TRIP B2
Grabau's "Transition Beds" – Key Elements in a Radical Revision of Helderberg Stratigraphy

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... transitional beds from the Manlius to the Coeymans extend to the foot of the Coeymans ledge... The fauna of the transition beds... represents oscillating conditions between the Manlius and the Coeymans.

Amadeus W. Grabau (1906)

Recognition of an erosional interval between the Cayugan and Helderbergian has been tardy ... as late as 1906... Ulrich and others were talking about AManlius transition beds≅ in east-central New York and the Helderberg region.

G. H. Chadwick (1944)

The lateral gradation which exists between the Coeymans limestone at Cherry Valley and the Olney-Jamesville members of the Manlius formation constitutes nearly indisputable evidence for the contemporaneity of at least parts of the Manlius and Coeymans formations.

L.V. Rickard (1962)

The Manlius-Coeymans cryptic unconformity in eastern New York is particularly well documented by the erosional loss of as much as 4 metres of section encompassing more than three PACs...

P.W. Goodwin and E.J. Anderson (1988)

INTRODUCTION AND PREVIOUS WORK

The nature of the contact between the Manlius and Coeymans formations is a recurring theme in the literature of the Helderberg Group. In the early twentieth century, Grabau (1906) interpreted the contact as gradational, with a distinctive zone of Atransition beds≅ present between true Manlius and true Coeymans. Grabau=s transition beds are best developed in eastern New York in and near the Schoharie Valley and appear to be absent from other areas (Fig. 1).

In succeeding decades, the contact was regarded as a disconformity, with views varying as to the magnitude of hiatus. Goldring (1935, 1943) indicated that as early as 1927, Chadwick saw evidence for some hiatus (see also Chadwick 1944). In central New York, Smith (1929) described the contact of the Jamesville Member of the Manlius Formation with the overlying Coeymans as unconformable. Logie (1933) felt that the erosion was significant with the Elmwood, Clark Reservation and Jamesville members of central New York absent in eastern parts of the state via erosion. Chadwick (1944, p. 152) reported the contact as Airregular, undulating≅ and concurred with Logie that the absence of the higher members of the Manlius in eastern New York was the result of significant erosion.

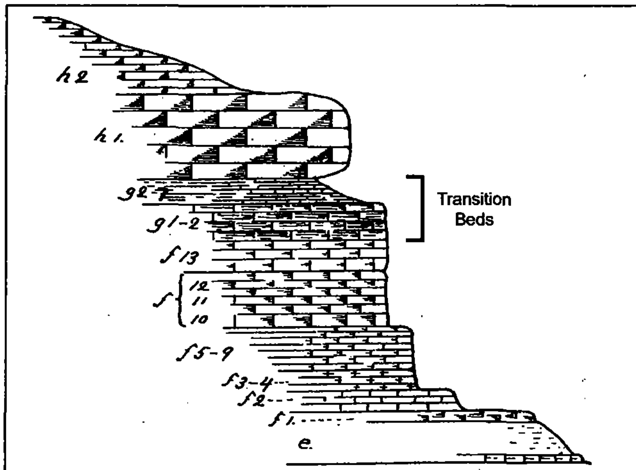

Fig. 1 Grabau's "Transition Beds" at Becker's Quarry in Schoharie. Modified slightly from Grabau (1906)

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Rickard (1962) reinterpreted the Manlius-Coeymans contact as sharp, but conformable in eastern New York. In central New York, he saw the contact as complex with portions of the Coeymans Formation (e.g., Dayville Member) and higher parts of the Manlius (Elmwood, Clark Reservation and Jamesville members) and other members of the Coeymans (Deansboro/Ravena members) intertonguing (Fig. 2). Rickard's stratigraphy became the foundation for nearly all succeeding work on the Helderberg Group. The most notable example is Laporte's (1969) reconstruction of depositional environments.

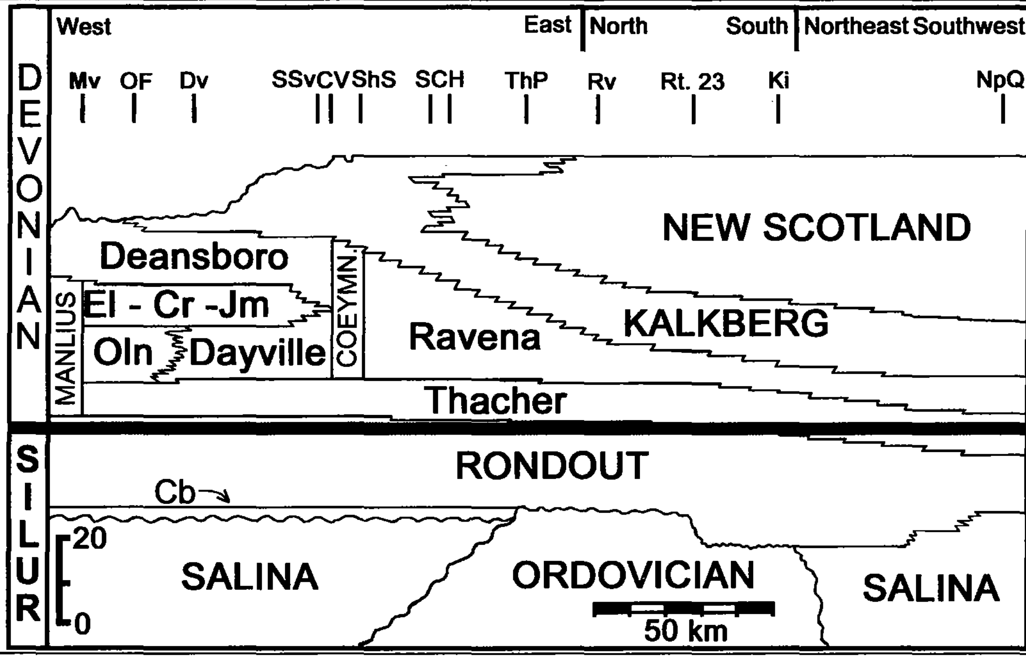


Fig. 2 Rickard's (1962) synthesis of lower Helderberg stratigraphy. Figure is from Ebert and Matteson (2003), modified from Barnett (1977). Formation and group names are shown in upper case. Member names are in lower case. Coeymn. = Coeymans Formation. Members of the upper portion of the Manlius Formation, in ascending order, are Oln = Olney Member, El = Elmwood Member, CR = Clark Reservation Member, Jm = Jamesville Member. Cb = Cobleskill Limestone. Locations are abbreviated as Mv = Munnsville, OF = Oriskany Falls, Dv = Dayville, SSv = Salt Springville, CV = Cherry Valley, ShS = Sharon Springs, SCH = Schoharie outcrops - Howe Cave Quarry and I-88, ThP = Thacher Park, Rv = Ravena, Rt. 23 = Catskill, Ki = Kingston, NpQ = Nearpass Quarry, New Jersey. Vertical scale in meters is approximate. Silurian - Devonian boundary is based on biometric trends in *Ozarkodina remscheidensis* (Barnett 1977).

Rickard (1962, p. 105) acknowledged the possibility that a Apost-Jamesville≅ (sub-Coeymans) disconformity in central New York might extend into the middle of the Coeymans in east-central New York and to either the top or base of the Coeymans in the Hudson Valley. However, he discounted this interpretation based on the absence of an obvious faunal or physical break and the presence of the transition beds at Cherry Valley. Later, Rickard and Zenger (1964, p. 51) reported that Aa layer of pebbles and abundant *Favocites* sp. occupies the position of the Jamesville with Dayville and Deansboro crinoidal limestones with *Gypidula coeymanensis* below and above≅ in portions of the Richfield Springs 15' Quadrangle. Whereas this may be viewed as evidence for erosional truncation of the Jamesville below the Coeymans, Rickard and Zenger (1964) retained the interpretation of Rickard (1962) of gradational facies relationships, as did Laporte (1969).

In the 1980's, Goodwin and Anderson published a series of papers outlining and applying their hypothesis of Punctuated Aggradational Cycles (PACs – a type of small scale allostratigraphic cycles) to the Helderberg Group in New York and elsewhere in the Appalachian

Basin. Where the Coeymans Formation overlies the Thacher Member of the Manlius Formation, Goodwin and Anderson (1988) interpreted the contact as a minor, cryptic unconformity. They documented the progressive cutting out of more of their PACs from central New York eastward. However, they continued to support coeval relationships between higher parts of the Manlius and the Coeymans formations by correlating PACs through these units.

SIGNIFICANCE OF THE PROBLEM

Are these conflicting interpretations of unconformity or gradational contact mutually exclusive, or does the truth lie somewhere between the extremes? Clearly, early workers like Smith, Logie, Chadwick and later Goodwin and Anderson saw physical evidence for unconformity. In contrast, Rickard presented faunal evidence in a coherent stratigraphic framework which supported gradational relationships. Laporte's (1969) sedimentologic study lent additional support. Rickard's interpretation was strongly influenced by the presence of Grabau's transition beds between the two formations. Those that described the Manlius - Coeymans contact as unconformable either dismissed the transition beds with derision or did not mention them at all. It seems apparent that the existence, nature and distribution of these enigmatic transition beds may hold the key to understanding the stratigraphic relationships between the Manlius and Coeymans formations.

One might argue that understanding the nature of the contact between these two formations is a rather trivial matter. However, there are implications beyond these competing interpretations. The Siluro-Devonian sequence of New York State is the Appalachian Standard Succession (Johnson and Murphy 1969). Within this Standard Succession lies the Silurian – Devonian systemic boundary. Rickard (1962; 1975) and Barnett (1971; 1977) placed the boundary within the Helderberg Group in the vicinity of the Rondout – Manlius contact. However, this placement is not based so much on index fossil biostratigraphy as it is on an attempt to be consistent with Rickard's stratigraphic framework of coeval facies. Earlier workers (e.g., Clark 1889; 1900; Schuchert 1900) placed the boundary considerably higher, namely at the Manlius – Coeymans contact. So, there is more at stake than geologica esoterica. The accurate identification of a major biostratigraphic boundary and its attendant global correlation hang in the balance. Without accurate placement of the boundary, correlations between the Standard Succession in New York and other areas within the Appalachian Basin become problematic and comparisons to global sea level curves become increasingly suspect.

TRADITIONAL STRATIGRAPHY

For over 150 years, the formations of the Helderberg Group have been the subjects of stratigraphic, paleontologic and sedimentologic investigation. Comprised of limestones, shaly limestones and dolostones, the Helderberg Group crops out in central and eastern New York State (Fig. 2). Rickard (1962) recognized eight formations, which he regarded as diachronous lithofacies. This correlation made it possible for Laporte (1969) to give a detailed reconstruction of paleoenvironments along a transect from nearshore, peritidal environments (Manlius Formation), through subtidal shoals (Coeymans Formation) to shallow and deeper shelf settings

(Kalkberg and New Scotland formations). This interpretation literally became the Atextbook example≅ of sedimentation in clear-water (i.e., carbonate) epeiric seas (e.g., Prothero, 1990).

Although Laporte (1969) did not address the sedimentology of the transition beds, their presence was a key factor in enabling Rickard to synthesize facies relationships, which then allowed Laporte to interpret paleoenvironments. So, what exactly are the transition beds?

GRABAU'S TRANSITION BEDS AND THE MANLIUS - COEYMANS CONTACT

Grabau (1906, p. 247) described the transition beds as Athin bedded lime sandrocks and lime mudrocks, with shaly argillaceous beds.≅ Grabau also reported lenses of lime mudrocks embedded in some of the shales. Faunally, the transition beds are dominated by the brachiopod *Stropheodonta varistriata* and echinoderm debris. Grabau (1906) measured the total thickness of the transition beds ranging from 3.66 meters to 4.01 meters (12 ft. to 13 ft. 2 in.) in the vicinity of Schoharie (Grabau 1906).

Reexamination of these beds in the vicinity of Schoharie, New York has provided several key insights. First, the transition beds are indeed a recognizable unit, distinctly different from the typical Manlius below and Coeymans above. Rather than an alternation of Manlius and Coeymans lithologies (sensu Grabau 1906), the transition beds actually comprise two units which differ from both the typical Manlius of eastern New York and from the Ravena Member of the Coeymans (Fig 3).

Subdivision of the transition beds

The lower portion of the transition beds comprise skeletal packstones, wackestones and mudstones (6-18 cm beds) with a macrofauna dominated by brachiopods, especially *Stropheodonta varistriata* and *Howellella vanuxemi*, pelmatozoans, such as *Lasiocrinus scoparius*, *Conularia* sp., ramose and fenestrate bryozoans, and gastropods. Packstone and wackestone beds display sharp bases and have planar-laminated to undulose tops. Most beds are normally graded, but extensive bioturbation obscures other internal structures. Infiltration fabrics are common in the coarser packstones. These sedimentologic features and the shallow-water aspect of the fauna suggest a tempestite origin. Muddy tempestites in the lower transition beds are interbedded with dark, carbonaceous shales, which have yielded an abundant, carbonized biota comprising scolecodonts, poorly preserved annelid soft tissues and *Medusaegraptus*, a non-calcified, aspondyl, dasycladacean alga (Matteson, Natel and Ebert, 1996). The lower transition beds are separated from unquestionable beds of the Thacher Member of the Manlius Formation by a sharp, non-depositional discontinuity. The lower transition beds are separated from the upper transition beds by an erosional disconformity (see below).

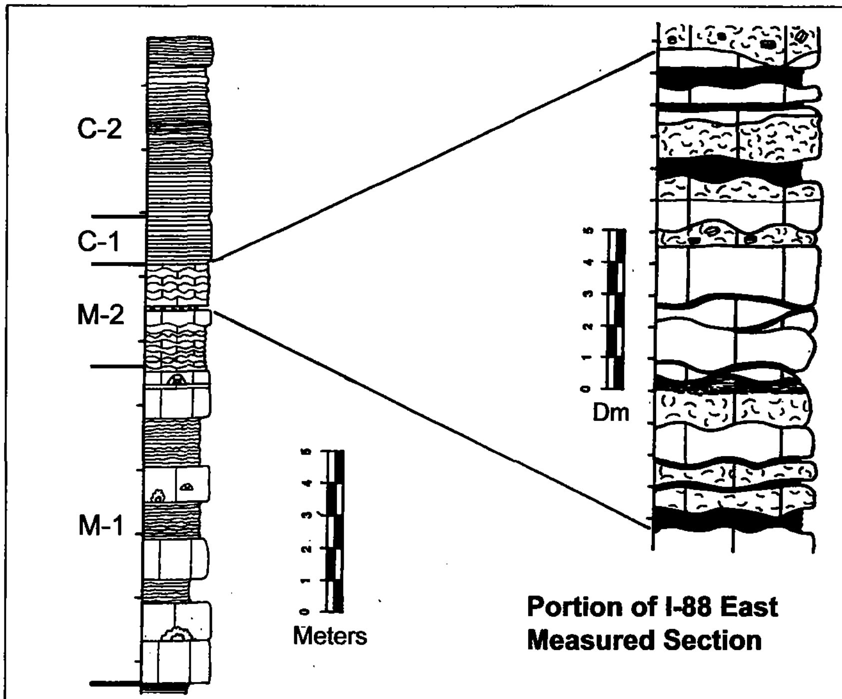


Fig. 3 Measured section from I-88, Schoharie area showing two-fold division (M-2 and C-1) of Grabau's transition beds. M-1 = Thacher Member of the Manlius Formation; M-2 = Green Vedder Member of Manlius Formation (a.k.a. "thin-bedded upper Thacher of Rickard (1962)); C-1 = Dayville Member of Coeymans Formation (sensu Rickard (1962)); C-2 = Ravena Member of Coeymans Formation. Enlarged column shows heterolithic character of Green Vedder Member. Dm = decimeters.

Limestones of the upper transition beds are crinoid-brachiopod grainstones and packstones, which commonly rest with sharp, erosive contacts on interbeds of finer-grained lithologies (variably argillaceous, dolomitic, ostracod - peloid grainstones and packstones to wackestones). Some bedding planes are littered with long, articulated stems of the crinoid *Ctenocrinus pachydactylus* (see Grabau 1906). Imbricate shells, crudely graded bedding and obrution assemblages imply a tempestite origin. Because the coarse packstones and grainstones are similar to the facies that comprise the Coeymans Formation, their presence reinforced the appearance of a gradual transition between the Manlius and Coeymans formations. However, the top of the transition interval is marked by a third, sharp erosional discontinuity.

From the description above, it seems clear that the Manlius – Coeymans contact in the Schoharie area is not a simple disconformity, yet it is not a gradational interfingering either. Rather, the "transition beds" comprise two distinct units that are not typical Manlius or Coeymans. Therefore, the questions are: 1) what are these units and 2) can they be correlated outside of the Schoharie area? Further, how significant are the discontinuities that underlie the lower transition beds and cap the lower and upper transition beds and can they be traced laterally?

Clockville Discontinuity, Terrace Mountain Unconformity and Correlation of the Lower Transition Beds

The surface that separates the lower transition beds from the more typical, thick-bedded Thacher Member of the Manlius Formation is a newly recognized discontinuity produced by sediment starvation and possible sediment bypass. For ease of discussion, we refer to this surface as the Clockville Discontinuity, a name derived from the excellent road cut at Clockville, NY.

The Clockville Discontinuity is sharp and locally erosional. At the type section, isolated pockets (up to 6 cm deep and 12 cm wide) are scoured into the top of the typical Thacher and filled with coarse skeletal grainstone, a lithology which is atypical for this part of the section and different from those that comprise the typical Thacher below and the lower transition beds above. Skeletal debris includes resistant echinoderm ossicles, fragments of thick-shelled brachiopods and rare branching bryozoans. The Clockville Discontinuity is abruptly overlain by beds referable to the lower transition beds, which appear to represent a significantly deeper environment of deposition than the typical Thacher below. Therefore, it seems likely that the Clockville Discontinuity is a flooding or transgressive surface.

Goodwin and Anderson (1988) recognized a cryptic unconformity at the top of the Thacher Member of the Manlius Formation in central and eastern New York. For ease of discussion, we have christened this surface the Terrace Mountain Unconformity (Ebert and Matteson 2001a; 2001b; 2003), after the excellent exposure on I-88 on the flank of Terrace Mountain near Schoharie. From Cherry Valley westward, the Dayville Member of the Coeymans Formation and its western equivalent, the Olney Member of the Manlius Formation overlie this unconformity (Goodwin and Anderson (1988). We have correlated the Terrace Mountain Unconformity from the Syracuse area through Cherry Valley to Schoharie, where we recognize it as the surface that marks the top of the lower transition beds. The Terrace Mountain Unconformity has a gently angular nature on a regional scale (see Goodwin and Anderson 1988). At individual outcrops, the contact displays minor erosional relief, ranging from a few millimeters (Fig. 4) up to nearly 10 centimeters. Intraclasts of Thacher-type lithology occur rarely in the bed immediately overlying the Terrace Mountain Unconformity.

If our correlation and that of Goodwin and Anderson (1988) is correct, then the beds between the Clockville Discontinuity and the Terrace Mountain Unconformity should have some affinity with the Thacher Member of the Manlius Formation by their position in the sequence. If this is the case, then why have they been recognized separately as part of the transition beds? The answer lies in their distinctive lithology, paleocommunity and taphonomy, which differ from usual characterization of the Manlius as comprising thick-bedded peritidal lithologies (Laporte 1969).

The lithologies of the lower transition beds comprise an association of poorly skeletal limestones in decimeter beds alternating, in part, with dark, organic-rich, calcareous shales. Moreover, the fauna and flora of these interbeds and their distinctive taphonomy are unique in this part of the section. Matteson, Natel and Ebert (1996) originally described this paleocommunity and its preservation from the exposure along I-88 on Terrace Mountain and correlated it some 140 km westward as far as Chittenango Falls. The interval thickens westward from Schoharie and the beds bearing the carbonized biota clearly occur within the Athin bedded upper Thacher≅ that Rickard (1962) recognized between Manlius, near Syracuse and Oriskany Falls in central New York. Limestones within this portion of the Thacher are also dominated by *Stropheodonta varistriata* and *Howellella vanuxemi* (Rickard, 1962, p. 54) and include *Lasiocrinus scoparius*. The carbonized flora and fauna in the shaly interbeds is distinctive and consistent across the outcrop belt. Thus, the lower portion of the Grabau=s transition beds is a traceable unit within the Thacher Member of the Manlius Formation. We refer to this unit as the Green Vedder Member (informal) of the Manlius Formation, after the excellent exposure along Green Vedder Road, outside the large active quarry at Oriskany Falls. Although Rickard did not trace this unit eastward from Oriskany Falls, some of Rickard's descriptions (e.g., R-117, Cullen) indicate that he may have recognized the unit farther to the east. In fact, the Green Vedder Member, with its signature biota and taphonomy, is present at Cherry Valley, Sharon Springs, and Schoharie. East of Schoharie, the lower transition beds/Green Vedder Member are removed by the Terrace Mountain Unconformity. However, a small outlier of the Green Vedder Member has been identified at Ravena.

The Howe Cave Unconformity and Correlation of the Upper Transition Beds

By virtue of their position above the Terrace Mountain Unconformity, it is reasonable that the upper transition beds should have some relationship to the Olney/Dayville interval which overlies the unconformity in central New York. However, owing to some general similarities in lithology, it is also possible that the upper transition beds are related to the Deansboro or Ravena members of the Coeymans Formation. This correlation is less likely because in the Schoharie Valley, the upper transition beds are separated from the superjacent Ravena Member of the Coeymans Formation by an abrupt, erosional discontinuity. We have dubbed this surface the Howe Cave Unconformity, a name derived from the inactive Howe Cave Quarry, where the surface was first observed truncating the upper transition beds. At the type locality and all locations to the east, the Howe Cave Unconformity is overlain by the Ravena Member of the Coeymans Formation. Westward from the type locality, correlation becomes more complex as the Howe Cave Unconformity rises stratigraphically, the upper transition beds thicken below it and additional, higher units are preserved.

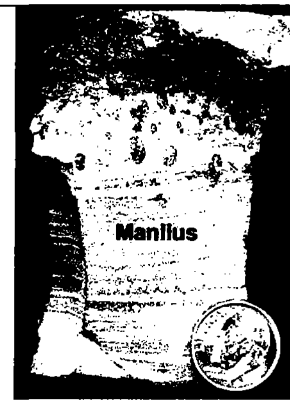
From its type section, the Howe Cave Unconformity descends eastward, thinning the upper transition beds to disappearance somewhere between Gallupville and John Boyd Thacher Park. As a result of this descent, the Howe Cave Unconformity merges with the previously described Terrace Mountain Unconformity and, at many localities, with the Clockville Discontinuity. Thus, the contact between the Manlius and Coeymans formations from Thacher Park eastward and south through the Hudson Valley is a composite of the Clockville Discontinuity, the Terrace Mountain Unconformity and the Howe Cave Unconformity. It was this composite unconformity that Chadwick (1944) described from the Hudson Valley. It was also from this composite unconformity that Goodwin and Anderson (1988) reported the loss of some 4.5 meters of section. Because the merging of these two unconformities was probably accomplished by truncation of the Clockville Discontinuity and the Terrace Mountain Unconformity beneath the Howe Cave Unconformity, we continue the use of the designation Howe Cave Unconformity for this surface throughout eastern New York, regardless of the presence or absence of the upper transition beds below the unconformity (Ebert and Matteson 2001a; 2001b; 2003).

Lithologically, the upper transition beds bear a striking resemblance to the Dayville Member of the Coeymans Formation. Indeed, they show remarkable similarities in fauna and taphonomy as well, particularly in the presence and preservation of articulated stems of the crinoid *Ctenocrinus pachydactylus*, which occurs at the Dayville type section and in the upper transition beds at Schoharie. These similarities strongly suggest that the upper transition beds are a previously unrecognized eastward extension of the Dayville Member. If this is the case, then the Dayville should exist between Schoharie and Cherry Valley, where Rickard acknowledged the presence of the Dayville Member.

From the Gallupville west to Sharon, New York, the upper transition beds vary between one or two meters in thickness down to a few decimeters locally owing to relief on the Howe Cave Unconformity. However, the Dayville/upper transition zone is nearly three meters thick at Sharon Springs and expands rapidly to approximately six meters at Cherry Valley, where Rickard indicates that it comprises the lower half of the Coeymans Formation. West of Cherry Valley, this interval is referred to as the Dayville Member of the Coeymans Formation (Rickard, 1962). Tracing of recognizable marker beds from the type section of the Dayville to Cherry Valley confirms assignment of the lower Coeymans at Cherry Valley to the Dayville Member. From these correlations, it is now apparent that the upper portion of Grabau=s transition beds in the Schoharie area is an erosionally thinned, eastward continuation of the Dayville Member, which Rickard (1962) had previously restricted to the area west of Cherry Valley. It is also clear that from Cherry Valley to Gallupville, the Howe Cave Unconformity occurs <u>within</u> the Coeymans Formation (between the Dayville and Ravena members) as defined by Rickard (1962).

At Cherry Valley intraclasts of Manlius aspect and favocitid corals, which encrust a sharp surface, mark the position of the Howe Cave Unconformity between the Dayville Member and the Deansboro/Ravena Member, both parts of the Coeymans Formation. West of Cherry Valley, the Howe Cave Unconformity rises stratigraphically and truncates units that have been regarded as parts of the Manlius Formation (Elmwood, Clark Reservation and Jamesville members). Intraclasts or lithoclasts of the Elmwood or Clark Reservation (?) have been observed in a discontinuous outcrop at Salt Springville, near Cherry Valley. Rickard and Zenger (1964) also reported such clasts in this area. Exposures where the Howe Cave Unconformity can be directly observed cutting the Elmwood and then the Clark Reservation members have not been found. We attribute this to the general paucity of outcrops in the area between Salt Springville and Jordanville and to the extremely limited thickness of these units (approximately 3 meters maximum in this area). From Jordanville westward, the Howe Cave Unconformity overlies the Jamesville Member of the Manlius Formation. Indeed, it is this unconformity that was reported by Smith (1929) and Logie (1933). In some exposures, such as the active quarry at Oriskany Falls, the Howe Cave Unconformity exhibits well-developed paleokarstic features (Fig. 4). Steep-sided solutional pits penetrate up to five centimeters into the top of the Jamesville and rounded lithoclasts of pebble to small cobble size litter the unconformity. At some locations, such as Jordanville, *in situ* colonies of stromatoporoids are truncated (Fig 4). In eastern New York (e.g., Catskill vicinity), the Howe Cave Unconformity is sharp, undulating and, displays *Trypanites* (?) borings (Fig. 4; see also Laporte 1969).

B



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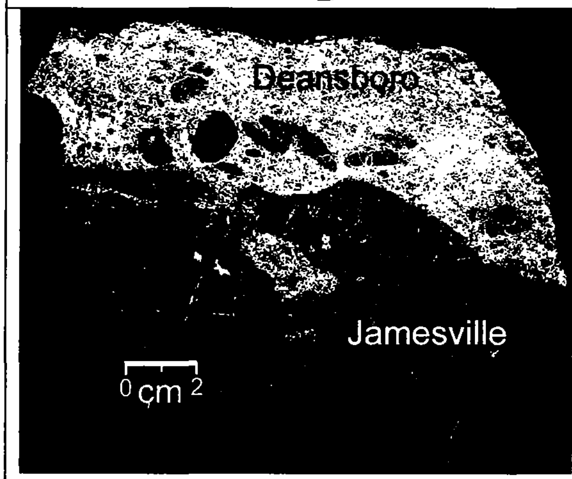

A

Fig. 4 The Howe Cave Unconformity at various outcrops: A) paleokarstic features at Oriskany Falls, B) truncated stromatoporoid colony at Jordanville, C) borings at Catskill.

The regionally angular nature of the Howe Cave Unconformity is much more pronounced than that which is displayed by the older Terrace Mountain Unconformity (Fig. 5). The Howe Cave Unconformity has greater stratigraphic relief and represents a much greater erosional vacuity. In central New York, the Howe Cave Unconformity overlies the Jamesville Member of the Manlius Formation. The subjacent Clark Reservation and Elmwood members of the Manlius are removed in a relatively narrow region around Salt Springville. From Cherry Valley to Gallupville, the unconformity truncates the Dayville Member. East of Gallupville, the Howe Cave Unconformity progressively bevels the Thacher Member of the Manlius Formation. Therefore, the stratigraphic relief on the Howe Cave Unconformity is at least 24 meters across 150 kilometers of outcrop.

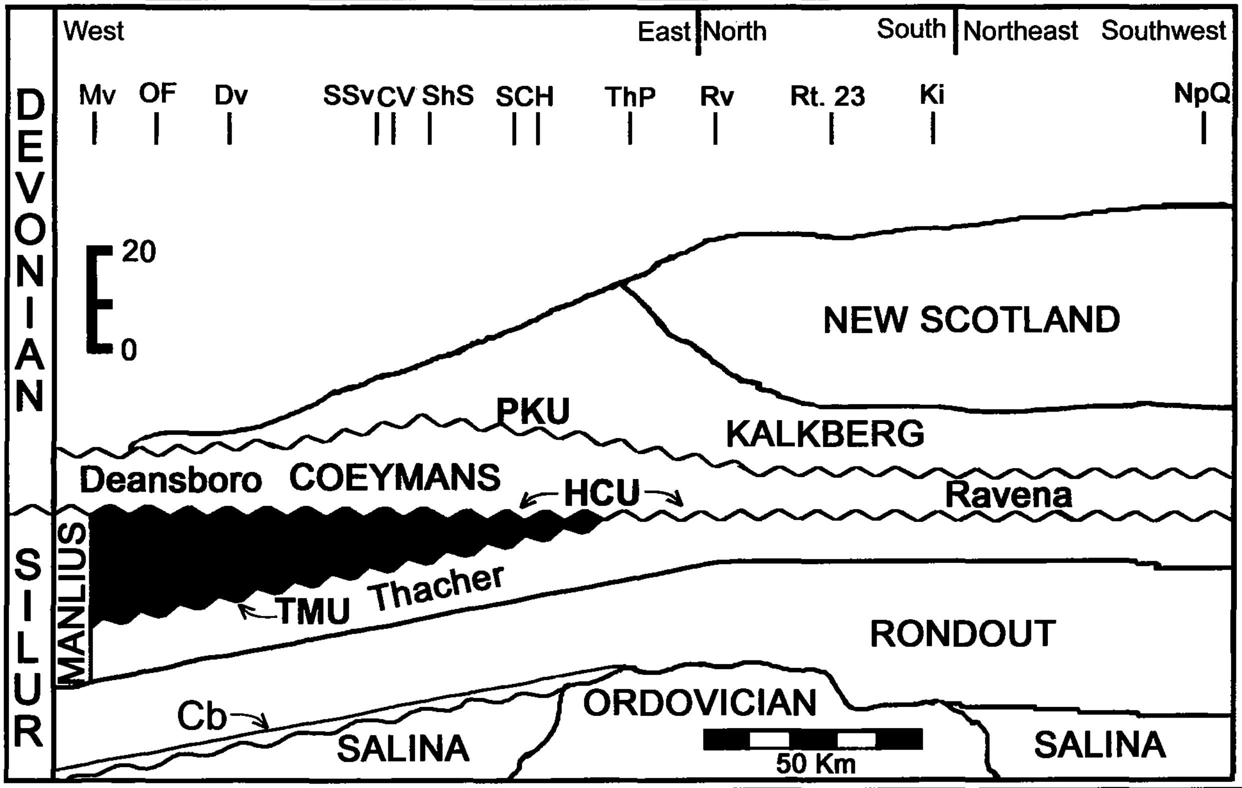

Fig. 5 Revised stratigraphy of the lower Helderberg Group, showing the Terrace Mountain and Howe Cave unconformities (after Ebert and Matteson 2003).

Stratigraphic Significance of the Terrace Mountain and Howe Cave Unconformities

The combined presence of the Terrace Mountain Unconformity in central New York and the eastern portions of the Howe Cave Unconformity precludes any portion of the Thacher Member of the Manlius Formation from having been coeval with other members of the Manlius Formation or any part of the Coeymans Formation (Fig. 5). Although Rickard (1962) acknowledged this possibility, he did not give it much credence. More significantly, the western portions of the Howe Cave Unconformity contradict the previously assumed lateral equivalence of the upper members of the Manlius Formation with portions of the Coeymans, Kalkberg and New Scotland formations (e.g., Rickard 1962; Laporte 1969). Owing to the temporal separation necessitated by the Howe Cave Unconformity, the widely cited paleoenvironmental spectrum interpreted by Laporte (1969) could not have existed. Goodwin and Anderson (1988) began the process of dismantling Rickard=s stratigraphy and Laporte=s paleoenvironmental reconstruction with their documentation of erosional loss beneath the surface that we term the Terrace Mountain Unconformity. Recognition of the Howe Cave Unconformity completes the disassembly of the Helderberg epeiric sea model (Ebert and Matteson 2001a; 2001b; 2003) and invalidates correlations of the small scale allocycles (PACs) of Goodwin and Anderson (1988) in central and eastern New York.

Recognition of the Terrace Mountain and Howe Cave unconformities carries additional implications for locating the Silurian - Devonian boundary in New York State. The existence of these unconformities changes the relative age relationships between the Coeymans Formation and the underlying Manlius and Rondout formations. Since these units can not be laterally equivalent to the acknowledged Lower Devonian Coeymans Formation, the question arises as to their age and the position of the Silurian - Devonian boundary. Previous projections of the boundary from eastern New York into portions of the Manlius and Rondout formations in the central and western areas are no longer tenable because they cross the Howe Cave and Terrace Mountain unconformities. The age of the Rondout and Manlius Formations and the position of the Silurian - Devonian boundary are considered below.

Silurian-Devonian Boundary and the Age of Helderberg Units

The nature of the Manlius-Coeymans contact is important in establishing the position of the Silurian-Devonian boundary in the Appalachian Standard Succession of New York. In the nineteenth century, the entire Helderberg Group was regarded as Silurian. Clark (1889, 1900) and Schuchert (1900) transferred most formations of the Helderberg Group to the Devonian. However, the Manlius and older units were retained in the Silurian. These designations were widely used until Rickard (1962) reinterpreted the lithostratigraphy.

Rickard=s (1962) interpretation of the Manlius-Coeymans contact as a facies change provided the rationale for reassigning the Manlius and portions of the underlying Rondout Formation to the Lower Devonian. The Ravena and Deansboro members of the Coeymans Formation bear the terebratulids *Cyrtina, Podolella* and *Nanothyris*, and the index conodont *Icriodus woschmidti* and are therefore unquestionably Lower Devonian (Barnett 1971; Rickard 1975). Since parts of the Manlius and Rondout formations were viewed as laterally equivalent to and therefore coeval with the Coeymans Formation, these units were also regarded as Lower Devonian (Rickard, 1962; 1975) despite the lack of any diagnostic paleontologic criteria. In Rickard=s reconstruction, the oldest part of the Coeymans Formation (Ravena Member) is in eastern New York. Therefore, the first occurrence of *I. woschmidti* at the base of the Coeymans in the Hudson Valley could be projected into the Manlius and Rondout formations in central New York. The absence of *I. woschmidti* from these formations could be explained as a consequence of facies preference and exclusion from unfavorable environments (e.g., Barnett 1977; Johannessen, et. al., 1997).

Lacking *I. woschmidti* in the Manlius and Rondout formations, Barnett (1971; 1972; 1977) utilized biometric trends in the more common and abundant elements of *Ozarkodina remscheidensis eosteinhornensis* and *O. r. remscheidensis* to locate the Silurian – Devonian boundary. The result was an inferred boundary that fell within the Manlius and Rondout formations, well below the first occurrence of *I. woschmidti* in almost all areas of the state. Because Barnett failed to distinguish between the subspecies *eosteinhornensis* and *remscheidensis*, Klapper (1981) questioned this placement of the boundary.

Milunich and Ebert (1991) discussed a sparse and fragmental conodont fauna from the Rondout and Manlius formations near Schoharie, but were unable to locate the boundary.

Johannessen, Natel, and Ebert (1997) indicated that the boundary might be considerably higher than the Rondout position projected by Barnett (e.g., 1977), for example, as high as 4 m above the base of the Coeymans at Cherry Valley and near the top of the transition beds in the Schoharie Valley, positions that are near the Howe Cave Unconformity.

Recognition of the Howe Cave Unconformity dictates that no part of the Manlius was coeval with the Coeymans. Indeed, the Coeymans Formation (Ravena and Deansboro members) is entirely younger than all members of the Manlius Formation. To test this reconstruction and to determine the age of the Manlius Formation, units above and below the unconformity were sampled for conodonts. Additionally, Rickard=s conodont collection, on loan from the New York State Museum was also studied.

Our samples and the Rickard collection clearly demonstrate that the first occurrence of *Icriodus woschmidti* is in the Ravena or Deansboro members of the Coeymans Formation, above the Howe Cave Unconformity. This is consistent with the findings of Barnett (1971) and Johannessen, Natel, and Ebert (1997) who attributed this to facies selectivity. However, sub-unconformity units (members of the Manlius and the Dayville Member), do not bear a more nearshore, coeval fauna.

If our correlations are correct, then the stratigraphically highest unit below the Howe Cave Unconformity is the Jamesville Member of the Manlius Formation. The Rickard collection and our samples from the Jamesville have yielded the following conodonts: *Ozarkodina confluens*, *O. excavata*, *O. remscheidensis remscheidensis* and *O. r. eosteinhornensis*. These taxa range from the Ludlovian through the P⊆ídolí stages. The presence of O. *remscheidensis eosteinhornensis* indicates a latest Silurian or P⊆ídolían age for the Jamesville. Thus, the conodont biostratigraphy corroborates the existence of the Howe Cave Unconformity and our interpretation of the temporal separation of the Manlius and Coeymans formations.

At Cherry Valley, portions of the transition beds/Dayville Member have yielded *Ozarkodina r. remscheidensis*, *O. r. eosteinhornensis* and *O. confluens*. The occurrence of *O. confluens* in these strata indicates a mid-P⊆ídolí age (Johannessen, et. al., 1997). Therefore, nearly half of the P⊆ídolí may be missing beneath the Howe Cave Unconformity in this area.

The presence of the Howe Cave Unconformity provides a satisfactory explanation for the stratigraphic distribution of *I. woschmidti*. The first occurrence of this proxy for the Silurian - Devonian boundary at the base of the Coeymans Formation is not the result of the appearance of a favorable environment as indicated by Barnett (1971). Rather, it is attributable to the resumption of deposition following the Howe Cave Unconformity. The Coeymans Formation (minus the Dayville Member) is the oldest Lochkovian unit in New York. Therefore, the Silurian B Devonian boundary occurs within erosional vacuity of Howe Cave Unconformity (Fig. 6), a placement which is consistent with the views of earlier workers (e.g., Logie, 1933; Goldring 1935, 1943; Schuchert 1943 and Chadwick 1944) who viewed the Manlius-Coeymans contact as a systemic unconformity (Rickard 1962, p. 49).

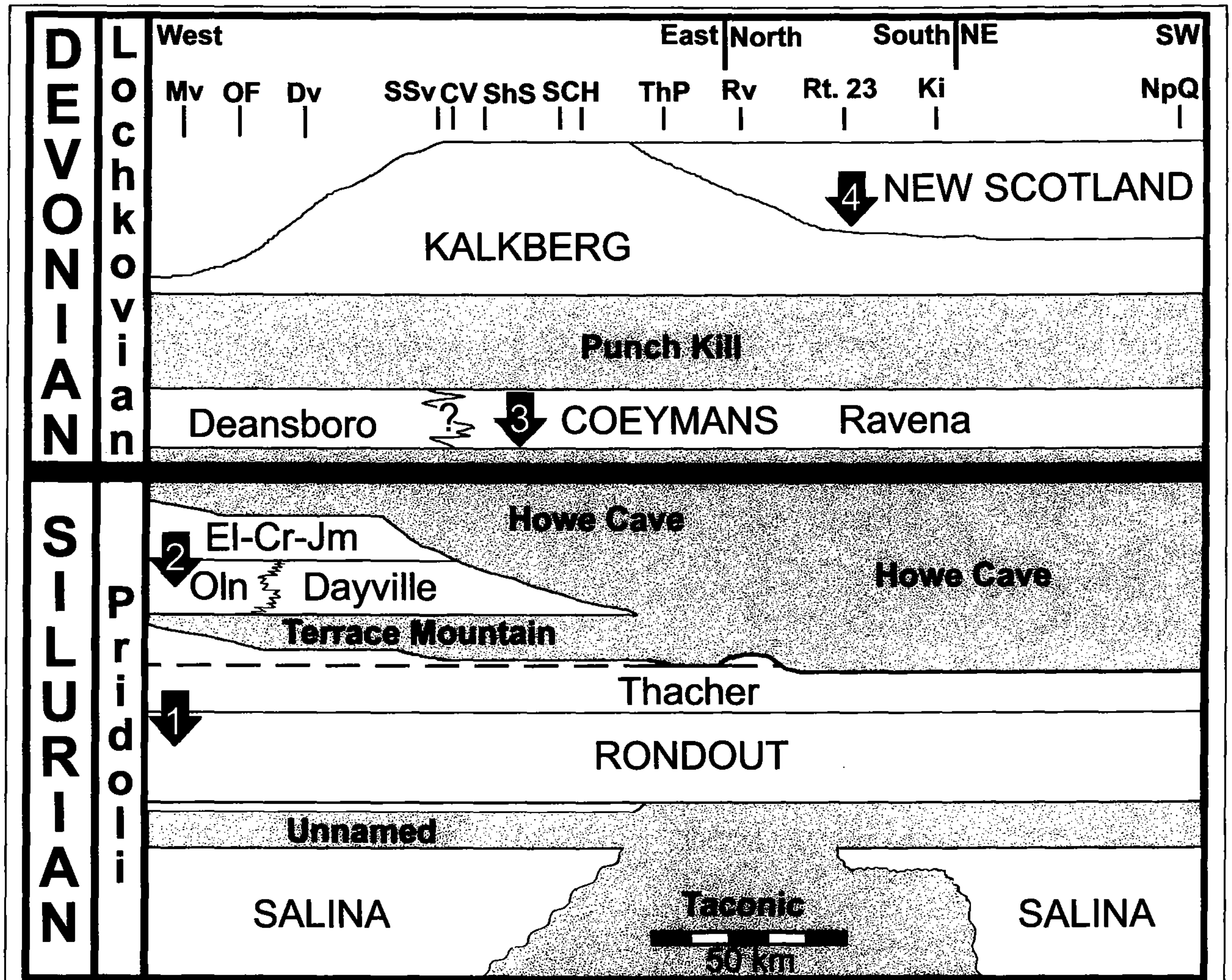

Fig. 6 Time-stratigraphic cross section of the lower Helderberg Group showing erosional vacuities of the Terrace Mountain and Howe Cave unconformities (after Ebert and Matteson 2003).

Reassignment of Dayville Member

The Dayville Member was defined as a unit within the Coeymans Formation by Rickard (1962), owing to general lithologic similarity. Faunal similarities are less pronounced, but Rickard felt that overall this unit was much more closely allied with the Coeymans despite its lateral equivalence with Olney Member of the Manlius Formation (Rickard, 1962, p. 72).

Throughout its extent, the Dayville rests with unconformity (Terrace Mountain Unconformity) on the Thacher Member of the Manlius Formation. It is overlain by higher members of the Manlius (Elmwood/Clark Reservation) from its western transition with the Olney to Salt Springville, near its previously presumed eastern limit. The Ravena Member of the Coeymans Formation overlies the Dayville from Cherry Valley eastward only where these units are brought into juxtaposition by the Howe Cave Unconformity. These relationships suggest that the Dayville is much more closely allied spatially and temporally with the Manlius than with the more lithologically similar Coeymans Formation. For these reasons, we suggest that the Dayville Member should be reassigned to the Manlius Formation.

SUMMARY AND CONCLUSIONS

Grabau's transition beds have proven to be key elements in a new understanding of stratigraphic relationships within the Helderberg Group (Fig. 5). The transition beds are underlain by the Clockville Discontinuity and comprise two units; each capped by a regionally extensive unconformity. The lower unit is an eastward extension of the Green Vedder Member (thin-bedded upper Thacher of Rickard (1962)) of the Manlius Formation, which is thinned below the Terrace Mountain Unconformity. The upper transition unit is an eastward extension of the Dayville Member, which should be reassigned from the Coeymans to the Manlius Formation. The Dayville/upper transition beds are truncated by the Howe Cave Unconformity such that they thicken westward from the Schoharie Valley and are overlain by higher units which are progressively preserved beneath the rising Howe Cave Unconformity. Conodonts indicate that this unconformity marks the boundary between the Silurian and Devonian periods, exactly as envisioned by Grabau in 1906 and earlier workers in the nineteenth century.

REFERENCES CITED

Barnett, S.G., 1971, Biometric determination of the evolution of *Spathognathodus remscheidensis*: a method for precise intrabasinal time correlation in the northern Appalachians: Jour. Paleont., v. 45, p. 374-300.

Barnett, S.G., 1977, Appalachians in The Silurian - Devonian Boundary: IUGS Series A, no. 5: 256-263.

Brett, C.E. and Ver Straeten, C.A. (eds.), 1997, Devonian cyclicity and sequence stratigraphy in New York State, Field Trip Guidebook published by the University of Rochester for the meeting of the Annual Meeting of the IUGS International Subcommission on Devonian Stratigraphy. 369p.

Chadwick, G.H., 1944, Geology of the Catskill and Kaaterskill quadrangles - Part II Silurian and Devonian geology with a chapter on glacial geology: N.Y. State Mus. Bull., n. 336: 251p.

Clark, J.M., 1899, The Hercynian question: a brief review of its development and present status, with a few remarks upon its relation to the current classification of American Paleozoic faunas: New York State Geologist Ann. Rept. 8, p. 62-91.

Clark, J.M., 1900, Notes on the Siluro-Devonic boundary: Science, n.s., 12, p. 406-408.

Ebert, J.R., Applebaum, R.H.S. and Finlayson, H.C., 1992, K-bentonites and detrital mudstones in the Helderberg Group (L. Dev.), New York: Implications for tectonic versus eustatic cyclicity: Geol. Soc. Am. Abstr. w Prog., v. 24, no. 3, p. 18.

Ebert, J.R., Deats, M.D., Chartier, M.G., Houston, S.D., McDaniel, B.L. and Miller, Z.D., 2000, Orientation of ripple crests and early cementation in the ribbon facies (intertidal) of the Thacher Member (Manlius Formation, Helderberg Group) in the Howe Cave Quarry: Geol. Soc. Am. Abstr. w Prog., v. 32, no. 1, p. A-15.

Ebert, J.R., and Matteson, D.K., 2003, Distal Stratigraphic Effects of the Laurentia - Avalon Collision: a Record of Early Acadian (P⊆ídolí-Lochkovian) Tectonism in the Helderberg Group of New York State, USA: Courier Forschungsinstitut Senckenberg, v. 242, p. 157-167.

Ebert, J.R., Matteson, D.K., and Natel, E.M., 2001a Early Acadian tectonism and Přídolí-Lochkovian eustasy in the Helderberg Group of New York State, USA: 15th Ann. Senck. Conf. Abstracts, Mid-Palaeozoic Bio- and Geodynamics - the North Gondwana - Laurussia Interaction, Joint Meeting Int. Geol. Corr. Prog. No. 421 and Subcomm. on Dev. Strat.: 34.

Ebert, J.R., Matteson, D.K., and Natel, E.M., 2001b, Parting the Helderberg Sea: cryptic unconformities and the Silurian - Devonian boundary in the classic epeiric sea sequence of New York: Geol. Soc. Am. Abstr. w. Prog., v. 33, n. 6, p.321-322.

Elrick, M., Getty, S., Ebert, J.R. and Asmerom, Y., 2002, U-PB Isotopic age dating of Devonian conodonts: a new method for dating Paleozoic marine sedimentary deposits?: Geol. Soc. Am. Abstr. w. Prog., v. 34, n. 4., p. 52.

Grabau, A.W., 1906, Guide to the geology and paleontology of the Schoharie Valley in eastern New York: N.Y. Mus. Bull. n. 92, p.1-386.

Goldring, W., 1935, Geology of the Berne quadrangle; with a chapter on glacial geology by John H. Cook: N.Y. State Mus. Bull. 303, 238p.

Goldring, W., 1943, Geology of the Coxsackie quadrangle, New York; with a chapter on glacial geology by John H. Cook: N.Y. State Mus. Bull. 332, 374p.

Goodwin, P.W., and Anderson, E.J., 1988, Episodic development of Helderbergian paleogeography, New York State, Appalachian Basin.- in McMillan, N.J, Embry, A.F., and Glass, D.J. (eds.), Devonian of the world: Can. Soc. Petrol. Geol., v.2, p. 553-568.

Griffing, D.H. and Ver Straeten, C.A., 1991, Stratigraphy and depositional environments of the lower part of the Marcellus Formation (Middle Devonian) in eastern New York State in Ebert, J.R. (ed.): New York State Geological Association Field Trip Guidebook, 63rd Annual Meeting, p. 205-249.

Gurney, G.G., and Friedman, G.F., 1986, Transgressive-regressive cycles in vertical sequences: and example from Devonian carbonates in Cherry Valley, New York: Northeastern Geology, v. 8, p. 201-217.

Hutchinson, D.M., 1977, Geologic setting of the upper Susquehanna and adjacent Mohawk region in Wilson, P.C. (ed.): New York State Geological Association Guidebook to Field Excursions, 49th Annual Meeting, A-4, p.1-13.

Johannessen, K.M., Natel, E.M., and Ebert, J.R., 1997, An Upper Silurian conodont-rich facies from the Rondout Formation of central New York: approximating the Ludlovian-P⊆ídolían boundary and a note on possible diagenetic influences on conodont color alteration indices (CAI): Geol. Soc. Am., Abs. w. Prog., v. 29, n. 1, p. 55.

Johnson, J.G. and Murphy, M.A., 1969, Age and position of lower Devonian graptolite zones relative to the Appalachian Standard Succession: Geol. Soc. Am. Bull., v. 80, n. 7, p. 1275-1282.

Klapper, G., 1981, Review of New York Devonian conodont biostratigraphy.- in Oliver, W.A., Jr., and Klapper, G. (eds.): Devonian biostratigraphy of New York, Part 1: Intl. Union of Geol. Sci., Subcomm. on Dev. Strat., p. 57-66.

Laporte, L.F., 1969, Recognition of a transgressive carbonate sequence within an epeiric sea: Helderberg Group (Lower Devonian) of New York State.- in Friedman, G.M. (ed.), Depositional environments in carbonate rocks, a symposium: S.E.P.M. Spec. Publ. no. 14, p. 73-101.

Liebe, R.M. and Grasso, T.X., 1990, The Devonian stratigraphy of Cherry Valley, New York: Northeastern Geology, v. 12, p. 7-13.

Logie, R.M., 1933, Stratigraphy of the Manlius Group of New York, unpublished manuscript, Dept. of Geology, Yale University.

Marshak, S. and Bosworth, W., 1991, Noncoaxial deformation along the northeastern edge of the Appalachian Plateau, New York: implications for faulting processes in orogenic forelands: Northeastern Geology, v. 13, n. 4, p. 263-270.

Matteson, D.K. and Ebert, J.R., 2001, Cystoids of the Coeymans Formation, Helderberg Group, New York State: a new species of *Lepocrinites* and *Lepocrinites gebhardi* revisited: Geol. Soc. Am., Abs. w. Prog., v. 33, n. 6, p. A-10

Matteson, D. K., Natel, E. M., and Ebert, J. R., 1996, Extending the stratigraphic range of a distinctive Silurian community: a Přídolían annelid and dasycladacean algae-dominated biota from the upper Thacher Member, Manlius Formation (Helderberg Group) of New

York.- The James Hall Symposium: Sec. Intl. Symp. on the Silurian System, Prog. and Abs., p. 74a.

Milunich, K. C. and Ebert, J. R., 1993, Conodonts and K-bentonites in the Helderberg Group (L. Dev., New York): an opportunity for time scale calibration in eastern North America: Geol. Soc. Am., Abs. w. Prog., v. 25, n. 2, p. 65.

Mylroie, J. E. and Palmer, A.N., 1977, Karst geomorphology of the Cobleskill area, Schoharie County, N.Y.: in Wilson, P.C. (ed.): New York State Geological Association Guidebook to Field Excursions, 49th Annual Meeting, B-7, p. 1-25.

Prothero, D.R., 1990, Interpreting the stratigraphic record: New York, NY, W.H. Freeman and Company, p. 146-149.

Rickard, L.V., 1962, Late Cayugan (Upper Silurian) and Helderbergian (Lower Devonian) Stratigraphy in New York: N. Y. State Mus. Bull. n. 386. 157p.

Rickard, L.V., 1975, Correlation of the Silurian and Devonian rocks in New York State: N.Y. State Mus. Map and Chart, n. 24, 16p.

Rickard, L.V., 1981, Stop 16 – Cherry Valley in Oliver, W.A., and Klapper, G. (eds.), Devonian stratigraphy of New York, Part 2. Stop Descriptions: IUGS Subcommission of Devonian Stratigraphy, p. 55-58.

Rickard, L.V., and Zenger, D.H., 1964, Stratigraphy and paleontology of the Richfield Springs and Cooperstown quadrangles, New York: N.Y. State Mus. Bull. n. 396, 101p.

Schuchert, C., 1900, Lower Devonic aspect of the lower Helderberg and Oriskany formations: Geol. Soc. Am. Bull., v. 11, p. 241-332.

Schuchert, C., 1943, Stratigraphy of the eastern and central United States: J. Wiley and Sons, New York, 1013p.

Smith, B., 1929, Influence of erosion intervals on the Manlius - Helderberg series of Onondaga County, New York: N.Y. State Mus. Bull. n. 281, p.25-36.

Smith, R.C., Berkheiser, S.W., and Way, J.H., 1988, The Bald Hill Bentonite Beds: a Lower Devonian pyroclastic-bearing unit in the northern Appalachians: Northeastern Geology, v. 10, p. 216-230.

Tucker, R.D., Bradley, D.C., Ver Straeten, C.A., Harris, A.G., Ebert, J.R., and McCutcheon, S.R., 1998, New U-Pb zircon ages and the duration and division of Devonian time: Earth and Planetary Science Letters, v. 158, p. 175-186.

Ver Straeten, C.A. and Brett, C.E., 1997, Lower and Middle Devonian foreland basin fill in the Catskill Front: stratigraphic synthesis, sequence stratigraphy, and the Acadian Orogeny in Brett, C.E. and Ver Straeten, C.A. (eds.), Devonian cyclicity and sequence stratigraphy in New York State, Field Trip Guidebook published by the University of Rochester for the meeting of the Annual Meeting of the IUGS International Subcommission on Devonian Stratigraphy. 369p.

FIELD TRIP ROAD LOG AND DESCRIPTION OF STOPS

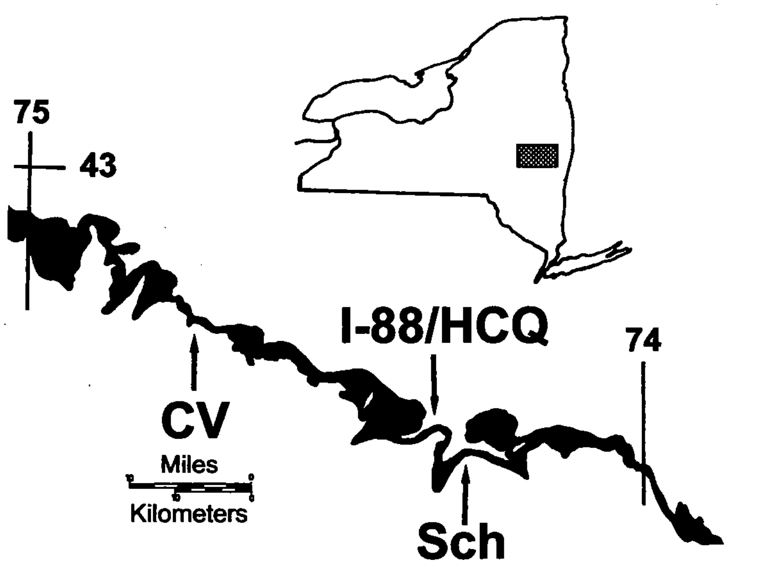

Fig. 7 Location map of Helderberg outcrop belt and approximate locations of field trip stops at Cherry Valley, Schoharie and Howe Cave Quarry. Major outcrop on I-88 is also shown.

Cumulative Mileage	Mileage between points	Description
0.0	0.0	Road log begins at the intersection of Ravine Parkway and West Street – the main entrance to the SUNY Oneonta campus
0.4	0.4	Turn left (east) at "graffiti wall" onto Center Street
0.8	0.4	Traffic light. Turn right (south) onto Maple Street
1.0	0.2	Intersection of Maple Street with Main Street. Continue straight (south) on James Lettis Highway
1.6	0.6	After underpass, traffic light for I-88 eastbound onramp. Turn left to get on highway.
6.2	4.6	Exit 17 for Rts. 7 and 28 to Colliersville and Cooperstown. Exit from highway.
6.55	0.35	End of off ramp. Turn left (north) on Rt. 28
6.9	0.35	Schenevus Creek. Note the well developed cut banks on large meanders.
8.0	1.1	Intersection with connector to Rt. 7. Continue north on Rt. 28
8.3	0.3	Outcrop of Gilboa Formation with well-developed ball and pillow structures (see Hutchinson, 1977). Opposite is NYSEG power station and dam on Susquehanna River to form Goodyear Lake.
16.3	7.7	Traffic light in village of Milford. Intersection with Rt. 166. Turn right (north) onto Rt. 166.
35.4	19.1	Traffic light in village of Cherry Valley. Turn right and continue

		north on Rt. 166.
36.8	1.4	Outcrops of Onondaga Formation.
37.4	0.6	Discontinuous outcrops of Tristates Group
37.5	0.1	Outcrop of Kalkberg Formation
37.6	0.1	Underpass for U.S. Rt. 20. Rt. 166 has ended and road is now Sprout Brook Road (Otsego County Rt. 32).
37.9	0.3	Outcrop of Coeymans Formation in contact with Kalkberg Formation. Contact is marked by a silt-rich bed and the Punch Kill Unconformity of Ebert and Matteson (2003). See also description below for **STOP 1.**
38.1	0.2	North end of large Helderberg outcrop. This is **STOP 1.**

STOP 1: Cherry Valley – Sprout Brook Road, Otsego County Rt. 32

This road cut is the stratigraphically lowest of a series on Sprout Brook Road (Cty. Rt. 32), Rt. 166 and, U.S. Rt. 20 that expose the entire Lower Devonian section that is present in New York State (See Brett and Ver Straeten, 1997). This outcrop corresponds approximately to Rickard's (1962) section number 94, which was measured in nearby Judd's Falls.

The section begins at the north end of the outcrop with approximately 1 meter of the Rondout Formation. The Rondout is abruptly overlain by the Thacher Member of the Manlius Formation. Near the top of the Manlius Formation, the style of bedding becomes thinner (decimeter scale) and intercalations of dark gray to black shale appear. These beds (total thickness = 0.82 m) constitute an erosionally thinned portion of the Green Vedder Member ("thin-bedded upper Thacher" of Rickard (1962)). These dark shale interbeds have yielded the carbonized biota discussed above and in Matteson, Natel and Ebert (1996).

The contact with the overlying Coeymans Formation has traditionally been placed at the appearance of the first, coarse crinoidal bed. This bed overlies the Terrace Mountain Unconformity (13.27 m from base of section). The lower Coeymans (6.03 m thick) comprises interbedded coarse and fine beds which Rickard equated with the Dayville Member. At the top of the Dayville Member, there is a change in the style of bedding to thicker and more irregular beds. The contact is marked by an erosional surface with several centimeters of relief. Sporadic, *in situ* favocitid corals encrust the contact. Rare, fine grained intraclasts indicate that this surface marks the position where the Elmwood and Clark Reservation members of the Manlius (which overlie the Dayville to the west) have been removed. This is the Howe Cave Unconformity (19.3m from base of section).

Overlying the Howe Cave Unconformity, thick, irregular to vaguely nodular beds of the upper Coeymans here have been referred to both the Deansboro and the Ravena members of the Coeymans Formation (see Rickard, 1962). This unit continues to the top of the outcrop (26.6 m). Using distinct horizons of chert and beds bearing holdfasts of the cystoid *Lepocrinites gebhardi*, we have correlated beds from the top of this outcrop with the base of the small outcrop 0.2 miles to the south on Sprout Brook Road. At the latter outcrop, 4.7 m of the Ravena Member is exposed. Thus, the maximum thickness of the Coeymans (Dayville and Ravena combined) is slightly over 19 meters. Previous accounts of the stratigraphy in this area (e.g., Rickard, 1962, 1981; Gurney and Friedman, 1986; Liebe and Grasso, 1990) reported a covered interval between the main outcrop and this smaller exposure and a total thickness of 30 meters for the Coeymans Formation (Rickard, 1981). However, it appears that these authors did not take into account the regional dip, which is approximately two degrees in this area. When relative elevations, the regional dip and the distance between these exposures are utilized, the top of the large outcrop and the base of the smaller exposure coincide. Thus, it appears that previously published measured sections for Cherry Valley have exaggerated the thickness of the Coeymans Formation by as much as 50%. Although we will not visit the smaller exposure on this trip, the Punch Kill Unconformity (Ebert and Matteson, 2003) is well exposed here, where it separates the Coeymans Formation from approximately 2 m of the Kalkberg Formation.

Taken together, the Green Vedder beds and the Dayville Member appear to constitute a gradational transition between the Manlius (proper) and Coeymans formations (Rickard, 1962, 1975, 1981). However, such a gradation cannot exist owing to the presence of the regionally traceable Terrace Mountain and Howe Cave unconformities which cap each unit respectively. Furthermore, the upper Thacher (Green Vedder Member) and Dayville Member exposed on Sprout Brook Road correlate to the west with units bearing the same names. They are distinct units and not an ambiguous zone of transition, assignable to neither formation. When correlated westward, they are separated by other members of the Manlius Formation. When traced eastward, these units thin and become the zone that Grabau (1906) designated as transition beds in the Schoharie area. Grabau's (1906) transition beds (sensu strictu) will be seen at STOP 2.

Cumulative Mileage	Mileage between points	Description
38.6	0.5	After visiting **STOP 1**, continue north on Sprout Brook Road for approximately 0.5 miles (0.3 miles from north end of outcrop). At this point, the shoulder is wide on both sides of the road. Execute a U-turn and return south on Spout Brook Road.
39.4	0.8	Cross under Rt. 20
39.5	0.1	Turn right onto ramp to enter U.S. Rt. 20 eastbound.
39.7	0.2	Kalkberg outcrops
40.0	0.3	Railroad overpass. Kalkberg outcrops with well-developed K-bentonites (see Smith, Berkheiser and Way, 1986; Ebert, Applebaum and Finlayson,1992; Tucker, et.al., 1998). Kalkberg is disconformably overlain by the Oriskany Sandstone.
40.1	0.1	Outcrops of Tristates Group which also bears K-bentonites (see Ver Straeten and Brett, 1997).
40.4	0.3	Begin outcrop of Onondaga Formation. Edgecliff, Nedrow and Moorehouse Members are well exposed (see also Brett and Ver Straeten, 1997).
41.5	1.1	Small outcrop of Seneca Member of the Onondaga Formation. The Tioga-B (Onondaga Indian Nation) K-bentonite is exposed at the base of the outcrop. This outcrop has provided conodonts which are

		the subject of direct radiometric dating studies (Research is in progress, but see Elrick, et. al. (2002) for a preliminary report.)
42.0	0.5	Outcrop of the Marcellus Formation, including Union Springs, Cherry Valley Limestone and Chittenango members, exposed on Chestnut Street, sub parallel to Rt. 20 (see Griffing and Ver Straeten, 1991; also Brett and Ver Straeten 1997).
44.5	2.5	Outcrops of the Kalkberg Formation at the edge of Leesville. Exposed section is similar to the outcrop at Cherry Valley (40.0 in this road log).
45.9	1.4	Outcrops of Kalkberg at edge of Sharon Springs. Section is similar to Leesville and Cherry Valley.
46.2	0.3	Traffic light at intersection with Rt. 10. Continue east on U.S. 20.
49.4	3.2	Outcrop of Onondaga Formation.
62.1	12.7	Turn right (south) onto Rt. 30A at traffic light in Sloansville.
63.6	1.5	Outcrop of Ordovician flysch of the Schenectady/Frankfort Fm.
66.0	2.4	Junction with Rt. 7. Turn left to continue south on Rt. 30A
67.2	1.2	Turn right at blinking light to continue south on Rt. 30A. Cross over I-88. Note view of Terrace Mountain to the right.
67.8	0.6	Dunkin' Donuts – a convenient rest stop in this area.
68.3	0.5	Junction with Rt. 30. End of 30A. Continue straight on Rt. 30 south.
69.8	1.5	Junction with Rt. 443. Continue on Rt. 30.
71.6	1.8	Turn right onto Bridge Street.
72.2	0.6	Cross bridge
72.5	0.3	Turn right onto Terrace Mountain Road
72.6	0.1	Pull over on right – note that shoulder is not overly wide! Outcrop on left is **STOP 2**.

STOP 2: Terrace Mountain Road, Schoharie

In the vicinity of Schoharie, there are numerous outcrops of Grabau's (1906) transition beds. This exposure on Terrace Mountain Road probably postdates Grabau's investigations, however it is one of the most accessible outcrops for examining these beds. Therefore, we selected it for this trip, rather than one of Grabau's "classic" outcrops, many of which still exist.

In this exposure, the twofold character of Grabau's transition beds is readily apparent. The lowest beds in the outcrop comprise a thinned eastward extension of the Green Vedder Member (Rickard's "thin-bedded upper Thacher). The Terrace Mountain Unconformity is marked by the abrupt appearance of coarse, crinoidal grainstones and packstones of the Dayville Member of the Coeymans Formation. Note that this is an extension of the term Dayville. In Rickard's (1962) stratigraphy, the Dayville did not extend eastward beyond Cherry Valley. Several of the Dayville beds display well-developed structures associated with tempestites: vertical grading, undulating to hummocky cross stratification and rare symmetrical ripple caps.

The Dayville has been substantially thinned from 6 m at Cherry Valley to approximately 1 m in the Schoharie area. This thinning is a result of the eastward descent of the Howe Cave

Unconformity, which separates the Dayville from the overlying Ravena Member of the Coeymans Formation. Minor local relief on the Howe Cave Unconformity is present in the Schoharie region, where the thickness of the Dayville remnant ranges from 0.7 to nearly 1.25 m at various outcrops.

Overlying the Howe Cave Unconformity, thick beds of the Ravena Member of the Coeymans Formation comprise the majority of this outcrop and they extend to the top of the exposed section. Upper portions of the Ravena display abundant club-like holdfasts of the cystoid *Lepocrinites gebhardi*. We are currently investigating the lateral extent of this subdivision of the Ravena Member (See also Matteson and Ebert, 2001).

Cumulative Mileage	**Mileage between points**	**Description**
72.7	0.1	Continue on Terrace Mountain Road to driveway for turn around. Return downhill on Terrace Mountain Road.
73.1	0.4	Turn left onto Bridge Street
73.3	0.2	Cross bridge
73.9	0.6	Turn left onto South Main Street (Rt. 30)
75.6	1.7	Junction with Rt. 443
77.0	1.4	Junction with Rt. 30A. Continue straight on Rt. 30A as Rt. 30 splits away to the right.
78.0	1.0	Cross over I-88
78.3	0.3	Blinking light at intersection with Rt. 7. Turn left to continue on Rt. 30A north. Rt. 7 west runs concurrently with Rt. 30A.
79.4	1.1	Intersection where Rt. 30A and Rt. 7 split. Continue west on Rt. 7.
80.5	1.1	To the left and uphill, a large outcrop of the Helderberg Group is visible on I-88. This outcrop exposes the Kalkberg, New Scotland and Becraft formations.
82.0	0.5	Traffic light. Turn right onto Howe's Cave Road (Schoharie County Rt. 8)
82.5	0.5	Cross railroad tracks.
82.6	0.1	Turn left (opposite Enders Avenue) onto Industrial Drive (private). This road forks almost immediately, keep to the right.
82.8	0.2	The original Lester Howe Hotel and future Cave House Museum. Also, original entrance to Howe Caverns.
82.9	0.1	Enter main Howe Cave Quarry – **STOP 3.**

STOP 3: Howe Cave Quarry

The inactive Howe Cave Quarry is the type section of the Howe Cave Unconformity. Clear truncation of the upper transition beds (eastern extension of the Dayville Member) in this quarry enabled recognition of this unconformity ***within*** the Coeymans Formation as presently defined. The truncation of beds in the Dayville is best observed in the weathered joint surface on the high wall at the entrance to the quarry, just beyond the old Lester Howe Hotel. In this face, the Green Vedder Member of the Manlius Formation (a.k.a. "thin-bedded upper Thacher) is also readily apparent. The upper part of the high wall is comprised of the massive Ravena Member, which, in parts, bears abundant holdfasts of *Lepocrinites gebhardi*. Elsewhere in the quarry, the Punch Kill Unconformity is exposed, overlain by approximately one meter of the Kalkberg Formation. This is visible at the top of the high wall in the main part of the quarry, but is only accessible for direct observation in a few places.

Other features of interest in the quarry include a thrust fault (Marshak and Bosworth, 1991; Mylroie and Palmer, 1977), extensive fields of ripples on the floor of the quarry (Ebert, et.al., 2000), numerous glacial striations on the surface above the quarry and, various karst and cave features associated with Howe Caverns and Barytes Cave (Mylroie and Palmer, 1977 and this volume), including the original entrance to Howe Caverns, adjacent to the Lester Howe Hotel.

The Howe Cave Quarry and Lester Howe Hotel will be centerpieces of the future Cave House Museum of Mining and Geology, a scientific and industrial educational facility, which is in the initial stages of development. In addition to various geologic, hydrologic and biologic aspects, the Museum will feature a history of mining and the mining industry, as well as multiple activities in which the public will be able to observe active mining, which is scheduled to resume in parts of the quarry. For additional information on the Cave House Museum, contact the Education Coordinator and member of the Board of Directors, Benson Guenther at the following:

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