The Helderberg Group and the Position of the Silurian-Devonian Boundary in North America

GEOLOGICAL SURVEY BULLETIN 1180-B

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By JEAN M. BERDAN

CONTRIBUTIONS TO STRATIGRAPHIC PALEONTOLOGY

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An historical summary including a review of pertinent literature

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By JEAN M. BERDAN

ABSTRACT

The literature on the Helderberg Group and its relation to the Silurian-Devonian boundary is summarized and evaluated, from the work of Timothy Conrad in 1839 and James Hall in 1851 to the present. Hall considered the Helderberg Group to be Silurian in age and included the Manlius Limestone as its basal member. Clarke, in 1889, and Schuchert, in 1900, placed the Helderberg in the Lower Devonian, because of faunal resemblances to the Lower Devonian of Europe, but they retained the Manlius in the Silurian because of supposed Silurian elements in its fauna. Examination of the literature shows, however, that the Silurian elements were not found in the type Manlius but in beds correlated with the Manlius in other areas. Recent study of the Manlius fauna has failed to reveal any forms in common with the underlying Cobleskill Limestone (Silurian), but several forms have been found in common with the immediately overlying Coeymans Limestone (Lower Devonian). This corroborates the assignment by Fisher and Rickard, of the New York Geological Survey, of the Silurian-Devonian boundary to the Rondout Limestone, between the Manlius and the Cobleskill, and their reassignment of the Manlius to the Helderberg Group. The boundary is believed to occur within the Keyser Limestone of West Virginia.

INTRODUCTION

During the past century the position of the Silurian-Devonian boundary in eastern North America has shifted gradually downward, as stratigraphic concepts have changed and refinements in methods of correlation have come into being. A review of the history of the changes in position of this boundary should start with New York State, because much of the early stratigraphic work on this continent was done there, and because the New York section has become the standard for North American stratigraphy. The Helderberg Group should receive special attention as it has been moved from one side of the line to the other with the passage of time. This report, based on recent studies, attempts to explain, in part, the reasons for earlier

determinations of the boundary. Figure 1 shows the generalized areal distribution of the formations and localities discussed in the text and shown on the correlation chart (fig. 2).

I am deeply indebted to Dr. Lawrence V. Rickard, of the New York State Geological Survey, who kindly loaned me his manuscripts on the Silurian-Devonian boundary before their publication.

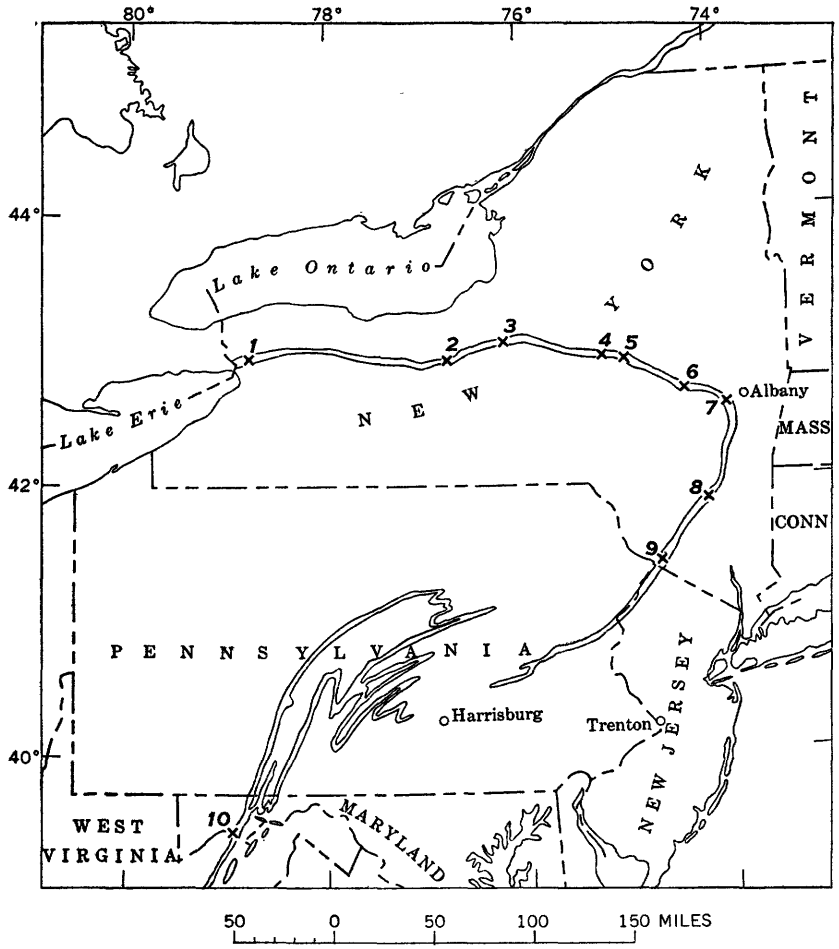

FIGURE 1.—GENERALIZED DISTRIBUTION OF UPPER SILURIAN AND LOWER DEVONIAN ROCKS DISCUSSED IN THIS REPORT

Numbers refer to columns shown on correlation chart. 1, Buffalo area, Erie County, N.Y.; 2, Cayuga Lake, Cayuga County, N.Y.; 3, Syracuse-Manlius area, Onondaga County, N.Y.; 4, Dayville area, Herkimer, County, N.Y.; 5, Jordanville, Herkimer County, N.Y.; 6, Schoharie, Schoharie County, N.Y.; 7, Helderberg area, Albany County, N.Y.; 8, Rosendale area, Ulster County, N.Y.; 9, Port Jervis area, Orange County, N.Y.; 10, Keyser, Mineral County, W. Va. Geology modified from the Geologic Map of the United States, U.S. Geological Survey, 1932.

HISTORY OF THE PROBLEM

The term Helderberg was apparently first used by Conrad (1839, p. 62) in a table of formations of New York, under his group 7, as Helderberg sandstones and Helderberg limestones. The Helderberg sandstones presumably are the Esopus Siltstone, for "*Fucoides caudagalli*" is given as the characteristic fossil. The Helderberg limestones, however, would seem to comprise the New Scotland Limestone and Becraft Limestone of present usage, although to judge from the fauna cited, the Onondaga Limestone may also have been included. If Conrad's "Second Pentamerus limestone" represents the Coeymans Limestone, that formation was considered distinct from the others of the group. In the following years, the term Helderberg was used by New York State geologists with little uniformity, and in its widest extent included all the beds between the Marcellus Shale and the Niagara Group (Wilmarth, 1938, p. 935). Then Hall (1851, p. 288) revised and subdivided the group into the Upper Helderberg (base of Marcellus to top of Oriskany) and Lower Helderberg (base of Oriskany to base of "Tentaculite or waterlimestone", now the Manlius), the Oriskany Sandstone being left as a separate unit between the two. A few years later Hall (1859) elaborated on his classification and summarized the stratigraphy of New York as it was then known. This study provided the basis for most subsequent work, and it is therefore worth considering his ideas in some detail.

Hall (1859, p. 26) considered the Niagara (Lockport of current usage) to extend far to the east, being represented nearly to the Helderberg Mountains by "a band of limestone, sometimes brecciated, and often associated with a concretionary calcareous shale which is nearly or quite destitute of fossils. Its most easterly recognized extension is on the Hudson River, where it is very obscurely developed, and not everywhere continuous." This limestone represents the Cobleskill and related formations of current usage. In discussing the Helderberg Group, Hall (1859, p. 33) states: "The Lower Helderberg group * * * has been so termed from its very complete development along the base of the Helderberg Mountains; constituting, in this part of New York, an important fossiliferous group."

Hall (1859, p. 33) described the members of the Lower Helderberg in ascending order, as follows: (1) The "Tentaculite limestone," (2) "a thin mass of limestone, consisting almost entirely of the coral *Stomatopora*," (3) "a limestone charged with great numbers of the broken shells of *Pentamerus galeatus*, and known as the Pentamerus limestone," (4) the "Delthyris shaly limestone," (5) "a compact crinoidal limestone," —and (6) the "Upper Pentamerus limestone." However, another list of Helderberg formations which differs slightly from the

one above is given later in the same paper (1859, p. 97). In ascending order the formations are the Tentaculite or Water Limestone, the Pentamerus Limestone, the Delthyris Shaly Limestone, the Encrinal Limestone, and the Upper Pentamerus Limestone. The Tentaculite Limestone rests on "Argillaceous and Magnesian limestones of the Onondaga-salt group," and the Upper Pentamerus Limestone is overlain by the Oriskany. The Onondaga salt group is shown underlain by the "Coralline or Niagara limestone."

In terms of current nomenclature, Hall's "Coralline or Niagara limestone" is the Cobleskill Limestone, and the "Onondaga salt group" is the Rondout Limestone. In his first list, units 1 and 2 are the Manlius Limestone, 3 is the Coeymans Limestone, 4 is the New Scotland Limestone, and 5 and 6 are the Becraft Limestone. It is interesting that in his first list he divided the Manlius and the Becraft into two units, but in the second list the Tentaculite Limestone (Manlius) is considered to include the "Stomatopora" beds, although the Becraft is still subdivided. The Kalkberg Limestone of present usage was apparently included in the New Scotland, and no mention is made of the Alsen Limestone and the Port Ewen Limestone overlying the Becraft.

In discussing the age of the Lower Helderberg, Hall (1859, p. 34–43) compared it with the European formations and concluded that both the Lower Helderberg and Oriskany should be retained in the Silurian System. However, he mentioned (1859, p. 40–41) that deVerneuil and other European geologists considered the Oriskany the base of the Devonian. Hall seems to have been influenced in his reasoning by the occurrence of eurypterids in the Waterlime Group (probably the Bertie Limestone of current usage) and of fish remains in the Upper Helderberg (Schoharie Grit and Onondaga Limestone). As the Downtonian of England, then considered the top of the Silurian, contains many eurypterids, and as the Old Red Sandstone, then and now considered Devonian, is characterized by fishes, Hall (1859, p. 34) equated the Waterlime Group with the Downtonian, the Upper Helderberg with the Old Red, and considered the Lower Helderberg and Oriskany as intermediate beds not represented faunally in England.

For the following 30 years Hall's correlations were accepted and remained unchallenged. Then John M. Clarke (1889) reviewed the position of the Silurian-Devonian boundary in Europe and carefully evaluated the faunas. He strongly suggested that the Lower Helderberg faunas were equivalent to the Hercynian of Germany and were Early Devonian in age by European standards. Incidentally, he also suggested that the Lower Helderberg was an offshore facies of the Oriskany, which he regarded as unquestionably Early Devonian. There is no direct indication in his paper of the formations which

he included in the Lower Helderberg, but he (1889, p. 427) states "Neither will there be efficient objection to the separation from the typical Lower Helderberg fauna, of what is customarily regarded as its basal member, the Waterlime." He then equated the Waterlime with "the Upper Ludlow and the Tilestones" (that is, the Downtonian, now considered Devonian) and considered it Silurian.

Ten years later Clarke and Schuchert (1899, p. 874–878), in an attempt to stabilize the New York terminology, proposed "Helderbergian," apparently as both a time and a rock unit, to be restricted to the formations previously known as Lower Helderberg, and considered it Early Devonian. The formations included in their Helderbergian Group were the Coeymans, New Scotland, Becraft, and Kingston beds (Alsen and Port Ewen Limestones of modern usage). The "Tentaculite Limestone" (Manlius Limestone) was specifically excluded (1899, p. 877), although no reason was given. All the names cited above were either proposed or used for the first time in their modern sense in this paper; also for the first time, type areas, if not type sections, were designated.

The following year saw the publication of five papers directly or indirectly concerned with the Helderberg Group and the position of the Silurian-Devonian boundary, by Clarke, Schuchert, H. S. Williams, Grabau, and Weller. Of these five papers, three appeared in succession in volume 11 of the Bulletin of the Geological Society of America. Schuchert (1900) again evaluated the European Lower Devonian, discussed its faunas, and compared the Helderberg fauna with the Lower Devonian of Europe. He followed Clarke (1889) in considering the Helderberg as Early Devonian and also excluded the Manlius Limestone from the Helderberg without giving his reasons. Schuchert (1900, p. 279–289) gave an extensive list of the Helderbergian fauna, including not only species from New York State but also species which he considered Helderbergian from Maryland and Virginia, Illinois and Missouri, Tennessee, Oklahoma, Maine and New Brunswick, and the Gaspé Peninsula and Nova Scotia. Schuchert's Helderberg in Maryland and Virginia included the upper part of the Keyser Limestone of present usage (1900, p. 271–272).

H. S. Williams (1900) presented arguments for leaving the Helderberg in the Silurian. He believed that the basis for placing the Silurian-Devonian boundary should be correlation with the European type section, that the Oriskany was the equivalent of the Lower Devonian in Europe, and that therefore the Helderberg should be considered Silurian. This, I believe, is the last important paper in which the Early Devonian age of the Helderberg is questioned. After this, the Helderberg was accepted as Early Devonian, and the principal con-

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troversy was where to put the base of the Helderberg, and consequently, the Silurian-Devonian boundary.

Grabau (1900) described the unconformity between the Manlius Limestone of western New York and the Onondaga Limestone. Grabau's Manlius, now the Akron Dolomite, was about 6 to 8 feet of massive buff-weathering dolomite overlain unconformably by the Onondaga and underlain by flaggy drab waterlimes. He also described the fauna (1900, p. 363–373).

Weller (1900, p. 27–28) in his description of the Manlius Limestone of New Jersey discussed the bases for determining the age of the Helderberg Group and followed Clarke and Schuchert in assigning it to the Devonian. However, he disagreed with them about the age of the Manlius and included it with the other Helderberg formations in the Devonian on faunal grounds. Later, however, he (1903, p. 217) assigned the Manlius to the Silurian, presumably because of an occurrence of some of the brachiopods from older formations.

Possibly the paper by Clarke is the most important of the reports on the Helderberg Group in New York State, as for the first time some of the reasons for excluding the Manlius and placing the boundary between the Manlius and the Coeymans are given. In "The Oriskany fauna of Becraft Mountain, Columbia County, N.Y.," he (1900) included a chapter on the "Devonic age of the Helderbergian fauna and the base of the Devonic System in New York," in which he discussed the fauna of the Manlius Limestone. After listing the fossils commonly occurring in the Helderberg section he comments (1900, p. 99) "At Union Springs, Cayuga Co., the Manlius limestone has a more prolific fauna than has been observed elsewhere west of Herkimer county * * *. The most favorable spot for the examination of this fauna is in the rocks exposed on Frontenac Island, just off the village of Union Springs." He then discussed the fossils found and stated (1900, p. 100), "I look on the discovery in this fauna of *Halysites catenulatus* as of much significance. Though not abundant, the species is thoroughly characteristic." And further, "It is perfectly clear without farther argument that the types expressed in the foregoing list are very positively indicative of Siluric age, and, furthermore, that they have nothing in common with the true Helderbergian fauna." On the following page (1900, p. 101, footnote 1) he lists the fauna described by Grabau from Erie County, N.Y., and states—

> The most striking feature of this little fauna is its similarity to that of the Coralline limestone of eastern New York, the representative of the Niagaran formation in that region * * *. Dr. Grabau's conclusion from the study of this fauna as well as of the tectonic relations of the strata in Erie County emphasizes the strongly Siluric character of the Manlius limestone.

From the vantage point of 60 years later, one of the most remarkable things about the above statements is that neither Clarke nor Grabau considered the possibility that the striking similarity between the "Manlius" fauna of Erie County and Frontenac Island and the fauna of the Coralline (Cobleskill) Limestone of Schoharie County might indicate that the "Manlius" of the western part of the State was, in fact, the equivalent of the Cobleskill Limestone of the east, not that the Manlius of the east was Silurian. As the Silurian age assignment of the Manlius was in part the consequence of this misconception, it may be well to review the reasons for the correlations of Clarke and Grabau. It should be remembered, first, that in 1900 no one had as yet questioned Hall's original identification, reiterated in 1873 (p. 321–335) of the Cobleskill Limestone of Schoharie County with the Niagara (Lockport Dolomite) of western New York. The stratigraphic sequence was similar in both areas (fig. 2). In Schoharie County, the Cobleskill rests on the Brayman Shale and is overlain by the Rondout Limestone, which, in turn, is overlain by the Manlius Limestone. In Erie County, the Lockport Dolomite rests on the Rochester Shale, is overlain by the Bertie Limestone, which, in turn, is overlain by the Akron Dolomite. It was logical to correlate the Rochester with the Brayman, the Cobleskill with the Lockport, and the Bertie with the Rondout, which meant that the Akron, above the Bertie, was equivalent to the Manlius. Until detailed stratigraphic tracing across the State was done, it was not apparent that the unconformity beneath the Onondaga cut out all the beds in western New York down to the Cobleskill equivalent.

This detailed stratigraphic work was forthcoming just 3 years later when Hartnagel (1903) published his excellent "Preliminary observations on the Cobleskill ("Coralline") limestone of New York." He showed that the Cobleskill overlies the Salina (Bertie Limestone in western New York) and demonstrated the presence of more than one horizon of the waterlimes, previously thought to be a single continuous unit. It is now known that waterlimes which have been mined for natural cement occur in at least four horizons. In ascending order, these are the Bertie, mined at Buffalo and underlying the Akron; the Rosendale Limestone, mined in the Kingston area in the Hudson Valley, and now considered equivalent to the Cobleskill; the Rondout Limestone of the same area, overlying the Cobleskill; and finally the Elmwood Limestone of the type Manlius of the Syracuse area. Of all these units, only the Bertie carries the extensive eurypterid fauna which was considered so significant by Hall, Clarke, and Schuchert in correlating with the Silurian of England.

In the same year, while Hartnagel's more detailed study was in press, Schuchert (1903a) studied the fauna of the Cobleskill and independ-

ently concluded on this basis that it was younger than the Salina. Schuchert (1903a, p. 177–178) comments on the presence of Cobleskill fossils in the lower part of the Rondout, and having decided that the Cobleskill, Rondout, and Manlius were intimately related, redefined the Manlius to include both the Cobleskill and the Rondout.

Hartnagel (1903, p. 1165–1175), in a supplementary note added after his paper had gone to press, disagreed with Schuchert on grouping the Cobleskill with the Manlius. He states (1903, p. 1172–1173)—

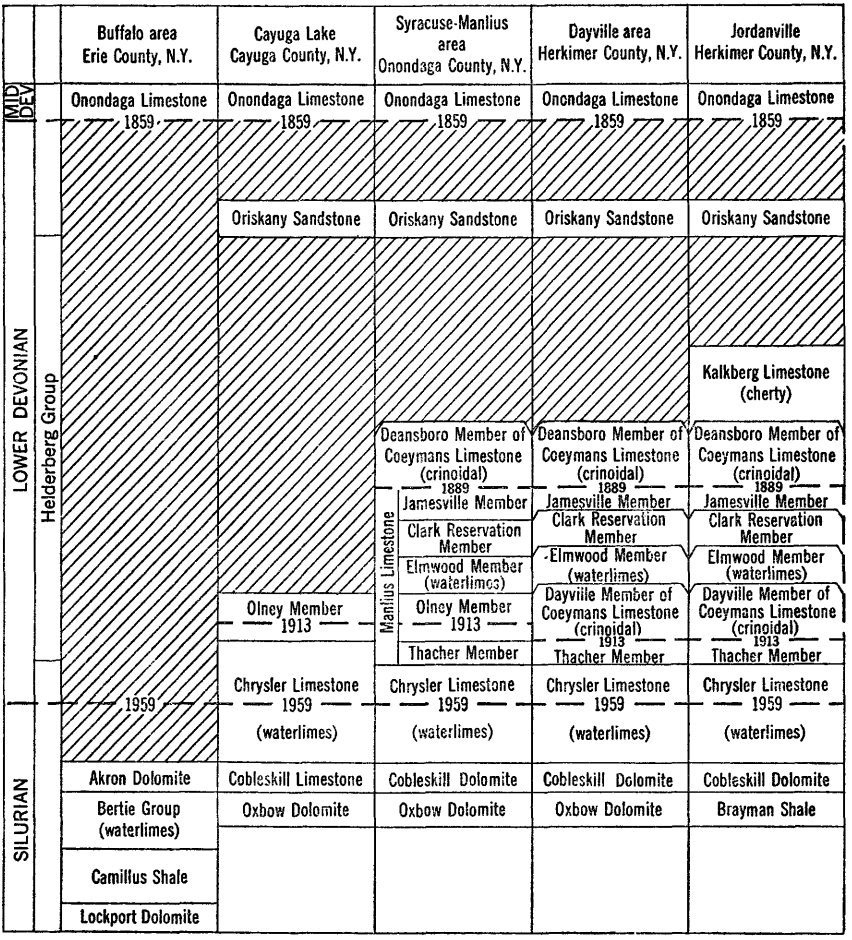
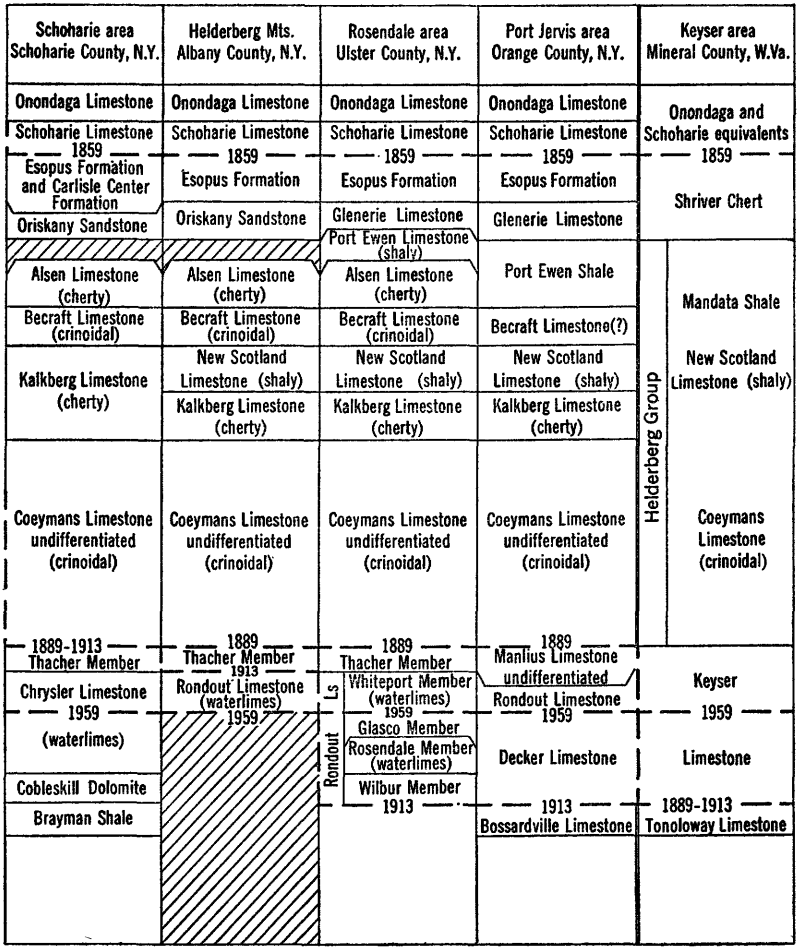


FIGURE 2.—CHART SHOWING FORMATION IN AREAS

Dates between formations show position of Silurian-Devonian boundary according to Hall, 1859; Clarke, correlations based on Rickard,

Among the chief reasons advanced by Mr. Schuchert for including the Cobleskill with the Manlius formation is the statement that the fauna of the Cobleskill does not contain a single Niagaran species, while it does contain a few species in common with the Manlius. I agree fully with Mr. Schuchert that the Cobleskill and Manlius contain species in common and I have shown more species in common to the two formations than has he, but I do not agree with him that the Cobleskill is without Niagaran elements * * *. The presence of these important Niagaran elements justifies one in keeping the Cobleskill formation distinct from the Manlius limestone.



DISCUSSED IN TEXT AS CORRELATED AT PRESENT

1889; Ulrich *in* Swartz, 1913; and at present. Silurian correlations based on Fisher, 1959; Devonian 1962, and Cooper and others, 1942.

In view of the subsequent problems about the age and correlation of the Manlius Limestone, examining the evidence presented by these authors in some detail is worthwhile. On investigating the species which, according to Schuchert, occur in both the Manlius and the Cobleskill Formations in the light of present knowledge, it becomes apparent that none of his Manlius species come from the typical Manlius of New York State, but from the beds he considered Manlius in Maryland and Virginia, that is, the lower part of the Keyser Limestone. However, Hartnagel (1903, p. 1133), who gives extensive faunal lists by localities, cites the Manlius species "*Spirifer*" *vanuxemi*, "*Stropheodonta*" *varistriata* and *Tentaculites gyracanthus* from the Cobleskill of Frontenac Island and the Cobleskill species "*Orthothetes*" *interstriatus* and "*Whitfieldella*" *sulcata* from the Manlius at the Shaliboo quarry 1 mile south of Union Springs. These two localities are the only places listed by Hartnagel where Manlius and Cobleskill fossils occur together. As more recent studies have shown that the Manlius and Cobleskill faunas are distinct, and as the age of the Manlius, and consequently the position of the Silurian-Devonian boundary, hinges on the supposed Cobleskill elements in the Manlius fauna, it may be worth noting that subsequent collecting from Frontenac Island has failed to reveal any Manlius fossils in the Cobleskill there. The Shaliboo quarry is now flooded, and neither Manlius nor Cobleskill is accessible at present.

Hartnagel (1903, p. 1131) acknowledged the use of the collections and notes by D. D. Luther for the Union Springs area, and he himself may possibly have made no collections there. Two explanations for Hartnagel's faunal lists are therefore suggested. One is that the collections he studied were mixed. This might easily happen, as the Cobleskill in the Union Springs area is atypical; much of it is dark-blue-gray limestone very much like the Manlius in lithology. The other possible explanation lies in erroneous identifications of the fossils. In October of 1954 I examined a collection at the New York State Museum, possibly one of those studied by Hartnagel. This collection, N.Y.S.M. No. 2055, is identified as follows in the locality register: "The dark uppermost Silurian (Manlius) limestone above the Eurypterus beds, with Ilionia, Halysites, etc., Frontenac Island, Union Springs. J. M. Clarke & D. D. Luther, collected, 1899." This collection contains a typical Cobleskill fauna, but some specimens labelled as the Manlius "*Stropheodonta*" *varistriata* appear to be rather the typical Cobleskill species *Leptostrophia bipartita*; other specimens labelled as the Manlius "*Spirifer*" *vanuxemi* are too poorly preserved to identify precisely, but they are probably the Cobleskill *Howellella corallinensis*. All things considered, it seems improbable

that the Manlius and Cobleskill faunas, which are entirely distinct elsewhere in the State, should be in the same horizon only at Union Springs.

A year after Hartnagel's and Schuchert's work on the Cobleskill, Harris (1904) published a paper entitled "The Helderberg invasion of the Manlius," in which he pointed out that between Manlius, Onondaga County, and Herkimer, Herkimer County, beds of crinoidal limestone with elements of the Coeymans fauna occur interbedded with typical Manlius lithologies. This fact had been noted by Clarke (1900, p. 98–99) and Hartnagel (1903, p. 1169–1170), but without comment or conclusions. Harris (1904, p. 1) suggested that the Manlius and Coeymans faunas were more closely related than had hitherto been thought, but avoided mentioning whether he considered the Manlius Silurian or Devonian in age. He, too, included a Cobleskill species, "*Orthothetes*" *interstriatus*, in his list of Manlius fossils from the Shaliboo quarry. Thus, the Manlius remained in the Silurian and was generally considered Silurian for the next 40 years. For example, Grabau (1906, p. 114) described "transition beds" between the Manlius and the Coeymans, but he still considered the Manlius Silurian and the Coeymans Devonian.

Meanwhile, difficulties had arisen about the age and correlation of the beds called Helderberg in Maryland and Virginia. C. K. Swartz (1913, p. 96–98) has summarized the early history of Helderberg studies in this area, and, except for a few pertinent points, it will not be repeated here. It is of interest that Schuchert (1903b, 413–419) correlated the beds in Maryland with those of New York and used the New York State names. The beds constituting what is now known as the Keyser Formation were called Manlius and Coeymans, the division between them being placed slightly above the zone of *Gypidula coeymanensis* var. *prognostica*. He (1903b, p. 417) commented on the similarity of the fauna of the lower part of his Manlius to that of the "Coralline" (Cobleskill) limestone of New York and the Decker of New Jersey. He considered the Manlius to be Silurian in age, and thus drew the Silurian-Devonian boundary in the middle of the Keyser. Ulrich (*in* Stose and Swartz, 1912, p. 8–9), on the other hand, in discussing the faunal zones of the Helderberg Limestone, included the Manlius of Schuchert in the Helderberg and stated that most of the brachiopods continue into the overlying Coeymans and New Scotland faunal zones, although the corals and ostracodes are more closely related to forms in the underlying Tonoloway. He also correlated the lower part of the Helderberg of Maryland with the Decker of New Jersey. The name Keyser is not used in this report, although it had been introduced by Ulrich (1911, p. 563, 590, 591) in the preceding year without description or definition.

At the same time, Ulrich (1911, p. 590–593) stated his reason for considering the Keyser as Early Devonian in age and including it in the Helderberg Group. This was the appearance of Helderbergian types of fossils in the Keyser, which, according to the principle that the age of a formation should be determined by the introduction of new forms rather than the extinction of old ones, led him to consider the Keyser Early Devonian in age.

In 1913 the Maryland Geological Survey published its volume on the Lower Devonian of the State. C. K. Swartz (1913) contributed a chapter on the correlation of the Lower Devonian in which he described the Helderberg Limestone and included the Keyser as a member. He divided the Keyser into two main faunal zones, the *Chonetes jerseyensis* zone and the *Favosites helderbergiae* var. *praecedens* zone, each with several subzones. He indicated (1913, p. 98) that these two zones coincide approximately with two lithologic units, the lower being a nodular limestone and the upper rarely nodular but containing many shaly beds. In discussing the correlation of Maryland with other areas, he noted that the faunas of the *Chonetes jerseyensis* zone were very similar to those of the Decker of New Jersey and the Cobleskill of New York and mentioned that Weller (1903) had correlated the Cobleskill and Decker, although Hartnagel (1903) considered the Cobleskill slightly younger. Swartz (1913, p. 115) then stated "If Hartnagel's correlation of the latter formations be accepted, the Keyser of Maryland represents the interval from the Wilbur to the Manlius of southeastern New York, inclusive."

As the Keyser was considered Early Devonian and the Manlius was considered Silurian, this correlation posed a problem. Swartz (1913, p. 115–118) discussed at considerable length a compromise theory proposed by Ulrich, who, on the basis of 1 day spent examining the type section of the Manlius, at Manlius, N.Y. (Ulrich, unpub. data, 1910), disregarded Hartnagel's stratigraphic placement of the waterlimes. Ulrich correlated the waterlimes in the Manlius (now the Elmwood Member) with the Rondout; he correlated a fossiliferous zone in what is now the Olney Member with the Decker; and he considered the remainder of the Olney to be the true Manlius. Thus, the upper part of the type Manlius (now the Jamesville, Clark Reservation, Elmwood, and part of the Olney) was considered by him to be the Keyser equivalent and Devonian, and the lower part of the Olney was typical Manlius and Silurian in age. Ulrich further considered the Manlius in eastern New York to be the equivalent of the Keyser and Devonian, and the "typical Manlius" and Cobleskill, that is, high Silurian, to be represented by a hiatus in the Hudson Valley. Thus, he would refer the Decker, the Rondout, the upper beds at Man-

lius, and the Keyser to the Devonian, and draw the Silurian-Devonian boundary at the top of the "typical Manlius."

Swartz (1913, p. 117) objected to this theory on the grounds that the *Chonetes jerseyensis* fauna had never been found above the "typical Manlius" of central New York, whereas it was known to be present in the Cobleskill. Ulrich (Swartz 1913, p. 117, footnote 1) replied that the zones containing *Chonetes jerseyensis* were not present in central New York, with the possible exception of his "Decker Ferry" zone at Manlius, but that, as he had only spent half an hour looking for this horizon, its absence could not be proved. He would correlate the beds above the cement beds and below the Coeymans with the upper fourth or less of the Keyser in Maryland. Swartz (1913, p. 118–120) analyzed the Keyser fauna and concluded that its affinities were with the Helderberg and that it is transitional between the Silurian and Devonian, but that it should be put in the Devonian on the principle that the age of a formation is that of its youngest fauna. However, Swartz (1913, p. 110) stated that "The upper limit of the Keyser is probably limited by an unconformity which separates it from the overlying Coeymans or New Scotland."

Ulrich's proposed correlation was not regarded as completely satisfactory by very many geologists, but little detailed work on the problem was done during the twenties. The Keyser remained in the Devonian and the Manlius in the Silurian, but most geologists considered the Keyser of Maryland to correlate with the Cobleskill-Rondout-Manlius interval of New York. Reeside (1917, p. 193–199) reviewed the correlations and the faunas and concluded with Swartz that the Keyser belonged in the Helderberg and the Devonian on the principle that the age of a fauna is determined by its youngest elements. He considered that Ulrich's correlation with central New York had merit, but he emphasized that the correlation would not be considered proven until the Decker fauna was found in the beds at Manlius that Ulrich considered equivalent to the Decker. Here the problem rested for 12 years.

RECENT INVESTIGATIONS

The year 1929 marked the beginning of renewed efforts to resolve the discrepancy between the presumed ages of the Manlius Limestone and the Keyser Limestone, although the papers published in that year did not directly discuss the problem. Swartz (1929) traced the Helderberg Group, including the Keyser Limestone, across West Virginia and Virginia and demonstrated a change of facies with the introduction of sandstones to the southwest. He followed previous writers in considering the Keyser Devonian and part of the Helderberg Group. The same year Burnett Smith (1929) described the type section of

the Manlius Limestone and named five members, in ascending order, the Olney, Elmwood, Clark Reservation, Jamesville, and Pools Brook. He also distinguished the overlying Bishop Brook Limestone as an erosional remnant of Helderberg age. He did not, however, express any opinions about the age and correlation of the Manlius nor did he describe the fauna.

In 1931, R. M. Logie, a graduate student at Yale University, began the study of the stratigraphy of the Manlius Limestone throughout New York State. He examined the Manlius in the field during the summers of 1931–33 and found that some of the members named by Smith could be traced as far east as Vanhornesville, N.Y., that crinoidal limestones of Coeymans lithology appeared in the lower part of the section toward the east, and that the Manlius decreased in thickness by nearly 50 feet between Vanhornesville and Sharon Springs, N.Y. He interpreted this decrease in thickness as the result of an unconformity between the Manlius and the overlying Coeymans Limestone and considered this evidence for placing the Silurian-Devonian boundary between these two formations.

Logie had visited about 300 localities, measured 190 sections, and made extensive collections to determine whether or not the formation could be zoned faunally. His conclusions were never published, but his manuscript, notes, and collections remain at Yale, and have been available to subsequent workers.

In 1938, I was assigned the description of the Manlius and Cobleskill faunas as a dissertation problem at Yale. This investigation was based on Logie's collections and measured sections. The discussion of the faunas in the present paper is based on the dissertation.

Later, Davis (1953) studied the contact of the Manlius and Coeymans Limestones from Manlius east to Schoharie, N.Y. He listed the fauna from measured sections across the contact and concluded that there was a faunal, and to some extent a lithologic, gradation between the two formations. He made no statements, however, concerning the age of either limestone.

The most recent, and by far the most comprehensive, study of the stratigraphy of the Manlius and Coeymans, is the result of work by Lawrence V. Rickard, now senior paleontologist at the New York State Museum. Rickard began his study in 1952, and 3 years later published preliminary notes on his findings (Rickard, 1955a, b). Because of Rickard's work, Fisher (1959) placed the boundary between the Silurian and Devonian in the Rondout Limestone on the correlation chart of the New York State Silurian.

Rickard (1962), in his final report on the problem, traced the members of the Manlius Limestone eastward to the vicinity of Vanhornes-

ville, as did Logie; but he demonstrated that the decrease in thickness of the Manlius eastward is due to interfingering with the Coeymans, rather than an unconformity as believed by Logie. He named the crinoidal limestone of Coeymans lithology which occurs beneath the Clark Reservation and Elmwood Members of the Manlius at Dayville and Jordanville the Dayville Member of the Coeymans and applied the name Deansboro Member of the Coeymans to the crinoidal limestone overlying the Jamesville Member of the Manlius. Rickard has also named a new member of the Manlius, the Thacher, which is exposed in the Helderberg escarpment. In his opinion (1962, p. 93–97), the Manlius Limestone represents a lithified calcareous ooze, whereas the Coeymans Limestone is a lime sand, and the two facies interfinger. He concludes (Rickard, 1962, p. 117–119) that the Silurian-Devonian boundary is below the Manlius Limestone, and that the Manlius belongs with the Helderberg Group and is Early Devonian in age.

Study of the faunas of the Manlius and Cobleskill Limestones corroborates Rickard's conclusions. Work was concentrated on two of the most abundant groups, the brachiopods and the ostracodes. The brachiopods had with few exceptions been described by previous workers, but as the following lists show, most of them have been reassigned to other genera. Most of the ostracodes have not been described. One of the results of the study was the discovery that, with the possible exception of one leperditiid, the two formations have no species and few genera in common.

The Cobleskill fauna is relatively meager. The brachiopods include the following:

"Schellwienella" interstriata (Hall)
Leptostrophia bipartita (Hall)
Eccentricosta jerseyensis (Weller)
Cupularostrum litchfieldensis (Schuchert)
Machaeraria? lamellata (Hall)
Lanceomyonia? sp.
Protathyris nucleolata (Hall)
Protathyris sulcata (Vanuxem)
Howellella corallinensis (Grabau)
Howellella eriensis (Grabau)

Of these brachiopods, *Leptostrophia bipartita*, *Eccentricosta jerseyensis*, *Cupularostrum litchfieldensis*, and *Machaeraria? lamellata* have also been reported from either the Decker or the lower part of the Keyser, or both, and *Howellella corallinensis* is so close to *H. modesta* of the Keyser that they may prove to be synonymous.

The Cobleskill also contains the ostracodes *Zygobeyrichia? barretti* (Weller) and *Leiocyamus* sp. and the coral *Cystihalysites* sp. which

also occur in the Decker Limestone. The presence of *Cystihalysites* indicates a Silurian age for this fauna.

The typical Manlius fauna, that is, the fauna associated with the calcilutites of the Thacher, Olney, and Jamesville Members, is very poor in brachiopods and most other groups, the most diversification being shown by the ostracodes. The two characteristic brachiopods are *Mesodouvillina varistriata* (Conrad) and *Howellella vanuxemi* (Hall), although locally a species of *Meristella* is common. The ostracodes include *Herrmannina alta* (Conrad), *Kloedenia manliensis* (Weller), *Kloedenia crassipunctata* Swartz and Whitmore, *Saccarchites saccularis* Swartz and Whitmore, and several species of *Kloedenella*. Gastropods and pelecypods occur, but they are commonly very poorly preserved. *Tentaculites gyracanthus* (Eaton) is abundant on bedding surfaces. The upper part of the Thacher Member ("transition beds" of Grabau, 1906, p. 114) has a somewhat more diversified fauna; the brachiopods *Uncinulus mutabilis* (Hall) and *Cupularostrum? semiplicata* (Conrad) and a large ostracode fauna occur in these beds.

The Dayville Member of the Coeymans Limestone, which, as shown by Rickard (1962, p. 68–72), underlies the Elmwood Member of the Manlius and grades laterally into the Olney Member to the west, contains the following brachiopods:

Dalejina oblata (Hall)
Uncinulus mutabilis (Hall)
Mesodouvillina varistriata (Conrad)
M. arata var.
Leptostrophia planulata (Hall)
Schellwienella woolworthana var.
Strophonella punctulifera (Conrad)
S. cavumbona (Hall)
Howellella prognostica (Schuchert)
Meristella praenuntia Schuchert
Cyrtina sp.
Podolella sp.

The ostracodes include *Kloedenia montaguensis* (Weller), *K. granulata* (Hall), *Kloedenella planata* (Ulrich and Bassler), *Dizygopleura angustisulcata* Swartz and Whitmore, and *Thlipsuropsis digitata* Swartz and Whitmore. The cystoid *Lepocrinites gebhardtii* also is common. This cystoid, most of the brachiopods, and two of the ostracodes are generally considered to be indicative of the Coeymans. The ostracode *Kloedenia montaguensis* occurs in the Manlius Limestone of New Jersey.

It is apparent from the list of fossils given above that the type Manlius is closely related to the Coeymans faunally and is entirely distinct from the Cobleskill Limestone of Silurian age. Thus, Rick-

ard's conclusion that the Manlius belongs in the Helderberg Group and should be considered Lower Devonian seems entirely justified.

The problem of the correlation of the Maryland section with that of New York is not yet completely resolved. F. M. Swartz (1939, p. 47–50) has given an excellent review of the problem, discussing the correlation with the New York State section and listing the evidence for and against putting the Keyser in the Devonian or Silurian. He (1939, p. 49) concludes: "In view of the observations presented above, the writer believes it desirable to separate the Keyser limestone from the Helderberg group, and has tentatively referred the Keyser to the Silurian System." Woodward (1948, p. 36, 37), however, still considered the Keyser a member of the Helderberg Group, but he did not commit himself as to its age. Recently Boucot (1957; 1960, p. 291). has indicated that the upper part of the Keyser Limestone is Lower Gedinnian, and hence Lower Devonian, on the basis of the brachiopods, whereas the lower part is Ludlovian and Upper Silurian. The presence of *Cystihalysites* in the lower part of the Keyser (*Chonetes jerseyensis* zone) indicates a Silurian age for this part of the formation. A detailed study of the brachiopod fauna undertaken by Zeddie P. Bowen for a dissertation at Harvard may help to determine the position of the Silurian-Devonian boundary with respect to the Keyser.

SUMMARY

Most contemporary workers who have studied the problem would now consider the type Manlius Limestone as a lime-mud facies of the Coeymans lime sand, and place it in the Devonian as a part of the Helderberg Group. Its separation from the Helderberg and inclusion in the Silurian appears to have been based in part on (a) Grabau's early correlation of the Akron Dolomite with the Manlius; (b) the confusion of faunas in the Frontenac Island-Union Springs area, possibly due to mixed collections; and (c) Schuchert's correlation of the lower part of the Keyser Limestone with the Manlius. All three of these errors resulted in the inclusion of Silurian fossils in the faunal lists of the Manlius, instead of in the Cobleskill, Decker, and lower part of the Keyser, where they actually occur. A contributing factor was the confusion over the position of the waterlimes. Sedimentation was apparently continuous across the Silurian-Devonian boundary from New York to Virginia, and the placement of the boundary must be largely arbitrary and based on the evidence of fossils. The position of the boundary in New York (fig. 2) as shown by Fisher (1959) seems reasonable, for the lower part of the Rondout contains Cobleskill fossils and the upper part contains Manlius fossils. The Keyser of Late Silurian and Early Devonian(?) age is tentatively

considered to correlate with the Cobleskill-Roundout-Manlius interval of New York, with the boundary occurring in the middle of the formation. Further studies in progress will test the validity of this correlation.

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