in some respects to those of a shifting sea-level.

In temporary and transitional stages of sea-level two aspects should be called to attention. During a temporary stage of submergence wave action may be recorded only by lines of minor cliffs and benches developed on headlands. During a temporary stage of emergence the work of the waves will be confined to the flat bottom, moving finer material to deeper water, throwing up off-shore bars and barrier beaches. No sea cliff would result unless the stand of the water were so prolonged that a new profile of equilibrium became established and the shore eroded inland for some distance A conspicuous cliff and bench would require erosion to or beyond the former shore-line.

In the later Tertiary and the Pleistocene the land along the Atlantic Coast, on the whole, was rising, and each submergent phase permitted the sea to advance inland less far than a previous submergence. The less enduring of these submergent phases may have served, therefore, to partially destroy an older marine peneplane without developing a clear one of its own marked by a marginal cliff. So far, at least, as the Pleistocene is concerned it appears, also, that fluvial denudation during intervening emergent phases was vastly more important in the bulk of its work than was marine denudation during the submergent phases. Consequently, if we look beyond the Pleistocene into the Tertiary it is to be anticipated that the marks of the sea, if present, should become more and more obscure from the destructive effects due to all later fluvial denudation.

[To be continued]

ART. XXVI.—*Relative Densities of Igneous Rocks Calculated from their Norms;* by J. P. IDDINGS.

In discussing the relative densities of large masses of igneous rocks in connection with the problem of isostasy in lectures on Volcanism[1] delivered at Yale University in 1914, it was stated that an estimate of the relative densities of holocrystalline igneous rocks could be made from the calculated norm with reasonable accuracy, when the actual mineral composition of the rock, or the mode, was normative, or nearly so; that is, when the rock does not contain considerable hornblende or mica, or is not otherwise abnormative. In case these minerals are abundant the density of the rock must be slightly more than the estimated density, since hornblende and mica have higher specific gravities than their normative components.

The data on which the statement was based were not published at the time, but may be found useful in other calculations. The relative densities of certain minerals that occur pure in nature, or have been formed in laboratories, are definite quantities. Those of minerals with variable compositions, that is, isomorphous mixtures, may be estimated from the proportions of their hypothetical component molecules, such as the proportions of forsterite and of fayalite in an olivine. The specific gravities used in the calculations referred to were as follows:

SPECIFIC GRAVITIES.

Quartz	= 2·65	Diopside	= 3·28	Magnetite	= 5·17
Orthoclase	= 2·54	Enstatite	= 3·18	Ilmenite	= 4·73
Albite	= 2·61	Hypersthene[a]	= 3·33	Hematite	= 5·22
Anorthite	= 2·77	Hypersthene[b]	= 3·53	Apatite	= 3·20
Leucite	= 2·48	Forsterite	= 3·21	Pyrite	= 5·03
Nephelite	= 2·62	Olivine	= 3·27-3·37	Fluorite	= 3·18
Corundum	= 4·00	Fayalite	= 4·00		

[a] FeO, 14; MgO, 28.
[b] FeO, 27; MgO, 14.

By calculating the mass of each component of the norm of any analyzed holocrystalline rock, the sum will be the mass of the whole, which may be corrected for 100 per-

[1] Iddings, J. P.: The Problem of Volcanism, p. 123, 1914. Yale University Press, New Haven, Conn.

cent. The correspondence between the specific gravities of certain rocks, which have been determined with a balance, and those estimated from the norms derived from the chemical analyses of the same rocks has been found to be as follows:

1. Rhyolite, liparose, Four Mile Creek, Castle Mt., Montana, H. S. Washington's Tables of Rock Analyses (1903), p. 146, No. 28. Sp. gr. from norm, 2·62; corrected for H_2O, 2·61; from rock, 2·61.
2. Quartz-tourmaline-porphyry, liparose, same locality, H. S. W. Tables, p. 146, No. 29. Sp. gr. from norm, 2·62; corrected for H_2O, 2·59; from rock, 2·59.
3. Granite, lassenose, Muhlberg, Odenwald, Hesse; H. S. W. Tables, p. 180, No. 68. Sp. gr. from norm, 2·721; corrected for H_2O, 2·688; from rock, 2·665.
4. Gabbro, auvergnose, Minnesota; H. S. W. Tables, p. 332, No. 26. Sp. gr. from norm, 2·989; corrected for H_2O, 2·970; from rock, 2·967.
5. Essexite, essexose, Salem Neck, Mass.; H. S. W. Tables, p. 298, No. 3. Sp. gr. from norm, 2·917; from rock, 2·919.
6. Gabbro-diorite, auvergnose, Windsor Road, Baltimore, Md., H. S. W. Tables, p. 330, No. 14. Sp. gr. from norm, 3·006; from rock, 3·069.
7. Hornblende-picrite, wehrlose, Northmeadow Creek, Mont., H. S. W. Tables, p. 354, No. 2. Sp. gr. from norm, 3·25; from rock, 3·35.

From these examples it is seen that the hornblende-bearing gabbro, No. 6, and the picrite, No. 7, have higher specific gravities than those calculated from the norms, as already pointed out. When the possible sources of error in determining the specific gravities of rocks by ordinary methods are taken into account, the correspondence between the observed and calculated specific gravities in the cases cited is striking, and indicates that for purposes of generalization and for the comparison of the relative densities of large volumes of igneous rocks of hypothetical average compositions this method of estimating specific gravities is sufficiently accurate.

In the course of Silliman Lectures, already referred to, this method of estimating relative densities was applied to the discussion of isostatic conditions with respect to contrasted petrographical provinces, the average of all analyses of igneous rocks in each region being taken as an exponent of the mass of igneous rocks of each province, an assumption varying greatly in value in different cases, according to the number and range of the chemical analyses and the relative quantities of the various rocks in each region. From averages of chemical analyses estimated by F. W. Clarke for some large groups of rocks, the following specific gravities were calculated:

California	2·85	Great Britain	2·91
Colorado	2·80	Scandinavia and Finland	2·85
Yellowstone Park	2·85	Germany and Austro-Hungary	2·81
Atlantic Coast	2·89	Italy	2·86

The lowest value represents the normative density for the average of the igneous rocks analyzed from the High plateau of Southwest Colorado; the highest value, that for the igneous rocks of Great Britain.

The average of 43 chemical analyses of Hawaiian lavas, discussed by Whitman Cross, yielded a specific gravity of 3·12, and the average of 25 analyses of lavas from the Island of Réunion, prepared for Professor A. Lacroix, gave 3·12 also. Whereas the analyses of rocks from Tahiti and the neighboring Society Islands, published by Lacroix, represented such a large percentage of the relatively scarce trachytic and syenitic rocks that the average of the 15 analyses by no means represented the average composition of the rocks of the islands, which according to Lacroix are largely basalts rich in mafic minerals. The normative specific gravity for the average of these analyses is 2·96, which is too low to represent the relative density of the igneous rocks of the Petrographical Province of this part of the South Pacific Ocean.

A study of the islands by the writer in 1915 showed the great preponderance of basalts rich in olivine and pyroxene, with comparatively low content of feldspar. It also showed the relatively small amount of trachytic and syenitic rocks, which in an estimate of the average composition of the volcanic lavas of the islands may be considered a negligible quantity. An average of 17 analyses of representative rocks from Tahiti and the neighboring Society Islands, omitting those of trachytic lavas, furnishes a norm from which a specific gravity of 3·23 was calculated for an anhydrous mass, and of 3·20 for one containing the H_2O of the average analysis. Specimens of coarse-grained rocks from the cores of the dissected volcanoes of Tahiti proper and from the peninsula of

Taiarapu, which have the same chemical composition as the dominant lavas of those volcanoes, yielded the following values for their specific gravities determined in bulk:

			Mean
From core at head of Papenoo	Theralite	3·15	
Valley, Tahiti:	Olivine-gabbro	3·18	3·19
	Olivine-gabbro (?)	3.20	
	Peridotite	3·21	
From core at head of Tautira	Theralite	3·10	
Valley, Taiarapu:	Olivine-gabbro	3·12	3·20
	Peridotite	3·39	

These results show a reasonably close correspondence between the determined and estimated specific gravities for the rocks of these islands, and furnish a value considerably higher than that derived from the 15 analyses previously considered, which gave a normative density of only 2·96. The normative density found in this way for the province of these South Sea Islands is noticeably higher than those which have been estimated for Hawaii and Réunion.

ART. XXVII.—*Apthitalite* (Glaserite) *from Searles Lake, California;* by W. F. FOSHAG.[1]

The United States National Museum recently acquired through transfer from the United States Geological Survey boring samples of a well, G 75, sunk at Searles Lake, San Bernardino County, California. These samples were collected by Mr. Hoyt Gale during some of his investigations on the possible potash deposits in the United States. They consist mainly of halite, hanksite, trona, pirssonite, gay lussite and thenardite with some borax, northupite and sulphohalite. In working over this material one specimen was found consisting of tabular crystals embedded in a white powdery matrix and also crystallizing in open cavities. Upon close examination these crystals were found to be trigonal in aspect and suggested the mineral apthitalite. Tests with sodium cobalti-nitrite showed potash to be present in considerable amounts.

The embedded crystals ranged up to 20 mm. in size but were rough and not suited for accurate measurements. Occasional crystals in the open cavities, however, were of excellent development and a few of these were of sufficient brilliance to give sharp signals on the goniometer. The habit is simple, the only forms noted being the base and the rhombohedron r $(10\bar{1}1)$. Three angles measured between c and r from sharp signals gave 56°2′, 56°3′, and 56°4′. They vary in habit from very thin tabular to thick tabular.

The mineral is colorless with a vitreous luster. Hardness 3. Brittle. Under the microscope the mineral appeared uniaxial (+). The indices of refraction measured by the oil immersion method were found to be

$$\omega \pm 1{\cdot}490 \pm 0{\cdot}003, \quad \epsilon = 1{\cdot}496 \pm 0{\cdot}003.$$

The birefringence is weak, the thickest fragments showing yellow of the first order.

Material for analysis was carefully picked out but when examined under the microscope showed some intermixed halite. Aside from the halite no other impurity could be detected. The analysis gave the following results:

[1] Published with the permission of the secretary of the Smithsonian Institution.

K	32·46
Na	9·01
SO_4	53·71
Cl	4·76
H_2O	0·10
	100·04

or K_2SO_4 72·37%, Na_2SO_4 18·38%, NaCl 7·87%, or a ratio of K_2SO_4: Na_2SO_4 of about 4:1.

This is the first reported occurrence of apthitalite in the United States as far as the writer is aware and is interesting in that it is the first potassium mineral reported from Searles Lake. The mineral is also found sparingly at Stassfurt and Kaluscz and is the only rare mineral common to all three of these remarkable saline deposits. The Searles Lake mineral is directly associated with halite in well-defined octahedral crystals and rests upon a mass of borax which has been transformed by atmospheric exposure to a white pulverulent mass. The apthitalite itself however shows no alteration whatever.

United States National Museum,
Washington, D. C.

Art. XXVIII.—*Local Unconformity between the Berkshire Schist and the Stockbridge Limestone in Adams, Mass.;*[1] by T. Nelson Dale.

In the course of the tracing of hundreds of miles of boundary between the Berkshire schist and the underlying Stockbridge limestone in western Massachusetts and western Vermont by the writer and his former assistants a number of immediate contacts between these formations were observed.[2]

At some of these contacts the limestone, generally a calcite marble, becomes graphitic within a few feet of the schist, and the adjacent schist is also graphitic. At others, however, the two rocks have no common constituent and their relations indicate an abrupt change from calcareous to argillaceous sedimentation.

While working on the geology of Mount Greylock in 1886 the writer in bounding the small schist outlier, a mile S.SW. of Adams, and due W. of Maple Grove Station,[3] found that the schist within a few feet of its contact with the marble contained what appeared to be pebbles of marble.

In July 1919 while running the boundaries between the dolomitic and calcitic limestone of the Stockbridge limestone for a forthcoming U. S. Geol. Survey bulletin for the benefit of the lime industry the writer had an opportunity of revisiting the locality and obtained the following results.

The marble at a small opening about 200 ft. E. of the outlier and nearly W. of the station is so micaceous and feldspathic as to resemble a gneiss and has been used for curbing and even for construction. Prof. J. E. Wolff described the stone in the same monograph and also refers to similar feldspars in an earlier publication.[4]

The marble itself has an average grain diameter of 0·32 millim. but has micaceous laminae 0·1 inch apart which in

[1] Published by permission of the Director of the U. S. Geol. Survey.

[2] Some of the more accessible of these in Mass. are about the village of New Ashford. See U. S. Geol. Survey, Mon. 23, fig. 31, p. 138; fig. 32, p. 139; fig. 35, p. 140, 1894.

[3] Op. cit., Pl. I. The revised boundary makes this outlier almost 5000 ft. long and its greatest width about 700 ft.

[4] Wolff, J. E.: The geology of Hoosac Mountain and adjacent territory, op. cit., p. 64. Metamorphism of clastic feldspar in conglomerate schist, Bull. Mus. Comp. Zool., Cambridge, Mass., vol. **16**, No. 10, 1891.

thin section show grains of microcline with streaks of inclusions of graphite and muscovite arranged parallel to the laminae.

The nearest large outcrops on the western side of the outlier are 300-400 ft. from it and consist of white calcite marble rarely with a bed of dolomite. Within 500 ft. N. of the northern end there are gray and white calcite marbles with a N. strike. Calcite marble, nearly vertical, is in contact with the schist at its extreme northern end and recurs off and on for 500 ft. W.

The pebbles are of three kinds of rock: (1) Calcite marble, dark gray, graphitic. The calcite grains have a maximum diameter of 1·48 millim., estimated average 0·37 millim. It contains some quartz and muscovite and a few grains of apatite. (2) Calcite marble, dark gray, graphitic, also brownish. The calcite grains have a maximum diameter of 1·12 millim., estimated average 0·25 millim. It contains dolomitic rhombs within and between the calcite grains, also evenly disseminated quartz, some pyrite with limonite stain, and rarely a grain of albite. (3) One small pebble is a black very graphitic granular dolomite with a little quartz and pyrite. The dolomite rhombs and rhomboids, averaging about 0·033 millim. in diameter, lie in a groundmass of graphite with a few minute grains of quartz and a little pyrite.

The exact source of the graphitic calcite marble of (1) and (2) is as yet undetermined but may very well have been some of the uppermost beds of the Stockbridge limestone which are apt to be more or less graphitic. The marble outcrops about the outlier afford but a very incomplete exhibit of the uppermost beds. Furthermore the pebbles may have been transported some distance to their present location in the sea bottom.

This locality appears to be the only one known in the Taconic region affording evidence of any unconformity between these two formations. The recent mapping of the dolomitic and calcitic areas of the Stockbridge limestone in Berkshire County shows that in places, notably in the townships of Cheshire, Lanesboro and Stockbridge, the Berkshire schist rests immediately upon the dolomitic limestone which forms the lower horizon of the formation but in most places upon the calcitic limestone or upper horizon. This may be attributed either to the continuance of dolomitic sedimentation in places to the end of Stockbridge limestone time or else to an unconformity between the limestone and schist formations. Should the latter view be found correct it would corroborate the evidence from the pebbles.

Conclusions.—The calcite marble pebbles within the Berkshire schist indicate that portions of the Stockbridge limestone in western Massachusetts were within wave action when the streams on the landmass to the east were carrying argillaceous material into the great American mediterranean sea of Ordovician time. The very micaceous character of the marble of the Stockbridge limestone some distance below its contact with the schist shows that long before the arrest of calcareous sedimentation the streams had begun to discharge argillaceous material.

Springfield, Mass., March 20, 1920.

ART. XXIX.—*Fossil Botany in the Western World: An Appreciation;* by H. B. GUPPY.

As a student of plant-distribution through the greater part of a life now drawing towards its close, and as one who has done his best to avoid the entangling influences of geographical settings and dominant theories, I would ask you to grant me the privilege of a small space in your journal for the expression of my appreciation of the part now taken by paleobotanists in America in the investigation of the problems of distribution as far as the higher plants are concerned.

For Distribution is a great deal more than a tale of the Present, it is a story of the Past, and the interpretation of the connection between the two will largely determine the fate of any theory of evolution for organisms in general; and on the validity of such theories of development for things organic will depend for future generations the guidance or misguidance in things intellectual. So that the unearthing of a leaf or a fruit in the Cretaceous beds is a far more important matter than the action in its mere crudity might at first seem to suggest.

If I were asked what was the best I could wish for the workers, I should say without hesitation, plenty of good criticism. But one does not here mean the hostile criticism of the partisan who has been supporting some opposing theory all his life and will not have any angiospermous fossils in his bag. The sort of critics that would do them most good would be those of their own household, those who while believing in their mission as the preachers of the new era in things geological, not in America only but in the world in general, are not afraid to tell them some home-truths while working at their side. The writer feels very strongly that the hostile criticism should not come from those who have adopted a position that would be considerably weakened by the recognition of the reality of fossil angiosperms of existing genera in the Cretaceous deposits. They have too obviously taken sides, and choosers cannot be the best of critics.

The time when the Old World could serve as the standard for the New World is passing away, and the position will be reversed as knowledge progresses. But it will be changed not so much because the New World will reveal more of the secrets of the earth's history than the Old World, but because it will tell the story in a better way, that is to say, in a clearer and less ambiguous fashion. The problem of the Western World is in a relative sense a clean-cut problem. Here, far aloof from the other great land-masses, we have a continent that runs with the meridians almost from pole to pole. In the Old World there is more longitude than latitude, and we have in consequence two such problems, but the problems are not clean-cut and their issues are often confused. Thus, one is concerned with Europe and Western Asia and their southern extension, the African Continent. The other affects Eastern Asia, Malaya and Australasia. Although there will be a Mediterranean question in all three problems, for the Western World will have its Caribbæa and Eastern Asia will have its Malaya, yet for the most definite and the straightest of issues we shall have to look alone to the New World.

The geological record has not always been unkind to the student of the floras of the later ages in the western hemisphere. In its presentment of the problem at the outset its action is distinctly benign. For in a broad sense the generic types that first appear above the geological horizon are with him now. He begins with the cosmopolitanism of such types in the Cretaceous age and he ends with their more restricted distribution and somewhat greater specialization now. Since he discovers that he is not much nearer the origin of such plant-forms in the Cretaceous than he is at present, he shelves the question of origins, at least for a while. The geological record leaves the main problem at the finish almost as it presented it at the beginning; and for him the pre-Cretaceous story of these forms, that have preserved their essential characters through unknown ages, is as a tale untold. This is why I have said that the geological record has in a sense not been unkind to the student of angiospermous floras in the western hemisphere.

We find him then at the limit of the known, with blankness beyond; and he is thankful that there are no will-of-the-wisp problems to lure him on. Yet there is an air of unreality, almost of dreamland, about it all; and he falls into a reverie. He is watching the emergence of the primal forms of the flowering plants in the Cretaceous period; and as he watches, the problem is ever changing, just as one moving picture melts into another on the screen. Those old genera become the genera of today; and the genera of today, though the genera of a thousand ages, are "but as yesterday" in the history of the flowering plants. As he looks to see what happened in the "great between" he sees dim pictures of the translation of continents and seas, scenes where all is mutable except the organic shapes, and they seem to have no beginning and no end. The pre-Cretaceous history of these plants is presented as occupying untold ages that in their extension towards eternity transcended a thousandfold the time that has since elapsed.

Returning to his waking self he realizes that his point of view of the story of plant-life on the earth has shifted, and that his previous sense of values has altogether disappeared. The eons he has lost in the history of the plants, to the study of which he has devoted his life, carry him back to ages seemingly co-eval with those he had been accustomed to regard as possessing the first traces of organic life; and his interest in the order of succession of the great plant-groups has left him. He does not even trust himself to state the problem of Evolution. There are no modern problems, he laments. "All seems eternal now."

Yet the new lesson was there for him to learn. In the woods around him were growing the Liquidambar, the Sassafras, and other shrubs and trees that had flourished in the Mesozoic ages in the spot where he was standing. Their remains crowded the Cretaceous deposits exposed in the cliffs near by. Specimens of the past and of the present were in his hands. Though the difference in kind was very slight, he reflected that the difference in time, measured in human lives, amounted almost to eternity. It is a story of perpetuity rather than of change, he perceived; and it is one that for a long while we have been trying to decipher from the wrong end. We must write it all afresh from its beginnings.

Redland, Bristol, England.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Analytical Weighing.*—Since it appears that many chemists at the present time regard the use of long swings of the analytical balance as the best and most accurate method of weighing, since many recent text-books on quantitative analysis advocate this process, sometimes without even mentioning a simpler method, and since the teaching of long swing weighing has evidently grown in favor in recent times, Horace L. Wells, of the Sheffield Scientific School, has discussed methods of weighing and has presented a plea for the general use of short swings of the balance in weighing.

He argues that the long swing presents no greater absolute variation than a short one for the same difference in weight, because the balance acts as a pendulum and hence tends to swing equal distances on each side of the point of rest, whether the swings are long or short. With short swings the point of equilibrium may be readily observed as the middle point of the swing, but with very long swings there is a large retardation in each movement and a series of observations, with a complicated calculation, is required to find the point of equilibrium. The long swings cannot be read as easily and accurately as short ones on account of the more rapid movement of the former. The calculation of the point of equilibrium from long-swing readings is mathematically inexact, because the retardation diminishes with the length of the swing while the means of the values on each side are used in the calculation. For instance, with a retardation of $\frac{1}{4}$ of the distance from the starting point to the center, the latter being the point of rest, the swings $+ 10{\cdot}0$, $-7{\cdot}5$, $+ 5{\cdot}6$, $-4{\cdot}2$, $+ 3{\cdot}2$ are calculated, which give the point of equilibrium as $+ 0{\cdot}4$ instead of the correct point, 0; whereas swings $\frac{1}{20}$ the length of the others would give the readings $+ 0{\cdot}5$, $-0{\cdot}4$, $+ 0{\cdot}3$, $-0{\cdot}2$, $+ 0{\cdot}2$ from which the true center would be readily indicated by observation. The article presents several other arguments against the use of long swings, but these need not be mentioned here.

The conclusion of the article is as follows:

"If the arguments presented here are sound, as they appear to be, it is certainly very remarkable that many chemists have considered it desirable to force the reluctant analytical balance, when close to equilibrium, to give long swings, in place of its natural short ones, in order to do a vast amount of useless work. The suspicion is unavoidable that the simple pendulum principle of the balance has been lost sight of in the entirely false expectation that the absolute variation of a swing would be increased by lengthening it. Possibly it has been supposed that short swings would be more likely to stop or to be erratic than long ones, but this is contrary to the very great amount of experience of those who use short swings, and it is contrary also to the precepts of high authorities, such as Fresenius and Carnot, already alluded to in this article. There is little doubt that many have merely followed the example of others in adopting this astonishing practice, without due consideration of the matter, and perhaps the mathematical and physical aspects of the method, or possibly its spectacular features, have had some influence in leading to its adoption.

It is to be hoped that all recommendations of long-swing weighing will soon disappear from our text-books of quantitative analysis, so that our future workers in chemistry may not be in danger of being burdened with a preposterously laborious method."—*Jour. Amer. Chem. Soc.*, **42**, 411. H. L. W.

2. *The Use of Cupferron in Quantitative Analysis.*—The ammonium salt of nitrosophenylhydroxylamine, $C_6H_5.N.NO.ONH_4$, to which the shorter name cupferron was given as indicating the fact that copper and iron are precipitated by its use as a reagent, has attracted considerable attention among analytical chemists since its introduction about 10 years ago, and it has been frequently employed for quantitative separations and determinations. G. E. F. Lundell and H. B. Knowles, of the U. S. Bureau of Standards have recently performed a useful service by reviewing the possibilities and limitations in the employment of this reagent in connection with a study of their own in regard to its application for the determination of zirconium in its ores and metallurgical products. It is their conclusion that cupferron can be used advantageously in certain separations, such as iron from manganese, and iron and titanium from aluminium and manganese, but that many elements interfere with its use in the quantitative determination of copper, iron, titanium, zirconium, thorium and vanadium. Not only does each one of the elements just mentioned interfere with the determination of any of the others, but it is to be observed that there are many other interfering substances, such as lead, silver, mercury, tin, bismuth, cerium, thorium, tungsten, uranium in the quadrivalent condition, silica, and in certain cases when present in large amounts, phosphoric acid, alkali salts and alkaline earths. It is evident that the reagent should be employed only with proper precautions.—*Jour. Indust. Engr. Chem.*, **12**, 344. H. L. W.

3. *A Course of Practical Chemistry for Agricultural Students,* Volume II, Part I; by H. A. D. Neville and L. F. Newman. 8vo, pp. 122. Cambridge, England, 1919 (at the University Press).—The little book under consideration is the first of two parts of the second volume, the whole work consisting of three volumes. This part is devoted to such exercises in

pure organic chemistry as are considered essential for agricultural students, and is entirely qualitative, while a second part deals with quantitative estimations and technical analyses of food stuffs.

This first part presents a course of 22 laboratory exercises, giving explicit directions for the experiments, with explanatory notes in each case. The experiments are generally very simple in character, but they should give the student considerable familiarity with the more important classes of organic compounds that are important in connection with agriculture.

H. L. W.

4. *The Magnetic Susceptibilities of Certain Gases.*—Accurate experimental determinations of the magnetic susceptibilities of gases are very important for at least two reasons, (a) the number of gases heretofore investigated is small and the data obtained by different observers for the same gas are, in some cases, highly discordant, and (b) various theories of magnetization have been advanced from time to time which do not agree in all of their consequences and which can be tested and differentiated only after reliable data have been obtained.

The latest theory of magnetization of gases was developed by K. Honda and J. Ôkubo. According to the kinetic theory the molecules are assumed to rotate around their centers of mass as well as to experience translation between impacts. In the magnetic theory in question the molecules are treated as gyroscopes whose axes of rotation do not coincide, in general, with the magnetic axes. Accordingly the magnetic moment of a molecule is supposed to be resolved into two components one of which coincides with the axis of rotation and the other, perpendicular to this axis. Under the influence of a magnetic field the paramagnetic polarization arises from the parallel component and the diamagnetic polarization from the perpendicular component, the resultant polarization being the sum of the two. The resultant may be positive or negative according as the paramagnetic polarization is greater than, or less than, the diamagnetic polarization. This theory shows that the sign of the magnetization of a gas depends upon the shape of the molecules but not upon their magnetic moment.

In order to test this theory and other theories, and to obtain reliable numerical data, the magnetic susceptibilities of certain gases have been recently investigated by Také Soné. For details of the fairly complicated apparatus employed the reader must be referred to the original article. However, emphasis should be laid on the facts that the investigator took elaborate precautions to obtain the gases in as pure a condition as possible and that the entire work seems to be very thorough and trustworthy.

In the case of dry air the magnetic susceptibility was determined relatively to pure water as standard, the reliable value

—0·720 $\times$ 10^{-6} being assumed for the liquid. All the other gases studied were referred, in turn, to air as fundamental substance. The magnetic field was produced by a Weiss electromagnet, the pole pieces of which were adjusted at 1 cm. apart. For an exciting current of 10 amperes the region of the field involved had an intensity of 20,000 gauss.

The numerical data obtained are of sufficient general scientific value to merit quotation. The specific susceptibilities (χ) when multiplied by 10^6 are given as +23·85, +104·1, 0·423, —0·265, —0·360, —5·86 and —1·982, and the magnetic susceptibilities ($\kappa \cdot 10^6$) as +0·03084, +0·1488, —0·000836, —0·000331, —0·000452, —0·0104, and —0·0001781 for air, oxygen, carbon dioxide, chemically pure nitrogen, atmospheric nitrogen, argon, and hydrogen, respectively. The specific susceptibilities are referred to the state at 20° C., and the volume susceptibilities to that at 0° C. and 76 cm. pressure.

The usual assumption that the specific susceptibility of a gas is independent of the pressure was found to be valid, within the limits of experimental error, throughout the entire range of pressures employed, that is, from 1 to 68 atmospheres. The excellent agreement between the values obtained for air by direct experimentation and by calculation from the like data for the separate constituents of air showed not only that the numbers are dependable but also that the additive law underlying the computation holds. Incidentally, it was found that the susceptibility of air may not be calculated from that of oxygen alone but that the susceptibilities of argon and nitrogen have to be taken into account too, as the last named gases contribute about one per cent. to the total magnetism of air. Another important fact brought out by the investigation under review is that gaseous carbon dioxide is diamagnetic, whereas heretofore it had been supposed to be paramagnetic. The last part of the paper deals with the bearing of the experimental data on the various theories of magnetism. The conclusion finally reached is that, with the addition of a few reasonable auxiliary assumptions, the theory of K. Honda and J. Ôkubo accounts for the observed facts,—quantitatively as well as qualitatively,—better than any of the other theories proposed up to the present time.—*Phil. Mag.*, **39**, 305, 1920. H. S. U.

5. *A New Cadmium Vapor Arc Lamp.*—Intense sources of practically monochromatic radiations are important for many investigations in physical optics and spectroscopy but, unfortunately, the number of such sources at present available is very small. Lamps containing pure cadmium in transparent silica envelopes have indeed been designed and successfully used (Michelson, Fabry and Buisson, *et al.*). The employment of these lamps, however, is usually attended by serious difficulties, such as: the necessity for keeping the lower portions of the lamp cooled by running water, the adhesion of the metal to the

silica walls often resulting in the fracture of the container, the automatic increase in pressure requiring frequent pumping, the relative complexity of construction making repairs troublesome, etc. Accordingly, a brief account of a new cadmium lamp designed and tested by F. BATES, which seems to be free from all of the serious inconveniences pertaining to the earlier forms, may not be without interest.

The fundamental idea was to find a chemical element that would readily alloy with cadmium and possess a relatively low vapor pressure. It was discovered by trial that the rare metal gallium fulfilled the conditions admirably. The author says: "In fact, the addition of a few drops of gallium to ten or fifteen cubic centimetres of cadmium completely changed the texture of the latter, rendering it relatively soft and greatly reducing its tensile strength. Subsequently it was discovered that upon distilling the cadmium from the alloy at a pressure of 0·001 mm. of mercury, the minute quantity of gallium carried through was sufficient to completely change the character of the cadmium and to prevent adhesion between the cadmium and the walls of the lamp."

When finally filled and sealed off from the pump, the shape of the lamp was that of the letter U inverted, ∩, the lower ends consisting of vertical capillary tubes. The total internal volume of the silica envelope was about ten cm^3. The electrodes were made of tungsten wires which projected above the upper ends of the capillaries into the gallium-softened cadmium. The lower ends of these wires and of the capillary tubes were closed with lead seals of the type described by Sand. The precautions taken in filling a lamp of this kind may not be recounted in this place.

The lamp may be started by heating with a flame to vaporize some of the metal. The lead seals alone must be kept cool by directing a current of air against them. The energy required may be conveniently obtained from the ordinary 110 volt lighting mains. The lamp will operate continuously with a current as small as 3 amperes accompanied by a drop of 14 volts across the terminals. "The most satisfactory results, however, are secured with a current of about 7 amperes and a drop across the terminals of about 25 volts. Under this condition a practically pure cadmium spectrum of great brilliancy is obtained." The fact that the author found it difficult to bring out even a few of the gallium lines is just what might have been predicted from the spectroscopic behavior of this metal and the conditions of excitation prevailing inside the lamp.—*Phil. Mag.*, **39**, 353, 1920. H. S. U.

6. *The Inertia of a Sphere Moving in a Liquid.*—In connection with certain war-work on the oscillating mine G. COOK had occasion to make some observations on the speed and linear acceleration of spherical solids falling in water. It has been

shown long ago by Stokes that, when a solid body is in motion in a frictionless fluid of infinite extent, the effect of the fluid pressure is equivalent to an increase in the apparent inertia of the body. In the special case of a sphere this increase is theoretically equal to one-half of the mass of the fluid displaced. Accordingly some interest attaches to Cook's investigation from the theoretical, as well as from the practical, point of view.

The fluid used was water and it was contained in a cylindrical tank 15 feet in diameter and 30 feet in depth. The spherical body consisted of a mine-case 38·2 ins. in diameter, having a displacement of 1080 lbs., and being so ballasted as to weigh hydrostatically approximately one pound. A light cord ran from the mine-case around the drum of a specially-designed chronographic instrument that produced a graphical record from which simultaneous values of the speed and acceleration of the descending body could be readily calculated.

When the acceleration was plotted as ordinate against the square of the speed as abscissa it was found that the points could be represented,—within the limits of accuracy of the experimental data,—by the following linear relation

$$\frac{dv}{dt} = 0{\cdot}0193 - 0{\cdot}0494\, v^2.$$

Comparing this empirical equation with the more general formula

$$\frac{dv}{dt} = \frac{F}{M'} - \frac{kv^n}{M'},$$

and being given that $F = 0{\cdot}950 \times 32{\cdot}18$ poundals, it is clear that $n = 2$ and $M' = 1584$ lbs. Hence, the effective inertia M' is 1·47 times the displacement of the spherical body. Under the experimental conditions, which did not conform in all respects to the analytical hypotheses, the agreement between 1·47 and the theoretical value 1·50 may be considered as quite satisfactory. Incidentally, on the assumption that the resistance R is proportional to the square of the diameter of the sphere, that is, $R = k'd^2v^2$ the value of k' was calculated to be 0·241 ft. lb. sec. units.—*Phil. Mag.*, **39**, 350, 1920. H. S. U.

7. *Osservazioni e Ricerche Sperimentali sulle Scintille Continue;* by Lavoro Amaduzzi. Pp. 61, 12 figures, 2 plates. Bologna, 1919 (Nicola Zanichelli).—The material of this monograph is conveniently divided into three chapters. The first chapter is largely introductory and it contains a review of Hemsalech's and of Righi's classifications of electric sparks, a description of the type of apparatus suitable for the production of the four kinds of sparks, and a brief account of the present status of the problem. This part of the text is illustrated by a full-page plate presenting fourteen colored figures of electrical discharges.

The second and third chapters constitute the first and second parts of the author's experimental investigations. In the first part he enters into the details of the new experiments at some length and endeavors to correlate the observations that have been heretofore disputed. For example, he studied the dependence of the variations in the appearance of the discharge and of the number of discharges per second upon the resistance of the circuit, the effect of blowing streams of air across the spark-gap in various directions and through perforations in hollow spherical brass electrodes, etc. The second part of the research pertains to a special manifestation of the continuous spark, so-called. In it the author adduces experimental evidence to substantiate his hypothesis that the emission accompanying the pilot spark of a discharge in a circuit containing very high resistance has such characteristics as show its close relation to, but not its identity with, the discharge in rarefied gases.

On the whole, the work is valuable not only as a contribution to the experimental side of the subject but also because of the unifying point of view attained. On the other hand, the conclusions reached seem to be lacking somewhat in finality for the reasons that the colors were not analyzed spectroscopically and the number of gases studied was not sufficient to afford material for broad generalizations. H. S. U.

8. *Ions, Electrons, and Ionizing Radiations;* by JAMES ARNOLD CROWTHER. Pp. xii, 276, with 95 figures. New York, 1919 (Longmans, Green & Co.).—"The present volume is intended solely as a text-book from which students who have been grounded in the more elementary portions of Physics might obtain a systematic knowledge of its latest developments." The material selected may be roughly classified as pertaining to (a) the nature and properties of ions and electrons, and the phenomena involved in electric discharges in gases at atmospheric pressure and at lower pressures, (b) α-, β-, γ-, and X-rays, (c) radio-activity, and (d) the electron theory of matter.

The classical experiments of J. J. Thomson, Kaufmann, and others are deservedly described at some length, whereas less epoch-making investigations are wisely presented with more emphasis on the general principles involved than on the precise details of the experiments as actually performed by any one individual. To avoid undue distraction of attention the author has reduced the mathematical analysis to a minimum. The diagrams and type are large and clear, and the number of mechanical errors is very small. The chief adverse criticism that can be made fairly is that certain parts of the text are not presented in an up to date manner, thereby incurring the risk that the student may acquire impressions which will subsequently have to undergo appreciable modification and correction. This remark applies especially to the chapter (X) on X-rays. H. S. U.

II. Geology and Natural History.

1. *The Tetracentron-Drimys Question;* by G. R. Wieland (communicated).—Are *Tetracentron, Trochodendron,* and *Drimys* Specialized or Primitive Types? By W. P. Thompson and I. W. Bailey, Mem. New York Bot. Garden, vol. **6**, August, 1916, pp. 27-32, pls. 2-4.—The work here cited has been continued, but is recorded in its simpler phase as an instance where botanists disagree, and might continue to do so, were no Paleobotanic data available. As in so many instances, the evidence involves either an outright contradiction, or appears to permit both positive and negative inferences, with the balance in favor of either so even that biased opinion is difficult to avoid. The problem in itself is one of the most far reaching in structural botany, and it does seem that the larger facts of the fossil record may be conclusive.

The genera cited are of primitive wood type since they possess diffuse parenchyma, and show no vestiges of vessels in the root, the seedling, node, leaf, or other supposedly conservative regions. The fact that the stem-wood is without vessels has long been known, as also in *Zygogynum.* But it had been contended that vessels were earlier present, and that neither the *Araucaroid* pitting seen in *Drimys,* nor the scalariform wood of *Trochodendron,* could then be analogous to such features in coniferous stems. A heavy burden of proof rests on these views; for the resemblance to the tracheids and to the wood of pines is a very complete one.

The wood structure of the Magnoliaceæ, in passing from *Drimys* to the "tulip tree" is, if read forward, a virtual record of stem evolution from cycadeoid or old pine-like woods to differentiated angiospermous woods with abundant vessels. But if read backward, that is, as a series of reductions, post-Jurassic evolution within the Magnolia group and its allies seems to lead to contradictory end-results! It is far simpler to look on stem, and flower, as in part old, still generalized and even plastic. Furthermore, in *Tetracentron* the leaf gap with its subtending tracheids is very suggestive of that of the cycadeoids,—a comparison which does not lose by reason of abundant scalariform tracheids in both cases (Trochodendron). It is only the stipular feature that is not reconciled (Cf. pl. 4). On turning to the main problem these facts appear:—

Firstly, no one fails to see that there has been much parallelism in wood development amongst conifers, and also amongst angiosperms, in Cretaceous time.

Secondly, amongst the Cretaceous conifers, where the stem record permits partial interpretation, disappearance of the more ancient types, and modification towards the recent forms, is in full view. Again and again the genera are most difficult to place because simple of feature, and so related to several of the later variously modified families. The series from Long Island, so fully and thoroughly described by Hollick and Jeffrey, well repays study in this connection. So too the far older and widely distributed *Xenoxylon*.

Thirdly, complicated ray structure is a fairly late or Cretaceous-Tertiary feature of phanerogams. To name almost any fossil stem is to cite an example in proof; and moreover, those simpler coniferous and angiospermous types are the very ones which have mainly suffered extinction, or left their more specialized descendents.

Fourthly, the *Magnolia-Liriodendropsis* complex finds its great expansion in the lower Cretaceous, just where the relative abundance as fossils indicates the culmination of the conifers. Thus in the Comanchean of Kansas there are two dozen characteristic leaf types. Of compelling interest is the Liriodendron series, not only because of transitions to elliptiform species, but exactly because *Liriodendron* has complex wood structure, and is now ditypic (eastern United States, China).

Of course all ideas of stem structure in the Comanchean and Cretaceous Magnolias must rest on inferences like those cited. But it would leave the greater question in a very sombre light indeed, if it were found that the *Liriodendron* assemblage of Comanchean time made the transition toward modern types, then reverted, and suffered extinction anyhow. It is rather to be supposed that the early Magnolias appear abundant exactly because generalized, and that the known facts cannot be appealed to as an instance of "reversible evolution." These few observations on a many-sided subject at least tend to show that *Liriodendron* retains a place among the two or three greatest of all North American forest trees, a place like that of the redwoods among conifers, because of specialization. While the lesser *Drimys* befitting a great range from Mexico to Tierra del Fuego, is older, with the *Trochodendron* wood ancient.

2. *Illinois Geological Survey*, Frank W. De Wolf, Chief.—Bulletin No. 37, by Gilbert H. Cady, is devoted to the geology and mineral resources of Hennepin and LaSalle Quadrangles; it is a volume of 136 pp. illustrated by 6 maps and 36 text figures; the work has been done in connection with the U. S. Geological Survey. The area lies on the northern edge of the Illinois Coal Measures; the most important formations are the Pennsylvanian, in which coal occurs in various horizons, the LaSalle coal being of greater persistence and the only one now being mined.

Bulletin No. 40 discusses the oil investigations made in 1917 and 1918. It is stated that while the production of oil is second only to that of coal, the fields are nevertheless on the decline. Some hope is held out that new fields may be discovered and better methods of oil extraction may be developed.

3. *Minnesota Geological Survey*, William H. Emmons,

Director. Bulletin No. 14; by FRANK LEVERETT and FREDERICK W. SARDESON; with a chapter on climatic conditions in Minnesota, by U. G. PURSELL.—This bulletin discusses the surface formations and agricultural conditions of the south half of the state.

4. *Geological Survey of South Australia.*—Bulletin No. 7 is devoted to the "Phosphate Deposits of South Australia" and has been prepared by R. LOCKHART JACK. The most valuable deposits are those of lime phosphate, almost invariably found in close association with the Cambrian limestones. As the Cambrian series is very largely developed and has only been prospected for phosphates within a short distance of transport facilities, it is reasonable to expect that there are many phosphate bodies yet to be discovered and developed. The aluminium phosphate exists in considerable quantity at St. Johns and elsewhere but at present is not practically available.

5. *Vertebrate Zoology;* by HORATIO HACKETT NEWMAN. Pp. xiii, 432, with 217 figures. New York, 1920 (The Macmillan Company).—Teachers of the comparative anatomy of vertebrates have long felt the need of a suitable book to supplement the practical dissections in the laboratory. This need is adequately supplied by the present book, which gives a fairly comprehensive account of the classification, relationships and natural history of each of the classes of vertebrates. Particular emphasis is laid on the origin of the different groups as indicated by the ancestral forms in the paleontological record. The important theories concerning the ancestry of the vertebrates are discussed, and the living forms which have been supposed to represent ancestral types are described in detail. The organ systems of the representative examples of each class are properly left for the teacher to describe as a basis for the explanatory lectures which will naturally accompany the laboratory work.

The aim and general conceptions of the book are admirable and the subjects are as a rule well presented. A number of errors and inconsistencies of statement, however, indicate hasty proof-reading. The illustrations are also of the highest merit.

W. R. C.

6. *Mendelism;* by REGINALD CRUNDALL PUNNETT. Fifth edition; pp. xv, 219; with 7 plates and 52 text-figures. London, 1919 (Macmillan & Co.).

The great interest now taken in the problems of inheritance is well attested by the wide circulation which this book has had since its first appearance in 1905. Six editions have been printed in England and America, and it has also been translated and published in Swedish, German, Russian and Japanese. The book gives an excellent general account of the great progress made during the past few years in this important branch of biology. It is clearly written, with the avoidance of unnecessary technical terms, and is well illustrated by diagrams, text-figures and colored plates.

For those unfamiliar with the earlier editions it should be stated that in addition to the general explanation of the Mendelian principles of heredity, with typical illustrations from plants, animals, and man, there are chapters on variation and evolution in the light of the Mendelian discoveries; the economical aspects of increased crops and improvement of breeds of domesticated animals by application of the Mendelian laws; and, finally, the possibilities of applying these discoveries to the human race, with a view to the ultimate elimination of the unfit and defective stocks and the realization of superior races of mankind through the selective marriages of those with the best germ-plasm. W. R. C.

7. *Inbreeding and Outbreeding; their Genetic and Sociological Significance;* by EDWARD M. EAST and DONALD F. JONES. Pp. 285, with 46 illustrations. Philadelphia and London, 1919 (J. B. Lippincott Co.).—In this new volume of the series of Monographs on Experimental Biology the authors devote the four introductory chapters to a general account of the methods of reproduction and the mechanism of heredity in various groups of organisms. The succeeding chapters give the results of recent experiments in inbreeding and cross-breeding in many groups of plants and animals, with evidence and theoretical explanations of hybrid vigor, followed by a discussion of sterility in close and wide crosses and the rôle of inbreeding and outbreeding in evolution.

The authors demonstrate that the popular notion that even the closest inbreeding tends to degeneracy or sterility or other undesirable result is not in accord with the evidence either of experiment or of natural reproduction. Such inbreeding merely produces uniform strains of such characteristics as are present in the parental stocks. Therefore it is only in stocks which carry heritable defects that such defects appear according to the Mendelian law in the offspring. The superior characteristics which may be present in these stocks will likewise make their appearance, and by the selection and breeding of such offspring as show these desirable qualities a greatly improved breed may be established.

The benefits of moderately wide crosses, resulting in exceptional vigor in the first generation, are explained, with practical directions for securing the maximum production in crops and in domesticated animals and with many suggestions for the improvement of breeds. The last two chapters deal with human heredity, showing the results of various racial crosses and discussing the sociological problems involved. A sound and logical plan is outlined which would, if followed for a few generations, lead to a great improvement in both the physical and mental constitution of mankind and the elimination of a large proportion of human misery. W. R. C.

III. Miscellaneous Scientific Intelligence.

1. *The Carnegie Foundation for the Advancement of Teaching. Fourteenth Annual Report of the President,* Henry S. Pritchett, *and Treasurer,* Robert A. Franks.—The fourteenth year of the Carnegie Foundation closed on June 30, 1919. Since the beginning it has distributed seven million dollars in retiring allowances and pensions to 852 persons. There are now operative 347 retiring allowances and 183 widows pensions; the allowances average $1,943, the pensions $971. Of the total expenditures, $5,600,000 went to the associated list of 73 institutions. Of this total Harvard has received $556,000; Yale, $491,000; Columbia, $405,000; Cornell, $326,000; Amherst, Johns Hopkins, Massachusetts Institute of Technology, Princeton, Stevens Institute of Technology, Tulane University, the Universities of California, Michigan, Minnesota, Missouri and Wisconsin, each received more than $100,000, the average for these eleven institutions being $130,000.

The resources of the Foundation were increased during the year by three and one-third million dollars, two and one-half million from the Carnegie Corporation and the remainder from accumulated income. The total resources now amount to $21,-643,000, representing the permanent general endowment of $13,150,000, the endowment of the Division of Educational Enquiry of $1,250,000, and three reserve funds. One reserve fund, now amounting to $6,512,000 and increasing at the rate of six hundred thousand dollars a year, is to be spent, principal and interest, in the retirement during the next sixty years of the six thousand teachers now in the associated institutions. Another reserve fund, now a third of a million dollars, is to be accumulated to one million dollars and expended, principal and interest, in aiding universities and colleges to adopt the new plan of contractual contributory annuities inaugurated by the Foundation during the year. This plan has been formally adopted by twenty-nine institutions.

The Teachers Insurance and Annuity Association, established to carry out this plan, contracted for annuities representing one million dollars and life insurance representing three-quarters of that sum during the first six months of operation, and more than double these amounts during the first year. The Association is in no sense a rival of commercial insurance companies, having been established with a gift of one million dollars to provide for teachers in universities and colleges (without overhead cost), contracts of insurance and annuities that are inexpensive, especially adapted to the needs of teachers, and not to be had elsewhere.

The present report, the first issued since Mr. Carnegie's death, contains a tribute to his service to the teacher, remarkable in one who had had little formal education and no enduring recollection of any teacher who had realized for him personally the service of all teachers. ''His effort to be of service to the college teacher was part of a general desire to strengthen those forces in the social order that make for progress, for finer and simpler living, for nobler ideals. * * * It is one of the great satisfactions of Mr. Carnegie's trustees that he lived to take part in the working out of the plan now adopted, and that every step by which the original pension system has been transformed into a contractual and contributory plan was taken with his approval.''

Part III of the Report contains an interesting chapter on recent developments in the establishment of pensions in this country and in England. The Department of Educational Enquiry (Part IV) discusses certain current tendencies in Education. It also gives a summary of a bulletin just issued on ''Justice and the Poor'' as involved in legal relations. Legal education and the training of teachers are other subjects discussed, which call for careful consideration.

2. *Meeting of the National Academy of Sciences.*—The annual spring meeting of the National Academy was held in Washington in the U. S. National Museum on April 26 to 28. The advance program contained the titles of thirty-nine papers. The William Hale Ellery lectures this year discussed: ''The Scale of the Universe'' by Harlow Shapley of the Mount Wilson Solar Observatory, and Heber D. Curtis of the Lick Observatory. Further details will be given in the following number.

As affecting the future growth of the Academy, and its ability to more fully and satisfactorily perform the work for which it was organized, it is important to note that ''The Carnegie Corporation of New York has announced its purpose to give $5,000,-000 for the use of the National Academy of Sciences and the National Research Council. It is understood that a portion of the money will be used to erect in Washington a home of suitable architectural dignity for the two beneficiary organizations. The remainder will be placed in the hands of the Academy, which enjoys a federal charter, to be used as a permanent endowment for the National Research Council. This impressive gift is a fitting supplement to Mr. Carnegie's great contributions to science and industry.''

3. *Carnegie Institution of Washington.*—The latest publications of the Carnegie Institution are as follows:

No. 272. Contributions to Embryology. Vol. **9**, Nos. 27-46. Quarto, pp. v, 554, with numerous plates and text-figures. This volume is a memorial to the late Franklin Paine Mall, and the papers are contributed by former and present members of his staff in recognition of his inspiring leadership.

No. 282. Experiments in the breeding of Cerions; by Paul Bartsch. Pp. 55, 59 plates. Vol. **14** from the Department of Marine Biology.

No. 288. Hydration and Growth; by D. T. MacDougal. Pp. vi, 176.

No. 289. Fluorescence of uranyl salts; by E. L. Nichols and H. L. Howes, in collaboration with Ernest Merritt, D. T. Wilber and Frances G. Wick. Pp. 241.

4. *Water Power Development in Canada.*—A recent circular gives a detailed statement of the developed water power in Canada to Jan. 1, 1920. It states that "according to the statistics just compiled there is installed throughout the Dominion some 2,418,000 turbine or water-wheel horse power of which 2,215,000 horse power is actually and regularly employed in useful work. A large number of the plants now operating are designed for the addition of further units as the market demands. The ultimate capacity of such plants, together with that of new plants now under construction, total some 3,385,000 horse power. Of the total power installed, 1,756,791 h. p. or 72·7 per cent, is installed in central electric stations, which are engaged in the development of electrical energy for sale and distribution, for lighting, mining, electro-chemical and electro-metallurgical industry, milling and general manufacturing. In the pulp and paper industry 473,265 h. p. is utilized of which 381,631 h. p. is generated directly from water in pulp and paper establishments while 91,634 h. p. is purchased from hydro central electric stations. Hydro power used for other purposes and other industries is distributed as follows: for lighting purposes 434,613 h. p.; in mining industry 177,728 h. p.; in flour and grist mills 42,736 h. p.; in lumber and saw mills 37,918 h. p.; in other manufacturing industries 172,955 h. p. These figures are evidence of the widespread manner in which the Dominion's water power resources are being applied to the furtherance of its industrial development." The circular gives further particulars as to distribution, cost, etc. The only country which has a larger water power development (274 h. p. per 1000 population) is Norway.

5. *Publications of the British Museum of Natural History.*—The following have been received:

No. 6.—Report on Cetacea stranded on the British Coasts during 1918; by S. F. Harmer. Quarto, pp. 24 (with two text figures and one map).

Economics Series No. 2.—Birds beneficial to agriculture; by F. W. Frohawk. The preface is written by the Keeper of Zoology, Sidney F. Harmer.

6. *Annual Report of Bureau of Scientific Advice for India for 1917-18.*—War conditions have materially limited the functions of the Board but the results are briefly stated in the number recently received. The Thirty-fourth meeting was held in Simla on May 30, 1918 and the Thirty-fifth meeting at Delhi, on the 9th of December, 1918.

OBITUARY.

ALFRED J. MOSES, 1859-1920. By the death on February 27th of Alfred J. Moses, professor of mineralogy at Columbia University, the science of mineralogy has lost one of its most eminent and valued exponents. Professor Moses's work as a teacher, as a writer and as a scientific investigator can hardly be too highly esteemed and his loss to all branches of his profession is most keenly felt. His text book on Mineralogy, Crystallography and Blowpipe Analysis will for many years remain the standard in a large majority of the universities in which courses in these subjects are given. His work on The Characters of Crystals published in 1899 is the first treatise published in America upon Physical Crystallography, a branch of Crystallography which was early recognized by him as of primary importance to chemists, geologists and mineralogists and which has within very recent years assumed a scope, and developed practical applications which have more than justified his early visions of its future. H. P. WHITLOCK.

PROFESSOR CHARLES LAPWORTH, the veteran English geologist, died on March 13 at the age of seventy-eight years. Americans will ever be thankful to him for working out the very difficult Ordovician succession, where the strata are of dark to black shales, on the basis of the entombed graptolites. He was a born stratigrapher, with a genius for discerning the minute differences in the rock and faunal sequence. *Nature* says of him in part:

"It happened that the landscape of the Southern Uplands concealed under an aspect of simplicity, but revealed to the eye of genius, a rock-structure of extraordinary complexity, to which there was apparently no clue except a few obscure pen-like markings, called graptolites, in the Moffat shales; and these had been tried for the purpose, but 'turned down' as useless. Lapworth, however, determined to give them a second chance, and, as a result of systematic collecting, a keen eye for a country, and a retentive memory for minute, but significant, lithological variation, accompanied by a more elaborate piece of geological mapping than his predecessors had ever attempted, succeeded in proving that they could be used to unravel a rock-succession, even though it was more crumpled, inverted, and tangled than any other then known. The rock succession and tectonic structure thus made out were tested against the simpler succession and relations and the more normal fossils of the Girvan area, and proved correct. At the same time, the graptolite zones that Lapworth had established were tested by comparison with successions made out partly by others, but mainly by himself at home, and by workers in Scandinavia, Bohemia, etc., proving that he had successfully performed at Moffat the double feat of working out the succession by means of the structure, and the structure by the succession. The success of his own graptolite work and the keenness with which it was being followed up by young observers, led him to propose a new classification of the Rhabdophora, and to contemplate a monograph on the Order. This has now been completed by Miss Elles and Mrs. Shakespear under his guidance and editorship.

"As a great teacher Lapworth earnestly desired to equip his students to take their share in furthering the advance of science and to remove anything that could retard its progress. It was only fitting that the man who had stilled the Lowland controversy, and wrested its secret from the Highlands, should give the law in the 'Silurian' controversy and make the opponents sink their differences by the adoption of his term 'Ordovician.'"

John Alfred Brashear, widely known for his work in the manufacture of astronomical and physical instruments, died at his home in Pittsburgh on April 8 in his eightieth year.

Sir Thomas P. Anderson Stuart, professor of physiology in the University of Sydney, died on February 29 at the age of sixty-four years.

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THE

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[FOURTH SERIES.]

ART. XXX.—*A Tiny Oligocene Artiodactyl, Hypisodus alacer, sp. nov.*; by EDWARD L. TROXELL.

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

When in 1873[1] Professor Cope described the type of *Hypisodus minimus*, "the smallest of artiodactyls," little did Professor Marsh suspect that in the collection made in 1870 for the Yale Museum there was a very well-preserved skull a little smaller even than the type of Professor Cope. The specimen comes to light now as a result of the revival in vertebrate paleontology at Yale, under the direction of Professor Lull, made possible by the generous bequest of Professor Marsh himself.

There is a peculiar interest attached to the very small mammals: the primitive ancestors were all of that type, apparently, but about the only ones left of those tiny creatures in the Oligocene are the rodents and insectivores. Our interest is especially drawn to the very small deer which are so little known, and particularly to *Hypisodus*, where we find for the first time in America the long-crowned teeth of a grazing animal.

The classification of these little animals has been a difficult problem, for their strange characters show them to be too advanced to be ancestral to any members of the allied even-toed ungulates. Doctor Matthew[2] says they are near the chevrotains of southern Asia, and that therefore their nearest American allies are the Hyper-

[1] E. D. Cope, Synopsis of new Vertebrata from the Tertiary of Colorado, p. 5.

[2] W. D. Matthew, Mem. Amer. Mus. Nat. Hist., vol. 1, pp. 440-442. Bull. Amer. Mus. Nat. Hist., vol. 16, pp. 311-316, 1902; vol. 21, pp. 24-26, 1905; vol. 24, pp. 535-562, 1908.

tragulines—this relation is based primarily on the foot structure—but they are far more advanced even than these in the modernization of the long-crowned teeth, the premolar reduction, the form of the occipital region of the skull, and the orbit surrounded by a thin prominent ring. They resemble in many respects the little Recent Abyssinian deer called *Madoqua,* about the size of a hare.

Because of the nature of the incisor-like form of the lower canine and the first premolars, these animals have been compared to *Stenomylus,*[3] and represented as the only offshoots from an isolated stem, immigrants from a northern center of dispersal. *Stenomylus* is limited to the lower part of the Miocene, while *Hypisodus* is known only from the Middle Oligocene, commonly called the Brule clays or Oreodon beds in Nebraska, Wyoming, and South Dakota, and the Cedar Creek beds in northeastern Colorado. In many respects *Hypisodus* is like the primitive camels, it is true, but the resemblance is chiefly in the possession of archaic characters which might ally it to any of several types. It may be near a central group from which spring the Tragulidæ (Hypertragulidæ in America) on the one hand, and the Tylopodidæ (camels, etc.) on the other, and Professor Scott[4] seems to favor the latter.

Personally, I have been impressed from the beginning of my study, in a rather superficial way, perhaps, with the very camel-like form and arrangement of the molars: in their much greater anteroposterior than transverse diameter; in the prominent para- and metastyles, especially on M^3; in the lake; in the widely separated and angular lobes of the lower molars; and in the remarkable hypsodonty of all the teeth. It is evident, however, that these little animals are slightly off the main line of camel descent, if we admit that *Poëbrotherium* is truly in the direct line, since it is impossible to derive the latter from an ancestor more modernized in skull and teeth. *Poëbrotherium* has forty-four teeth, none of which are other than short-crowned, and the orbits are not enclosed by a bony ring.

[3] This peculiar relation to *Stenomylus* might be again pointed out in the case of the early camels, in which even *Protylopus* and *Poëbrotherium* (this does not apply to *P. andersoni* with the large canines) have the lower canine and first premolar scarcely larger than the incisors.

[4] W. B. Scott, A History of Land Mammals in the Western Hemisphere, p. 409, 1913.

Doctor Matthew has figured and described the limb and foot bones, and it is evident that, in modernization, the teeth and skull are much in advance of the evolution of the foot structure. The third and fourth metatarsals are distinct, but appressed (they may coössify with age); in other words, there is no cannon-bone even in the hind foot, which is always the more progressive. Although the lateral metatarsals II and V are very slender and thread-like, they are complete, yet the pes is functionally didactyl. The cuboid and navicular are coössified, likewise the radius and ulna, and the tibia and fibula.

Several specimens are represented in the Marsh Collection, mostly fragments of the lower jaws or of maxillaries, out of which two specimens in particular will be

FIG. 1.

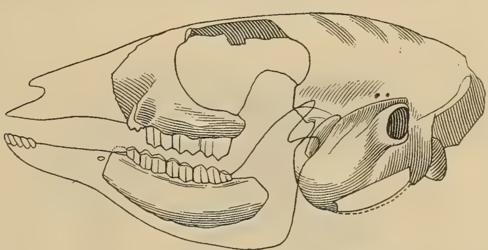


FIG. 1.—Skull and ramus of *Hypisodus alacer,* sp. nov. Holotype. Cat. No. 10033, Yale Fossil Vertebrate Collection. Natural size.

described, one the skull and ramus, the other a maxillary bone with the tooth series complete from the third premolar backward.

Hypisodus alacer, sp. nov.

(FIGS. 1-3.)

Of the holotype, Cat. No. 10033, Yale Fossil Vertebrate Collection, the skull and lower jaws alone were preserved, and of these the anterior parts are entirely gone. The skull is short and broad, the orbit large, and the otic bullæ so inflated that they occupy over a third of the vertical height of the skull. They seem to have had no cancellous tissue, are separated widely posteriorly, but in front are closely in contact. The external auditory meatus, situated well forward, opens at an angle of 45° toward the rear and is very large, having a diameter greater than that of the last molar tooth. The paramastoid processes are closely joined to the bullæ except perhaps at the tips. The occipital condyles are small compared to their wide separation of about 9 mm. The region above the occipital condyles is very full and heavy and, as Matthew states, furnished plenty of room for the large cerebellum.

Anteriorly the orbit extends well out over M^1 (a cameline character). Its antero-posterior diameter is over 14 mm., and above, the border curves well in toward the median line of the skull; at this point the frontal is not more than 7 mm. in width, giving an upward and forward direction to the eyes. The muzzle, which is lacking in the present specimen, is said to be slender, with no incisors in the premaxillary, but with a long post-canine

Fig. 2.

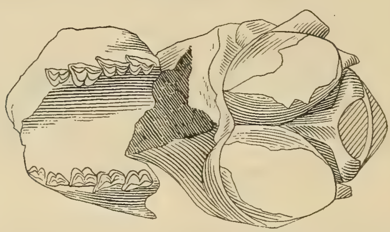


Fig. 2.—Palatal view of skull of *Hypisodus alacer*, sp. nov. Holotype. Cat. No. 10033. Natural size.

diastema. The palate forms a high arch and the molars are situated apart a distance equal to the length of the molar series.

The molar teeth are long-crowned or hypsodont, and in general form have the typical selenodont style of artiodactyl tooth. In the upper molars the anterior lobe of each is much larger, and therefore, because the inner borders are aligned, the teeth themselves are set at an angle, the metastyle (postero-exterior corner) rests against the middle of the tooth behind, while the parastyle (anterior) is set far out into the maxillary bone and overlaps the preceding tooth. Only in M^3 does the metastyle have room to develop a sharp fold, and thus the last superior molar is narrowed behind, forming what has been termed a "small heel column." A strong external ridge marks the position of the paracone, and in each specimen this part of the tooth stands highest. The metacone is compressed or planoconvex. The superior molars are not contracted at the root line, but carry the prismatic character of the crown beneath the border of the alveolus. The enamel is smooth on all the teeth, and there is no mesostyle.

The premolars $P^{3.4}$ are just appearing in the maxillary. P^4 has a veritable double lobe; the two cones corresponding to the para- and metacones of the true molars are distinct and the infolded crescents form lakes similar to those of the larger teeth. P^3 is similar to P^4; it has the two rudimentary cones and the two lakes, but these lakes are poorly formed, having very indefinite, low, inner borders resulting from the rudimentary condition of the protocone and hypocone (of molars).

The lobes of the molars in the mandible are all pris-

Fig. 3.

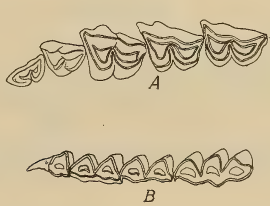


Fig. 3.—Crown view of (*A*) upper and (*B*) lower dentition of *Hypisodus alacer*, sp. nov. Holotype. Cat. No. 10033. Twice natural size.

matic, and are so uniform in size and form—including the posterior lobe of P_4—that it is difficult to differentiate the teeth. M_1 and M_2 each have two lobes; M_3 has three of nearly equal size, which slope forward slightly, and are not parallel but converge toward the crown. The antero-interior corner of each molar, the metastylid, consists of a very thin vertical edge folded inward at the line of contact with the tooth in front of it. The internal fold of enamel which gives rise to the lakes is early obliterated in the lower molars. The enamel is smooth on all the teeth and is exceedingly thin.

The fourth premolar in the ramus stands nearly perpendicular, and is composed of two or three lobes, the posterior one of which is molariform and might be taken for a part of the first molar. The anterior portion of the tooth is broken away and the thin root does not show whether or not it formed a single cone. This bit of information would be of especial benefit in distinguishing the species.[5]

The lower jaw is slender, and, judged from the imprint in the matrix, it has a long ascending ramus which slopes backward considerably as in the Camelidæ.

Hypisodus minimus Cope.

(Fig. 4.)

In this specimen, Cat. No. 10034, Yale Collection, a portion of the maxillary with the tooth series $P^{3.4}$, $M^{1.2.3}$, shows some very marked differences from that of the skull just described. In size it compares well with the type of *H. minimus*. The molars exhibit no basal shoulder but have distinct roots. They are hypsodont, except perhaps M^1, which is slightly more worn and

Fig. 4.

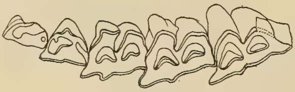


Fig. 4.—Crown view of upper molars and premolars of *Hypisodus minimus* Cope. Cat. No. 10034, Yale Fossil Vertebrate Collection. Twice natural size.

may be said to be subhypsodont; this tooth is smaller than M^3.

A minute sharp internal folding from the posterior corner of the protocone may be seen on $M^{1.2}$, but none appears on M^3. This is similar to an internal basal pillar, but is not basal in position. The valley between the internal lobes in M^3 is wide and open.

The fourth premolar resembles that of *Leptomeryx* rather than that of *Poëbrotherium,* the deuterocone being compressed longitudinally so as to give the tooth the form of a triangle. This cone is not high but is situated

[5] In all other specimens at hand, the more typical premolar has three cusps, the paraconid, protoconid and hypoconid appearing distinct on the outer side. These premolars have the appearance of milk teeth in the later forms, but we would not expect to find unworn milk teeth in a ramus along with well worn molars; furthermore, they are not three-"lobed" but simply have the three cusps—para-, proto-, and hypoconid—accentuated, a condition which we find in *Poëbrotherium* and other forms. Along with this type of fourth premolar, in the other specimens, we find P_3 with the same general composition of cusps, but of reduced size.

so low on the inner side of the tooth that in a well-worn specimen it is still distinct enough to remain separated and posterior. P^3, almost brachyodont, is compressed and trenchant, but yet has a lake entering between the deuterocone and tetartocone and running anteriorly to the paracone; in this it resembles P^4. On the molars and premolars of this specimen the lakes and crevices are filled with cement.

Summary.

Because of the difficulty of finding and collecting the parts of this tiny animal, its skeleton is not very well known. It is the earliest hypsodont artiodactyl yet found.

In attempts at classification, it has been placed with the camels, with the tragulids, and yet again separated out with *Stenomylus* to form an aberrant branch. The type is more advanced than the camels of the same period, but seems to fit in somewhere near *Leptomeryx* or *Hypertragulus,* and has also a slight resemblance to *Heteromeryx.*

Though the front limb is not known, the hind foot, generally the more advanced in evolution, still retains slender metatarsals II and V.

The specimen of *Hypisodus minimus* Cope in the Marsh Collection is a maxillary with five teeth (fig. 4); its size is close to that of Cope's type, and on that basis it will be classed with the latter. Several distinguishing features of the teeth may be enumerated: there is a fold on the posterior side of the protocone of both M^1 and M^2; M^3 is much larger than M^1 or M^2; the fourth premolar is triangular; P^3 is short-crowned and trenchant; and there is a coating of cement on many parts.

Hypisodus alacer, sp. nov., figs. 1-3, is about one-seventh smaller than the type of *H. minimus* Cope, as shown by applying the system of "ratios." The teeth are simpler than those of the other species, and the upper molars are of uniform size, M^3 being one-fifth smaller than Cope's type. Both P^3 and P^4 simulate the true molars in having two lobes each. The metastylid is well shown, and the posterior lobe of P_4 is molariform.

Measurements.	Cope's type of *H. minimus*	Ratios	*H. alacer*,[a] sp. nov.	*H. minimus*[b]
Length of three superior molars	·0120	91·7%	·0110	·0130
Length of last molar	·0050	80	·0040	·0059
Width of last molar	·0030	83·3	·0025	·0033
Length of five molars and premolars..			·0157	·0173
Length of three lower molars	·0130	90	·0118	
Length of third lower molar	·0058	86	·0050	
Width of third lower molar	·0025	92	·0023	

[a] Cat. No. 10033, Yale Coll.
[b] Cat. No. 10034, Yale Coll.

Art. XXXI.—*The Wasatch and Salt Lake Formations of southeastern Idaho;* by George Rogers Mansfield.[1]

Among the stratigraphic problems disclosed by the Geological Survey's detailed study of the phosphate beds in southeastern Idaho that of the Tertiary deposits is worthy of mention. The region thus far studied includes the Fort Hall Indian Reservation and the Montpelier, Slug Creek, Crow Creek, Lanes Creek, Freedom, Henry and Cranes Flat quadrangles, a total area of nearly 3,000 square miles; see fig. 1.

Tertiary system.

The Tertiary system in this region is represented by patches of sediments that vary greatly in texture, thickness, character, and degree of consolidation and that lie unconformably upon rocks of the older systems. Two series of these beds have been differentiated. The earlier of these is with little doubt largely Eocene. The later series presents conflicting paleontologic evidence. The available fossils are few and poorly preserved, chiefly gastropods. Some of them suggest Eocene age and others Pliocene. Possibly Oligocene beds may be included in one of the divisions. The later series of beds has long been tentatively considered Pliocene and it appears unwise to change this reference until more satisfactory evidence is available. The correlation of the various Tertiary patches thus rests mainly upon lithologic and structural data. The distinction between Eocene and Pliocene (?) in this region is locally difficult where limestones of the two groups are in contact or proximity. Thus certain beds now referred to the Pliocene (?) may prove to be Eocene. The combined thickness of the two Tertiary formations is probably more than 2,500 feet.

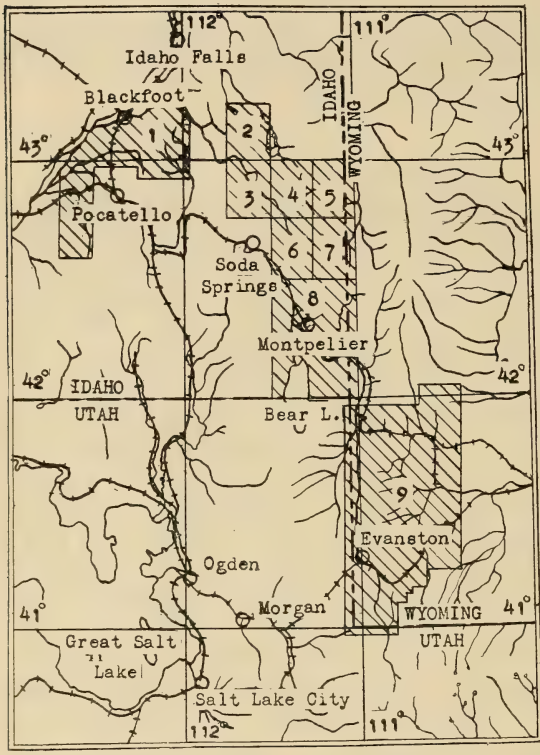
Eocene series.

The beds assigned to the Eocene series consist of conglomerates, soft sandstones, and fresh water limestones. They are referred to the Wasatch formation. The unconformity at their base is very pronounced.

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

Wasatch formation.—The Wasatch formation was named by Hayden[2] in 1869 from Wasatch station on the Union Pacific Railroad in Summit County, Utah.

The Wasatch deposits in neighboring regions of southwestern Wyoming have been subdivided by Veatch[3] into three formations: (1) the Almy formation at the base, consisting of reddish-yellow sandstones and conglom-



Explanation

1. Fort Hall Indian Reservation
2. Cranes Flat Quadrangle
3. Henry Quadrangle
4. Lanes Creek Quadrangle
5. Freedom Quadrangle
6. Slug Creek Quadrangle
7. Crow Creek Quadrangle
8. Montpelier Quadrangle
9. Veatch Prof. Paper 56

Fig. 1. Index map, showing location of areas.

erates, in some places with deep red color; (2) the Fowkes formation, white or light-colored rhyolitic ash with some calcareous beds; and (3) the Knight formation, consisting of reddish-yellow sandy clays with irreg-

[2] Hayden, F. V.: [Third Ann.] Preliminary field report U. S. Geol. Survey of Colorado and New Mexico for 1869, p. 90, 1869.

[3] Veatch, A. C.: Geography and geology of a portion of southwestern Wyoming, U. S. Geol. Survey, Prof. Paper 56, p. 88, 1907.

ular sandstone beds, closely resembling (1) lithologically but separated from (1) and (2) by an unconformity.

G. B. Richardson,[4] and later P. V. Roundy, with the writer, have examined parts of the field described by Veatch. They have come to the view that the Fowkes formation may in reality be a lens and that the postulate of unconformity between the Knight and Almy formations, which closely resemble each other lithologically, is doubtful or, at least, not compulsory. More extended study of the Tertiary formations of the general region of southwestern Wyoming and northern Utah will be necessary before a definite opinion on the matter can be rendered.

In southeastern Idaho the Fowkes formation has not been definitely recognized although at one locality rhyolitic debris has been found in beds at present assigned to the Pliocene (?). It is, too, impracticable to distinguish the Almy and Knight formations. The Eocene rocks are therefore described under the name Wasatch formation.

The principal areas occupied by the Wasatch formation are in the Bear Lake Plateau, southeast of which the formation is practically continuous with the Wasatch beds described by Veatch in southwestern Wyoming, and west of Bear Lake. Northward there are patches of greater or less size in parts of the Montpelier and Slug Creek quadrangles. The irregularities of shape, size, and distribution of these patches of the Wasatch formation all indicate that the sediments now found are but erosional remnants of a formerly much more extensive deposit.

The Wasatch formation of southeastern Idaho, so far as examined, consists mainly of coarse red conglomerate with pebbles or bowlders ranging from a fraction of an inch to three feet or more in diameter, largely subangular, though some are well worn and rounded, and consisting chiefly of Paleozoic quartzites and limestones, including many of Cambrian and Ordovician age. In the southeastern part of T.10S., R.43E. (southern part of the Slug Creek quadrangle) bowlders of basalt were noted with the conglomerate. The grouping of the bowlders is such as to suggest a small extrusion. Since no actual ledge of basalt was observed, these bowlders may have formed part of the conglomerate, though their

[4] Personal communication.

relatively fresh condition would make this seem unlikely. In the same locality, associated with the conglomerate, is a dense tan-colored limestone with included brecciated pisolites of dark gray, concentrically banded, crystalline limestone, half to three-fourths of an inch in diameter. There are also beds of non-pisolitic limestone of similar color and appearance. In the Montpelier quadrangle coarse red sandstones, locally concretionary, with minor amounts of reddish and purplish shales and limestone lenses or beds are associated with the conglomerates. In the vicinity of Glencoe west of Bear Lake isolated exposures of white pisolitic limestone, included in an area otherwise considered Pliocene (?) may represent inliers of Wasatch limestone uncovered by the erosion of white Pliocene (?) beds.

The exposed thickness of the Wasatch probably does not exceed 1,500 feet, but the beds have been greatly eroded and may have been much thicker.

No fossils of determinative value have been recovered from the Wasatch beds in southeastern Idaho but, as previously stated, these appear to be continuous in part at least with the Knight or Almy formation in southwestern Wyoming as mapped by Veatch, where the Knight beds have yielded both animal and plant remains, among them the first vertebrate bones obtained from the Wasatch, namely, species of Coryphodon, described by Cope as Bathmodon.[5]

Pliocene (?) series.

Unconformable upon the Wasatch beds in the southwestern part of the Montpelier quadrangle and elsewhere overlying unconformably various pre-Tertiary sediments there is a group of generally light-colored, grayish or yellowish conglomerates with associated marly, gritty, or sandy beds of similar tints that produce white or light-colored soils. Few fossils have been found in these beds and these furnish no very satisfactory data for age determination. The beds are tentatively regarded as of Pliocene age and are all included in the Salt Lake formation.

Salt Lake formation.—In 1869 the name Salt Lake

[5] Veatch, A. C.: Op. cit., pp. 89-96, 1907.

group was introduced by Hayden[6] in the following words:

"In the valley of Weber River, from Morgan City to Devil's Gate, there is a thickness of 1,000 to 1,200 feet of sands, sandstones, and marls of a light color for the most part, which I regard as of upper Tertiary age. These newer beds must have not only occupied this expansion of the Weber Valley but also all of Salt Lake Valley, for remnants of it are seen along the margins of the mountains inclosing Salt Lake Valley. . . . I found this series of beds so widely extended and so largely developed in Weber Valley and Salt Lake Valley, that I regard it as worthy of a distinct name, and in consequence have called it the Salt Lake group."

This term was introduced by Peale[7] into southeastern Idaho and has been employed in a quotational sense (the Salt Lake group of Hayden and Peale) in later publications on the region as the designation of the Pliocene (?) rocks. In the above citation the name appears to be used in a strictly geographical sense with neither a definite implication of lacustrine origin of the beds nor implication of connection with Great Salt Lake. It is true, however, that members of the Hayden Surveys did regard these beds as lacustrine in origin, for Peale,[8] referring to similar beds in Marsh Valley to the west, states:

"I believe they were deposited in the same lake that occupied this valley, Cache Valley, Salt Lake Valley, and the valley of the Upper Portneuf, and of Bear Lake Valley."

The long usage of the name in this region and the fact that it was directly applied by Peale to the beds under consideration make its retention desirable. It has been shown by Gilbert,[9] however, that these deposits long antedate the origin of the present Great Salt Lake and it is now believed that the beds, though probably partly lacustrine, are largely of fluviatile origin.

The modification of Hayden's term to Salt Lake formation appears to meet the need of an appropriate geographical name and at the same time to avoid doubt-

[6] Hayden, F. V.: U. S. Geol. Survey Terr., vol. 3, p. 92 (p. 192 in combined 1-3 Ann. Rept.), 1869.

[7] Peale, A. C.: U. S. Geol. Survey Terr., Eleventh Ann. Rept., pp. 588 and 640, 1879.

[8] Peale, A. C.: Op. cit., p. 567.

[9] Gilbert, G. K.: Lake Bonneville, U. S. Geol. Survey, Mon. 1, p. 214, 1890.

ful implications. The word formation is also applicable becàuse of the varied character of the constituent strata.

The Salt Lake formation is exposed in the Fort Hall Indian Reservation and in each of the quadrangles studied except the Cranes Flat. It commonly forms foot-hill slopes along some of the larger valleys, as on the western side of Bear Lake Valley in the Montpelier quadrangle, and in places it rises high on the flanks of the mountains as in the vicinity of Georgetown Canyon in the same quadrangle, where it includes elevations greater than 7,300 feet. In other places the formation covers large areas of moderately high hills, as southeast of Montpelier or north of Ovid in the same quadrangle, where it occupies more than a township and has a vertical range of more than 1,000 feet, rising to an elevation of 7,156 feet. Smaller patches occur on some of the higher hills as along the west flank of Red Mountain, in the northeastern part of the Montpelier quadrangle, where the Pliocene (?) deposits reach an elevation of 7,750 feet.

As most commonly encountered the Salt Lake formation consists of light gray or buff-colored conglomerates in which the matrix is white, relatively soft, loose textured, and calcareous. The pebbles are generally of local materials and rather angular, though many are subangular or even rounded. There is great variation in size, some of the bowlders being four or five feet in diameter, but many of the fragments are less than an inch in diameter. The grayish or light color of the conglomerate and the local nature and angularity of the pebbles serve in general to distinguish these conglomerates from those of the Wasatch formation, which are usually reddish, consist of better rounded materials, and are largely composed of older Paleozoic rocks. It is, however, locally difficult to make the distinction. Hills covered with conglomerate of the Salt Lake formation are strewn with countless pebbles and bowlders of sandstone, quartzite, limestone, and chert. Ledges are few and poorly exposed. At some places, as in the lower part of Georgetown Canyon in the Montpelier quadrangle, heavy ledges are exposed with a jumble of local materials of various sizes and shapes. The bedding in some places is fairly distinct, but there is little marked difference in the coarseness of the materials.

In addition to the conglomerates there are beds of white marls, calcareous clays, sandstones, and grits. These furnish a white soil and underlie considerable areas, particularly north of Ovid and a mile or more north of Georgetown. At the last named locality some of the white calcareous beds contain much rhyolitic material, in the form of glassy fragments of the walls of bubbles, and resemble parts of the Fowkes formation of Veatch in the Eocene of southwestern Wyoming. Beds of this type, however, are common in sediments of supposed Pliocene age in the Fort Hall Indian Reservation.

The thickness of the formation varies from a few inches at places bordering exposures of older terranes to more than 1,000 feet where old valleys filled with these beds have been re-excavated, as in Georgetown Canyon. Great erosion has occurred since these sediments were deposited, so that without doubt the maximum thickness was formerly much greater.

The formation is in many places nearly horizontal, but at other places it is inclined at angles varying from a few degrees to nearly vertical.

Some fossils have been collected from the Salt Lake formation but these are chiefly poorly preserved freshwater mollusks, which are not of determinative value. From clayey layers among conglomerate bands on the south side of Montpelier Creek the following forms, collected by C. L. Breger, were identified by W. H. Dall:

Pisidium sp.—common.
Valvata sp.—common.
Planorbis (round whorls, low spires) rare
Lymnaea sp.—rare.
Ostracods—abundant.

In collections from T.10S., R.42E., a short distance west of the southern part of the Slug Creek quadrangle, W. H. Dall has identified imperfect impressions of Planorbis and Sphaerium and from the west side of Bear River Valley in the same quadrangle a minute Planorbis, perhaps undescribed.

A collection from the forks of Miller Creek in the NW.¼ sec. 34, T.5S., R.46E., in the northeastern part of the Freedom quadrangle, yielded the following fossils identified by Dall and thought by him to indicate Eocene age:

Pisidium saginatum White.
Planorbis, resembling *P. aequalis* White.
Lymnaea of the type of *L. similis* Meek.

On the other hand, in collections from Pliocene (?) beds in the Fort Hall Indian Reservation, he has identified the following forms:

Succinea ? or *Lymnaea ?* internal casts, not otherwise identifiable.
Oreohelix (one or possibly two species) internal casts, not identifiable further
Bifidaria, internal cast, not identifiable further.

These he is inclined to regard as Pliocene (?).

From a locality in the SW.¼, SW.¼ sec. 23, T.7S., R.33E., in the western part of the Fort Hall Indian Reservation, where carbonaceous shales were exposed in an old coal prospect, plant remains were collected. These were examined by F. H. Knowlton and proved to be fragments of stems and bark not determinable.

Most of the fossils thus far found are of long-ranging types, but some, such as Oreohelix from the Fort Hall Indian Reservation, suggest later rather than earlier Tertiary age, while others, as noted above, suggest Eocene age. These light colored beds occur at sufficiently frequent intervals to make it reasonably certain that they belong together. The stratigraphic position of the beds at some localities, as along the west side of Bear Lake Valley, indicates that they are of later age than the Wasatch formation. They were regarded as Pliocene by Hayden and Peale.[10] In view of the unsatisfactory nature of the evidence it seems better to retain tentatively that interpretation.

[10] Peale, A. C.: U. S. Geol. and Geog. Survey Terr., Eleventh Ann. Rept. for 1877, p. 640, 1879.

Art. XXXII.—*The Piedmont Terraces of the Northern Appalachians;* by Joseph Barrell. With Plates V and VI.

Edited by H. H. Robinson.

[Continued from p. 362]

Criteria for recognition of fluvial and marine baselevels.

Outcrops of Unconformities.

It is evident that the problem of tracing a system of baselevels is distinctly complex. Where successive baselevels are present, criteria must be used, therefore, which will give the elevation of each one with a maximum degree of certainty. The baselevels must be traced from place to place and correlated by elevation, gradient, and similarity of record on rock formations of comparable resistance. On the seaward side of a region evidence of marine denudation must be expected during submergent phases and such may well be less noticeable over drowned interior lowlands, as at present illustrated by Chesapeake and Delaware Bays. Thus not only must the evidence of successive baselevels be sought, but the fluvial and marine phases must be discriminated from each other.

The oldest surface which concerns the present investigation is the floor on which the Potomac formations were laid down. Deposition extended intermittently through the whole of the Comanche period and four distinct formations separated by unconformities are recognized between the Potomac and Hudson rivers. These are, beginning with the oldest, the Patuxent, Arundel, Patapsco, and Raritan. All are continental deposits, although the Raritan shows a transition toward the marine conditions of the Cretaceous.

[The Raritan formation properly belongs in the Cretaceous rather than Comanche, but for the purpose of argument as to the complexity of the physiographic record it may be allowed to stand as given. The Raritan is separated from both the underlying and overlying formations by evident unconformities, whereas the overlying Cretaceous formations are apparently conformable among themselves.—Editor.]

The oldest of these formations, the Patuxent, rests on the crystalline rocks at Washington, whereas the youngest, the Raritan, forms the base in New Jersey. The surface of unconformity between the Patuxent and Arundel at Washington must come to be, therefore, between the crystallines and the Arundel at some locality farther northeast. Likewise, the unconformities at the base of the Patapsco and Raritan in turn bevel across the older erosion surfaces and become themselves basal. The base of the Potomac group is thus represented by four distinct erosion surfaces spaced through the Comanche period. At the very beginning of the later erosion history of the Appalachians the problem is already complex.

As all the Potomac formations are river deposits it follows that the surfaces below are subaerial peneplanes. This is seen in the deep decay of the crystalline rocks where they pass below the overlying formations. More convincing still is the stream channeling of the floors; it appears from the figures given in the Washington folio that these old valleys are one to three miles wide and about one hundred feet deep. The Arundel formation, where it outcrops, is recognized as lying within these valleys which had been eroded in the Patuxent. Nearer the headwaters of the streams these old valleys must have been cut in the crystalline floor.

The base of the Raritan is well exposed in New Jersey near Staten Island, as shown on the geologic map of the Passaic folio. The strike of the formation, where it rests on the soft Triassic rocks, is N 47° E and the dip is 45 feet per mile. Where the formation meets the resistant serpentine mass of Staten Island the base swings nearly four miles to the east. There is no evidence of post-Raritan faulting or warping; the serpentine still rises over three hundred feet above sea-level. Thus at the time of the Raritan deposition, the serpentine mass rose as a monadnock, probably over four hundred feet high, above a peneplain developed on the soft Triassic formation.

The floor of the Potomac group, therefore, consists of erosion surfaces of fluvial origin, as shown by the nature of the cover and the weathering and topography of the rock floor.

All the Coastal Plain formations of the Cretaceous and Tertiary periods are marine and many are separated by unconformities. The basal beds must rest on an erosion surface which was presumably subaerial but was modified by marine action. North of the Rappahannock River in Virginia these formations, however, rest on older unconsolidated deposits. The contacts are characteristically plane surfaces but difficult to trace in detail. There is evidence near Richmond and Petersburg that the Eocene beds were laid down on an irregularly eroded surface having almost as much relief as the present topography. The evidence consists of inliers of Pamunky (Eocene) among hills of Potomac material.[31]

South of the Rappahannock the Miocene beds overlap the older Coastal Plain deposits and rest on the crystalline rocks of the Piedmont Plateau. The character of this contact should be carefully studied. Judged from the geologic and topographic maps it is a very uniform plane surface. The beds have an average dip of ten feet per mile. The slope of the floor from which the Miocene has been stripped may be steeper west of the outcrop, indicating a westward advance of the sea during the deposition of the Calvert, which forms the lower part of the Miocene. There is no indication in this locality (Goochland and Amelia quadrangles) of the landward limits of the later Miocene formations, the St. Mary's and Yorktown, as the extension of these at a slope of ten feet per mile passes above the present surface of the Piedmont Plateau for a distance of more than eighty miles.

The Fall Line and Relation of Marine Planation to Geologic Formations.

The shore-line of southern New England departs somewhat from the northward extension of the fall line which separates the Coastal Plain and the Piedmont Plateau and cuts across the geologic formations to an exceptional degree. During the later Mesozoic and Tertiary, however, the shore-line must have been much more nearly parallel to the fall line throughout its length and thus less markedly oblique to the older mountain structures, as indicated in fig. 1.

The fall line is merely the belt of recently exposed floor at the inner margin of the Coastal Plain. This

[31] Samuel Sanford. Underground Water Resources of the Coastal Plain Province of Virginia. Va. Geol. Survey, Bull. No. 5, 1913, pp. 17-18.

floor dips more steeply than the grade of the streams and gives rise to rapids. When the land stood lower the Coastal Plain extended farther westward and the fall line lay west of its present position. It has existed only during the youthful stages of the river grades. As the streams have sunk to baselevel after each uplift the fall line has disappeared. There is no evidence, as was once thought, that the fall line marks a fault which has separated the Piedmont Plateau from the Coastal Plain. On the contrary, no such fault is needed to explain the existence of the fall line; indeed, the manner in which the Coastal Plain deposits extend for many miles westward up the interfluvial slopes shows that such a fault does not exist.

Only during the most widely submergent phases of crustal oscillations has marine planation acted on the surface of the Piedmont Plateau. Through by far the greater part of later geologic time fluvial denudation has been acting and destroying such marks as the sea left. Evidence of marine planation must be sought, therefore, through the mask of later cycles of fluvial erosion. The older traces can only remain on the hard rocks where these were favorably exposed to the attack of the sea but have been protected, in a measure, from later fluvial denudation. The protected situations are interfluvial ridges on hard formations which were subjected to marine planation and which are remote from the principal drainage channels.

It would thus appear that a particular phase of marine planation is apt to be developed on a particular geologic formation. But on a single formation it will be difficult to tell if the original erosion forms are due to fluvial or marine action, especially after further erosion in later cycles. The evidence will be clearest where an old shore-line crosses a single geologic formation of uniform hardness one part of which shows higher levels and one character of topography and drainage as contrasted with another lower part. In particular, southern New England is adapted to show these relations most convincingly.

Enduring distinctions between fluvial and marine erosion.

We have seen that streams, even those of moderate size, are well able to cut their channels quickly down to grade and that where they have been diverted the portion of their channels (wind gaps) across the outstanding ridges will endure for a long period because the agent which formed it was more competent than any other to act on resistant rocks.

Likewise, waves are an effective erosive agent especially for cutting headlands and when working at shallow depths of water. The headlands tend to be cut on belts of resistant rock determined for that reason as interfluvial ridges during a previous cycle of fluvial denudation. The action of the sea is thus concentrated upon the hard rocks spared by the rivers. The power of the sea, however, ceases to act at a given locality after an emergence of the land and consequently the benches and cliffs which have been cut will endure for a long period, though in modified form.

A cliff is especially enduring when cut in very resistant rock. Streams may trench it. All the land slopes may become, in fact, the result of later fluvial action and yet the old coast-line back of the younger shore may remain as a definite break in the continuity of the upland, better visible from a distance than when viewed from among its remnants. Looked at across the direction of the drainage the old interfluvial ridge will be seen sloping down at the place of the old sea cliff from a higher and more rugged country to one of a different character.

The effect of marine planation, as expressed in cliff cutting, will be at a minimum when a fluvially baseleveled land is but slightly submerged. It will be at a maximum when submergence to as much as 200 feet affects a land whose surface had been previously reduced to a maturity characterized by rather strong relief. In a region of complex structure, such as southern New England, this topographic stage would mean that many of the interfluvial ridges were prominent because of greater resistance. The previous fluvial erosion, by widening the valleys, gives the waves room for attack. They may cut platforms miles in width in front of residuals which may rise as dissected plateaus several hundred feet in height. The effect of this contrast in relief will remain even after subsequent uplift and erosion of the combined features of fluvial and marine denudation to advanced maturity.

To sum up, the most favorable conditions for prolonged resistance of marine peneplanes to subaerial erosion are as follows. When a prolonged cycle of fluvial denudation has passed, leaving the softer formations as lowland plains and the harder formations as prominent interfluvial ridges, submergence to about 200 feet will produce wide embayments over the softer formations and will give rise to chains of islands where monadnocks rise above the surface of the harder formations. Let the submergence be prolonged and these islands will be eroded to a markedly uniform level, giving an accordant series of broad hilltops on the formations best suited to preserve them. A small subsequent uplift, with correspondingly gentle grades in the master streams, will greatly lengthen the endurance of these platforms through later time.

The rock benches in general will keep some portion of their veneer of gravel until erosion has reached maturity in a later cycle. Before the rock floor of the marine benches can be eroded the adjacent surface slopes must be destroyed, soil and gravel must creep down to the stream channels and be swept away. The last traces of the veneer will be found in favored situations. On the nearly flat hilltops the largest cobbles will stay longest as residual bowlders. Also at the base of former cliffs wave-rolled gravel may be protected for a time because of burial under talus. Even the marginal conglomerates may form masses of considerable resistance. Fluviatile conglomerates may predominate at first over those of marine origin, but such are deposited in places favorable for early removal during the following cycle of erosion. The true marine conglomerates deposited on wave-cut benches though less in quantity are more favorably situated for preservation.

Editorial note on the projected profile of the terraces of western Massachusetts and Connecticut.

The projected profile of the New England terraces, as they are developed in western Massachusetts and Connecticut, is shown by pl. V; it extends in a north-south direction from Mount Graylock to Long Island Sound and embraces an area 90 by 17 miles. In order to bring out the terraces to best advantage a direction of view N 55° E was chosen, which is approximately parallel to their trend, and the vertical scale was greatly exaggerated.

Professor Barrell selected this particular region for illustrating the terraces because throughout its extent they extend across the strike of the geologic formations, or it might be more proper to say, they were developed on a complex of metamorphic and igneous rocks the generally resistant nature of which has favored preservation of the broader erosional features. This profile can be adequately understood only by studying it in connection with the topographic and geologic maps of the area covered, or better still in the field, and in the light of the sequence of events outlined by Professor Barrell in his paper on "Post-Jurassic History of the Northern Appalachians."[32] The terraces shown on the profile are those recognized by Professor Barrell in 1912 and in the absence of any definite evidence to the contrary may be accepted as final.

The names, elevation of the inner restored margins, and the age of the terraces are as follows:

Becket	2,450	Cretaceous
Canaan	2,000	"
Cornwall	1,720	Oligocene
Goshen	1,380	Pliocene
Litchfield	1,140	"
Prospect	940	"
Towantic	740	"
Appomattox	540	"
New Canaan	400	Pleistocene
Sunderland	240	"
Wicomico	120	"

A study of the profile should convince one that the hilltops which form the sky-line can not well be considered parts of a single uplifted and tilted peneplane. It may be said that the sky-line consists of several parts with roughly concave outlines and as the erosion surface, broadly considered, is quite independent of the nature and structure of the rock formations, it would be necessary to assume a very special and arbitrary form of warping to fit it. This point would be still more evident if the profile were extended across Long Island so as to show the seaward extension of the bed-rock surface and the overlying sedimentary formations.

When that part of the profile below the Cornwall ter-

[32] Bull. Geol. Soc. Amer., vol. 24, 690-691, 1913. See, also, the latter part of this section and the entire following section.

race is examined carefully it is seen that the hilltops most probably fall into a series of benches separated by intervals of 100-200 feet, as shown by the dashed lines. The Goshen, Litchfield, and Prospect terraces are most clearly marked, whereas the Towantic and lower terraces are less plainly defined on the sky-line but have a well marked re-entrant character. The evidence in favor of the three upper terraces—the Becket, Canaan and Cornwall—is less decisive and will be touched on later; it was the character of the topography in the region south of the Cornwall terrace especially that led Professor Barrell to consider a marine origin for the terraces.

By reference to the preceding table it will be seen that there is no likelihood of any definite evidence of marine planation being found in the region covered by the two oldest terraces—the Becket and Canaan—nor, presumably, in that covered by the Cornwall terrace, for this region has been exposed for too long a time to subaerial erosion. Professor Barrell stated in reply to a question raised by Professor D. W. Johnson that "The two higher terraces are less well preserved, and conclusions in regard to them rest therefore not so much on their internal evidence as from the broader relations of these terraces, on the one hand, to the well-preserved ones at a lower elevation on the seaward side, and, on the other hand, to the different character of the topography on the side of the mountains, especially the sharpness of that line diagonal to the structure which separates the highest terrace from the still higher and mountainous uplands." The topographic break referred to is shown on the profile where the inner margin of the Becket terrace cuts across the southern slope of the Mount Graylock massif. This feature of the topography was traced from the above locality first northeastward for about fourteen miles and then in a more northerly direction along the eastern flank of the Green Mountains well into Vermont. It was shown to persist with little regard to structure and variation in rock formations and was considered as approximately fixing the position of the Cretaceous shore-line.

In the region covered by the Becket and Canaan and probably the Cornwall terraces, then, only evidence of subaerial erosion is to be expected. In the region covered by the younger terraces, on the other hand, although the topography is mainly the result of fluvial erosion, some evidence of marine action should be expected in the form of beveled interfluvial ridges and remnants of sea cliffs. It seems doubtful if the presence of marine sediments should be expected, for the region, in addition to fluvial erosion, has been subjected to strong and prolonged glacial erosion and in any case the till cover greatly decreases the chances of finding any pockets of sediment that might remain.

It is not necessary to discriminate between glacial and marine planation, unless in very detailed study, as the effects of the former are strictly subordinate. The till cover, however, quite effectively masks the actual configuration of the bed-rock surface, with which the study is primarily concerned, and should be allowed for. Professor Barrell was allowing for the effects of glaciation in his field work, but it will be understood that no allowance has been made for them on the general profile (Plate V). Very commonly what appear to be steep, and in some instances precipitous, rock slopes at the southern ends of ridges are buried under till, a situation that adds to the difficulty of definitely recognizing old sea-cliffs. Nevertheless, steep southern slopes appear to be a rather characteristic feature of Connecticut topography, and in this connection an observation by R. S. Tarr, made in 1890, is of interest. In describing the topography of the region in which he was mapping glacial deposits he said:

> "The hills in the area covered by the Derby atlas sheet are flat topped and lack the rounded forms characteristic of the hills in Massachusetts . . . In many places precipices are found, particularly at the southern ends of the hills . . . These precipices are also well shown in the neighborhood of Waterville, north of Waterbury."[33]

It is suggestive that three of Professor Barrell's shore-lines cross the Derby region and the steep hills near Waterville fix the position of a fourth.

It will be seen that the Goshen "shore-line," the location of which is shown in fig. 1, is thus the dividing line between two regions which should be expected to show rather notable differences in topography. The region northwest of this line has been undergoing subaerial erosion since the Cretaceous and the topography is

[33] Unpublished field report.

wholly the result of that process; on the other hand the region southeast of that shore-line has been undergoing subaerial erosion for a much shorter time and consequently evidence of marine planation should be expected to remain, that is, the present topography represents the combined effects of marine and later subaerial erosion. To discriminate definitely between them requires the development of new criteria and the use of highly refined methods of study in the field.

The positions of the restored surfaces indicate the extent to which the present surface is supposed to have been lowered by subaerial erosion since the different terraces were cut. The amount ranges from nothing for many of the hills in the localities covered by the lowest and youngest terraces to fifty feet for the highest hills in the localities covered by the oldest terraces. It is entirely reasonable to suppose that unreduced remnants of the Pleistocene terraces may exist where the rocks are resistant and it is a rather common assumption that practically unreduced remnants of the Cretaceous peneplain also still exist. It has seemed to me, however, that the logic of Professor Barrell's argument in favor of many cycles of marine erosion with the probable reduction of the land in one or more of the later fluvial erosion cycles to as low a relief as it had in Cretaceous time calls for a greater degradation of the oldest marine terraces than has been assumed.

The slopes of the restored terraces appear to be drawn in a systematic manner. Those of the terraces from the Becket to the Prospect, inclusive, are essentially parallel and average seven feet per mile, that of the Towantic is four feet, whereas for the lower terraces it is two feet per mile. All slopes are toward the south. As the terraces are assigned a marine origin it is to be assumed that they had an initial seaward slope of five to ten feet per mile, within which range the slopes of the upper terraces fall. On the other hand the slope given the lower terraces, which are less well developed, may be supposed to represent the planation of interfluvial ridges without the establishment of a profile of equilibrium. On this basis it would appear necessary to conclude that the region covered by the entire profile had experienced only vertical uplift because the present slopes of the terraces, as restored, are the same as the initial slopes developed below sea-level.

In one of his last papers—"Rhythms and the Measurement of Geologic Time"[34]—Professor Barrell described, however, a type of movement involving "progressive tilting combined with rhythmic oscillation of baselevel" which he illustrated by the relation of the formations of the Atlantic Coastal Plain and which an unfinished drawing shows he also applied to the New England region. When the entire Appalachian Province is considered it is to be presumed that progressive doming at an irregular rate combined with recurrent phases of emergence and submergence of the land would more nearly describe the actual character of the crustal movement.

The attitude of the Pliocene and Pleistocene terraces may be considered in general agreement with the conception of the crustal movement as stated in the foregoing paper, because on the basis of accepted conclusions tilting had nearly ceased by the close of the Miocene. It would seem, however, as though the Becket, Canaan, and Cornwall restored terraces should have steeper slopes than the younger terraces because they were cut on the flank of the domed area where the effect of later tilting should be recognizable. The reason for this apparent discrepancy is not clear. It is possible that the profile antedates the conception of the crustal movement, the former was drawn in 1912 whereas the latter was not published until 1916, or the record may have been considered too complex to be adequately represented. A reason of a different nature concerns the suitability of existing residuals for the restoration of the oldest terraces, a point that Professor Barrell recognized and that has been touched upon.

The suggestion may be noted here that if the attitude of the terraces is correctly shown and if tilting was as pronounced in southern New England as it was farther south—the scanty well records appear to show that it was—then the untilted position of the highest terraces may indicate a much younger age for them than has been assigned.

A careful study of the profile and maps both topographic and geologic, coupled with some acquaintance with the region, has left the definite impression that Professor Barrell's conclusion as to the marine origin of the terraces below the Cornwall is well taken. Also, if the topographic break between the Becket terrace and

[34] Bull. Geol. Soc. Amer., vol. 28, pp. 789-795, 1917.

the higher mountainous areas is correctly interpreted as fixing the position of the Cretaceous shore-line, then the Becket and Canaan terraces would have essentially the positions indicated on the profile.

It should be noted that Professor Barrell, in his early studies, recognized two peneplanes in the region covered by the oldest terraces to which he assigned a subaerial origin. They lie at lower elevations than the restored marine terraces and, it may be said, appear to be parts of what has long been considered a single erosion surface—the uplifted and dissected "Cretaceous" peneplain. The profile gives evidence of such a surface, but hills which rise distinctly higher should be considered eroded remnants of the Cretaceous marine peneplanes. If this upland is rightly considered as indicating peneplanation, and the concensus of opinion is that it does, then the interesting question arises, under Professor Barrell's interpretation of the physiographic history, as to the time of planation. Discussion of this point logically falls in the next section (History), but it may also be conveniently considered here in connection with the general profile of the terraces.

Professor Barrell considered that the Eocene was a "long period of subaerial erosion" and the same may be said for the Miocene. During both these epochs the shore-line was supposed to be located not far from the present shore of Long Island Sound and consequently it may be concluded that the region under discussion was considerably elevated during both epochs as the result of uplift combined with the tilting movement which was in progress. Further, it must be granted that there was sufficient time during both epochs for erosion to reduce the land to low relief if the existing surfaces correctly indicate former peneplanation. On the other hand, it may be supposed that peneplanation could not have occurred in the Oligocene because the position of the shore-line far inland from the present coast would indicate a low elevation above sea-level for the region and a correspondingly slight degradation; nor in the Pliocene and Pleistocene, for then the land was being uplifted and erosion confined largely to valley cutting.

It appears, therefore, that if two peneplains are to be recognized the older may be given an Eocene age, the younger a Miocene; or if but one peneplain was developed it should probably be assigned a Miocene age. And in any case, disregarding exact epochs, it is evident that the long-recognized peneplain of western Massachusetts and northwestern Connecticut should be considered as having been developed in its final stages in Tertiary rather than in Cretaceous time.

The foregoing is the conclusion I have come to from a study of Professor Barrell's published work and his field notes. One consequence which follows from it may be noted, namely, that the evidence of fluvial erosion contemporaneous with the cutting of the Pliocene and Pleistocene marine terraces would presumably be confined to composite valley slopes, rock terraces, and stream deposits, depending upon existing conditions in any case. And further, as the uplifts during these two epochs appear to have been rapid and some of the halts short, an incomplete record should be expected, when the resistant nature of the rock formations is considered, even on the larger streams and certainly in the headwater regions of all streams.

What Professor Barrell's exact opinion may have been as to the age of these subaerial peneplanes I can not personally say; the subject did not come up in conversation and I have found nothing that specifically bears on it in his notes. Both Dr. Buwalda and Mr. Bissell have told me, however, that Professor Barrell stated to them not long before his death that he thought none of the Appalachian erosion surfaces antedated the Tertiary. Dr. E. W. Shaw writes: "As I understood Professor Barrell he thoroughly agreed with my contention that all of the surface of the Appalachians has been developed since the Cretaceous."

In view of this situation it would seem best not to attach too great weight to the exact dates in the sequence of events given by Professor Barrell in his original paper. It is evident that some of them eventually might have been changed. So far as the evidence goes there appears no reason why the entire region might not be considered as having undergone subaerial erosion during both the Eocene and Oligocene and to a large extent have been submerged during the Miocene; and the exact age of the youngest terraces also appears at present to be open to question.

As those who have made the effort will well appreciate, the determination of dates on the basis of physiographic evidence alone is more or less unsatisfactory, depending upon the extent to which unknown factors of importance outnumber the known. The present confusion as to the dating of Appalachian erosion surfaces is traceable to this situation and it should be noted that the tendency to consider these surfaces younger than they were thought to be, or presumably are still thought to be by most geologists, is due not so much to additional evidence bearing on the problem as to a reinterpretation of existing evidence on the basis of new conceptions of a general nature, such as an increased length of geologic time and a greater effectiveness of erosion processes.

Editorial note on the physiographic history of the region.

Professor Barrell states in the abstract of his paper on "Post-Jurassic History of the Northern Appalachians" that the sequence of events therein outlined "rests largely on an analysis of the profiles." The main profiles referred to are (1) the general profile of the terraces of western Masschusetts and Connecticut (Pl. V), (2) the profile showing the relation of the unconformities between the formations of the Costal Plain to the erosion surfaces of the Piedmont and South Mountains (Pl. VI), and (3) presumably the profile of the Piedmont terraces of Maryland (Pl. VI), although in part this is practically a duplicate of the section shown by the preceding profile. No doubt the sequence of events outlined was intended to hold for the entire region from New England to Maryland; on the other hand, certain unfinished figures and notes indicate that it applies most definitely to the former region.

The Jurassic and Cretaceous erosion cycles were sharply differentiated by Professor Barrell for reasons which are stated in the sections "The Jurassic Erosion Cycle" and "The Post-Jurassic Erosion Cycles" of his paper on the "Upper Devonian Delta of the Appalachian Geosyncline."[35]

On the basis of physiographic evidence he considered that the Cretaceous sea covered Massachusetts and Connecticut to the base of the Green Mountains, whereas in Maryland and Pennsylvania it extended over both the

[35] This Journal, 37, 102-105, 1914.

Piedmont and South Mountains, as shown by the upper figure in Pl. VI. The restored upper surface of the Cretaceous deposits is shown by the curved line which passes slightly above the summits of the South Mountains and beneath the present surface of the country about 10 miles southeast of Washington. A note on the drawing indicates that the slope of this surface in the vicinity of Washington was to be increased from 29 to 31 degrees. The effect of this at E 10 miles would be to place the surface 170 feet instead of 300 feet above sea-level, making the estimated original thickness of the formation at this point 150 as against 280 feet. Also the surface would meet the base of the Eocene formation at 50 to 60 miles instead of at 80 miles east of Washington, thus considerably reducing the distance through which the Cretaceous formations were beveled in the succeeding erosion cycle.

The restored surface is shown as lying less than 100 feet above the highest summits of South Mountains and as below one peak (Quirauk Mt., Md.). As it represents the upper surface of the Cretaceous deposits it will be seen that post-Cretaceous erosion is assumed to have left a considerable number of practically unreduced Cretaceous residuals. "The fair degree of preservation of that [Cretaceous] plain upon resistant rocks and the present broadly mountainous character of the Appalachians are due largely to the comparative recency of the last strong upward movements, which appear to date from the close of the Miocene."[36]

The linear projection of the base of the Eocene passes over the Piedmont and meets the eastern slope of the South Mountains at an elevation of 1,400 feet. The base would pass over the Piedmont even if it were bent down in a manner similar to the restored Cretaceous surface. It would appear quite possible, therefore, that the sea might have covered the present Piedmont surface in whole or in part during the Eocene. Professor Barrell considered, however, that the Cretaceous terraces in New England had experienced a notably greater dissection than those at lower elevations, which indicated a long time interval, and consequently he assumed that during the Eocene there had been "emergence of several hundred feet and retreat of the shore to the region of the present Coastal Plain." As a result it must be sup-

[36] Loc. cit., p. 105.

posed that the Eocene marine plain and shore-line were obliterated by erosion, largely marine, in later times.

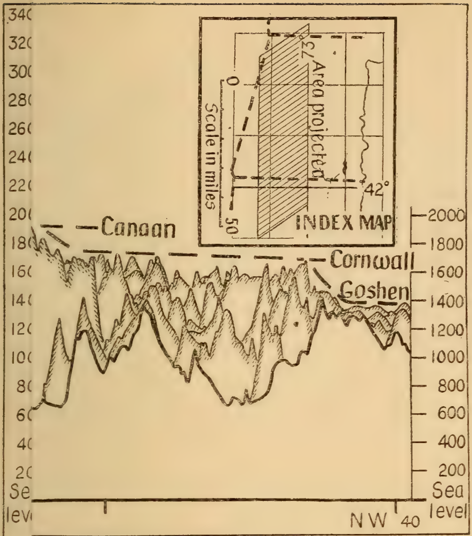
During the Oligocene a probable submergence of the land occurred and the Cornwall terrace was cut. The emergence which followed in the Miocene caused a greater retreat of the sea than occurred in the Eocene, as shown on an unfinished drawing, and no terrace of this age was recognized because, like the Eocene terrace, it must have been too greatly modified, or more likely, entirely destroyed by later erosion. The sequence of events outlined in this and the preceding paragraph is based primarily on physiographic evidence from Massachusetts and Connecticut and should be considered, therefore, as applying particularly to that region.

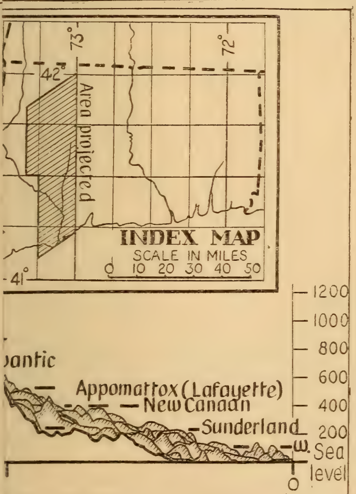
By the end of the Miocene the tilting which had been in progress since the Jurassic had nearly ceased and the later movements of the Pliocene and Pleistocene were due largely to vertical uplift. For limited areas the tilting component of the movement would be too small to be detected, but for the entire region under discussion, and for a much larger area during the Pleistocene, it would appear that the domal uplift recognized in the Cretaceous was still in progress.

The submergent phase at the close of the Miocene or beginning of the Pliocene again brought the sea over the land and the Goshen terrace was cut in early Pliocene. Thereafter intermittent uplift caused retreats of the sea and the cutting of the Litchfield-Towantic set of terraces in the Pliocene and the lower terraces in the Pleistocene, the latter being pre-glacial. And in this connection preglacial means pre-Wisconsin. As Professor Barrell has recognized eight terraces as cut in these two periods it may be inferred that no submergent phases of consequence occurred during this time. The Goshen terrace now has an altitude of over 1,300 feet, which is the basis for the statement that "the last strong upward movements" appear to date from the close of the Miocene.

There is a difficulty in forming a complete idea of events due to the lack of information as to the character of the land surfaces over which the sea advanced at different times, or to place the emphasis a little differently, the extent of subaerial erosion during the periods of emergence which intervened between those of submergence. It will have been noted that Professor Barrell

Plate V.


INDEX MAP
Area projected
Scale in miles
0
50
73°
42°
Canaan
Cornwall
Goshen
2000
1800
1600
1400
1200
1000
800
600
400
200
Sea level
NW
40


INDEX MAP
SCALE IN MILES
0 10 20 30 40 50
Area projected
73°
72°
42°
41°
Appomattox (Lafayette)
New Canaan
Sunderland
1200
1000
800
600
400
200
Sea level
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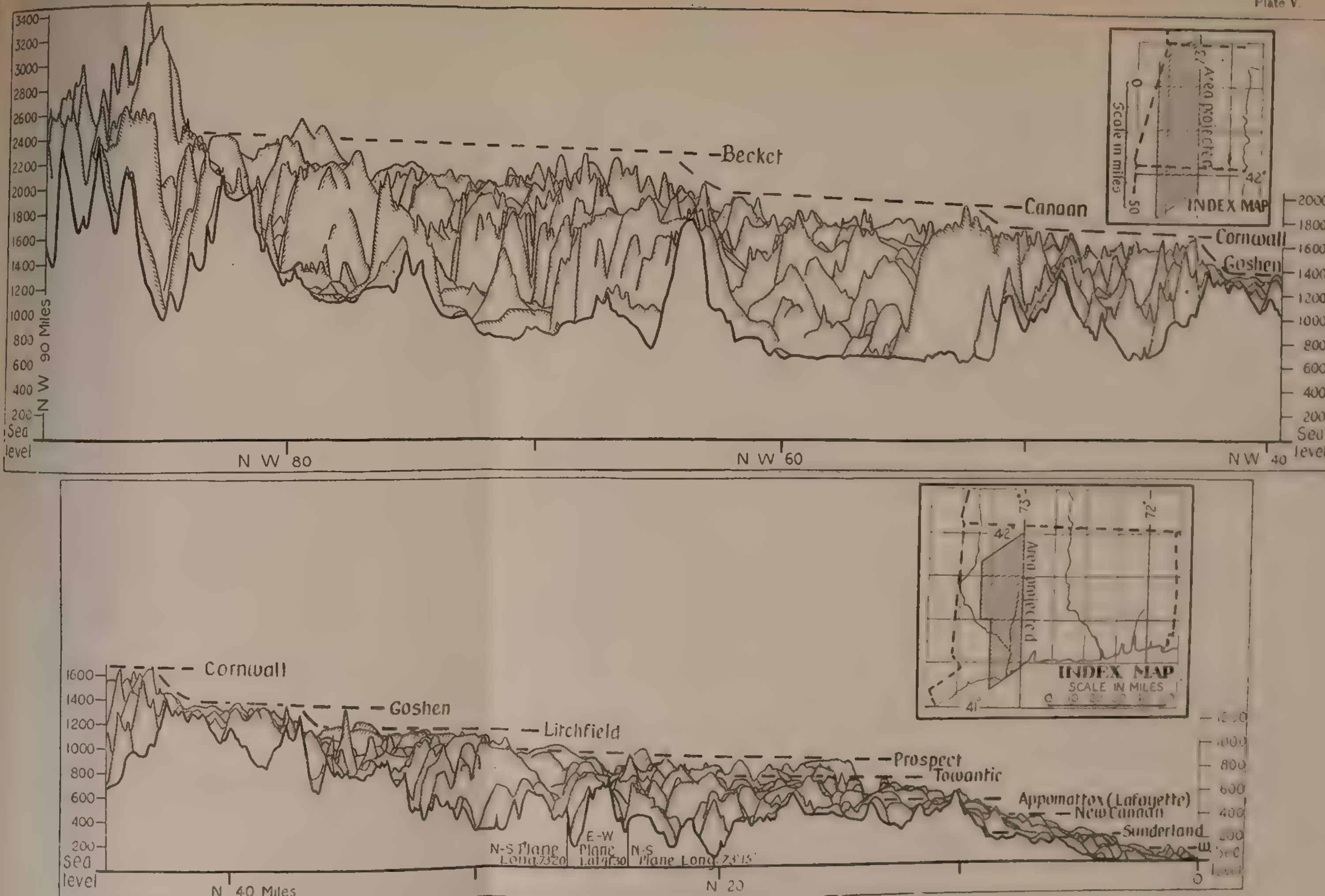
posed that the Eocene marine plain and shore-line were obliterated by erosion, largely marine, in later times.

During the Oligocene a probable submergence of the land occurred and the Cornwall terrace was cut. The emergence which followed in the Miocene caused a greater retreat of the sea than occurred in the Eocene, as shown on an unfinished drawing, and no terrace of this age was recognized because, like the Eocene terrace, it must have been too greatly modified, or more likely, entirely destroyed by later erosion. The sequence of events outlined in this and the preceding paragraph is based primarily on physiographic evidence from Massachusetts and Connecticut and should be considered, therefore, as applying particularly to that region.

By the end of the Miocene the tilting which had been in progress since the Jurassic had nearly ceased and the later movements of the Pliocene and Pleistocene were due largely to vertical uplift. For limited areas the tilting component of the movement would be too small to be detected, but for the entire region under discussion, and for a much larger area during the Pleistocene, it would appear that the domal uplift recognized in the Cretaceous was still in progress.

The submergent phase at the close of the Miocene or beginning of the Pliocene again brought the sea over the land and the Goshen terrace was cut in early Pliocene. Thereafter intermittent uplift caused retreats of the sea and the cutting of the Litchfield-Towantic set of terraces in the Pliocene and the lower terraces in the Pleistocene, the latter being pre-glacial. And in this connection preglacial means pre-Wisconsin. As Professor Barrell has recognized eight terraces as cut in these two periods it may be inferred that no submergent phases of consequence occurred during this time. The Goshen terrace now has an altitude of over 1,300 feet, which is the basis for the statement that "the last strong upward movements" appear to date from the close of the Miocene.

There is a difficulty in forming a complete idea of events due to the lack of information as to the character of the land surfaces over which the sea advanced at different times, or to place the emphasis a little differently, the extent of subaerial erosion during the periods of emergence which intervened between those of submergence. It will have been noted that Professor Barrell



Pl. V. Projected profile of the terraces of western Massachusetts and Connecticut.

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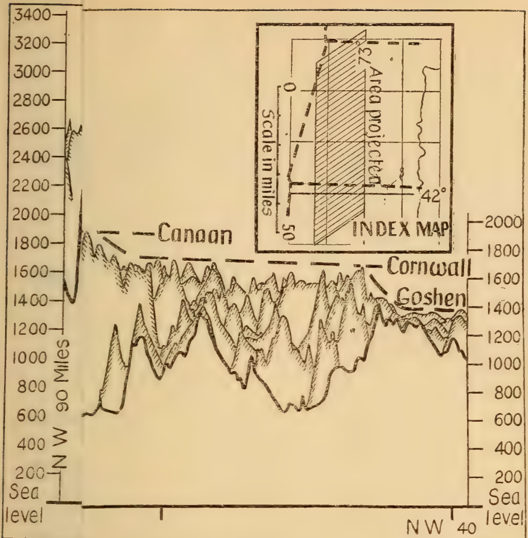
INDEX MAP
Area projected
Scale in miles
0
50
73°
42°
Canaan
Cornwall
Goshen
N W 90 Miles
N W 40
3400
3200
3000
2800
2600
2400
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1800
1600
1400
1200
1000
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600
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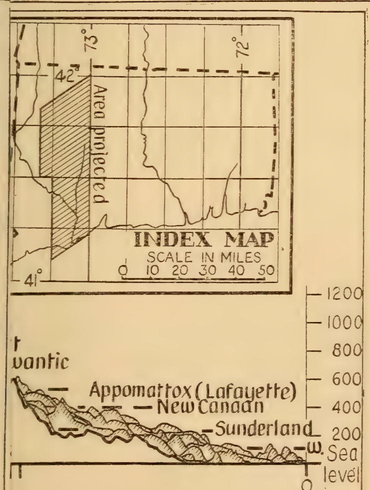
200
Sea level


INDEX MAP
SCALE IN MILES
0 10 20 30 40 50
Area projected
73°
72°
42°
41°
Appomattox (Lafayette)
New Canaan
Sunderland
1200
1000
800
600
400
200
Sea level
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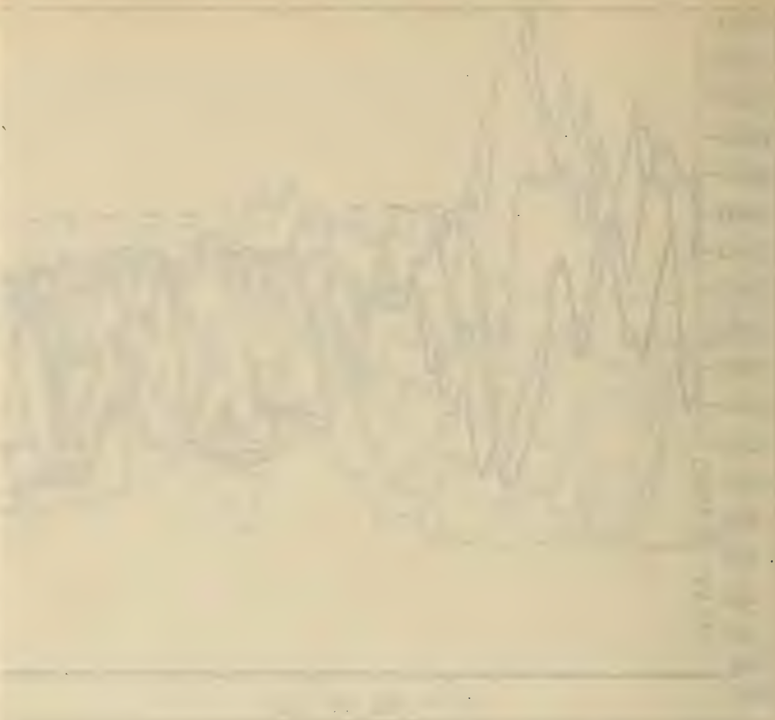

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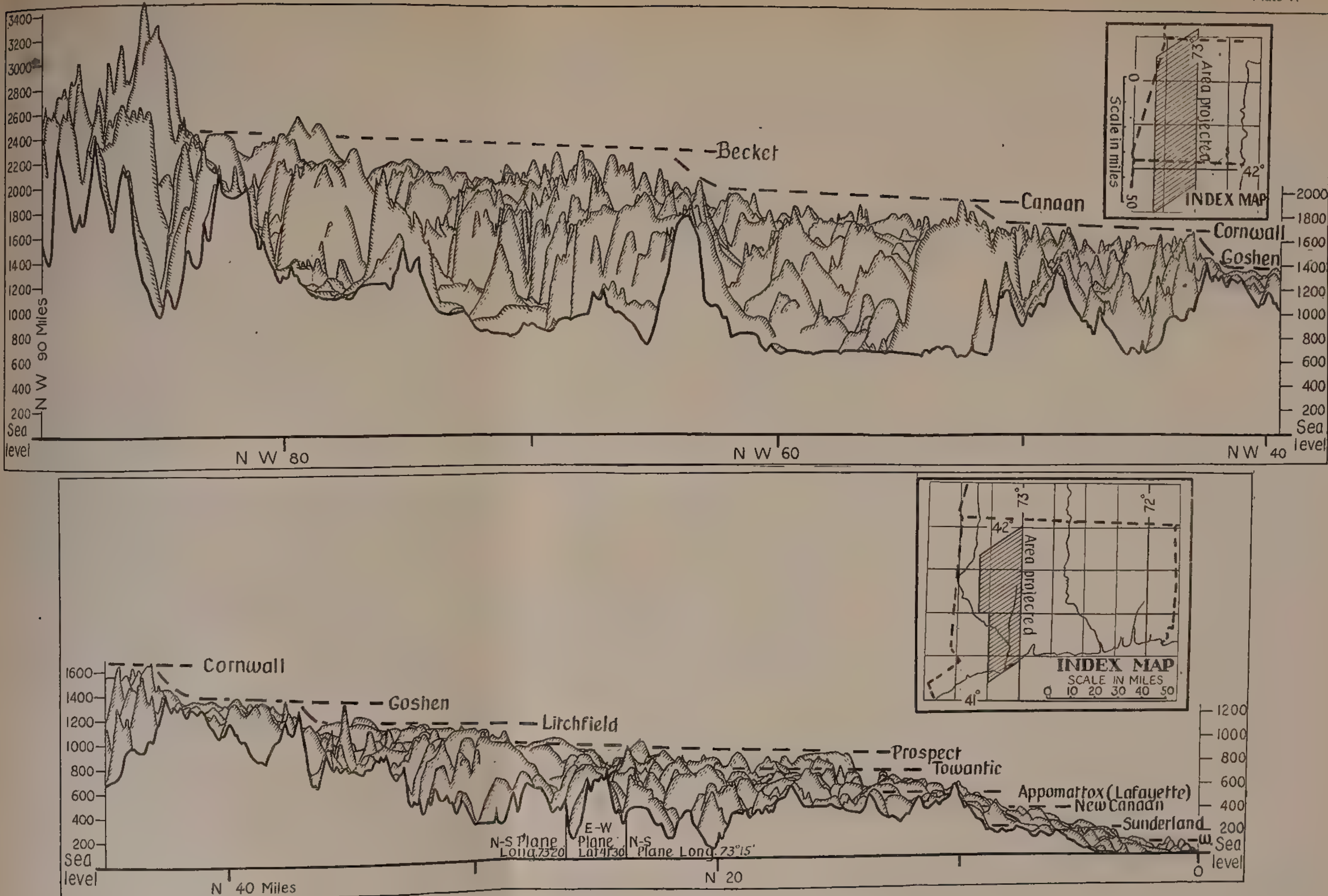
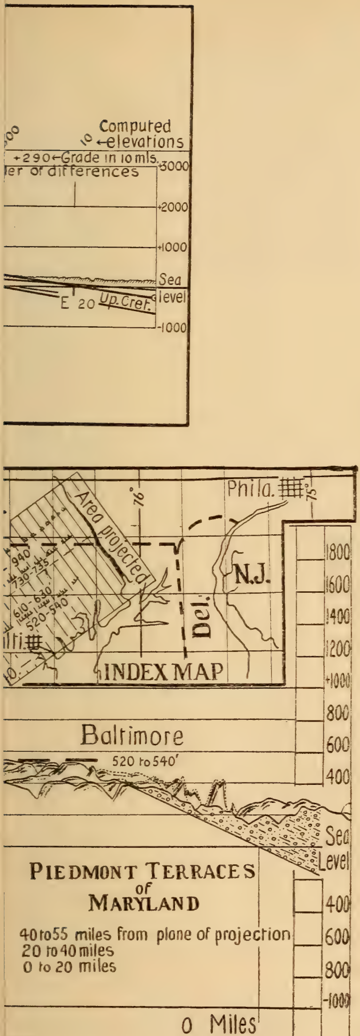


Pl. V. Projected profile of the terraces of western Massachusetts and Connecticut.

Plate VI.



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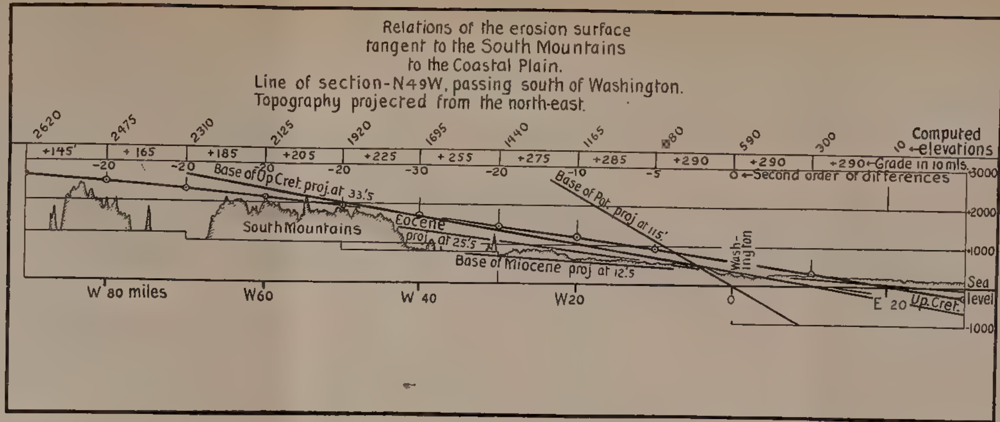
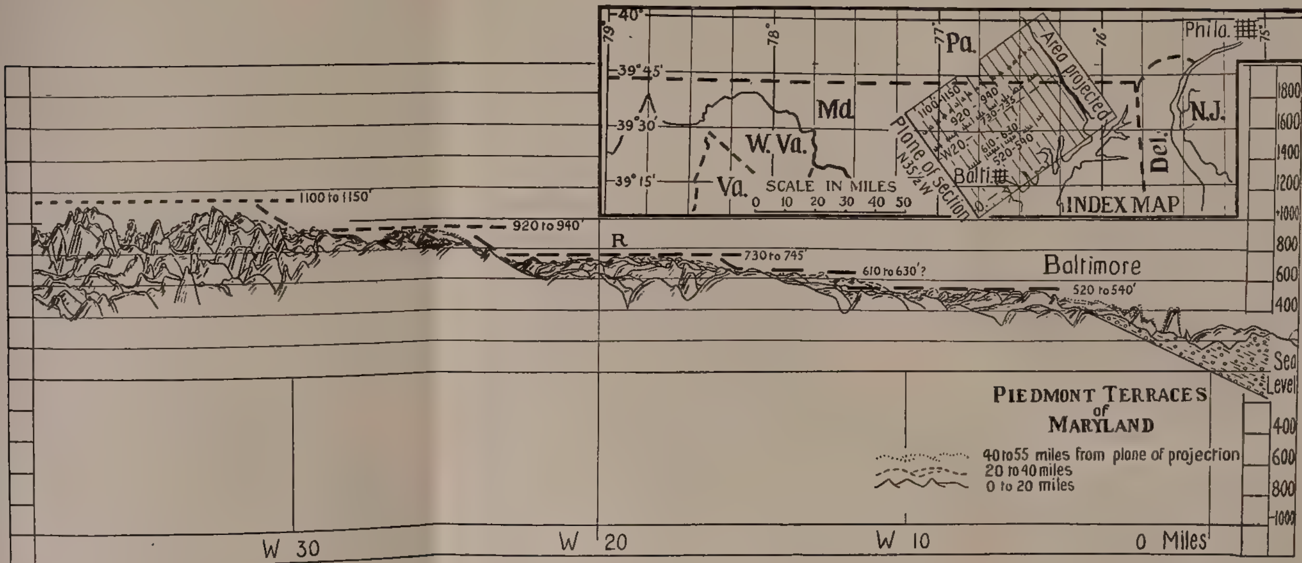

Relations of the erosion surface
tangent to the South Mountains
to the Coastal Plain.
Line of section-N49W, passing south of Washington.
Topography projected from the north-east.
Computed elevations
Grade in 10 mls.
Second order of differences
Base of Up Cret. proj. at 33.'5
South Mountains
Eocene proj. at 25.'5
Base of Miocene proj at 12.'5
Base of Pot. proj at 115'
Washington
Up. Cret.
Sea level
W 80 miles
W60
W 40
W20
E 20


Pa.
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W. Va.
Va.
N.J.
Del.
Phila.
Balti.
Area projected
Plane of Section N35½W
SCALE IN MILES
0 10 20 30 40 50
INDEX MAP
1100 to 1150'
920 to 940'
730 to 745'
610 to 630'?
520 to 540'
R
Baltimore
Sea Level
PIEDMONT TERRACES
of
MARYLAND
40 to 55 miles from plane of projection
20 to 40 miles
0 to 20 miles
W 30
W 20
W 10
0 Miles

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did not describe these surfaces in his early articles, the explanation being, no doubt, that his attention was then concentrated on the marine phase of the problem. Later, however, when he began to study in detail the process of marine denudation in order to formulate criteria, the character of the land surfaces assumed a place of importance, as appears in this article. The topographic features due to fluvial erosion proper were also being searched for and preliminary former grades for several of the large rivers had been worked out. For the Connecticut, for example, Professor Barrell recognized four such grades which appear to be correlated with the Litchfield, Prospect, Towantic or Appomattox, and Sunderland marine terraces. The description of the marine and subaerial elements in the topography of western Massachusetts and Connecticut is, however, one of the unwritten parts of his article so that what follows is an interpretation rather than a statement of Professor Barrell's ideas.

The surface over which the Cretaceous sea advanced was one characteristic of old age in a normal cycle, the softer rocks being rather perfectly reduced and the resistant ones having moderate relief. This surface may be considered equivalent to the fundamental plane of reference, the "Jurassic" or "Cretaceous" peneplain, recognized by earlier investigators. Whether this surface was reduced to a true marine plain is purely conjectural, for no trace of it now remains; Professor Barrell stated in his original address that "the [original surface of the] Cretaceous peneplain of subaerial denudation, as modified by marine planation, was destroyed by subaerial erosion in Tertiary time."

Likewise the character of only a part of the surfaces over which the sea advanced in the Eocene and again in the Miocene can be determined, for these surfaces to a large extent were later destroyed. However, as the shore-lines during these two periods were supposed to have been located not far from the present shore of Long Island Sound, it is evident that the greater part and perhaps the whole of the present region was then exposed to subaerial erosion. It thus seems reasonable to infer that the main outlines of the present topography were etched by erosion during the Eocene and that in a general way they have persisted in that part of the region not later covered by the sea.

The sea thus advanced over a subaerially denuded land in the Oligocene cutting the Cornwall terrace and again in the Pliocene cutting the Goshen terrace. The land in both instances was supposed to have been reduced to old age, for "slight submergences and crustal rest are sufficient to account for the planing inland by the sea." The initial advance of the sea, in any instance, was supposed to be due to a depression of the land and from this it may be inferred that wave planation during this stage did not produce a great amount of change in the form of the surface; it may have been restricted to the beveling of the tops of interfluvial ridges. On the other hand, after the downward movement of the land had ceased, planation would have been more pronounced, but the advance of the sea would have been slower and finally must have been checked by the initiation of an emergent movement. Under these conditions it would seem that the degradation effected by the sea should have been moderate and as a result the outcrops of rock formations should not have been greatly changed.

It would also appear on this interpretation that the volume of the sediments brought down by the rivers would have been moderate and that the production of marine conglomerates would have been small except, perhaps, during the stage when the sea was working against a stationary coast.[37]

If the marine plain were uplifted with little change in slope the main streams, under the given conditions, would tend to become located again on much the same courses they had before the terrace was cut. On the other hand, if the plain were somewhat tilted and warped, as would seem more probable, then a notable amount of drainage along new lines should be expected which at first would be consequent on the sedimentary cover and later would be superimposed upon the underlying crystalline floor. As is well known, the courses of several of the large rivers of the Appalachian region in part have been explained as superimposed; Davis considered, for example, that the lower course of the Connecticut was so located upon the metamorphic and igneous rocks from a cover of Cretaceous sediments. Such an explanation also holds under Professor Barrell's

[37] As bearing on this point see section "Relations of rate [of denudation] to the cycle of erosion," pp. 760-761 in "Rhythms and the Measurement of Geologic Time."

interpretation of the physiographic history of the region, but it should be noted that the time when superimposition took place must be set much later, i. e., post-Miocene.

The sequence of events outlined by Professor Barrell is notably different from older schemes; in fact it appears to have but two points in common with them, namely, the initial and the final dates. The divergencies are plainly enough brought about by the recognition of many marine baselevels and by other new interpretations of the physiographic evidence. There appears no reason to doubt the correctness of Professor Barrell's view that the physiographic history of the Appalachian region is much more complex than has been generally supposed, but whether all the erosion surfaces in the regions specified were originally the result of marine denudation is a question for future workers to determine. The opinion may be ventured that future study will not result in much increasing the number of normal erosion cycles that can be recognized; it is to be expected, rather, that the increase will be in the number of partial cycles. And also it would seem as though the number of marine cycles should distinctly exceed the number of normal cycles, although this point depends somewhat upon the question whether such crustal oscillations as are indicated by the Connecticut terraces should be considered as producing interruptions in the normal cycle or as inaugurating new cycles. In any case the two cycles are commensurable only under the single condition of prolonged crustal rest and as Professor Barrell has pointed out, it is becoming increasingly evident that this condition is the exception rather than the rule.

Very likely the conception of the marine origin of the erosion planes will not gain quick acceptance because the physiographic history of the Appalachian region is so well organized on the basis of the fluvial origin of the erosion surfaces, and for the more general reason that fluvial denudation has come to be looked upon as much more competent than marine denudation to develop extensive erosion planes. The prevailing opinion would appear to be that it is difficult to recognize marine plains, on the basis of physical characteristics, after they have been uplifted and modified to any extent by subaerial erosion, and presumably it should be more difficult to detect the effect of partial marine planation, as on an interfluvial ridge, except under the most favorable conditions. This difficulty has been due in some measure, it is felt, to a lack of suitable criteria by means of which one may distinguish between the results of fluvial and marine denudation. An important phase of Professor Barrell's study was the development of such criteria and his work has opened up a number of very interesting lines of investigation. It may be surmised, also, that the hypothesis of many erosion planes of marine origin may stimulate others, as it did Professor Barrell, to detect and correlate in a comprehensive way some of the finer topographic features the importance of which has been made evident.

Editorial note on the Piedmont Terraces of Maryland.

Professor Barrell was led to study the Piedmont terraces in Maryland, in 1912, because of certain questions that had arisen in connection with his New England field work of the previous year. He had observed at several localities elongated flat-topped hills or ridges which he thought might be remnants of a marine plain. Because of the possibility that critical features might have been obliterated by glaciation he noted at the time that it would be necessary to "look for similar features in an unglaciated region and if sea cliffs are found, look for retreatal gravels." Before going into the field in 1912 he had reached the conclusion, however, that the Connecticut terraces were of marine origin and had tentatively assigned a similar origin to the Piedmont terraces of Maryland on the basis of the similarity of the projected profiles of the two regions. As a result of this conclusion Professor Barrell's main interest, when he visited the Maryland localities, centered about the possible presence of marine gravels.

It may be said in brief that gravels were observed on the 520-540 and 730-745 foot terraces (Plate VI) of a character and in positions which indicated to Professor Barrell their marine origin. Reference to this point is found in the discussion of the original address (p. 695). On the higher terraces, however, nothing suggesting water-worn gravels was seen.

The "Lafayette" formation was studied in the region west and northwest of Catonsville. At the highest point on the terrace, elevation 540 feet, the surface was found to be covered with gravel embedded in a clayey loam. The pebbles were of white quartz, stained yellowish and reddish, and of all sizes up to a maximum of 3 inches. Some were "beautifully ellipsoidal" but most, although showing distinct signs of water wear, were subangular. Many pieces had one rounded side and many of the larger pebbles were broken, from which it was concluded that the disintegration in place of water-worn gravel had given rise to the rough angular material.

From an inspection of the Patuxent formation north-east of Baltimore Professor Barrell concluded that the gravel beds were sufficient to supply all the gravel seen

FIG. 18.

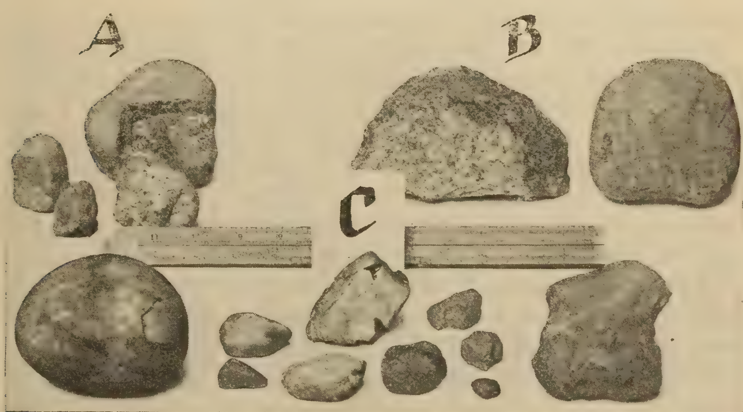

FIG. 18.—The Reisterstown gravels.

in the "Lafayette" near Catonsville. He noted that the formation at that locality was practically identical with the Patuxent north-east of Baltimore and questioned whether it might not actually be the latter formation. He decided, however, that this was probably not the case because of the noticeable concentration of gravel at and near the surface, which he ascribed to wave work.

Professor Barrell was especially interested in the evidence he found in the vicinity of Reisterstown, Md., consisting of water-worn pebbles and cobbles, indicating the presence of gravels on the 730-745 foot terrace. He considered that this evidence pointed to a marine origin for the terrace, his argument being the same as in the case of the lower terraces.

The region about Reisterstown is briefly described as a very gently rolling and but little dissected upland remnant. Water-worn material was found at three localities: (A) in cultivated fields just south of the road to St. George, at an elevation of 720 feet, (B) in a cultivated field, three-tenths of a mile from the turnpike, on the north side of the road that leaves the Reisterstown turnpike one-half mile south of town and runs south-west, (C) in a field north of road that crosses the above road beyond locality (B) and one-quarter mile south-east of the crossroads. Some of the collected material is shown in fig. 18 and is lettered as above. In regard to localities A and B it is noted that "fields contain many pebbles and a few larger fragments of coarse vein quartz weathered from the underlying mica schist."

The common residual material in the vicinity of Reisterstown was found to be a coarse gray quartz rock which weathered easily and was rarest as good water-worn pebbles (left-hand specimen, fig. 18, B.). White vein quartz was rather common; it formed most of the small pebbles and was not much water-worn. No quartzite was observed in place but the most perfectly rounded pebbles were of this rock (left-hand specimen, fig. 18, C.).

To sum up, then, Professor Barrell considered it improbable that these gravels were of fluviatile origin for reasons briefly stated in the original discussion referred to, whereas their wide-spread distribution on terraces, such as are shown by the profile (Pl. VI), led to the more logical conclusion that they were of marine origin. It is true that these gravels and their associated sediments have yielded no marine fossils, nor indeed fossils of any description, and in the absence of generally accepted criteria for distinguishing between fluviatile and marine gravels on a physical basis, there may be expected a diversity of opinion as to their origin depending largely on one's general point of view. This being the case, it is evident that a large field is open to discriminating study.

Art. XXXIII.—*Studies in the Cyperaceæ;* by Theo. Holm. XXIX. *Carices æorastachyæ: Salinæ* Fries. (With 8 figures drawn from nature by the author.)

In outlining the grex: *Æorastachyæ* Drejer (*Symbolæ* Caricologicæ) points out the following characters as the most important: "Perigynia ut in grege *C. microrhyncharum,* cui maxime affinis, sed sæpe coriacea; spicæ ut in illa, sed in pedunculis longis filiformibus basi distincte ocreatis demum pendulæ.—In borealibus terris incipit distigmatica (*C. hæmatolepis, filipendula, cryptocarpa, macrochæta, Lyngbyei*) in temperatis evadit tristigmatica (*C. limosa*). Color spicarum in plurimis fuscescens (*Carices* nuper nominatæ), in paucis viridis (*C. crinita, maritima*)." Furthermore in the chapter dealing with diagnoses, synonymy and affinity, the following species are mentioned as pertaining to this grex: *C. glaucescens* Ell., *phacota* Spreng., *Arnottiana* Nees, and *salina* Wahlenb. Several other species may be added,[1] and the grex comprises about forty species in all.

No "*formæ hebetatæ*" are known of this grex; all the species have the spikes well differentiated, and among the most evolute species we meet with such types as the polystachyous *C. ternaria* Forst., *C. tuminensis* Kom., *C. Arnottiana* Nees, *C. Darwini* Boott, and *C. subdola* Boott, in which the inflorescence is very ample, decompound, with several (2 to 3) spikes proceeding from the axils of the leafy bracts. In some species the terminal spike is gynæcandrous: *C. prælonga* C. B. Clarke, *C. incisa* Boott, *C. cernua* Boott, and sometimes in *C. Prescottiana* Boott, and *C. phacota* Sprgl. In *C. Magellanica* Lam. the lateral spikes are constantly, the terminal frequently gynæcandrous. Otherwise the species show the general habit with the terminal spike staminate, the lateral pistillate or not infrequently androgynous (*C. salina* Wahlenb., *C. cryptocarpa* C. A. Mey., *C. aperta* Boott etc.). Most frequently the spikes are borne on long peduncles, and drooping, and the subtending bracts are generally long and foliaceous, but not sheathing. The color of the pistillate spikes varies from green to light brown or dark purplish; the scales of the pistillate

[1] The author: Greges Caricum (this Journal, vol. 16, p. 457, December, 1903).

flowers are very seldom obtuse; they are mostly acuminate, mucronate or aristate. The perigynium shows several structures, membranaceous or coriaceous, more or less turgid or compressed, but with the beak very short, entire or slightly emarginate. The geographical distribution is quite extensive; some of the members of the *C. salina* alliance are arctic, and *C. subspathacea* Wormskj. is circumpolar, beside *C. rariflora* Sm.; several of the species abound in the boreal regions of both worlds, while others show a more southern distribution, extending to the Himalayas, Japan, Java etc., beside New Zealand. And with respect to the most evolute types, these are to be sought in New Zealand: *C. ternaria* and *C. subdola,* in Korea: *C. tuminensis,* in Ceylon: *C. Arnottiana,* and on the shores of the Straits of Magellan: *C. Darwini.* Some very local types are represented by for instance: *C. Lyngbyei* Hornem. (Færoe Islands), *C. capillipes* Drej. (Iceland), *C. hæmatolepis* Drej. (Greenland), *C. stygia* Fr. (Alaska, Finmark), and *C. nesophila* nob. (Alaska).

Among the types indigenous to this country, *C. crinita, C. gynandra, C. glaucescens,* and *C. littoralis* are confined to the Atlantic slope, while *C. magnifica, C. Schottii, C. lacunarum,* and *C. cryptochlæna* occur only on the Pacific coast.

In classifying the species in sections it will be seen, that several of these stand quite isolated, and are difficult to combine with the others, for instance *C. aperta, C. nesophila, C. glaucescens* etc. On the other hand some very natural groups are represented by the *Salinæ,* the *Cryptocarpæ,* the *Limosæ* etc. According to the structure of utriculus, the number of stigmata, and partly also the composition of the inflorescence, the distribution of the sexes etc., the grex may be outlined as follows:

A. Stigmata two.

- *a.* Terminal spike staminate, the lateral pistillate or androgynous.
    1. Salinæ Fr.: *C. subspathacea* Wormskj., *reducta* Drej., *salina* Wahlenb., *halophila* Nyl.
    2. Cryptocarpæ nob.: *C. cryptocarpa* C. A. Mey., *capillipes* Drej., *Lyngbyei* Hornem., *hæmatolepis* Drej., *cryptochlæna* nob.
    3. Crinitæ nob.: *C. crinita* Lam., *gynandra* Schw., *maritima* O. F. Muell.

4. Apertæ nob.: *C. aperta* Boott, *pruinosa* Boott.
5. Magnificæ nob.: *C. magnifica* Dew., *Schottii* Dew., *lacunarum* nob.

β. Terminal spike gynæcandrous, the lateral pistillate.

6. Phacotæ nob.: *C. phacota* Sprgl., *incisa* Boott, *cernua* Boott, *prælonga* C. B. Clarke, *Prescottiana* Boott, *Kiotensis* Franch. et Sav.

γ. Spikes in fascicles of 2 or more.

7. Ternariæ nob.: *C. ternaria* Forst., *tuminensis* Kom., *subdola* Boott, *Darwini* Boott, *Arnottiana* Nees.

B. Stigmata three, seldom two.

δ. Terminal spike staminate, the lateral pistillate or androgynous (gynæcandrous in *C. Magellanica*).

8. Macrochætæ nob.: *C. macrochæta* C. A. Mey., *scita* Maxim., *flavocuspis* Franch.
9. Nesophilæ nob.: *C. nesophila* nob.
10. Glaucescentes nob.: *C. glaucescens* Ell.
11. Limosæ nob.: *C. littoralis* Schw., *limosa* L., *laxa* Wahlenb., *rariflora* Sm., *stygia* Fr., *Magellanica* Lam. In the last of these the lateral spikes are gynæcandrous, and frequently also the terminal.

As stated above the grex contains only highly developed types, and none of these, not even the most evolute *Ternariæ*, may be looked upon as representing so-called "*formæ desciscentes.*" These *Ternariæ*, being distigmatic, represent actually a lesser developed stage than the more simple types with three stigmata: the *Macrochaetæ*, *Nesophilæ*, *Glaucescentes*, and *Limosæ*, which, moreover, culminate in the remarkable *C. Magellanica* with all the spikes gynæcandrous. In other words we prefer to combine all these sections from *Salinæ* to *Limosæ* as one main group comprising altogether "*formæ centrales*," with the tristigmatic at the end of the grex, as the most evolute types. At the same time we may consider the *Ternariæ* as the most evolute of the distigmatic types, but of these only.

Considered from a geographic point of view the *Æorastachyæ* are a strange commingling of types from the northern and southern hemisphere, from the arctic to the antarctic zones, and, to a large extent, following the coasts of the Atlantic and Pacific. The *Salinæ* are characteristic of Scandinavia and Lapland; the *Cryptocarpæ* have their home principally in Iceland, Greenland, and on the shores of Behring Sea; the *Crinitæ* are natives of the Atlantic States, but one of these, *C. maritima,* occurs also in Scandinavia; the *Macrochætæ* and *Nesophilæ* are from the northern coasts of the Pacific, especially Alaska with adjacent islands. With exception of *C. littoralis* the *Limosæ* are decidedly boreal types, and *C. rariflora* is circumpolar. While the *Phacotæ* are indigenous to the Himalayas, and some to Japan, we have seen that the *Ternariæ* are extremely scattered from Korea to Ceylon, and farther south to New Zealand and the Straits of Magellan. Therefore it seems very natural that the grex has produced quite a series of types of strikingly well marked characteristics, when we consider the extremely wide geographic range from north to south with the corresponding variation of climatalogic conditions.

In order to demonstrate the characteristics of the various sections enumerated above, we shall discuss these in the order mentioned, and the *Salinæ* will thus be the first ones to be treated. In subsequent papers it is our intention to continue these descriptive notes, which we hope will be of some interest to students of Caricography.

Salinæ Fr.

Carex salina Wahlenb.

In describing *C. salina* Wahlenberg[2] distinguished two well marked varieties: α *cuspidata,* and β *mutica,* the former resembling *C. maritima* O. F. Muell., the latter *C. aquatilis* Wahlenb. By some subsequent authors *cuspidata* has been accepted as representing a subspecies of *salina* comprising a number of varieties with the squamæ more or less mucronate, and with the leaves flat; with respect to *mutica,* this has also been treated as a subspecies of *salina,* consisting of a small number of varieties with the squamæ muticous, and with the leaves involute; of these the latter (*mutica*) is mainly arctic, the former, on the other hand is distributed farther south, the western coast of Scandinavia, Finland, Scotland, etc. Almquist[3] has contributed an interesting classification of these various plants, but he includes *C. hæmatolepis*

[2] Wahlenberg, G.: Flora Lapponica, p. 246. Berlin, 1812.

[3] Almquist, S.: Om formerna af *Carex salina* Wg. (Bot. Notiser for 1891, p. 125, Lund, 1891.) See also: Hartman, C. I.: Skandinaviens Flora, 11th ed., p. 465. Stockholm, 1879.

Drej. and *C. cryptocarpa* C. A. Mey. as varieties of *cuspidata.* In other words according to this author *cuspidata* comprises: α *Kattegatensis* Fr. with forma *Ostrobottnica* Almqv., f. *hæmatolepis* (Drej.), f. *filipendula* (Drej.) (*C. cryptocarpa* C. A. Mey.), and β *borealis* Almqv. with f. *discolor* (Nyl.).—

Mutica is by this author: α *subspathacea* (Wormskj.) with f. *curvata* Drej. and f. *nardifolia* (Wahlenb.), beside β *flavicans* (F. Nyl.).—M. N. Blytt[4] makes a similar disposition, including *C. cryptocarpa* and *C. hæmatolepis* as mere varieties of *C. salina,* but he evidently considered *C. subspathacea* as representing something more than a variety, since he marked it with an asterisk. A very different view was held by Drejer,[5] who separated several of these as species distinct from *salina,* viz.: *C. subspathacea* Wormskj. with forma *stricta* Drej., and f. *curvata* Drej., *C. reducta* Drej., *C. hæmatolepis* Drej., *C. filipendula* Drej. with α *variegata,* β *littoralis,* and γ *concolor, C. Lyngbyei* Hornem., and *C. capillipes* Drej. At that time Drejer knew only *C. cryptocarpa* from the description, and the fact, that his specimens of *C. filipendula* from Greenland showed the perigynia very plainly, and not hidden by the squamæ as indicated by the name "*cryptocarpa,*" made him believe that both were distinct species; but having sent specimens of *C. filipendula* to Kunze, for comparison, Drejer was informed that the species were identical, even if the name was misleading.—

In his several, and very important, contributions to the knowledge of Scandinavian *Carices* Elias Fries[6] accepts *C. salina* Wahlenb. with two forms: α *cuspidata:* "squamis aristatis," and β *submutica:* "squamis muticis *mucronatisve*"; but *C. subspathacea* is described as a separate species with two forms: *planifolia,* and *nardifolia,* and Fries considered this to be a nearer ally of *C. aquatilis* and *C. rigida* than of *C. salina.* In the synopsis of the distigmatic *Carices*[7] this same author enumerates *C. Lyngbyei,* and *C. cryptocarpa* as examples of "*Aphyllopodæ,*" *C. salina,* and *C. subspathacea* representing "*Polyphyllopodæ*"; in this same paper Fries

[4] Blytt, M. N.: Norges Flora, vol. 1, p. 217. Christiania, 1861.

[5] Drejer, S.: Revisio critica Caricum borealium in terris sub imperio Danico jacentibus inventarum. (Naturhist. Tidsskr., vol. 3, p. 34.) Hafniæ, 1841.

[6] Fries, Elias: Novitiarum Floræ Suecicæ. Mantissa tertia, p. 145. Upsala, 1842.

[7] Same: Synopsis Caricum distigmaticarum, spicis sexu distinctis, in Scandinavia lectarum. (Bot. Notis., p. 106, Lund, 1843.)

describes *C. epigejos* from Lapland and Norway, which he took to be the plant named so by Læstad; according to Andersson the species described by Fries is, however, a different plant, known now as *C. discolor* Nyl. (Spicileg. Fl. Fenn. III. p. 12). Finally in his Summa vegetabilium[8] Fries describes *C. halophila* Nyl., *C. salina* Wahlenb., *C. subspathacea* (Fl. Dan. t. 1530) *C. Lyngbyei* Horn., and *C. cryptocarpa* C. A. Mey. as distinct species.

While referring *C. cuspidata, C. hæmatolepis* (non Drej.) and *C. mutica* to the one species *salina* Wahlenb., Andersson[9] admits that these with respect to habit and certain characters are just as well distinct as a number of others, *e. g. C. digitata* and *ornithopoda, C. limosa* and *irrigua, C. ericetorum* and *præcox* etc. Furthermore Andersson states, that Lindeberg presented him with a large collection of these forms gathered almost at a single station (the island Hisingen near Götheborg), beside that Blytt brought together a similar collection of forms from Christiania.

As specifically distinct from *C. salina* the author enumerates *C. subspathacea* Wormskj., *C. discolor* Nyl., *C. Lyngbyei* Horn., *C. cryptocarpa* C. A. Mey., and *C. halophila* Nyl. In other words Andersson adopts principally the same classification as proposed by Fries. With regard to *C. hæmatolepis* cited by the author his diagnosis and figure (Pl. II. f. 37) show plainly enough that the plant is *C. Kattegatensis* (Fr. ind. sem. hort. upsal. 1857).—

Among the *Carices,* which inhabit Greenland, Lange[10] enumerates the various species proposed by Drejer, holding the same view as Fries that *C. cryptocarpa,* and *C. hæmatolepis* (vera) are specifically distinct from *C. salina.* Finally Hjelt[11] adopts the classification proposed by Almquist, placing *C. hæmatolepis* Drej., and *C. cryptocarpa* C. A. Mey. as mere forms of *C. salina* * *cuspidata* α *Kattegatensis* Fr.—

From a systematic point of view *Carex salina* Wahlenb. has thus been treated by some of the most excellent

[8] Same: Summa vegetabilium Scandinaviæ, p. 231. Upsala, 1846.

[9] Andersson, N. I.: Skandinaviens Cyperaceer, p. 49. Stockholm, 1849.

[10] Lange, Joh.: Conspectus Floræ Groenlandicæ. (Medd. om Grönland, Part 3, p. 140.) Copenhagen, 1880.

[11] Hjelt, Hjalmar: Conspectus Floræ Fennicæ, Pars III, p. 278. Helsingfors, 1895. *Carices distigmaticæ* determined and arranged by S. Almquist.

botanists in Scandinavia, who were familiar with the plant through observations in the field, or by means of the copious material brought together and deposited in the Museums of these countries. However, while the aim of the classification was the same, to demonstrate the mutual affinities of the various types represented by this species, it is to be regretted, that some authors have deemed it necessary to include under *C. salina* some other species, which are certainly not conspecific: *C. subspathacea* Wormskj., *C. hæmatolepis* Drej., and *C. cryptocarpa* C. A. Mey.—

As already indicated in the preceding *C. salina* is quite a variable species, containing about ten varieties and forms, all of which are well marked, and readily to be distinguished from the species mentioned above.

Typical *C. salina* (Figs. 1-4) may be described as follows:

Rhizome loosely cæspitose to stoloniferous; leaves yellowish green, erect, flat, about 3-4 mm. broad, as long as the culms or a little longer; culms erect, about 10-25 cm. in height, triquetrous, scabrous or almost smooth; staminate spikes 1 or 2, linear; pistillate spikes 2 to 4, erect, 1½ to 2½ cm. long, of a yellowish brown color, pedunculate, the uppermost sometimes androgynous; the bracts subtending the pistillate spikes are foliaceous, reaching the staminate spike or above this, not sheathing; scales of the pistillate flowers ovate to ovate-lanceolate, light or dark brown with a broad midrib (of three veins) extending to the apex of the scale or beyond this as a mucro or short arista; perigynium shorter than the scale, but a little broader, obovate to broadly ovate, plano-convex, faintly veined, the beak very short, slightly emarginate; stigmata 2.—Common on the sea-shore of Sweden (Halland and Bohuslæn), along the entire coast of Norway from Christiania-Fjord to East-Finmark, and on the shores of the White Sea, Northern Russia. It is, on the other hand, very rare in North America, and the only specimens, we have seen, so far, of the typical plant are those collected by Walter H. Evans: Alaska, on flat in rich soil, Kussiloff, July 29, 1898, and by John Macoun: Prince Edward Island: Mt. Stewart, July 11, 1888.—

By Hartman (l. c.) the species is considered the most variable of all the distigmatic, and it seems a very difficult task to arrange these varieties and forms in a natural way so as to show the cause of the structures

modified. Through the kindness of our friend, the late Professor Axel Blytt of Christiania, we have received a copious material of Norwegian *Carices,* among which a number of varieties of *C. salina* are represented, and a comparison of these with a number of Swedish, and some few North American specimens may be drawn up as follows:

forma 1. *pumila* M. N. Blytt (Fig. 5).—Rhizome stoloniferous; culms very short, from 4 to 7 cm. in height, sometimes curved; leaves very narrow, longer than the culms; spikes 3 to 4, the terminal staminate, the lateral pistillate, very short, sessile, and almost contiguous, subtended by leafy bracts overtopping the staminate spike; scales obtuse, dark purple or brownish, shorter than the straw-colored perigynium.

Russian Lapland: shores of the arctic sea; Finmark. Var. *β pallida* M. N. Blytt.—Culm sharply triangular, stiff, erect, about 30 cm. high; leaves narrow, but flat, longer than the culm; staminate spikes 2 to 3; pistillate spikes 2 to 3, dense-flowered, androgynous, c. 3½ cm. long, contiguous, erect, the lowest pedunculate, subtended by leafy, short bracts, scales yellowish brown, mucronate, longer and almost as broad as the obovate, pale perigynium.

Norway: Christiania: Lian. Var. *γ fuscescens* (M. N. Blytt).—Culm tall, about 75 cm. high, triangular; leaves broad, flat, about as long as the culm; spikes 7, the uppermost 3 staminate, long and slender, the others pistillate, or the uppermost androgynous, remote, about 6 cm. long, cylindric, denseflowered, all pedunculate and somewhat drooping; bracts foliaceous, very long; scales light brown, aristate, longer, but narrower than the straw-colored perigynia.

Norway: Christiania and Mandal. Var. *δ obtusa* A. Blytt).[12] This peculiar variety was discovered by A. Blytt, and seems to be very rare. Rhizome stoloniferous, culms erect, smooth, about 25 cm. high; leaves flat, much longer than the culms; spikes 4 to 6, the terminal and uppermost 1-2 staminate, linear, the others pistillate, pedunculate, especially the basal, erect or sometimes drooping, cylindric and denseflowered, quite thick; bracts foliaceous, but relatively short, the basal barely reaching the terminal spike; scales dark colored, almost black, ovate, obtuse, as long as the perigynia, but narrower than these; perigynia green, broadly oval, obtuse,

[12] Blytt, A.: Botaniske Observationer fra Sogn. (Nyt. Mag. f. Naturv., p. 81, 1869.)

faintly nerved, the beak very short, emarginate. Readily distinguished from the other varieties by the obtuse scales, of which the midrib contains a single vein instead of three, and by the very broad perigynia.

Norway: gravelly seashore, Midttunvaagen near Evindvig, associated with *C. maritima* and various forms of *C. salina.*

Var. ε *cæspitosa* A. Blytt.—Caespitose; culms slender, erect, from 15 to 25 cm. in height; leaves flat, broad, longer than the culm; spikes 5 to 6, the terminal and uppermost 2 staminate, the others pistillate, erect, contiguous, denseflowered, short peduncled; bracts foliaceous, the basal overtopping the inflorescence; scales dark colored, mucronate, longer, but narrower than the pale green perigynium.

Norway: Holmestrand; Evindvig; Christiania. Var. ζ *Kattegatensis* Fries.—Stoloniferous; culms erect, 20-50 cm. high; leaves deep green, flat and broad, about as long as the culm. Spikes long and slender;[13] the terminal, and sometimes the uppermost 1 or 2 lateral, staminate, the others, 2 to 4, pistillate, seldom androgynous, all remote and borne on slender peduncles, erect or somewhat drooping; bracts foliaceous, as long as the inflorescence, or a little longer; scales varying in color from dark brown to deep purplish with a usually broad, light midrib, extended into a short mucro or a long arista, narrower, but much longer than the light green perigynia.

This variety is quite frequent along the coasts of Norway, Sweden and Finland, and has also been found in Scotland; in North America it has been found in the northern parts, from Labrador to Massachusetts, besides in Alaska: Tatiklak and Kussiloff (Walter H. Evans).—

While the Scandinavian plant is extremely variable, occurring in a number of forms often associated with each other, the American representative is also quite well marked in this respect. In specimens from New-

[13] With regard to the number of staminate and pistillate spikes we found in 38 Scandinavian specimens:

1 staminate in	8 specimens	1 pistillate in	7 specimens
2 " "	25 "	2 " "	14 "
3 " "	4 "	3 " "	13 "
5 " "	1 "	4 " "	4 "
	38 specimens		38 specimens

foundland (legit Stuvitz) the pistillate spikes are long, slender, borne on long, filiform peduncles, spreading or almost erect, and the scales are aristate; in Nova Scotia (Belleview Cove) the plant is very tall and slender with the pistillate spikes more denseflowered, and with the scales bearing very long aristæ; some specimens from Herb. William Boott (Medford, Mass.) represent this variety, but are more robust, the pistillate spikes are cylindric, compact, short-peduncled, and the scales aristate. In Labrador we meet with several forms, some very robust, others more slender, exhibiting the same habit as the Scandinavian, and with the scales merely mucronate. Then in Alaska the plant is quite tall, broad-leaved and with the thick, denseflowered spikes distinctly peduncled, but erect, and with the scales acuminate, but neither mucronate nor aristate. Several of our Scandinavian specimens correspond exactly with these Alaskan, but are less robust as to culm and foliage.

Var *η Thulensis* Th. Fries.—Stoloniferous; culms erect, glabrous, 20-25 cm. high; leaves deep green, flat, longer than the culms; spikes relatively short, the terminal staminate, the lateral two to three pistillate, 2, 5 cm. in length, long-peduncled, but erect, remote, and subtended by foliaceous bracts, much longer than the inflorescence; scales of staminate flowers pale-brown with the midrib excurrent so as to form an arista; scales of pistillate flowers almost black with broad, green midrib extended into a long arista; perigynium light green, elliptic, prominently three-nerved, with a short, entire beak, broader and longer than the body of the scale; stigmata 2 or 3.

In marshes of St. Paul Island, Behring Sea, collected by James M. Macoun (No. 16,618).

Besides these forms and varieties *Carex salina* Wahlenb. is known also to produce hybrids with several of the distigmatic *Microrhynchæ* and *Æorastachyæ*, and Almquist (l. c.) enumerates these as follow:

1. *aquatilis* × *salina* = *C. halophila* Nyl.
2. *rigida* × *salina* (*borealis*).
3. *vulgaris* × *salina* = *C. spiculosa* Fr.
4. *Hudsonii* × *salina*.
5. *acuta* × *salina*.
6. *maritima* × *salina*.

Of these hybrids the three last mentioned were collected near Götheborg by Lindeberg.

Carex subspathacea Wormskj.

By Drejer (Revisio critica p. 34) the species is described as follows:

"Spica mascula 1, femineis 2 breve pedunculatis erectis oblongis, bracteis foliaceis spathaceis nervosis, squamis valide trinerviis basi fructum obvolventibus mucronatis perigynio subelliptico plano-convexo brevioribus, rostro brevi subemarginato, stigmatibus 2-3.

Sub duplici forma imprimis occurrit.

α *stricta* (Figs. 7-8) culmo stricto spicis plurifloris.

Radix stolonifera culmos solitarios fasciculosque steriles emittens. Culmus erectus, semipedalis, trigonus, sulcatus, lævis. Folia culmea culmo breviora (summum longius) plana, striata, apicem versus scabrata. Spicæ 3. Bracteæ spicæ fem. foliaceæ, ea spicæ inferioris spicas femineas superans masculam attingens sed ea brevior, spicam suam involvens, apicem versus margine scabriuscula; ea spicæ fem. superioris spicam superans. Spicæ ♀ pedunculatæ, inferior longius, superior brevius, erectæ, oblongæ. Squamæ ♀ subovatæ basi marginibus fructum involventes, dorso nervis tribus validis percursæ, obtusæ, mucronatæ, ferrugineæ dorso late viridiscentes margine hyalino nullo, perigynio breviores. Perigynium (immaturum) obovatum obsolete nervatum (?), rostratum, rostro brevi emarginato. Spica ♂ linearis, squamis imbricatis apice rotundatis submucronatis, cæterum squamis ♀ similibus.

Hæc forma *C. lividæ* quodammodo similis est, quæ tamen abunde differt bracteis vaginantibus, non spathaceis, squamis uninerviis cet.

β *curvata* (Fig. 6) caule humiliore curvulo, spicis paucifloris, squamis perigynio multo brevioribus.

Specimina hujus formæ magis adulta. Eximie stolonifera est, culmi debiles 2-3 pollicares, spicæ fem. 1-2 breve pedunculatæ, approximatæ vel subremotæ, ovato—oblongæ 3-5—floræ; bracteæ longissimæ culmum multo superantes; squamæ ♀ perigynio multo breviores; perigynium (maturum) subellipticum planoconvexum prorsus enerve, rostro brevi subemarginato, stylo exserto apicato; caryopsis obovato-ovalis oblique trigona basi styli apicata."—

Widely distributed throughout the arctic regions of both worlds and β *curvata* is circumpolar; α stricta is known from Greenland, Alaska, and arctic Norway.

γ *nardifolia* Fr.—Generally a little taller, with the leaves very narrow, involute; pistillate spikes sessile; the scales dark colored with broad, yellow midrib.

Lapland, on the seashore.

Carex reducta Drej.

This very rare species, known only from a few stations in southwest Greenland, shows the same habit as the preceding *α stricta*, but the scales of the pistillate flowers have only a single midvein, not composed of three. Drejer (l. c. p. 36) describes it as follows:

"Spica ♂ 1, ♀ 2 brevissime pedunculatis oblongis erectis, bracteis inf. foliaceis nervosis subspathaceis brevissime auriculatis, squamis uninerviis basi perigynium obvolventibus mucronulatis, perigyniis subobovatis plano-convexis enerviis superne margine asperato-denticulatis, rostro brevissimo subemarginato, stigmatibus 2."

However according to Lange (l. c.) the scales are not mucronate but muticous; this author agrees with Drejer in placing the species as a near ally of *C. subspathacea.*

In comparing these three species of *Salinæ* it must be pointed out that, so far, no intermediate forms have ever been observed, so as to question the validity of *C. subspathacea* and *reducta* as species, although the former has been found associated with some of the varieties of *C. salina,* in Finmark for instance. *C. subspathacea* gives an excellent picture of an arctic, circumpolar type, and more so than the forma *pumila* of *C. salina.* The numerous varieties of *C. salina* show several points of intergradation between each other and cannot be considered as anything but varieties, although their general habit and color of spikes cannot be explained as caused by the environments, since several of these are frequently associated with each other in the northern as well as in the southern parts of Scandinavia.

While *C. subspathacea* represents a truly arctic type, partly also *C. reducta, C. salina* is undoubtedly of a southern origin, possessed by a remarkable power to develop types of very characteristic structures.

EXPLANATION OF FIGURES.

FIG. 1. *Carex salina* Wahlenb. from Vardoe in Finmark (Norway); natural size.

FIG. 2. Staminate scale of same; enlarged.

FIG. 3. Pistillate scale and utriculus of same; enlarged.

FIG. 4. Utriculus of same; enlarged.
FIG. 5. *Carex salina* Wahlenb. forma *pumila* M. N. Blytt (*β borealis* Almq.) from Lapland; natural size.
FIG. 6. *Carex subspathacea* Wormskj. *β curvata* Drej. from Bernard Harbour (Lat. 68° 47′ N. Long. 114° 46 W.); natural size.
FIG. 7. *C. subspathacea* Wormskj. *α stricta* Drej. from St. Paul Island, Behring Sea; the pistillate scale; enlarged.
FIG. 8. Utriculus of same; enlarged.

Clinton, Md., February, 1920.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Substitutes for Platinum Wire in Bead and Flame Tests.*—C. C. KIPLINGER, of Mt. Union College, calling attention to the waste in platinum arising from its extensive use in the form of wire for qualitative tests, states that it has been found feasible to use the rod of graphite from a lead pencil for making bead tests. A piece of the "lead" 5 to 6 cm. in length is held by tongs in the Bunsen flame until the end is red-hot, then dipped in borax and returned to the flame and then held at such an angle that the borax glass forms a hanging drop at the end of the rod. The tests are made as usual in this drop. A piece of the rod will serve for two tests at least, and often the graphite can be scraped clean enough to permit the use of several beads with one piece. The borax bead adheres firmly to the graphite, yet the cold glass may be readily removed with a knife. The reducing action of the carbon does not appear to interfere materially with the usual tests.

For flame tests the method of Ehringhaus is mentioned, where a glass tube 15 cm. long and 6 mm. internal diameter is bent at an angle of about 45° rather near one end, the opening of the shorter end is reduced to about 3 mm. by heating, a slip of filter paper is rolled up so as to fit this opening tightly, and is introduced so as to project about 3 cm., then the longer arm of the tube is filled with the solution to be tested, or with dilute hydrochloric acid if a powder is to be tested on the paper. The paper wick is finally inserted into the flame, but the burning paper tends to mask the color of the flame, although it is possible to eliminate this difficulty partly by using a horizontal flame and bringing the upper edge of the paper wick barely within the bottom portion of the flame.

The author has found that a clean iron nail not less than 3 mm. in diameter is useful for flame tests. The head of the nail is best adapted for the purpose. The nail can be cleaned and burned free from sodium, and generally the spectra of iron salts do not interfere.—*Jour. Ind. Eng. Chem.*, **12**, 500. H. L. W.

2. *The Employment of Boric Acid in the Volumetric Determination of Ammonia.*—About seven years ago Winkler in Germany proposed the substitution of boric acid for sulphuric acid in the fixation of ammonia distilled over in the course of the Kjeldahl process for the determination of nitrogen. This method has the advantage that the amount of boric acid in excess need not be known, since this acid is so weak that the ammonia combined with it can be titrated directly with sulphuric acid when suitable indicators are employed, so that only a single volumetric solution is needed for the titration. Winkler obtained good results by his method, using methyl orange and Congo red as indicators, and the process was used later by Adler, who found it desirable in titrating to employ a color standard made by adding 0·15 cc. of 0·1 normal sulphuric acid and a few drops of methyl orange to 250 cc. of distilled water. The titration then of the ammonia distillate, fixed by 50 cc. of 4 per cent. boric acid solution and containing the same amount of methyl orange, until the standard color was reached, gave the correct result.

M. F. Scales and A. P. Harrison of the U. S. Department of Agriculture have studied this method rather elaborately and recommend it as being convenient and accurate. In making the titrations they advise the subtraction of 0·35 cc. from the burette reading where 1 cc. of the sulphuric acid solution is equal to 1 mg. of nitrogen, in order to correct for the effect of the presence of 50 cc. of 4% boric acid. They obtained excellent results both with Congo red and methyl orange as indicators, but prefer bromophenol blue as giving a sharper end-reaction, especially when the light from an electric bulb is passed through the liquid against a white reflecting surface until the disappearance of the purple color.—*Jour. Ind. Eng. Chem.*, **12**, 350. H. L. W.

3. *Historie de la Chemie*, par Maurice Delacre. 8vo, pp. 632. Paris, 1920 (Gauthier-Villars et Cie).—The manuscript of this interesting historical essay was finished in 1916 at Ghent where the author was a Professor in the University, but on account of the German occupation it was not until 1918 that it could be sent to France, finally through the assistance of Cardinal Mercier. In Paris the work was crowned by the Institute of France with the award of the Binoux prize.

The book presents the subject in an attractive way, showing the progressive development of the science and presenting biographical accounts of many of the masters, as well as extracts from their writings. It is written from an unusual point of view, as the author admits in his preface that he considers the discovery of facts more important than the development of hypotheses. He says that he has lived too much in the midst of theories and has been obliged to teach them for too long a time not to have conceived an incurable aversion to them. In spite of this extreme attitude the author has not failed to give a good account of the important chemical theories, at least of the older ones, but he has given less prominence than usual to some of the chemists that are usually very highly praised. For instance, he appears to have done scanty justice to the wonderful work of Cavendish, and he places the great master, Berzelius, in a decidedly subordinate position.

Except for some discussion of the positions of the atoms in organic compounds, this book scarcely touches the history of chemistry since 1860. The name of Mendeléeff and his periodic system of the elements are not mentioned, and although much attention is given to Berthollet in connection with mass action, the development of modern physical chemistry is neglected, and the names of Arrhenius, Ostwald and Nernst do not appear in the book. Although the author states in his preface that our table of atomic weights is one of the two principal achievements to be considered, little is said of the work of Stas, while the name of T. W. Richards, the master of atomic weight work, is not mentioned. The book may be regarded as giving a good account of the early history of chemistry up to about 1860, but as being very deficient in the history of the science since that time.

H. L. W.

4. *College Textbook of Chemistry*, by WILLIAM A. NOYES. 12mo, pp. 370. New York, 1919 (Henry Holt and Company).—This book is designed for students who are beginning the study of the subject. The author has tried to avoid the presentation of many more topics than the student can possibly remember by omitting many of the facts that are ordinarily given in books of this class, and bringing those that are given as far as possible into close logical relations. It does not appear from an examination of the book that this simplification has been carried too far, for a great number of important facts remain, and the fundamental principles of the science are well presented. At the close of each chapter there is a summary of its contents which should be of considerable aid to the student. At the ends of the chapters there are also questions or exercises which introduce a satisfactory amount of chemical calculations. The book contains no directions for laboratory work, so that for the usual college course it would need to be supplemented by another book containing such directions. H. L. W.

5. *A Positive Ray Spectrograph.*—As is well known, the analysis of positive rays by electric and magnetic fields, giving deflections at right angles to each other, was very completely worked out by J. J. Thomson during his epoch-making investigations of this subject. "This method, though almost ideal for a general survey of masses and velocities, has objections as a method of precision, many rays are lost by collision in the narrow canal-ray tube, the mean pressure in which must be at least half that in the discharge-bulb; very fine tubes silt up by disintegration

under bombardment; the total energy available for photography falls off as the fourth power of the diameter of the canal-ray tube.'' This quotation from a recent paper by F. W. Aston indicates the difficulties which he has largely overcome in designing the new precision spectrograph briefly described below.

The positive rays after arriving at the cathode face pass through two very fine parallel slits of special construction, and the emergent thin ribbon of rays is spread out into a spectrum by the electric field established between two parallel plates. The planes of these plates are appropriately tilted with respect to the plane determined by the long axes of the two slits in order to give free passage to the rays in their curved paths. The slit boundaries were made of aluminium as it was found that this metal suffers no appreciable disintegration by bombardment. The loss by collision (mentioned above) was minimized by exhausting the region between the slits to as high a degree as possible. After leaving the electric field the widened beam of rays fell approximately normally upon a stop or diaphragm which was so placed and adjusted as to transmit only a selected portion of the beam. After this, the rays transmitted traversed a magnetic field between the circular pole-pieces of an electromagnet. The direction and sense of the magnetic field were such as to bend the paths of the rays in a direction exactly opposite to that of the deflection produced by the electric field.

This arrangement of parts has the effect of bringing the rays to sharp linear foci in a plane which intersects the plane determined by the two slits at about the center of the electric field and which makes a certain angle with the undeviated ribbon. In short, the rays act as if they had come from an effective line source in the middle of the electric field so that the focusing is efficient both as regards definition and intensity. Obviously, the photographic plate is placed in the focal plane mentioned above. The author says: ''The field between the plates can be adjusted to allow the brightest part of the electric spectrum to be used which, as has been shown, is in general the same for all normal rays under steady discharge, and the values of e/m can be compared very accurately from the positions of their lines relative to those of standard elements which can be brought to any desired position on the plate by varying the magnetic field strength.''—*Phil. Mag.*, 38, 707, 1919. H. S. U.

6. *The Constitution of Atmospheric Neon.*—The primary object which F. W. Aston had in mind while designing the positive ray spectrograph, very briefly described in the preceding notice, was to develop a method for producing ''mass-spectra'' which would give a sufficiently high degree of precision to enable a final decision to be made concerning the alleged complex nature of neon. In a later paper the same investigator gives a detailed account of the important results obtained with his new apparatus. It is not necessary to enter into the details of the research

in this place. Suffice it to say that the numerical data given and the spectrograms reproduced in the paper show that, beyond all question, neon contains two isotopes having atomic weights 20·00 and 22·00 respectively. The accuracy is estimated at about one-tenth of one per cent. In order to give the accepted density of atmospheric neon the proportions by volume of the lighter and heavier isotopes are computed to be respectively 90 per cent and 10 per cent. The ratio 9:1 agrees closely with the estimated ratio of intensities of the corresponding mass-spectral lines. The original paper also contains some evidence for the existence of a third isotope, but this question is as yet by no means settled.—*Phil. Mag.*, **39**, 449, 1920. H. S. U.

7. *Lecture Experiments in Acoustics.*—The first sentence of a recent paper by H. KAYSER may be translated as follows: "I should like to make known two experiments which I have performed for many years in my lectures but which, as far as I am aware, are otherwise unknown." Since this holds for Germany, as the experiments are new to the present writer, and as they are undoubtedly very good, it seems desirable to give a free translation of Kayser's account of the demonstrations.

"1. It is in general very difficult to cause an observer, who has not a fine-trained musical ear, to hear a combination tone. This can be accomplished very easily for a difference tone if this tone be made variable instead of constant. I use two small glass whistles (each having the form of a sprayer) which give very intense notes. The whistle that gives the higher tone is open, while the other is closed by a piston which can be readily pushed in and drawn out. When the two whistles are blown simultaneously with the mouth the difference tone is produced but, for the most part, not detected. If, however, during the blowing, the piston be displaced so as to cause the lower tone to rise then the frequencies of the two whistles approach each other and hence the difference tone falls steadily lower. We then have the constant pitch of the first whistle, the rising pitch of the second whistle and, at the same time, the falling pitch of the difference tone. The sound of this falling note is easily detected even by the most untrained observer."

"2. From the prongs of a vibrating tuning-fork there proceed several trains of waves which, due to destructive interference, establish silence in certain directions; four such directions obtaining around the fork. To demonstrate this fact, I set up a resonator for the fork-tone by partially filling a cylindrical graduate or stand pipe with water to such a depth as to make the air column equal to a quarter wave-length of the fork-tone, that is, equal to the length of the resonance base-box belonging to the fork. If the vibrating fork (unscrewed from its sounding box, of course) be held horizontally with its prongs over the open end of the tube then, in general, the tone is heard very distinctly. If, however, the fork be rotated around the long axis of its stem four positions in one complete revolution will be found at each of which almost complete silence prevails, that is whenever one of the four directions of destructive interference coincides with the vertical axis of the resonance column. If, while the fork is held fixed in one of these positions, a tube made of card-board or of glass be pushed over one of the prongs (especial care being taken to avoid touching the prongs) then the sound becomes much louder, since the waves from the covered prong are screened off and interference is precluded. By alternately screening and unscreening the prong with the pasteboard cylinder the sound can be raised and lowered at will. I think that this is one of the most striking demonstration experiments in interference.''—*Phys. Ztschr.*, p. 11, Jan., 1920. H. S. U.

8. *Poiseuille's Law for Compound Tubes.*—The question as to whether Poiseuille's law holds for complex systems of tubes having many branch points is undoubtedly one of importance in the study of the blood circulation of vertebrates and it may not be without interest to experimental physicists. This problem has been successfully attacked by J. SCHLEIER with the apparatus described in the next paragraph.

A trunk-tube of 0·32 mm. internal diameter was blown larger at one end and divided into two branches. By means of short sections of rubber tubing each of these branches was connected with a single tube that was in turn forked into two branches. This process of doubling and connecting was repeated until the outer circle of tubes comprised 64 separate segments, the total number of tubes being 126. All of the tubes at the end of the system were united in a single outlet tube. The lengths of the tubes decreased from the intake end of the system to the middle and then increased to the outlet end. The least and greatest lengths were 2·5 cm. and 15 cm. respectively. The tubes next to the outlet pipe had the largest diameter, namely 0·51 mm. The end of the system was also provided with a set of vertical tubes by means of which the lateral pressure could be determined. Each tube was separately calibrated both as to circularity and uniformity of bore by the usual mercury thread method. Carefully distilled and repeatedly filtered water was used as the liquid. Compressed air, at a pressure of 130 cm. of water, was employed to drive the liquid through the system.

The loss of ''head'' was calculated, by the aid of Poiseuille's formula, from the viscosity of water at the prevailing temperature, the dimensions of the tubes, and the mass of water that flowed out of the system per second. The mean of a number of runs was found to give a calculated value slightly less than 7 per cent lower than the loss of head actually observed. A discussion of the unavoidable additive errors arising from the lengthening of the system by the rubber connecting tubes, from the irregularities at the branch points, from the curvature of the stream lines at these points, and from the calibrations of the numerous separate tubes, showed that the total error could be fully accounted for both in magnitude and in sense. Accordingly, the author concludes that Poiseuille's law may be applied to a complex system of capillaries made up of any number of branches.—*Phys. Ztschr.*, p. 14, Jan., 1920. H. S. U.

II. Geology and Mineralogy.

1. *United States Geological Survey;* George Otis Smith, Director. The following publications of the Survey have recently been issued (see earlier lists, vol. **48**, pp. 75, 77 and pp. 476, 477):

Fortieth Annual Report of the Director to the Secretary of the Interior for the year ending June 30, 1919. Pp. 200, 2 pls., 1 text figure. The growth of the Survey is strikingly brought out by the figures given by Dr. Smith. During the forty years of its existence the personnel has increased from 39 to 967 and the total annual appropriation from $106,000 to $1,437,745. The history of the Survey from its beginning in 1880, with Clarence King as Director, is a subject full of interest and one that merits full treatment elsewhere; those who have had the privilege of following its development may well marvel at the amount of valuable work that has been accomplished. The United States Geological Survey is an institution in which the country as a whole may take pride as well as each one of the many men who have had a place in its army of workers.

The year covered by the present report has seen the readjustment from special war activities to the regular program of scientific work. It is hardly necessary to add that the record of service in the Army and Navy on the part of members of the Survey was distinguished in many different lines, personal and otherwise. Looking back over the long period during which the Survey has existed, the gradual change from strictly scientific work to that of an economic nature is more and more conspicuous. This change has been inevitable and when the results are taken into account hardly to be regretted. It is lamentable, however, that the salaries of the geologists connected with the Survey and engaged, for example, in the search for oil and gas, are pitifully small as compared with those paid by outside organizations. It is stated that of the group of thirty oil geologists of ten years' experience only two now remain with the Survey.

The progress made in mapping the country and in investigating its water power possibilities are important topics dealt with in detail in the pamphlet noticed.

Other recent publications are as follows:

Topographic Atlas.—One hundred and twenty-five sheets.

Folios.—No. 210. Herman-Morris Folio; by Frederick W.

SARDESON. Pp. 10, 4 maps, 12 text figures. This folio embraces the Herman, Barrett, Chokio and Morris quadrangles in Minnesota.

PROFESSIONAL PAPERS.—No. 115. The Copper Deposits of Ray and Miami, Arizona; by F. L. RANSOME. Pp. 188, 54 pls., 29 figs.

Nos. 116, 117. The Sunset-Midway oil field, California. No. 116. Part I. Geology and oil resources; by R. W. PACK. Pp. 179, 45 pls., 15 figs. No. 117. Part II. Geochemical relations of the oil, gas, and water; by G. S. ROGERS. Pp. 100, 2 pls., 8 figs.

No. 118. Some American Jurassic Ammonites; by JOHN B. REESIDE, JR. Pp. 38, 24 pls., 1 fig.

No. 119. Reptilian faunas of the Torrejon, Puerco and underlying Upper Cretaceous formations of San Juan Co., New Mexico; by CHARLES W. GILMORE. Pp. 68, 26 pls., 33 figs.

No. 125-B. Gradations from continental to marine conditions of deposition in Central Montana during the Eagle and Judith River Epochs; by C. F. BOWEN. Pp. 11-21, pl. IV. No. 125-C. Pliocene and Pleistocene fossils from Alaska; by W. H. DALL. Pp. 23-37, pls. V, VI.

BULLETINS.—No. 666. Our Mineral Supplies; H. D. McCASKEY and E. F. BURCHARD, geologists in charge. Pp. 266, 1 pl., 6 figs.

No. 692. Mineral Resources of Alaska; report on progress of investigations in 1917; by G. C. MARTIN and others. Pp. 420, 10 pls., 13 figs.

No. 694. Bibliography of the metals of the platinum group: Osmium, platinum, palladium, iridium, rhodium, ruthenium, 1748-1917; by J. L. HOWE and H. C. HOLTZ. Pp. 555.

No. 695. The Data of Geochemistry; by F. W. CLARKE. Pp. 829. This is the fourth edition of a work which has proved of great value to geologists in all civilized countries. The first edition of 716 pages was published by the Survey in 1908 (see vol. **25**, p. 458).

No. 696. A Catalogue of the Mesozoic and Cenozoic Plants of North America; by F. H. KNOWLTON. Pp. 815.

No. 698. Bibliography of North American Geology for 1918, with subject index; by J. M. NICKLES. Pp. 145.

No. 699. The Porcupine Gold Placer District, Alaska; by H. M. EAKIN. Pp. 28, 8 pls.

No. 700. The analysis of Silicate and Carbonate Rocks; by W. F. HILLEBRAND. Pp. 283. (Fourth edition.)

No. 709, A, B. Triangulation and primary traverse in Delaware, Maryland, West Virginia, Florida; by R. B. MARSHALL, chief geographer.

No. 710. Parts C-F. On various deposits of manganese ores.

No. 711. Parts D-H. On oil, gas, coal, and peat from different localities.

No. 712. Parts A-G. The Alaskan Mining Industries.

Water Supply Papers.—Surface water supply of the United States; Nathan C. Grover, chief hydraulic engineer. No. 401, 1915, Part I. Nos. 436, 439, 440, 442, 443, 444, 1916, Parts VI, IX, X, XII, A, B, C. Nos. 454, 455, 458, 1917, Parts IV, V, VIII.

No. 446. Geology and ground waters of the western part of San Diego County, California; by A. J. Ellis and C. H. Lee. Pp. 318, 47 pls., 18 figs.

No. 448. Gazetteer of streams of Texas; prepared under the direction of Glenn A. Gray.

No. 450, A. Geology and water resources of the Gila and San Carlos Valleys, Arizona; by A. T. Schwennesen. Pp. 29, 4 pls., 2 figs. 450, B. Ground water in Lanfair Valley, California; by D. G. Thompson. Pp. 24, 2 pls., 1 fig.

Mineral Resources of the United States. Numerous advance chapters, 1916, 1917, 1918. A pamphlet by James M. Hill on platinum and allied metals in 1918 states that the production of crude placer platinum will hardly exceed 700 ounces a year and may be less if the present high price is much reduced.

2. *United States Bureau of Mines.*—It is announced that Dr. Van H. Manning, director of the Bureau of Mines since the death of Dr. Holmes in 1915, has resigned that position to accept the position as Director of Research with the recently organized American Petroleum Institute. Dr. Frederick G. Cottrell, who has been connected with the Bureau since 1911, having been made chief chemist in 1916, chief metallurgist in 1916 and assistant director in 1919, has been nominated to succeed Dr. Manning.

Recent Bulletins of the Bureau are given in the following list (see earlier, vol. **48**, p. 78):

No. 78. Approved explosion-proof coal-cutting equipment; by L. C. Ilsley and E. J. Gleim. Pp. 52, 18 pls., 3 figs.

No. 95. A glossary of the mining and mineral industry; by Albert H. Fay. Pp. 754.

No. 150. Electrodeposition of gold and silver from cyanide solutions; by S. B. Christy. Pp. 171, 8 pls., 41 figs.

No. 162. Removal of the lighter hydrocarbons from petroleum by continuous distillation; by J. M. Wadsworth. Pp. 162, 50 pls., 45 figs.

No. 183. Abstract of current decisions on mines and mining, reported May-August, 1919; by J. W. Thompson. Pp. xxii, 167.

No. 196. Coal-mine fatalities in the United States during the year 1919; compiled by A. H. Fay. Pp. 86.

A number of Technical Papers have also been issued.

3. *The Geology of the Mid-Continent Oil Fields;* by T. O. Bosworth. Pp. 314, 32 maps and figs. New York, 1920 (The Macmillan Company).—In this volume there is presented by an Englishman a readable account, with not too much detail, of the history of development, the statistics, and the relations of the

oil and gas accumulations to the geology and structure of eastern Kansas, Oklahoma, and north central Texas. The character of the oil and gas is also discussed, along with the production of helium and gasoline from the natural gas, and something is said of the salinity of the water of the oil fields. The geologic terminology is American. For anyone wishing a good general account of the Mid-Continent oil fields, and references to the more technical publications on the areas, this book is recommended. C. S.

4. *The Mackenzie River Basin;* by CHARLES CAMSELL and WYATT MALCOLM. Geological Survey Canada, Mem. **108,** 154 pp., 14 pls., 1 text fig., 1 map, 1919.—This valuable compilation brings together concisely the present knowledge of the economic possibilities of the Mackenzie Basin and particularly the observations of travelers in regard to the geological formations and their possible mineral resources. The senior author has long been directly acquainted with the region and is, therefore, enabled to write much at first hand. A large map gives the known distribution of the geologic formations along the various water routes of travel. C. S.

5. *Recherches Géologiques et Pétrographiques sur le District Minier de Nicolai-Pawda;* by LOUIS DUPARC and AUGUSTIN GROSSET. A Monograph published in Geneva, 1916. 294 pp., 62 figs., 54 photographic reproductions, 7 pls., and an atlas containing a geological map.—This monograph is an exhaustive study of the geology of the district about the village of Pawda, situated at the confluence of the Pawda and Lialia rivers on the eastern watershed of the Ural Mts. near latitude 59° 15′ N. The rock formations of the region show igneous rocks, including deep-seated, effusive and dike types, and metamorphic and sedimentary rocks. The deep-seated igneous rocks are mostly basic, consisting of the gabbros, together with smaller amount of pyroxenites, peridotites, dunites, hornblendites and a quartz-diorite. The acid rocks are represented in much smaller amounts, chiefly by an amphibole-granite. The effusive rocks, while showing also both basic and acid types, belong largely to the diabase group. The dike rocks are very numerous, presenting the three types, melanocratic, mesocratic and leucocratic. They vary in size from narrow ribbons to immense dikes. All these igneous rocks belong apparently to a single petrographic province, being derived from a single magma by differentiation. The metamorphic rocks consist also of basic types derived from related igneous rocks and of acid types derived from quartzites.

The valuable mineral deposits of the region consist in ores of iron which have been formed by segregation, by contact processes or by alteration; of chromite formed by direct segregation; of copper in veins; of gold in quartz veins and in gravels; and of platinum in placer deposits. Of these various metals, platinum is by far the most important, this district being the third in value of its platinum production of the districts in the Ural Mts. There are two dunite areas immediately in the region and a third contributory to it. From these three centers the platinum has been distributed to the gravels of the rivers of the area.

W. E. F.

6. *New Mineral Names;* by W. E. FORD (communicated—continued from vol. **47**, pp. 446-448, June, 1919):—

Bäckströmite. G. AMINOFF. Geol. För. Förh., **41**, 473, 1919. Orthorhombic. $a:b:c = 0{\cdot}7393 : 1 : 0{\cdot}6918$. In small prismatic crystals or in larger crystals without terminations. Frequently in oriented intergrowths with crystals of pyrochroite, so that the base (0001) of the latter is parallel to (010) of bäckströmite. Comp.—$Mn(OH)_2$. From X-ray pictures it is thought that the bäckströmite has undergone a molecular change to the structure of pyrochroite. It has also frequently further altered to manganite. From Långbanshyttan, Sweden. Named after Helge Bäckström.

Bismutoplagionite. E. V. SHANNON. This Journal, **49**, 166, 1920. A plagionite-like mineral containing chiefly bismuth instead of antimony, $5PbS{\cdot}4Bi_2S_3$. From Wickes, Jefferson Co., Montana.

Cocinerite. G. J. HOUGH, this Journal, **48**, 206, 1919. Massive. Color, silver-gray, slowly tarnishing to black. Streak, lead-gray. $H = 2{\cdot}5$. $G. = 6{\cdot}14$. Comp.—Cu_4AgS. Found in 1901 in the Cocinera mine of the Mexican Copper Co., at Ramos, San Luis Potosi, Mexico.

Echellite. N. L. BOWEN. Amer. Min. **5**, 1, 1920. Probably orthorhombic. Fibrous, in radiating spheroidal masses up to 1 cm. in diameter. $H. = 5$. Color white. $\alpha = 1{\cdot}530$: $\beta = 1{\cdot}533$; $\gamma = 1{\cdot}545$; $2V = 50°$. Fibers elongated parallel to Y. Comp.—$(Ca,Na_2)O{\cdot}2Al_2O_3{\cdot}3SiO_2{\cdot}4H_2O$. From a basic intrusive, found at Sextant Portage, Abitibi River, Northern Ontario. Named from the French *échelle, ladder,* in allusion to the stepped character of the molecular ratios.

Ferrazite. T. H. LEE and LUTZ FLORES DE MORAES, this Journal, **48**, 353, 1919. A so-called "fava" found associated with diamond from Brazil. Color, dark yellowish white. $G. = 3{\cdot}0$-$3{\cdot}3$. Comp.—$3(Ba,Pb)O{\cdot}2P_2O_5{\cdot}8H_2O$. Named after Dr. Jorge Belmiro de Araujo Ferraz.

Gavite. EMILIO REPOSSI, [Att. Soc. Ital. Sci. Nat., **57**, 131-155, 1918], Amer. Min., **4**, 132, 1919. Apparently a variety of talc, said to differ from that mineral in the amount of water present and in its solubility in acids. Found in the Gava valley, Italy.

Manganfayalite. JOHN PALMGREN, [Bull. Geol. Inst. Univ. Upsala, **14**, 109-278, 1917], Chem. Abs., **13**, 1197, 1919. Name given to a manganese-rich fayalite found in a eulysite rock from Södermanland, Sweden.

Oruetite. S. PINA DE RUBIES, [Anal. soc. espan. fis. quim., **17**, 837, 1919] Amer. Min., **4**, 15, 1919. Lamellar structure. Perfect cleavage. H. = 1·5. G. = 7·6. Metallic luster. Color, steel-gray. Fusible. Comp.—Bi_8TeS_4. From Serrania de Ronda, Spain.

Pyrobelonite. G. FLINK. Geol. För. Förh., **41**, 433, 1919. Orthorhombic. $a:b:c = 0·80402 : 1 : 0·65091$. In very slender needle-like crystals showing, a(100), m(110), n(120), e(201), c(001), d(011), f(031), p(111) and o(221). Color, fire-red. Powder, orange-yellow or reddish. Elongation positive. Probable optical orientation; Opt. —; Ax. pl. || $c(001)$; Bx_{ac} || a axis. Indices high. H. = 3·5. G. = 5·377. Comp.—A hydrous lead-manganese vanadate, $4PbO·7MnO·2V_2O_5·3H_2O$. Apparently related to descloizite. Found associated with hausmannite, barite, and calcite at Långbanshyttan, Sweden. Named from πῦρ, *fire* and βελονη, *needle,* in allusion to its acicular crystals and red color.

Sobralite. JOHN PALMGREN, [Bull. Geol. Inst. Univ. Upsala, **14**, 109-278, 1917], Chem. Abs., **13**, 1198, 1919. A triclinic variety of pyroxene found in a eulysite rock from Södermanland, Sweden. Optically +. $Z : c = 48°$, $Y : c = 55·1°$, $X : c = 62·2°$. Colorless. Named after Professor J. M. Sobral.

Sphenomanganite. G. FLINK. Geol. För. Förh., **41**, 329, 1919. A variety of manganite which shows sphenoidal crystal forms from Långbanshyttan, Sweden.

Villamaninite. W. R. SCHOELLER and A. R. POWELL. Min. Mag., **19**, 14, 1920. Isometric. In irregular groups of rough crystals showing cube and octahedron and in small radiating nodular masses. H. = 4·5. G. = 4·4-4·5. Color, iron-black. A disulphide, RS_2, with R = Cu and Ni, with smaller amounts of Co and Fe. A little selenium replacing sulphur was noted. Probably a member of the Pyrite Group. Comp.—Cu, 19; Ni, 18; Co, 7; Fe, 4; S, 50; Se, 1·5. Occurs disseminated in crystalline dolomite from Cármenes district near Villamanín, Prov. Léon, Spain.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—At the recent meeting of the National Academy, fifteen new members were elected, as follows: William Duane, Harvard University, physicist; Dr. James Rowland Angell, psychologist and recently elected President of the Carnegie Corporation; Wilder Dwight Bancroft, Cornell University, chemist; Dr. Bailey Willis, Leland Stanford University, geologist; Joel Stebbins, University of Illinois, astronomer; Hans F. Blichfeldt, Leland Stanford University, mathematician; Henry Prentis Armsby, Pennsylvania State College, chemist; A. J. Carlson, University of Chicago, physiologist;

Lewis R. Jones, University of Wisconsin, plant pathologist; George Washington Pierce, Harvard University, physicist; Clarence Erwin McClung, zoologist; Elmer Peter Kohler, Harvard University, chemist; Charles K. Leith, University of Chicago, geologist; Elmer V. McCollum, Johns Hopkins University, chemist; Harris J. Ryan, Leland Stanford University, electrical engineer.

Dr. Frank D. Adams, President of McGill University, Montreal, was elected a foreign associate member; also Marie E. C. Jordan, College of France; François A. A. Lacroix, Musée d'Histoire Naturelle, Paris; Heike K. Onnes, University of Leyden; Sir David Prain, Royal Botanic Gardens, Kew; Santiago Ramon y Cajal, University of Madrid.

New members of the Academy's council elected were Arthur L. Day, Geophysical Laboratory, Washington, and T. H. Morgan of Columbia University.

2. *Carnegie Institution of Washington.* ROBERT S. WOODWARD, *President. Year Book No. 18, 1919.* Pp. xvi, 380.—The year covered by the present volume is made notable in the history of the Institution since in it came the death of the founder, the able business man and broad-minded philanthropist, Andrew Carnegie. This took place at his home in Lenox, Mass., in August, 1919, when Mr. Carnegie had nearly concluded his eighty-fourth year It is fitting that the personality of Mr. Carnegie and his work, not only in connection with the Institution but also his many other useful activities for industry and the country at large, should be dwelt upon at length in this place. The year of 1919 was also marked by the death of two of the most eminent Trustees of the Institution, Andrew D. White and Theodore Roosevelt.

The influence of the world war had its effect upon the Carnegie Institution as well as upon the many Bureaus immediately connected with the Government. This was true of the work of the Geophysical Laboratory in developing the optical glass industry; in the manufacture of precision micrometers for the Bureau of Standards and of optical instruments by the staff of the Mount Wilson Observatory; in the construction of special devices for the Navy by the Department of Terrestrial Magnetism; in the investigation of the effects of undernutrition in the Nutrition Laboratory. These are some of the contributions made by the Institution in response to the Nation's call.

Notwithstanding these demands upon its energies the departments named have also gone on, so far as possible, with their regular work, while other departments have been able to keep their activities up to the maximum. Of the latter may be mentioned in particular the following with the names of their directors: of Botanical Research (D. T. MacDougal); of Embryology (George L. Streeter); of Experimental Evolution and of Eugenics (C. B. Davenport); of Marine Biology (Alfred G. Mayor).

Especially noteworthy are the numerous investigations of the Desert laboratory at Tucson, Arizona, devoted particularly to the fundamental features of growth, nutrition and metabolism of plants of arid regions; the director of the laboratory, Dr. MacDougal, has had a large part in the many investigations of which a digest is given in the volume. Another epoch-making advance is the completion of the 100-inch Hooker telescope, described, with a summary of the important results already obtained with it, by the director, Dr. George E. Hale. The pages (217-264) devoted to these subjects are some of the most interesting and original in matter that the present volume contains.

The total sum appropriated by the Institution during 1919 was $1,612,602 which has been exceeded only once, namely, in 1914; of this sum nearly $850,000 was for the large projects. Twenty-nine volumes have been issued in the year aggregating 8,265 pages. Since its beginning four hundred and one volumes have been sent out by the Institution embracing a total of more than 111,000 pages.

The latest volumes received (see the last number, pp. 387, 388) are as follows:

"No. 53, vol. III. Egyptological Researches: The bilingual decrees of Philæ; by W. Max Müller. Quarto, pp. 88, 40 plates. Professor Müller died suddenly on July 12, 1919, but Dr. Henry F. Lutz has taken charge of the publication of this volume, making only a few minor changes in the text.

No. 290. Plant Indicators: The relation of plant communities to process and practice; by Frederic E. Clements. Pp. xvi, 92 plates, 25 text figures.

4. *The Industrial Arts Index.* (The H. W. Wilson Company, New York City.)—This is a cumulative index to engineering, trade and business periodicals. The number in hand (dated March, 1920) is No. 3 of Vol. VIII and contains 178 pages; the papers are grouped as to subjects, arranged alphabetically. This number includes references for January, February and March; upwards of 120 journals are referred to in the Index. The announcement is made on the cover that the Special Libraries Association annual meeting was to be held in New York City on April 14 to 17.

Obituary.

James M. Macoun, chief of the biological division of the Geological Survey, Canada, died January 8, aged 58.

W. Pfeffer, the plant physiologist, died in Leipzig on January 31, at the age of seventy-five.

R. Messel, F.R.S., the able industrial chemist, died on April 18 in his seventy-third year.

INDEX TO VOLUME XLIX.*

* This Index contains the general heads, Botany, Chemistry, Geology, Minerals, Obituary; under each the titles of Articles referring thereto are included.

CONTENTS.

Barker