ART. IV.—*The Devonian System of North and South Devonshire;* by H S. WILLIAMS.

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LAST fall I had the pleasure of examining the typical sections of Devonian rocks in Devonshire, England. I went over the southern sections at Torquay, Saltern Cove and Newton Abbot and neighborhood under the guidance of Mr. Ussher of the Geological Survey, who has recently made careful study of the localities for the survey map, and in North Devonshire I had the guidance of Mr. T. M. Hall, a local geologist at Pilton, who has an admirable collection of the fossils and is personally familiar with the ground. I went across the section from Barnstaple to Ilfracombe collecting fossils myself at the fossiliferous zones of Ilfracombe, Sloly and Pilton, Toporchard, Strand and Barnstaple. In Pilton, also, I saw the admirable collection of Mr. Hall In London I examined the collections in the Jermyn Street and South Kensington Museums, at the former place Mr. Newton kindly showing me survey material not yet reported upon, and at South Kensington Mr. Etheridge showing me his original maps and pointing out the peculiarities of the sections. I also had opportunity, through the kindness of Mr. Whidborne, of examining the collection of fossils from the limestone of Lummaton. This collection, which was reported upon by Mr. Davidson in his Monograph on the British Devonian fossils is, perhaps, the finest collection in England of the fossils of that zone. In this study of the English Devonian that which impressed me most vividly was, 1st, that the fossils are very closely allied to the species in the New York Devonian, although in the great majority of cases passing under different names, and, 2d, that the rocks in their appearance, composition and order are as different as two distinct systems well can be. Not only do they differ from those of New York, but the South Devonshire section is utterly unlike that of North Devonshire, quite as unlike as the Old Red sandstone farther north is from either.

In North Devonshire, the whole series, from the Foreland grits and Lynton slates up to the Pilton beds, is made up of siliceous slates, grits and occasional argillaceous slates, and here and there intercalated beds of impure limestone. The colors are grays and purples with light browns and yellows for the grits. Slaty structure prevails throughout and obliterates or makes difficult of detection the true bedding of the rocks. Fossils are rare except in the limestone layers of the middle part and in the slates and shales of the upper part. The rocks

are regarded as having a general dip a little west of south, and the outcrops lie in belts obliquely across the county from northwest to southeast and are in order, from below upward, the Lynton, Hangman, Combe Martin, Haggington, Ilfracombe, Mortehoe, Pickwell Down, Baggy, Croyde, Pilton and Barnstaple beds. The last are conformably overlaid by shales and limestones and grits of the Carboniferous age which occupy the interval separating them from the Devonian of South Devonshire. Some faults are recognized but they are few and simple.

In South Devonshire the rocks are greatly disturbed, broken by faults, standing at various angles, folded and distorted; eruptive rocks frequently cut through them and beds of volcanic ash are interstratified with them. Hence has arisen great dispute and uncertainty as to the true order of succession of the deposits although their fossils were referred to the Devonian age nearly fifty years ago.

The most conspicuous member of the Southern Devonian is the great Devon limestone. This is seen at Torquay, at Newton Abbot and farther south at Plymouth. It is blue or white in color, and sometimes red and shaly near its base. There are also great masses of argillaceous red shales which are considered as belonging above it. The character of the succession is generally interpreted to be a series of red slates and shales and grits followed by the limestone, which is again followed by a red shale. At Torquay the shore for a mile south of the town is made up of Triassic conglomerate with pebbles of Devonian limestone, fine red argillaceous slates, not only laminated but so twisted and contorted that neither lamination nor original bedding can be followed continuously for more than a few feet. With this are associated other red slates and limestones and dikes of eruptive rock. These are all so confused that except for the fossils found in them their order of sequence could hardly be determined.

One peculiar feature of the sections as seen about Ogwell and Newton Abbott is the presence of beds regularly interstratified with the limestones and shales, composed of volcanic ash. These "Schalsteins," Mr. Ussher tells me, sometimes contain fossils, and in places they are ten or twenty feet thick.

It will be seen, without comment, that the South Devonshire sections, from which most of the middle and lower Devonian fossils have been obtained, are valueless for determining the order of sequence of the faunas. There are many places (I saw such near Newton Abbott) where limestones, appearing very similar in color and structure, and within a stone's throw of each other, hold distinct faunas. In fact the interpretation of the order of the beds is a matter of the greatest difficulty even when occasional fossils appear.

In North Devonshire the difficulty is not so great, but even there the fossils are rare, and the contorted and slaty structure of the beds, even without the occasional faults, has caused grave dispute as to the true relation of the beds. As classified by Mr. Robert Etheridge, the North Devonshire section is divided into Lower, Middle and Upper Devonian, as follows:

Lower.—The *Foreland grits* and the *Lynton* and *Woodsbay slates*, with fossils in the Lynton slates and in limestone beds intercalated in the higher part of the series.

Middle.—Shales and slates with occasional thin beds of impure limestone, from the *Hangman* and *Trentishoe grits* inclusive of all the coast rocks of the north shore as far as to Morthoe. The Lower beds of Combe Martin and Haggington in their calcareous layers holding the *Stringocephalus*, or Middle Devonian fauna, and the beds about Ilfracombe hold a somewhat higher fauna.

Upper.—From the *Pickwell Down Sandstones* all the slates, shales and grits with occasional calcareous streaks across to the south line of North Devonshire at Barnstaple Bay (called *Marwood*, *Baggy*, *Croyde*, *Pilton*, *Barnstaple*, etc., beds).

It is with this section more particularly that the classification of the New York system was compared in the first surveys. And when we notice that the fauna we now consider as Lower Devonian (i. e., that of the Corniferous limestones), is little represented there and that the Hamilton fauna is largely made up of species quite distinct from those of North or South Devonshire, it is not surprising that T. A. Conrad in the preliminary reports of the State survey drew the line between the Silurian and Devonian of the New York system at the top of the Hamilton formation. Before becoming acquainted with them I expected the original Devonshire sections and fossils to throw some light upon the problem of proper classifications of the Devonian system, but I came away convinced that for internal evidence as to the order of sequence or even the precise composition of the faunas the Devonshire sections are extremely unsatisfactory. It is probable that the fossils of the Plymouth and Newton Bushel limestone formed the basis for the notion of a Middle Devonian. These limestones furnished the fossils which were recognized by Lonsdale, in 1839, as constituting a fauna intermediate between the Silurian and Carboniferous, a determination which resulted in the establishment of a new system, the Devonian. It is, however, quite uncertain what fauna followed or what preceded this limestone in South Devonshire. The rocks about Pilton and Barnstaple, Marwood and Sloly in North Devonshire furnished the originals of the Upper Devonian fauna. The Ilfracombe fauna was

identified as in general equivalent to that of the South Devonshire limestones and thus became Middle Devonian, while the Lynton fauna and the faunas of the shales of South Devonshire were assigned to the Lower Devonian because they were below the Middle limestone fauna.

There appears to be no well defined Lower Devonian fauna for England nor any uniform character of deposits to represent it. What occurs below the Middle Devonian limestone is in all cases fragmental; arenaceous slates, grits, or what the Germans call "*schists*," prevail. In North Devonshire the limestone occurs in lenticular masses in the Ilfracombe slates. In South Devonshire the limestones of Plymouth, Torquay and Newton are more or less massive. In Belgium and North France they are represented by the Givetienne limestone. In the German area it is the Eifelien Kalk and the Stringocephalus limestone. In Russia, the Urals, and in Siberia a limestone holding a similar fauna is seen. Below these limestones are slates, conglomerates, sandstones, called by various names: Lynton, Spiriferen sandstein, Gédinnien, Coblenzien, etc., in many sections not recognized at all; in the more northern and western districts called "lower old red."

In North Russia, also in Wales, reaching into Somersetshire (the county bordering North Devonshire on the east) are seen the "old red sandstones." These are more typically represented in Scotland and across the Channel in Ireland.

During the same geological interval, while the estuary, or as Professor Geikie calls them, fresh-water lake deposits of the Old Red Sandstone were being deposited in the north and as far south as the borders of Somersetshire, sands and muds with occasional layers of limestone and marine fossils were deposited in North Devonshire and, still farther, in the Southern Devonshire district, and in the northern parts of Europe a limestone was forming continuously for all the central part of the period and a rich coral and purely marine fauna occupied the region. M. Charles Barrois advances the opinion that the different Devonian limestones of Europe ought to be referred to different Devonian stages, viz: the coral reefs of Erbray to the Gedinnien, those of Brittany and Spain to the Coblenzien, those of Cabrieres to the Eifelien, and those of the Ardenne to the Givetienne and Frasnienne.—*Faune du Calcaire d'Erbray*, p. 335, Lille, 1889.

Much of the difficulty and confusion seen in attempts to correlate the various sections comes, I am convinced, from a commonly accepted assumption that formations must be correlated entire, whereas, as in the above example, the lenticular limestones of Ilfracombe undoubtedly represent the massive limestone formation of the south, while the shales and fragmental

layers represent the condition of a more northern area, and doubtless when fossils are obtainable will be found to represent distinct (at least local) faunas.

It must be evident that the marine invertebrate faunas of the whole Devonian are but the equivalents of the vertebrate fauna and the flora of the Old Red Sandstone. This striking law is easier to accept and practically understand than the other, viz: that marine invertebrate faunas of very different species with few and possibly in many cases no common forms actually co-existed in the same ocean at the same time. With this second law in mind it is clear to see that the shifting of currents in the ocean—the oscillation upward and downward of the land in relation to the sea-level, the many changes in the relations of land and sea, of which there are unmistakable evidence—all these events must have produced mixing and changing of the faunas over any particular spot, not only constantly but to an extent we can scarcely conjecture from the very slight evidences preserved.

As the off-shore and deeper sea faunas of to-day differ from those living between tides on the coast, so we must believe they differed in the Devonian age. As the fauna off the Florida coast differs from that of Labrador now, so we must believe there were striking differences between the faunas of the warm ocean of the equatorial regions and the faunas of the colder polar regions of the same sea for a time as far back as such differences in climate existed.

When, therefore, we attempt to draw parallel lines to connect the stratigraphical series of New York or other parts of America, with those of England or the continent of Europe, the mere identity of species in their numerical relations is an unsatisfactory guide.

The species that are found identical both sides the sea are likely to be species whose vertical range is as long as a whole system, and the closely related forms may be either (*a*), one the successor of the other, or (*b*), one the modified migrant of the other. As to the relationship between two separate faunas, the one following the other, the difference in species and genera is often greater than that between either of the faunas and the one next below it in a like kind of deposit. As an example, we may cite our Genesee shale and Marcellus shale whose respective faunas more closely resemble each other than either of them does that of the Hamilton fauna between. To eliminate errors of this kind we should compare faunas of like deposits with each other, not because the terrane of the one region has in its beginning and ending any necessary relationship with the corresponding one of the other region, but because conditions of life are likely to have been more nearly uniform where the deposits are alike.

If we examine the Devonian limestone fauna of Devonshire we find its generic combinations very similar to those of the Corniferous limestone of our Appalachian basin, but the same genera are also seen in the calcareous strata of the Hamilton formation, and the specific types of the genera running through the whole system are more closely allied with those of our Hamilton, and even Chemung horizons than with those of our Lower Devonian. The great prominence of corals reminds us of the Corniferous, but when we compare the Brachiopods we find numerous forms, the representatives of which do not appear in our Appalachian sections till after the Hamilton terrane is passed. Such are *Spirifera disjuncta*, *Rhynchonella pugnus* and *acuminata*, *Spirifera curvata*, *Orthis striatula*, *Rhynchonella cuboides*, etc.

Some of these are not in the main limestone on the continent, and there are some indications of a separation of the fauna, in the sections of the Hartz and of Russia, more nearly corresponding to our division into Middle and Upper Devonian. And even in the more western sections of Europe the Frasnienne, as distinguished from the Givetienne limestone contains a decidedly later fauna than the latter. It appears probable that the limestones of South Devonshire represent the general interval between the close of our Corniferous and the early part of our Chemung formation.

Another problem is here suggested, viz: was there any migration of the faunas? For the determination of this point I have made a study of the Cuboides fauna, tracing it from New York to England, Belgium, France, Germany, Russia, Siberia, Persia and China. There seems to be good evidence that this fauna whose place is at the top of the Devonian limestone periods of these regions had a center of distribution nearer north France than either eastern America on the one hand or China on the other. If we take this as a uniform horizon, homotaxially, it may be said that a considerable number of species (including forms, under different names, which are very closely allied modifications of the same races) appeared before the "Cuboides" stage in the English, European and Russian sections, but not till after that stage in the New York sections.

In the sections of the interior of North America this particular fauna has not been recognized. *Rhynchonella castanea* Meek, of the MacKenzie River basin and Nevada, although in some respects resembling *R. cuboides* Sow., appears to be specifically extinct. The few species which occur in the "Cuboides zone" of Europe and range across the continent of America, in their generic history appear to represent a Carboniferous stage of development, and while abundant in the Euro-

pean sections are not common with us. The *acuminata* and *pugnus* types of *Rhynchonella* are known to us at the base of the eastern Chemung terrane, in Iowa at a doubtfully determined horizon, and in other western localities in association with Carboniferous faunas. In England and Europe they are conspicuous in association with what are called "Middle Devonian" faunas. *Spirifera disjuncta* is with them a Middle, as well as Upper, Devonian form. With us it is characteristic of the final Upper Devonian fauna alone.

A comparison of the fauna of the Upper Devonian of North Devonshire with our Devonian fossils shows that it is represented by our Chemung fauna, and although there are indications that it is a later fauna, as in its *Productus* with a row of strong spines along the center ("*Prod. curtinotus*" T. M. Hall), the ordinary forms are "*Productus* (or *Strophalosia*) *productoides*" and "*Chonetes Hardrensis*." The Carboniferous aspect of this Pilton fauna is not more marked than the Upper Devonian aspect of the fauna of the limestones of Ilfracombe and Newton.

Comparison of these European Devonian sections and their fossils with the corresponding ones of the Appalachian basin leads me to the hypothesis that the marine faunas of the Devonian had different histories in the two areas. There is a continuity in the succession from the lowest to the highest faunas of the system in Europe which we do not find in the American series. The explanation which seems to me most probable is that the Middle and Upper Devonian faunas of Europe (probably also down to the Lower Devonian fauna) were merely successive stages of the life inhabitants of a common and more or less continuous basin. That during this period the Appalachian basin was bounded on the east by a considerable barrier and was partially separated from the central continental basin by the Cincinnati uplift.

Up to the close of the Hamilton the Devonian faunas in the Appalachian and in the Central North American basin were extensions of the same general fauna, but they differed markedly from the corresponding European faunas.

With the Tully limestone an incursion of species of the European fauna began, and the following Chemung fauna shows a resemblance to the Upper Devonian of Europe, especially in those species which were present, themselves or in their ancestral representatives, in the European Middle Devonian. In the sections along the central part of the Appalachian basin where the Tully limestone appears holding the European "Cuboides" fauna, the Hamilton fauna is abruptly stopped, but on the eastern side of the basin the Hamilton appears to continue on, even mingling with the few

Chemung species which appear on that side, while on the western side of the basin a distinct fauna, the Waverly, succeeds the Hamilton with no trace of the Chemung or "Cuboides" faunas between.

This American Carboniferous (which we call "Sub-carboniferous"), marine fauna offers as strong contrast with the homotaxial fauna of Europe as do the respective Middle Devonian faunas of the two regions.

It seems to me not unreasonable to assume that the opening of some channel to the north or east allowed migrants of the Devonshire "Cuboides" and Upper Devonian faunas to enter the Appalachian basin, but that they did not advance far enough southward to appear west of the Cincinnati axis. While the general rise of temperature with the approach of the Carboniferous conditions caused the northward shifting of the rich "Sub carboniferous" faunas to occupy the Appalachian basin and, at the same time, the elevation of land to the northeast cut off communications from that direction and prevented any marine forms from thriving north of Pennsylvania during the period extending from the cessation of the Chemung fauna onward. From this stage on, all along the eastern and northern part of the Appalachian basin, there was no pure marine life, the sediments pass from fine red and gray muds to micaceous shales and sandstones and conglomerates, and finally, elevation of the continent into dry land is clearly indicated by the presence of coal deposits from Pennsylvania to Kansas.

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