BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 11, PP. 333-346

SILURIAN-DEVONIAN BOUNDARY IN NORTH AMERICA

BY

HENRY S. WILLIAMS

ROCHESTER
PUBLISHED BY THE SOCIETY
MAY, 1900

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 11, PP. 333-346 MAY 21, 1900

SILURIAN-DEVONIAN BOUNDARY IN NORTH AMERICA.

BY HENRY S. WILLIAMS

(*Read before the Society December 28, 1899*)

CONTENTS

Page
Questions involved in determining geological boundary planes 333
The questions defined 333
Top of the standard Silurian system, the "Tilestones" (= Downton sandstone) of Wales 334
Base of the typical Devonian system not known 334
Oriskany fauna of America equivalent to lowest arenaceous Devonian fauna of Europe 336
Hercynian faunas Eodevonian 337
Is the Lower Helderberg equivalent to the Hercynian? 337
The real problems in determining the Silurian-Devonian boundary for America. 337
Character of the evidence as to transition 337
Merostomes and fishes 338
Salt basins of Waterlime and Onondaga of the interior and their absence in Maine and New Brunswick sections 338
Introduction of Oriskany fauna coincident with elevation of present Atlantic border of continent 339
Transition from marine Silurian to Old Red sandstone in Wales synchronous with appearance of Oriskany fauna in eastern America 340
Summary of geological and stratigraphical argument 341
The paleontological argument 341
Nature of the evidence 341
The Tilestone fauna recognized in the Upper Arisaig by J. W. Salter 342
Fifteen Lower Helderberg species recognized in Arisaig section by Doctor Ami 344
Place of Tilestone fauna in Arisaig section equivalent to transition from marine to estuary conditions in Gaspé section, and to first appearance of Oriskany in Maine and New Brunswick 345
Summary and conclusions 346

QUESTIONS INVOLVED IN DETERMINING GEOLOGICAL BOUNDARY PLANES

THE QUESTIONS DEFINED

In the determination of the boundary plane for the rocks of a geological province between two great systems, such as the Silurian and Devonian, there are two distinct questions involved:

1. Conformity to established usage in the application of names and definitions, and

2. Determination of the correlation of local and definite faunas of the region in question with the particular faunas of the standard sections.

The discussion of the first question must conform to rules accepted by those judging the questions. The general principle of historical priority of usage is accepted by all geologists as a fundamental principle in the application of names and their definitions to faunas, formations, and classification.

TOP OF THE STANDARD SILURIAN SYSTEM, THE "TILESTONES" (=DOWNTON SANDSTONE) OF WALES

According to this general principle, the standard definition of the Silurian system is that applied by Murchison to the system so named by him in the classic monograph called "The Silurian System," published in 1839. By this standard the upper limit of the Silurian system is fixed for all future workers. This upper limit was originally placed at the base of the "Tilestones" (Downton sandstone), the highest Silurian formation being the upper Ludlow rock, near Downton castle.* The "Tilestones," lying immediately above it conformably, were then included in the Old Red sandstone.†

In later elaborations of the system the "Tilestones" were transferred to the Silurian because their fossil contents agreed in the main with the fauna of the Ludlow rock below; and Murchison made the explanation that originally it had been associated with the "Old Red" because it was often of reddish color and decomposed to a reddish soil.‡ To this have been added the Ledbury shales of Salter, some 300 feet of red, gray, and purple shales and sandstones, containing Pterygotus and Cephalaspis,§ which by geologists now are recognized as included with the Ludlow rock in the upper part of the Silurian system of Wales.‖ Not only Merostomes (Eurypterus and Pteygotus) and fishes (Onchus, Cyathaspis, and Pteraspis), but also land plants are reported from these upper beds of the Silurian system. The marine invertebrate faunas cease at this point in the Welsh section, and are followed by Old Red sandstone.

BASE OF THE TYPICAL DEVONIAN SYSTEM NOT KNOWN

The Devonian system was established on a different basis. The fossils collected at Plymouth, Torquay, etcetera, in South Devonshire, were

*See Silurian System, p. 197.

† Loc. cit., p. 181.

‡ Siluria, ed. 1854, p. 138.

§ See Quarterly Journal, vol. xvi, p. 193; vol. xvii, p. 152.

‖ Kayser: Text-book of Comparative Geology, trans. by Lake, 1893, p. 65.

determined by William Lonsdale to belong to a marine fauna intermediate between those of the Silurian and the Carboniferous rocks, and the rocks containing them were therefore constituted a system by Sedgwick and Murchison in 1838. These fossils mark the rocks which were accepted as the marine equivalents of the Old Red sandstone, to which was applied the name of "Devonian system;"* but in this definition of the Devonian system the lower limit, stratigraphically, was not known in Devonshire. Further elaboration of the lower formations and faunas of the Devonian system has resulted from the study of other faunas in other regions. In the Ardennes and Rhenish regions the lowest Devonian has been called Gedinnian (Dumont, 1848), and in some places rests directly on Cambrian rocks. The Gedinnian is followed above by the Coblenzian (Dumont, 1848). These more western representatives of the European Eodevonian are chiefly shales, sandstones, and grits. On going eastward limestones with marine faunas are met with, and they constitute the Hercynian of the lower Hartz (Kayser, 1870). In Bohemia there is a series of limestones and shales, passing from an unmistakable Devonian horizon (étages G H) downward gradually and conformably into Silurian beds (étage E, Barrande, 1846). In this gradual change in the petrographic make-up of the formations on going eastward, the question to be determined is the place of the division plane between the two systems, in terms of stratigraphy as well as in terms of fossil faunas.

On the principle of priority, one fact can not be ignored. The paleontological boundary can be settled only by first determining how high up in the strata the Silurian fauna is present. In every step it is the base of the Devonian which is uncertain, and every determination of a base of the Devonian is subject to revision until it can be shown that it does not transgress the upper boundary of an established top of the Silurian. The Devonian must adjust to that Silurian limit which is already fixed.

The answer, then, to the first question is clear:

(*a*) The upper limit of the standard Silurian system is already established by definite formations and faunas, and no settlement of any particular case can violate this established precedent. On the other hand, the lower limit of the Devonian in Europe is still under debate, and if lower faunas are discovered which can be shown to be more recent than the Neosilurian faunas, they are to be placed in the Devonian and not added to the Silurian.

(*b*) But this further point is established—*i. e.*, in cases where the correlation with typical standards is doubtful, reason must be shown to prove that the fauna in question is more recent than standard Silurian faunas

* Trans. Geol. Soc. (2), vol. v, 724-727; Quarterly Journal, vol. viii, p. 3.

before it can be put into the Devonian system. So long as the Konieprussian fauna* is recognized to be older than any of the other Devonian European faunas of the same facies, there is insufficient reason for classing it in the Devonian. It must be regarded as Silurian or transitional until it can be proven to be beyond question younger than the youngest of the known standard Silurian faunas. It may be above the Ludlow and still represent the Downton sandstone and Ledbury shales, which are above the Upper Ludlow rock of the typical section, but are still typical Silurian formations.

(*c*) And, thirdly, for determining the equivalency of formations or faunas in other countries, the same final reference to and comparison with the standard Silurian faunas is necessary when doubt is present as to which side of the line the fauna is to go.

(*d*) In the case of the American formations the general question must be determined upon a comparison of the faunas of America with the original standards; of these the upper limit of the Silurian is established by typical sections and faunas; the lower limit of the Devonian seems to be fairly well established in terms of faunas of the facies of sandstone and arenaceous shales, but is in question as to those of a purely calcareous facies. Of the latter, the faunas of Hercyn, Erbray, F_2 Menian, and G and H of Bohemia are accepted as Devonian by paleontologists of Europe, but F_2 Konieprussian can not be taken as of established position above the line so long as its affinities are nearly equally with both the lower and higher faunas, and its exact relation to the typical faunas in Wales is uncertain.

ORISKANY FAUNA OF AMERICA EQUIVALENT TO LOWEST ARENACEOUS DEVONIAN FAUNA OF EUROPE

Taking up the second question, the determination of equivalency, this is no longer a matter to be settled by precedent or priority, but by a close scrutiny of the component species of the individual faunas and their comparison with standards.

In a general way, the facts for America are as follows:

The Oriskany fauna of America has been regarded as the American equivalent of the faunas of the more arenaceous formations at the base of the Devonian system of Europe by De Verneuil, Sharp, Bixby, and James Hall, who examined the fossils when their original classification was prominently before geologists. The only doubt was as to whether the Oriskany might not more properly be classified with the Lower Helderberg in the Silurian. Conrad (and Hall at first) drew the bound-

*The fauna of the Konjepruser-kalk, F_2, Barrande, 1846.

ary plane still higher in the New York series, but I find no suspicion that the plane was put too high till the Hercynian question arose.

HERCYNIAN FAUNAS EODEVONIAN

In the recent studies of the Hercynian problem it has been established with a fair degree of certainty that the Hercyn and Erbray faunas are Eodevonian, and in a general way an equivalency is established between these faunas and those of the arenaceous beds of the Gedinnian and Coblenzian, not to go into particulars as to the precise place in these étages to which each belongs.

It is also fairly well established that the Oriskany fauna at least represents the same stage of faunal evolution and the same general effects upon a considerable number of different genera, which was expressed in Eodevonian time in western Europe.

IS THE LOWER HELDERBERG EQUIVALENT TO THE HERCYNIAN?

There is difference of opinion, however, regarding the correlation of the Lower Helderberg fauna with European faunas; but there appears to be unanimity of opinion among European paleontologists (Kayser, Frech, Barrois, and others) that while the Lower Helderberg fauna shows affinities with the Hercyn, Erbray, and other faunas of Europe, it is somewhat older; also there seems to be general unanimity of opinion among those discussing the question that the European fauna coming most nearly to equivalency with the Lower Helderberg of America is the F_2 Konieprussian fauna of Bohemia.

The real Problems in Determining the Silurian–Devonian Boundary for America

CHARACTER OF THE EVIDENCE AS TO TRANSITION

Accepting these determinations as satisfactorily established, how do the facts affect the question as to the boundary plane between the Silurian and Devonian systems in North America?

It leaves the burden of proof with those who contend that the Lower Helderberg is not in the Silurian; for it is known to be below the base of the Oriskany, and always below, wherever the Oriskany fauna is known in America. Although several species, and closely allied species, appear to associate the two faunas, the case is clear in America that the passage from Lower Helderberg to Oriskany marks a conspicuous evolutional stage in the history of the Paleozoic faunas of North America.

Furthermore, it is clear that this evolutional stage is clearly marked in western Europe by a similar change in the specific characteristics of

the species on passing from the top of the Silurian to the first faunas of the Devonian of that region.

In the typical Welsh region the conspicuous geological event marking the passage from Silurian to Devonian is the change from marine to fresh-water conditions and sedimentation, the latter being represented by the Old Red sandstone. This passage was associated with the appearance in the Ludlow of fish and merostomes, and those who have based their opinions on the New York and interior sections of American rocks have assumed that the place of prominent appearance of Eurypterids (viz, the Waterlime), is equivalent to the zone of the "Tilestones" of Europe.

An examination of the Maine, New Brunswick, and Gaspé sections facing toward the Atlantic, and much nearer to Wales, brings out clearly the invalidity of this interpretation. In this eastern region of America the gradual emergence of land, affecting the marine faunas and finally terminating the marine faunas for Paleozoic time, was of a similar nature to that on the opposite shore of the north Atlantic. Furthermore, the exact stage of the physical transition is at a similar point in the evolution of its marine organisms.

MEROSTOMES AND FISHES

The Merostomes, as Walcott has shown, were represented in the Utica (Echinognathus) and possibly in still more ancient pre-Cambrian time. So, too, the fishes are not appearing for the first time in the Ludlow; but, as again Walcott has shown, they were well developed in Trenton time (Astraspis, Eriptychius, etcetera, from Canyon City, Colorado).

Hence the argument based on supposed identity of the Waterlime with the top of the Ludlow because of the appearance in both of merostomes and fishes loses its force. We are obliged from the evidence to believe that throughout Silurian time both fishes and merostomes were in existence. They are liable to occur at any place in the system where the conditions of their living were represented by the formation of strata in which the faunas could be preserved.

SALT BASINS OF WATERLIME AND ONONDAGA OF THE INTERIOR AND THEIR ABSENCE IN MAINE AND NEW BRUNSWICK SECTIONS

In the New York and interior regions there were conditions which shut out, locally, the sea, and in these brackish water pools fish and merostomes appeared; but a comparison of the marine faunas of these regions, below and above the Waterlime, proves that the local elevation, which is expressed in the Onondaga and Waterlime, as well as in the Guelph and Galt, was quite distinct from and at a much earlier geo-

logical period than those elevations of far wider extent which introduced the Oriskany faunas. These latter elevations brought about conditions in the extreme east of America quite similar to those of the Old Red sandstone of the opposite side of the Atlantic. The rarity of merostomes and fishes in the Gaspé sandstone does not disprove its general equivalency in time with the Old Red Sandstone period of Wales and Scotland.

If we approach the subject from this wider point of view and follow it down into the particulars of equivalency, the details confirm the grander facts. In the Maine and New Brunswick region, though there is evidence of continuous sedimentation from the base of the Silurian (Anticosti series) through to the Carboniferous, there is no evidence of the local shutting out of the sea, represented by the Guelph, Onondaga, and Waterlime of the interior continental region farther inland.

Nevertheless, the Silurian faunas of these eastern provinces pass through the same faunal evolution observed in the Niagara, Lower Helderberg, and Oriskany stages of the interior, but the separation of the faunas is less marked. In the Anticosti and Gaspé limestone faunas the passage from Niagara to Lower Helderberg is gradual. In several reported cases in this eastern province, species (such as *Halysites catenularia*) which in the interior are characteristic of Niagara and lower range up into association with a fauna which in its general facies is equivalent to the Lower Helderberg, and in the Gaspé limestones the passage upward is still gradual until traces of the Oriskany appear, thus indicating a continuation of similar environmental conditions throughout the whole of Silurian time without the marked change of conditions represented by the Onondaga formation of the interior.

On the other hand, there was a marked change of conditions for the whole eastern province at about the time of the Oriskany fauna. In the Gaspé peninsula this is represented by the change from limestone to sandstone, and an almost total disappearance of marine species, and the frequent presence of land plants.

In eastern Nova Scotia, at Arisaig, the same transition is seen, while in western Maine the marine fauna does not cease till after the Oriskany fauna has appeared. This great change in conditions, contemporaneous with the appearance of the Oriskany, is evident in New York and down the Appalachians as far as Virginia, Tennessee, and even on to Georgia and Alabama.

INTRODUCTION OF ORISKANY FAUNA COINCIDENT WITH ELEVATION OF PRESENT ATLANTIC BORDER OF CONTINENT

Thus the evidence is quite clear to one studying the minute details of the case that it was the introduction of the Oriskany fauna which

was biologically coincident with the physical raising of the eastern border of the continent, an elevation which for the Acadian provinces shut out marine conditions permanently, and made dry land after the Coal Measures had been accumulated.

This series of geological events corresponds closely with the events recorded on the British isles, expressed by the estuary conditions of the Old Red, terminating in the Coal Measures, and the final protrusion of land permanently above marine surface. The evolutional changes in the invertebrate organisms, on passing from the Ludlow into the Gedinnian and Coblenzian faunas of western Europe, are also closely paralleled by the evolution taking place in America at this same stage of events on passing from Lower Helderberg to Oriskany.

In America the evidence is clear that the Oriskany fauna was not evolved immediately subsequent to the Waterlime stage, although the Oriskany sandstone immediately follows the Waterlime fauna at Springport, New York. We know that here the Lower and Upper Pentamerus and Delthyris shaly faunas are older than the Oriskany, and also that they are older than the beginning of those physical conditions which mark the great mass of sediments of the Gaspé sandstone.

In Europe it is believed that the Hercyn and Erbray limestones are equivalent to the arenaceous Coblenzian and Gedinnian of western Europe, but it is not perfectly clear what stratigraphical relation exists between the Konieprussian and the arenaceous faunas further west. The doubtful interpretation of the European equivalency should not be allowed to controvert the positive evidence we possess in America as to the place in the time scale at which the transition took place there.

TRANSITION FROM MARINE SILURIAN TO OLD RED SANDSTONE IN WALES SYNCHRONOUS WITH APPEARANCE OF ORISKANY FAUNA IN EASTERN AMERICA

The above evidence points to the conclusion that the appearance of the marine Oriskany fauna among the formations in eastern America marks the exact stage in the geological history which across the Atlantic, in western Europe, is represented by the transition from Silurian to Old Red in Wales, and farther south by the modification of marine faunas from those of the Ludlow into the first arenaceous faunas of the Gedinnian and Coblenzian of western Europe. In regions where these physical conditions did not prevail, a marine fauna of the lower type undoubtedly continued on with less modification, and it is not the continuing of species characteristic of the Silurian into the Devonian which can gainsay the correlation based on positive evolution of new faunas. Where the limestone sedimentation continued unbroken, as in Bohemia, it may be difficult to determine the exact place in the series

which represents the transition from the Ludlow to Devonian of the western sections, but in America we are not left in doubt on this point. The Oriskany has a definite and exact place in the historical succession, and it was during the living of the fauna of the Lower Helderberg stage that the events happened which rapidly modified some and destroyed other species and left a clearly new fauna, first seen in the Oriskany, to dominate the whole eastern border oceans of the American continent.

Summary of Geological and Stratigraphical Argument

The geological and stratigraphical argument may be summed up in the following words: A comparison of the geological history of the two continents facing each other, at the point where they most nearly approach each other, shows a general uniformity in the order and sequence of sediments throughout the Silurian. This fact is particularly marked in those points by which the eastern sections differ from those of the interior of North America (that is, absence of either an Onondaga basin or a sharp separation of the Niagara and Lower Helderberg faunas).

This comparison also shows that the geological changes which are expressed in a sharp transition from marine to brackish water deposits terminate the Silurian sections for both continents, and that the place of this transition is definitely located in America where the Oriskany fauna follows that of the Lower Helderberg. The inference is that the place of this transition in America represents, in time, the corresponding place of transition in the standard sections in Wales. In Wales this is the boundary plane between the Silurian and the Old Red Sandstone phase of the Devonian system.

The Paleontological Argument

NATURE OF THE EVIDENCE

It remains to show that paleontological evidence confirms this conclusion. Two cases are in evidence, namely, the recognition of the Tilestone fauna at the top of the Silurian section at Arisaig, Nova Scotia, and the recent discovery of the same fauna in the Chapman sandstone of northern Maine.

In both cases the faunas are the most recent Paleozoic marine faunas of their respective sections, and they appear at the point of transition from the typical Silurian into the Old Red Sandstone phase of the Devonian.

The "Tilestones" have already been referred to as constituting the topmost formations of the typical Silurian system. Their fauna is

quite distinct, in the majority of its species, from the Ludlow fauna of the underlying calcareous shales and limestones, but it is made up chiefly of marine species, with some traces of land plants and of merostomes and fishes, of types similar to those which follow. Nevertheless, a few characteristic Ludlow species tie the Tilestone fauna with the typical marine Silurian. The formation was more definitely described by geologists following Murchison, and now goes under the names Downtonian, Downton sandstone, and Ledbury shales. The fauna is evidently a transition fauna, and, as far as reported, appears only in sections in which the following formations lack purely marine fossils.

THE TILESTONE FAUNA RECOGNIZED IN THE UPPER ARISAIG BY J. W. SALTER

This Tilestone fauna was first discovered on the American continent by Doctor D. Honeyman, in the Upper Arisaig rocks of northern Nova Scotia. The identification of the fauna with the Tilestone fauna of Wales was made by J. W. Salter, then paleontologist of the Geological Survey of Great Britain; an account of it was first published in 1864.

The Arisaig rocks were brought to notice by Doctor J. W. Dawson* (the late Sir William Dawson) in 1849, who then interpreted them to be of Silurian age. In "Acadian Geology" they were referred to the Devonian.† Honeyman,‡ having studied the fossils and compared them with Murchison's Siluria, considered them mostly equivalent to the Upper Ludlow in 1859. In the following year Dawson,§ after more careful study and the identification of fossils by James Hall, published a further description of the rocks, in which he referred the series to the "upper part of the Middle Silurian, probably with a part of the Upper Silurian." In the same volume the species of the fauna are described by James Hall.‖

In his descriptions of the species of this fauna James Hall considered most of them new, and because of resemblance in a few cases to Clinton species, they were supposed by him to represent a Clinton horizon, and I observe that the species are now commonly listed as Clinton species. It appears to be this interpretation to which Salter refers in the passage quoted below. It appears further, from notes published later by Honeyman, that this peculiar fauna occurred in the uppermost part of the zone D of his 1864 paper, which was called E in that article.¶ This shows that the fauna follows, in the Arisaig section, the representative

* Quarterly Journal Geol. Soc., vol. vi, p. 347.

† See Acadian Geology, 1855 edition.

‡ On the fossiliferous rocks of Arisaig. Trans. Lit. and Sci. Soc. Nova Scotia, 1859.

§ On the Silurian and Devonian Rocks of Nova Scotia. Can. Nat. and Geol., vol. v, 1860, p. 132.

‖ James Hall: Description of new species of fossils from the Silurian rocks of Nova Scotia. Can. Nat. and Geol., vol. v, 1860, p. 144.

¶ Trans. Nova Scotia Inst., vol. iv, p. 55.

of the Lower Helderberg. Preparatory to the international exhibition of 1862, Doctor Honeyman* made a collection of the Arisaig fossils for Sir R. Murchison, which were submitted to J. W. Salter for identification. By this means the equivalency of the Upper Arisaig fauna was established.

Regarding this identification Honeyman writes in the paper above cited:

"Sir Roderick Murchison, at my request, very kindly asked Mr Salter to examine it [collection of Arisaig fossils and rocks], who accordingly inspected my divisions of fossils, and, studiously avoiding all inquiry into the opinions already entertained, he unhesitatingly referred my Upper Ludlow to the Ludlow Tilestone my Wenlock (?) to the Aymestry limestone, and Hall & Dawson's Clinton to a repetition of the Ludlow Tilestone." †

In this paper Honeyman published a list of the species of the Upper Arisaig from the rocks west of Arisaig pier, near McAra's brook, containing fifty-eight entries. In this list are found four species identical with the Tilestone fauna of Murchison's Silurian system; two others are apparently identical, but differently named, and most of the species of the two faunas are very closely related representative species.

In 1887 a report on Nova Scotian geology was published in the Annual Report of the Canadian Geological Survey by Fletcher and Faribault.‡

The section of the upper 1,038 feet of the Arisaig rocks is given in this report of 1887 as follows. It is compiled from the exposures along the gulf shore between McAra's brook and Arisaig pier. It is E 6 of their classification, and is called Lower Helderberg. It rests on E 5, the Niagara. The junction of the two at Joseph McDonald's cove is shown by a photograph taken by T. C. Weston (number 6, opposite page 40P):

Section of Silurian Rocks at Arisaig in descending Order

E 6. LOWER HELDERBERG:

	Feet
1. Reddish and purplish altered flags with bright emerald green blotches and layers; more or less argillaceous, flinty, and splintery, containing thin calcareous layers full of blackened shells. The red and purple beds greatly predominate. They end about 15 yards northeast of McPhersons brook. Dip, 166°<46°	100
2. Dirty green, greenish, and gray quartz-veined flags and shales, holding encrinities and shells in abundance; seen in Stonehouse brook as well as on the shore. Veins cut across the bedding and are sometimes three inches thick; perhaps unconformable to 1. Dip, 207°< 41°; end at the mouth of Joseph McDonalds brook	310

* On the Geology of Arisaig, Nova Scotia, by D. Honeyman, Quarterly Journal Geol. Soc., vol. xx, 1864, p. 333, etc.

† Quarterly Journal Geol. Soc., vol. xx, p. 334.

‡ Rept. Geol. Survey and Expl. in counties of Guysborough, Antigonish, Pictou, Colchester, and Halifax, Nova Scotia, from 1882 to 1886, by Hugh Fletcher and E. R. Faribault, pp. 1P to 163P.

	Feet
3. Dirty greenish rocks, finely ripple-marked, full of fossils. Dip, 203°< 32°	205
4. Dirty green and gray, rubbly or prismatic, rusty weathering argillo-arenaceous flags; the bottom of Doctor Honeyman's group D—Lower Helderberg or Ludlow Tilestone (Quarterly Journal of the Geological Society of London, 1864). Dip, 194°<38°	393
5. Indian red crumbly prismatic marl, with a thin band of gray limestone full of fossils; in the upper part mixed with bright green patches and full of calcareous nodules, like the rock of Indian brook, cape George. The green of the beds immediately overlying is brighter than usual, and the whole mass is more or less concretionary and nodular. This is Doctor Honeyman's "red stratum" (op. cit., p. 336), and is also described in Mr Weston's section and shown in view number 6. Dip, 169°<34°. It has been traced more than half a mile eastward of the Trunk road	30

The classification of the rocks of the whole Arisaig section is as follows:

E^6	Lower Helderberg	=	division D of Doctor Honeyman	=	Upper Ludlow Tilestone.
E^3	Niagara	=	C	=	Aymestry limestone.
E^2	Upper Clinton	=	B^1	=	Lower Ludlow.
	Lower Clinton	=	B	=	Lower Ludlow.
E^1	Medina	=	A	=	Mayhill sandstone. (p. 37P).

The part of the section given above constitutes division E^6, Lower Helderberg, of this classification.

FIFTEEN LOWER HELDERBERG SPECIES RECOGNIZED IN ARISAIG SECTION BY DOCTOR AMI

The species collected by Mr Weston from this Arisaig section in 1886 were identified by Doctor H. M. Ami, and a report of them is published in the Proceedings of the Nova Scotian Institute in 1892.* In this list 15 species are Lower Helderberg species. The species of the western collection described by Billings† were all collected, according to the Fletcher and Faribault report (p. 48P), by Mr Weston from the upper part of this formation [E^6, Lower Helderberg], west of Stonehouse brook, where fish remains were also obtained by him. They are identified as of Upper Silurian age by Billings, and all the species are described as new except one—*Sanguinolites anguiliferus?* McCoy.

The rocks for this portion of Nova Scotia succeeding the Silurian of the Arisaig section were classified by Fletcher and Faribault as Devo-

* Silurian fossils from Arisaig, Nova Scotia, by H. M. Ami (read April 11, 1892), Proc. and Trans. Nova Scotian Inst. of Sci., Halifax, 2d ser., vol. i, pt. i, pp. 185–192.

† Paleozoic Fossils, vol. ii, part i. 5. On some of the fossils of the Arisaig series of rocks, Upper Silurian, Nova Scotia, pp. 129, etc.

nian.* Their identification with previously described formations of the eastern provinces is as follows:

F^3, Upper Red slate and sandstone	= Mispec group.
F^2, Middle gray sandstone and slate group	= Dadoxylon sandstone and cordaite shale.
F^1, Lower conglomerate group	= Bloomsbury conglomerate.
E^6, Lower Helderberg	

PLACE OF TILESTONE FAUNA IN ARISAIG SECTION EQUIVALENT TO TRANSITION FROM MARINE TO ESTUARY CONDITIONS IN GASPE SECTION, AND TO FIRST APPEARANCE OF ORISKANY IN MAINE AND NEW BRUNSWICK

The paleontological evidence of this Arisaig section appears therefore to be as clear as the general geological evidence in fixing the place of the Silurian-Devonian boundary for the American continent. This evidence may be summed up as follows:

In the Arisaig section, at the point where the marine conditions pass up into non-marine, a transition fauna appeared (D of Honeyman's paper), which was unhesitatingly identified as the equivalent of the topmost fauna of the typical Silurian system of Great Britain by the official paleontologist of that survey, during the lifetime of Murchison, the founder of the Silurian system.

This fauna appeared after the Lower Helderberg fauna was in the region, as shown by the recognition of at least fifteen Lower Helderberg species in the Upper Arisaig formation by Doctor Ami.

No marine paleozoic fauna later than the Nictaux, containing some Oriskany species, is recorded for this Nova Scotia region.

In New Brunswick, in the Gaspé peninsula, the same general sequence is repeated. The Gaspé limestone carries a fauna which has been defined as equivalent to the Niagara and (its upper part) Lower Helderberg. No Tilestone fauna has been identified in these rocks, but the place of transition from the limestones into the following Gaspé sandstones was recognized long ago by Logan as nearly equivalent to the Oriskany of the New York section. The following sandstones contain almost no marine fossils, but hold plants (Psilophyton, etcetera) of Devonian age. The place of termination of the marine faunas is equivalent to the place of the transition in the Arisaig section from upper Arisaig to Devonian; and both correspond as closely as could be wished with the transition from Silurian into Old Red sandstone in southern Wales.

In Maine I have recently recognized another representative of the Tilestone fauna, in a formation to which I gave† the name of Chapman

* Loc. cit., p. 49P.

† Bulletin No. 165, U. S. Geol. Survey.

sandstone, in the report on the geology of Maine above referred to. The identification of this fauna with the Tilestone fauna of Murchison was made before I observed the fact that Salter had positively identified Honeyman's Arisaig fauna D as equivalent to the Tilestone. In presenting the facts before the Society, I have therefore given precedence to the Arisaig facts, and I omit the paleontological argument by which the correlation of the Chapman and Tilestone fauna is established, which will be published hereafter.* The species of the Chapman sandstone and the upper Arisaig are, in several cases, identical, so far as I can judge from reading the descriptions, and the whole contents of the two faunas are very much alike. The Chapman sandstone fauna is the latest of the marine Paleozoic faunas of Maine, and, what is still more significant, a Psiloplyton stem is found associated with the marine fossils in the Chapman sandstone. In the Chapman sandstone there are a few species with which to correlate the fauna with another, found in western Maine, about Moose river, in which a distinctly Oriskany fauna is recognized. This shows that the Chapman fauna is closely related to the Lower Oriskany of New York. In Maine (Aroostook county), the Square Lake limestone, which is correlated with the upper part of the Gaspé limestone, contains a distinctly Lower Helderberg fauna, thus establishing for the Lower Helderberg a place in the scale earlier than the representative of the Welsh Tilestone (my Chapman sandstone), and hence unquestionably in the typical Silurian system.

Summary and Conclusions

Thus, the Arisaig, the Gaspé, and the Maine sections are in harmony in fixing the exact boundary between the Silurian and Old Red sandstone (Devonian) on the American continent. As near as I am at present able to identify this boundary in the New York sections, it comes very close to the transition from the Lower Oriskany of Becraft mountain into the Upper, or pure Oriskany of Oriskany falls. This point will be developed as the faunas are more fully studied. The facts already noted, however, are clear in establishing the fact that the Lower Helderberg fauna lies below the Chapman sandstone, and the equivalent upper Arisaig, faunas, both of which are the paleontological representatives on this continent of Murchison's Tilestone fauna (Downton sandstone and Ledbury shales), the highest known fauna of the typical Silurian system.

*See Am. Jour. Sci., vol. ix, p. 203.