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BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE GIVETIAN HAMILTON GROUP IN PENNSYLVANIA AND NEW YORK

by

James O. Brown

A dissertation submitted to the Graduate Faculty in Earth and Environmental Sciences in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

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ABSTRACT

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Adviser: Professor John A. Chamberlain, Jr.

Revisions to previous chronostratigraphic correlations (cf. Ellison 1966, Willard 1939, Brett and Baird 1994, Slattery 1995) of the rocks at the sections studied within Pennsylvania to those of New York are proposed that include:

1. The Montebello and Sherman Ridge Members of the Mahantango Formation in the Harrisburg, Pennsylvania area are correlative with the Kashong Shale and Windom Shale Members, respectively of the Moscow Formation of New York;

2. The upper part of the Mahantango Formation at Bowmanstown is equivalent to the New Lisbon and Windom Shale Members of the Moscow Formation of New York. However, the uppermost portion previously referred to as the Mahantango Formation is now recognized as correlative to the Tully Mesosequence. In particular, fossil assemblages associated with the distinct Nis Hollow Member of Pennsylvania indicate this unit to be

correlative with the Taunton Beds of the Windom Shale of New York;

3. The portion of the Port Jervis section is recognized as older than previously indicated by Slattery (1995).

Historically the differentiation of the Mahantango Formation within Pennsylvania has proven difficult due to thick beds of sediments dominated by fine-textured clastics. The use of sequence stratigraphic concepts in conjunction with sedimentary, biostratigraphic, paleoecologic, and subtle lithologic differences of beds has provided a basis for the correlations proposed in this study.

The above listed observations differ from those proposed by Slattery (1993, 1995) who suggested a penecontemporaneous nature for the Harrisburg localities with those of the Bowmanstown, PA and Port Jervis, NY sections. Further, none of these localities concur with the suggestion of Slattery (1993, 1995) that these rocks are correlative to the contact of the Tichenor Limestone with the Ludlowville Formation of New York. In the case of the Harrisburg and Bowmanstown localities, the rocks studied are slightly younger than anticipated while the Port Jervis is too old. These newly recognized correlations leave suspect the Type II boundary correlation as proposed by Slattery (1995) that was considered correlative with the older Tichenor Limestone of New York.

The term "Tully Mesosequence" is proposed for recognizing penecontemporaneous beds with a wide array of lithologies that are correlative with the classic Tully Limestone of central New York. The use of the term "mesosequence" (sensu Friedman et al. 1992, Friedman and Sanders 2000) is proposed in order to recognize chronostratigraphically equivalent beds that have a wide array of facies and to avoid either a biostratigraphic or lithostratigraphic emphasis for the recognition of this unit as has been used with varying levels of success in the past. At least three parasequences are recognized within the Tully Mesosequence. The youngest of these is basically equivalent to the Upper Tully Member of Heckel (1969, 1973). The Upper Tully Member is the geographically most widespread and has been most readily referred by others as the Tully Zone (Epstein et al. 1974), Tully Member (Faill et al. 1978) or Tully-correlative (Friedman and Johnson 1966).

This work reports the first occurrence of a unique pyritized microfauna from the Lower Member of the Tully Mesosequence at Lock Haven, Pennsylvania. This "small shelly fauna" (sensu Dzik 1993) consists of minute, postlarval specimens of pelecypods, gastropods, and dacryoconarids which typically have calcareous shells as adults. Also present are specimens whose adult shell composition is less certain, but is considered to probably have been chitinous. This latter group includes ctenosome bryozoans, egg shells or blastomeres of possible arthropods, and the enigmatic *Jinonicella*. Potential significant paleontologic contributions derived from this study include the first reported discovery of *Jinonicella* from North America and a ctenosome bryozoan showing unusual body preservation.

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Success is measured by going from failure to failure with enthusiasm.

Winston Churchill

CHAPTER ONE

STATEMENT OF THE PROBLEM

The Upper Middle Devonian (Givetian) rocks of New York and Pennsylvania have been studied for nearly 150 years (Sevon and Woodrow 1985). These Givetian rocks are collectively referred to as the Hamilton Group. Despite this long term of study, consensus among stratigraphers in Pennsylvania on large scale correlations at ranks below the formation rank (and even at the formational rank) has been elusive.

A part of this problem is derived from an emphasis on lithologic characteristics as the basis of correlations. Recent studies of Faill et al. (1978) and Prave and Duke (1991) have shown the short-comings of strictly lithologic dependency on a local scale within the Mahantango Formation without additional means of chronostratigraphic control. Both of these studies have attempted to used sedimentary patterns and/or sequence stratigraphic methods to enhance their correlations. However, these studies as with many of their predecessors, have emphasized the use of the less common, coarser textured units as potential members (Faill et al. 1978) or marker beds (Prave and Duke 1991) within the Mahantango Formation of the Hamilton Group. What is apparent is the localized nature of these coarser textured beds versus the more wide-spread distribution of finer textured beds. Neither of these studies place much emphasis on the chronostratigraphic significance of fossiliferous beds, although Prave and Duke (1991) do recognize the sequence stratigraphic significance of key hiatal contacts.

The use of fine-textured beds with potentially greater lateral distribution has not been widely attempted in the correlation of the Hamilton Group within Pennsylvania. This study uses methods established over the last twenty years in New York state as best summarized by Brett and Baird (1994). These workers have used a synthesis of paleontologic, lithologic, and allostratigraphic units along with sequence stratigraphic boundaries to achieve distal correlations. Presented herein are new correlations concerning individual beds within the Pennsylvania portion of the upper Hamilton Group as based on this synthetic method.

CHAPTER TWO

BACKGROUND

Stratigraphic Units of This Study

The locations of the sections studied and the outcrop belt of Middle Devonian rocks in Pennsylvania are shown on Figure 1. These Middle Devonian rocks, in part or entirely, have been referred to as the Hamilton Group (Rickard 1975, Sevon 1981, Sevon and Woodrow 1985). The two units within the Hamilton Group that are the focus of this study are the Mahantango and Tully Formations. The Mahantango Formation consists predominantly of fine-textured siliciclastic units (Epstein et al. 1974, Sevon et al. 1989). An exception to this condition occurs in the south-central Pennsylvania area where sandstones and conglomerates are also common (Faill et al. 1978). At its type locality in New York, the Tully Limestone is a fine to coarse-textured carbonate-bearing unit with a unique fauna (Cooper and Williams 1935, Heckel 1973). However, elsewhere within the Appalachian Basin rocks correlative with the Tully vary, although its unique fauna or stratigraphic position between lithologically-distinct units can still be recognized (Heckel 1973). This has lead to the term "Tully" within the Appalachian Basin being referred to as a 'Formation' (Sevon and Woodrow 1985), 'Member' (Faill et al. 1978; Hoskins et al. 1983), or

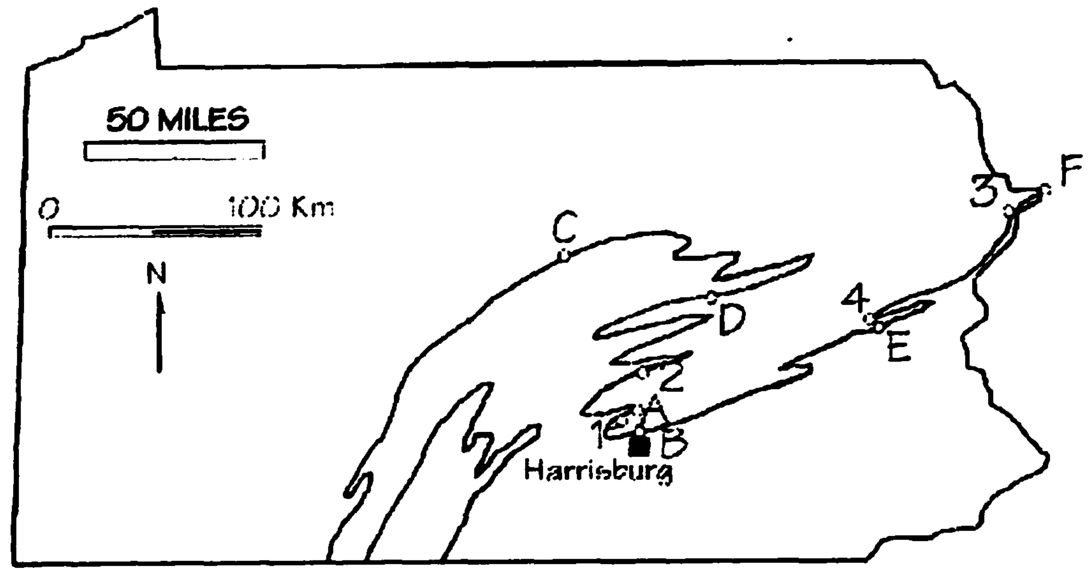


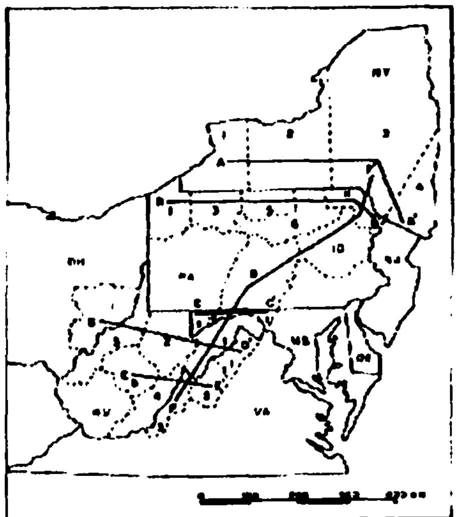
Figure 1 - Locations of sections studied: Girty's Notch (A), Rockville (B), Lock Haven (C), Riverside (D), Bowmanstown (E), Port Jervis, New York (F), Watts (1), Dalmatia Quarry (2), Raymondskill Creek (3) and North Weissport (4).

'Fossil Zone' (Epstein et al. 1974) in addition to a 'Limestone' (Berg et al. 1983). This is in part indicated by the stratigraphic correlation charts of Sevon and Woodrow (1985) which lists different surnames for this unit from West Virginia to New York. These data are represented in Figure 2. Also shown on Figure 2 is the variability of the lower and upper boundaries of the Tully, both of which have variously been placed either within or above the Hamilton Group.

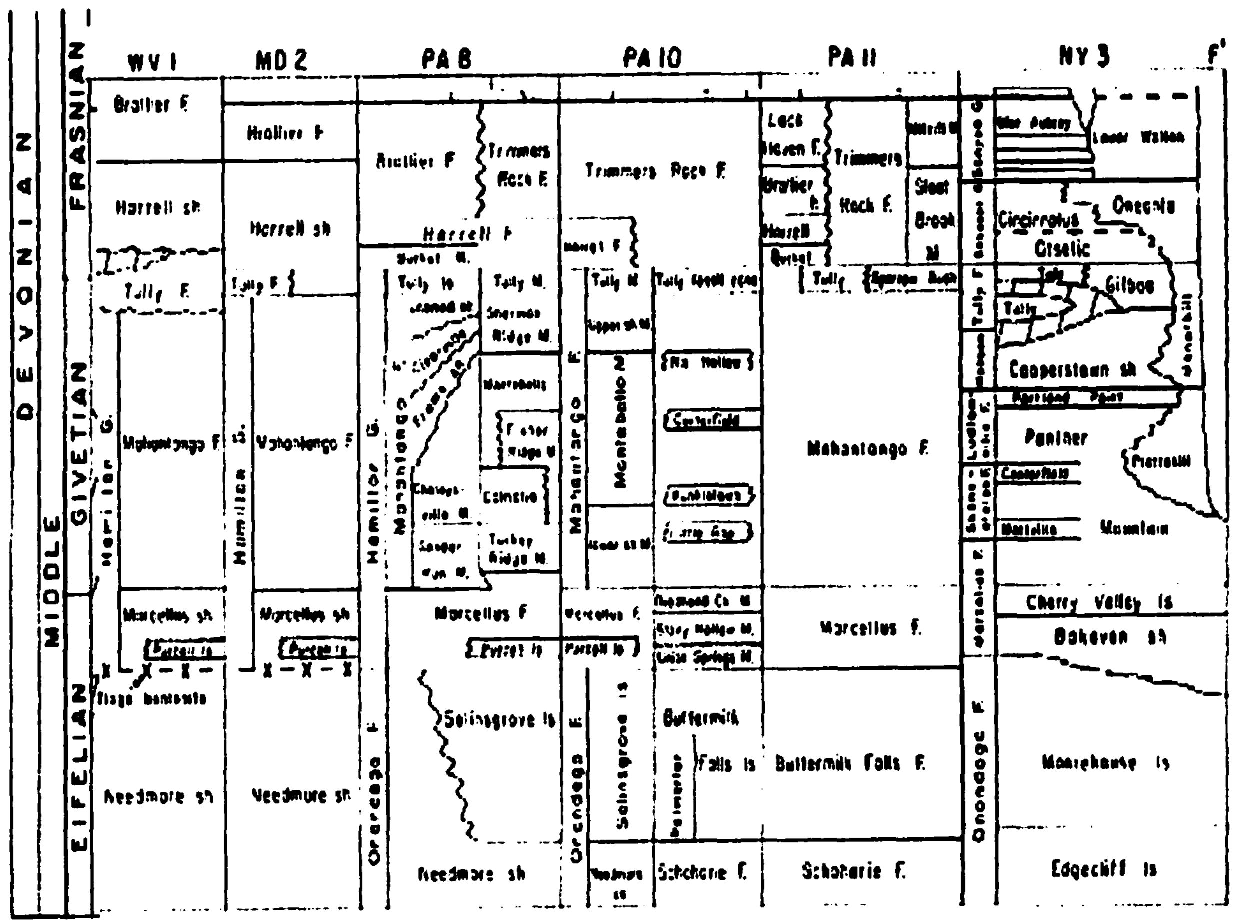
Except where noted within this paper, the term 'upper Hamilton' refers to both the Mahantango and Tully Formations along with their stratigraphic equivalents or members. This usage concurs with more recent publications (Sevon and Woodrow 1985; Brett and Baird 1994) concerning the stratigraphic nomenclature and relationship of these two units (Figure 2).

The age of the Mahantango Formation is recognized as uppermost Middle Devonian or Givetian (Sevon and Woodrow 1985). The Mahantango Formation of Pennsylvania is basically equivalent to the Skaneatales, Ludlowville, and Moscow Formations of New York State (Willard 1939, Ellison 1965).

In contrast to the Mahantango Formation, the age of the Tully Formation has been debated as to whether it is Middle Devonian (Givetian) or Upper Devonian (Frasnian) (Rickard 1975, Kirchgasser 1975, Faill et al. 1978, Heckel



A. Location map for lines of stratigraphic correlation charts. Dashed lines and numbers represent arbitrary areas within each state for which specific stratigraphic terminology applies.



B. Section F-F'.

Figure 2 - Stratigraphic Correlation Chart for the Devonian of the Applachian Basin. Source: Sevon and Woodrow (1985, Figures 1 and 7).

1973, Ziegler et al. 1976 and Klapper 1981). Most older references favored an Frasnian age based on ammonoid biostratigraphy and the uncertainty in conodont zonation existing at the time of the studies (Rickard 1975, Kirchgasser 1975). Subsequent refinement of both conodont zonal boundaries and ammonoid zonal boundaries has lead to the recognition of an uppermost Givetian age for the Tully (Kirchgasser et al. 1988). The entire Tully as well as younger overlying sedimentary rocks of the Penn Yan Shale and Geneseo Shale members of the lower Genesee Formation of New York are now recognized as Givetian (Brett and Baird 1994). The Givetian age of the Tully concurs with the reported age of the overlying lowermost Burket Member of the Harrell Shale in southern Pennsylvania which is recognized as lowermost Frasnian (Weary and Harris 1994).

Both the Mahantango and Tully Formations can be subdivided into formal and informal subunits at most of the sections studied. These subunits are listed on Figure 3. The Mahantango Formation in the Harrisburg area (localities "A", "B", "1" and "2" of Figure 1), can be formally subdivided into the Fisher Ridge, Montebello and Sherman Ridge Members (Figure 3). These three units are respectively dominated by fine clastics, coarse clastics and fine clastics. The studied portion of the Mahantango Formation at the Bowmanstown, Lock Haven and Riverside localities (Figure 1) basically lack distinct coarser

WEST / NW — EAST / SE

LOCATION (ID NO. in FIG. 1)		LOCK HAVEN (C)	RIVERSIDE (D)	DALMATIA QUARRY (2)	GIRTY'S NOTCH (A)	WATTS (1)	ROCKVILLE (B)	NORTH WEISSPORT (4)	BOWMANSTOWN (E)	RAYMONDSKILL CREEK (3)	PORT JERVIS, NY (F)
REFERENCE(S) UNITS		Heckel (1969) Willard (1939)	Heckel (1969) Willard (1939)	Ellison (1965) Slattery (1993)	Ellison (1965) Slattery (1993)	Ellison (1965) Slattery (1993)	Ellison (1965) Slattery (1993)	Heckel (1969) Epstein, et al. (1974)	Heckel (1969) Slattery (1993) Epstein, et al. (1974)	Slattery (1993) Fletcher & Woodrow (1970) Sevon et al. (1989)	Slattery (1993) Fletcher & Woodrow (1970) Sevon et al. (1989)
Harrell Fm. or Trimmers Rock Fm.		Burket Memb.	Burket Memb.	Burket Memb.	Burket Memb.	Burket Memb.	Burket Memb.	Burket Memb.	Burket Memb.	Sloat Brook Memb.	Sloat Brook Memb.
HAMILTON GROUP	TULLY	Upper Lower	Upper Lower	Undifferentiated	Undifferent.	Undifferent.	Undifferent.	Undifferent.	Upper Lower	Sparrow Bush	Sparrow Bush
HAMILTON GROUP	MAHANTANGO	Undifferentiated	Undifferentiated	Sherman Ridge Member Montebello Member Fisher Ridge Member Dalmatia Member Turkey Ridge Member	Sherman Ridge Member Montebello Member Fisher Ridge Member Dalmatia Member Turkey Ridge Member	Sherman Ridge Member Montebello Member Fisher Ridge Member Dalmatia Member Turkey Ridge Member	Sherman Ridge Member Montebello Member Fisher Ridge Member Dalmatia Member Turkey Ridge Member	North Weissport Member Nis Hollow Member Unnamed Shale Memb. Centerfield Memb.	Unnamed Shale Memb. Nis Hollow Member Unnamed Shale Memb. Centerfield Memb.	Undifferentiated	Undifferentiated
HAMILTON GROUP				Marcellus Fm.	Marcellus Fm.	Marcellus Fm.	Marcellus Fm.	Marcellus Fm.	Marcellus Fm.	Marcellus Fm.	Marcellus Fm.

Notes:
1) Only stratigraphic names recognized at each section are listed: no statement of unit thickness or bounda
Cited references do not necessary use or recognize all names shown.
2) Refer to Figure 1 for locations.

FIGURE 3 - RECOGNIZED STRATIGRAPHIC UNITS AT STUDIED SECTIONS

textured or calcareous beds which are typically used for subdividing into members. An exception at Bowmanstown (Epstein et al. 1974) is a distinct slightly coarser textured siltstone unit referred to as the Nis Hollow Member (Figure 3). With the exception of the Nis Hollow Member, the studied portion of the Mahantango Formation at these localities is dominated by fine-textured sedimentary rocks. Informally, two fine-textured members can be recognized at the Bowmanstown locality based on their stratigraphic position below or above the Nis Hollow Member. The base of the lower fine-textured member was not determined during the course of this study, but at Bowmanstown it is recognized as lying above the fossiliferous Centerfield Member as defined by Epstein et al. (1974). An upper finer textured member occurs between the Nis Hollow Member and the overlying Tully (Figure 3). Both the Nis Hollow and Centerfield Members are readily found in northeast Pennsylvania with their farthest mappable southwest extent being in the Bowmanstown area (Epstein et al. 1974). Consequently, ready recognition and differentiation of the two informal finer-textured members becomes more difficult towards the west. As will be discussed, the use of formal stratigraphic names should ultimately be established for such fine-textured members of the Mahantango Formation.

The Tully Formation of central New York is divisible into several locally mappable members and beds (Figure 4) which were formally proposed by Heckel (1973). More significant on a regional scale, are the larger-scale subdivisions of the Lower and Upper Tully Members separated by an intraformational unconformity as recognized by Heckel (1969, 1973) and subsequent workers (Rickard 1975; Ziegler et al. 1976; Sevon and Woodrow 1985). Recently, a middle member (see Figure 4) has been recognized by Baird and Brett (1998).

Geologic Setting

Studies on Devonian stratigraphy of the Appalachian Basin have recognized the predominantly siliciclastic rocks of the Hamilton Group as part of the Catskill Complex (Sevon and Woodrow 1985). This complex has its greatest development in eastern New York state, but it extends southward into Pennsylvania and other southern states (Shepp 1963, Sevon 1981, Woodward and Ahrensbrack 1973, Sevon and Woodrow 1985, Dennison 1985a,b). The sedimentary sequence of the Hamilton and overlying Geneseo Group has been referred to as a tectonic delta complex (Friedman and Johnson 1966, Johnson and Friedman 1969). Other authors have recognized the Hamilton as a depocenter basin supplied by a series of river systems carrying sediments derived from the uplift of the Acadian orogenic highlands to the south and east (Faill 1985; Prave and Duke 1991). This

State of New York Units		State of Pennsylvania Units
Formation or Member	Bed or Bed Sets	
Overlying Unit: Geneseo Shale: Leicaster Pyrite Mb.		Harrell or Trimmers Rock Fm. (Burket Sh. Member)
Tully Fm.: Upper Member	Fillmore Glen Moravia Bellona Coral West Brook	Tully Formation or Member (Sometimes referred to as Sparrow Bush Fm./Memb. in NE PA.)
(Middle)	Taughannock Falls Smyrna	
Lower Member	Carpenter Falls Vesper Tully Valley Meeker Hill Fabius Cuyler Deruyter	
Underlying Unit: Moscow Fm.: New Lisbon Mb. of east NY		Mahantango Formation

References Used: Heckel (1966, 1973), Ellison (1965), Faill et al. (1978), Epstein et al. (1974), Sevon et al. (1989), Fletcher and Woodward (1970), Brett and Baird (1994).

Figure 4 - List of Subunits Recognized by Heckel (1966, 1973) for New York and Pennsylvania.

river system magnafacies (Gordon 1988) is best preserved in northeastern Pennsylvania and eastern New York (Burtner 1963, Buttner 1968, 1972) and contains some of the earliest large size land plants (Goldring 1924, 1927). Some of the earliest records of marine organisms adapting to fresh-water environments are also preserved in these rocks (Gordon 1988, Friedman and Chamberlain 1995, Friedman and Lundin 1998). The depositional scenario of these Middle and Upper Devonian rocks lead Friedman (1988) to refer to them as a tectonic fan-delta complex. Deformation of the Hamilton Group during the Acadian Orogeny when overlying Catskill sediments were deposited appears to have been minimal (Faill 1985). However, the subsequent geologic history of these rocks includes uplift and folding associated with the creation of the Appalachian Mountains during the late Paleozoic Alleghanian Orogeny (Faill 1985). This and possibly other tectonic activity (Friedman 1987a,b Friedman and Sanders 1982) has created considerable structural deformation such as observed in this study at Bowmanstown (Epstein et al. 1974). Conodonts observed within this study show a color alteration index (see Epstein et al. 1977) of about 3.5 to 4.0 which further indicates deep burial as proposed by Friedman and Sanders (1982).

Previous sedimentologic and stratigraphic work on the Hamilton Group, both locally and regionally, have produced numerous interpretations of the depositional environment. As summarized by Prave and Duke (1991) these interpretations include: a fluvial-dominated delta (Willard 1935, Ellison 1965, Kaiser 1972, Faill et al. 1978), a storm-dominated prograding shoreline (Goldring and Bridges 1973) and a system of storm-generated shelf sand ridges (Sarwar and Smoot 1983). In addition, for the coarse-textured portion of the Mahantango Formation in central Pennsylvania, Prave and Duke (1991) have proposed "a shoaling succession produced by the progradation of a tide-influenced shoreline into a storm-influenced marine basin".

All of these ideas have merit when one places them in the larger scale context of a tectonic fan-delta complex (Friedman 1988) or a foreland basin (Prave and Duke 1991). The foreland basin is, in a general plate tectonic context, a basin occurring between fold-thrust belts and a craton (Mitchell and Reading 1986). These tectonic and non-marine aspects of the Hamilton Group and Catskill Formation (Fletcher 1963, 1967) have potential sequence stratigraphic correlations with the marine rocks of this study as suggested by the presence of cyclic and rhythmic depositional patterns (Buttner 1968). This is further indicated by transitional near-shore facies located between true marine and non-marine facies (Friedman and Johnson 1966, McCave 1973, Goldring and Lagenstrassen 1979, Gordon 1989) that have in part chronostratigraphic correlatives with the rocks of this study.

Sequence Stratigraphic Terms and Concepts Used in This Paper

Sequence stratigraphy terminology used in this paper follows the suggestions of Brett et al. (1990), Brett (1995), Friedman and Sanders (2000) and Hancock (2000). The specific studies of Brett et al. (1990) and Brett (1995) apply a combination of stratigraphic, sedimentologic and paleontologic methods to the New York portion of the Appalachian Basin in order to recognize correlative boundaries and beds within a sequence stratigraphic context. Within a general sequence stratigraphic context, Friedman and Sanders (2000) make recommendations on terminology in order to avoid what they refer to as "semantic bucaneering". Also within a general context, Hancock (2000) summarizes the advantage of a nomenclatorial, rather than a numerical, terminology to recognize sequence stratigraphic units.

When attempting to define sequence stratigraphic units, several types of stratigraphic control are desired in order to assure reasonable accuracy (Van Wagoner et al. 1990). These are:

1. Seismic stratigraphy
2. Correlation of depositional ("sequence")

boundaries, in particular non-depositional surfaces;

3. Recognition of depositional patterns and their position relative to paleostrandline/base level

4. Biostratigraphy and/or chronostratigraphy that are able to give time-stratigraphic indication.

With the exception of seismic stratigraphy, this study attempts to use the other three above-noted stratigraphic controls in order to achieve refined correlations within upper Givetian rocks in Pennsylvania. Unfortunately, the collection of geophysical information, for seismic stratigraphic analysis as stressed by Friedman and Sanders (2000), is not readily applicable to either the New York or Pennsylvania areas. This is due to the size of the area involved and, especially for Pennsylvania, the structural alteration of the units in question. However, a potential mechanism for sea level changes within the upper Givetian is the possibility of preliminary glaciation episodes that are now recognized for the Upper Devonian (Streel et al. 2000). This suggests that a sequence stratigraphic mechanism was in place at this time even without the ability of conformation through seismic stratigraphy.

Terms with sequence stratigraphic connotations or concepts that are used or referred to in this study are:

Depophase - A group of transgressive-regressive cycles of eustatic origin whose boundaries are defined by prominent regressions (rephrased from Johnson et al.

1985).

Depositional Cycle (or Pattern) - A series of beds (or facies) whose deposition represent a single event or which has occurred between two sedimentary events. One example would be the cyclothems of the Pennsylvanian (cf. Krumbien and Sloss 1963, p. 536-538) representing a single deposition event occurring between two eustatic events. Another example, which has been used for some of the sections studied, is the coarsening upward pattern of tide-dominated to storm-dominated facies associations (Slattery 1995, Prave and Duke 1991). In this type of depositional cycle, the re-occurrence of the tide-dominated facies associations represents a new depositional pattern indicating a sea level change.

Facies Association - One or more types of facies (Table 1) representing a single genetic part of a depositional cycle (see Slattery 1995, Prave and Duke 1991). For example Facies Association #4 is noted as consisting of swaly sandstone beds in Table 1 and is interpreted to represent the storm-dominated upper shoreface. Adjacent facies associations of the same depositional cycle, if preserved, would be either Facies Association #3 consisting of finer sandstone of the storm-dominated upper shoreface or Facies Association #5 consisting of sandstones representing

TABLE 1

SUMMARY OF FACIES ASSOCIATIONS AS DEFINED BY PRAVE AND DUKE (1991) AND SLATTERY (1993)

FACIES ASSOCIATION	TYPES OF FACIES	GENERAL CHARACTERISTICS
#1	a) hemipelagic shale b) bioturbated mudstone c) mudstone with distal tempestites	Distal offshore deposits of mainly hemipelagic mudstones and shales with some thin, distal tempestites
#2	a) mudstone with thin hummocky cross-stratified storm beds b) mudstone with thick hummocky cross-stratified storm beds c) bioturbated argillaceous sandstone	Proximal offshore mudstone interbedded with tempestites
#3	a) "hummocky to burrowed" sandstone couplets b) amalgamated hummocky cross-stratified beds c) trough cross-bedded sandstone	Fine sandstone from the storm-dominated upper shoreface
#4	swaley sandstone bodies	Swaley facies sandstones from the storm-dominated upper shoreface
#5	a) tabular, thin beds of fine to medium sandstone with variable lamination types; beds commonly separated by shale partings b) same as above but bioturbated by traces of *Skolithos*	Tide-dominated channel-mouth shoals (ebb-tidal deltas?) from the lower-upper shoreface
#6	a) trough cross-bedded medium to pebbly sandstones: lateral accretion surfaces may be developed locally b) trough cross-bedded to cross-laminated medium sandstones; lateral accretion surface may be present locally c) largely structureless medium to coarse sandstone	Sandy subtidal (to intertidal?) flats and tidal channels incised to subtidal depths on the shoreface
#7	a) erosive-based single bed lag (inter-ridge facies) b) multi-bed lags interbedded with thin mudstones (inter-ridge facies) c) intensely bioturbated lag (inter-ridge facies) d) low-angle. cross-bedded thick lag deposits (ridge facies)	Reworked lag deposits of argillaceous sandstone to conglomerate, forming a system of transgressive, storm-generated shallow marine sand ridges

tide-dominated channel-mouth shoals (refer to Table 1). Facies Associations emphasize the use of depositional patterns ("item 3" of the above-listed stratigraphic controls for sequence stratigraphic correlations as noted by Van Wagoner et al. 1990).

Facies Tract - "A group of different but genetically interconnected sedimentary facies of the same age" (Friedman et al. 1992). A series of facies associations forming a single depositional cycle as noted above would form a facies tract.

Highstand Facies Tract - "Deposits associated with times of maximum submergence" (Friedman et al. 1992).

Lowstand Facies Tract - "Deposits resulting from conditions accompanying times of maximum emergence of an undaform" (Friedman et al 1992). An "undaform" is equivalent to a shelf and is defined as "the flat surface of a basin-marginal terrace" by Friedman et al. (1992).

Mesosequence - "A stratigraphic unit intermediate in rank beneath between parasequence and sequence (Friedman et al. 1992). Mesosequences "are units that are bounded by surfaces of unconformity or by basinward extension of such surfaces" (Friedman and Sanders 2000).

Parasequence - "A sequence of layers that begins at the base with the products of a marine submergence, includes the products of seaward progradation of a coastal region and ends at the top at the base of the layer deposited by the following marine submergence" (Friedman et al. 1992).

Sequence Boundary - A widespread boundary that separates all of the rocks above from all of the rocks below (Van Wagoner et al. 1990, p. 4). A sequence boundary is typically marked by an unconformity or their correlative conformities (Mitchum et al. 1977). Such horizons are recognized as derived from eustatic changes representing a new phase of submergence (Friedman et al. 1992).

Transgressive Facies Tract - "The basin-margin deposits resulting from conditions associated with rapid submergence of an undaform" (Friedman et al. 1992).

Types I and II Boundaries - A Type I sequence stratigraphic boundary is associated with rapid sea level falls whose "unconformities are characterized by both subaerial and submarine erosion" (Wilson 1991). For example, such a boundary is characterized by incised valleys on the shelf (undaform). A Type II sequence stratigraphic boundary is associated with slow sea level falls whose "unconformities do not show submarine erosion, because coastal onlap does not shift basinward of the shelf edge" (Wilson 1991).

Therefore, a Type II boundary lacks incised shelf valleys. In this study, I consider Type I and Type II boundaries to be geologic concepts that can not readily be differentiated in the field. These "terms" have been used to describe the magnitude of sea level change indicated by sequence boundaries identified within the Hamilton Group (Slattery 1993, 1995). However, several investigations (Woolfe et al. 1998, Boyd et al. 1989, Kidwell 1988) question the usefulness of an incised shelf in recognizing different types of sequence boundaries. For example Woolfe et al. (1998) studied a Type I magnitude boundary of a Holocene lowstand in Australia and were unable to locate any incised shelf. Another problem, in the opposite sense, was reported by Boyd et al. (1989) using mapped sequence stratigraphic units within the Mississippi delta. Boyd et al. (1989) discovered an incised shelf between sequence boundaries that does not appear derived from a eustatic change. Both of these studies make questionable the use of Type I versus Type II classification scheme in the recognition of sequence boundaries. In addition to these studies, Kidwell (1988) used Miocene fossil assemblages to also show that not all hiatal boundaries have a eustatic origin allowing for sequence stratigraphic correlations.

Heckel's Dilemma of Stratigraphic Control and the Stratigraphic Code: Before Sequence Stratigraphy

In his 1966 dissertation and subsequent 1973 Geological Society of America Memoir, Heckel was confronted with the problem of how to define the Tully Formation as required by the stratigraphic code (ACSN 1961). As discussed by Heckel (1966, 13-15; 1973), while Vanuxem (1838, 1842) initially recognized the Tully Formation as a Limestone unit, many subsequent workers identified the Tully based on its distinctive fauna. This Tully fauna is present in various sandstone, siltstone and shale lithologies in addition to the classic limestone facies. Subsequent workers, in particular Cooper and Williams (1935), working in New York state and Willard (1935a,b, 1939) working in Pennsylvania, recognized the Tully as a stratigraphic unit based on its biofacies and stratigraphic position. This unique fauna-bearing stratigraphic unit contrasted with adjacent formations which, on a regional scale, retained a more consistent lithology. Therefore, the Tully Formation, while still typically referred to as a Limestone, was treated as a legitimate stratigraphic unit with a diverse lithology and a distinct fauna.

In addition to the above conditions in some areas, distinct hiatal contacts were also recognized within as well as at the contacts of the Tully (Heckel 1973). In a modern day sequence stratigraphic context, these hiatal boundaries or their basinward extensions indicate the Tully to be a mesosequence (sensu Friedman and Sanders 2000). Further, the various named units within the Tully (see Figure 4) as recognized by Heckel (1973) are here, either individually or in combination, recognized as parasequences (sensu Friedman and Sanders 2000) based on the presence of hiatal contacts or distinct depositional patterns. On a larger scale, the Tully Mesosequence lies within the lower part of Depophase IIa as proposed by Johnson et al. (1985). However, the term Tully Mesosequence is proposed in this study. This term follows the nomenclatural suggestion of Hancock (2000) rather than the use of an additional numerical subdivision such as Depophase IIa1.

In Pennsylvania the recognition of the Tully has been more problematic than in New York because of a preference for a strict lithologic definition as a limestone (see Faill et al. 1985, Sevon et al. 1989, Epstein et al. 1974) rather than as a rock unit defined by stratigraphic position. A good example of this bio- versus litho-stratigraphic code dilemma noted by Heckel (1966, 1973), is shown by Epstein et al. (1974) who recognized a fossil-bearing Tully zone within the Mahantango Formation. Other workers in Pennsylvania have recognized either the Tully Formation or Member (Ellison 1965) or a correlative unit such as the Sparrow Bush Formation (Fletcher and Woodrow

1970) (Figure 4). Heckel's (1966, 1969, 1973) detailed work in New York state also included reconnaissance at five sections in Pennsylvania, three of which (Lock Haven, Riverside and Bowmanstown) are included within this study.

Heckel's petrographic work recognized several different facies with in the classic carbonate and shale-bearing parts of the Tully Mesosequence in New York (Figure 4). He proposed several bed names for these facies and attempted to correlate them within New York state as well as into Pennsylvania (Heckel 1966, 1969, 1973). However, more significant to the current study was the identification by Heckel (1966, 1973) within the Tully of a disconformity creating an autocyclic succession of upper and lower members. These members have been used and recognized by subsequent workers (see Rickard 1975, Klapper 1981, Brett and Baird 1994). This disconformity enabled Heckel (1966, 190-199; 1973) to recognize a major datum line within the Tully Mesosequence. The significance of this disconformity within the Tully Mesosequence is that it can be used to define a wide-spread boundary that can serve as a datum for sequence stratigraphic correlations.

Work after Heckel (1969, 1973) has had varied results in recognizing his proposed subdivisions of the Tully Mesosequence. For example, in New York these named beds of were used as point of reference by Ziegler et al. (1976) and Klapper (1981) for the recognition of conodont subzones. However, in Pennsylvania Faill et al. (1978) were unable to recognize Heckel's lithostratigraphic units. In addition, Faill et al. (1978) considered the thick sequence of carbonate beds in north central Pennsylvania recognized by Heckel (1969) as the Tully to be a facies, with member status within the Mahantango Formation.

Heckel's work was published prior to the widespread acceptance of sequence stratigraphy. However, Heckel (1966, 1973) was intuitively using sequence stratigraphic concepts. The application of sequence stratigraphic concepts help to better define and correlate the Tully Mesosequence from at least five perspectives. First, Heckel's detailed work showed the Tully as a stratigraphic unit that was more than just a limestone. By recognizing, emphasizing and tracing unique beds or bed sets which laterally changed from limestone to predominately siliciclastic, Heckel was establishing parasequence beds. Second, the disconformities, (that is sequence or parasequence boundaries) associated with the Tully appear to be regional in nature. Third, Heckel (1966, 1973) recognized that these unconformities have correlative conformities (sensu Mitchum et al. 1977) that towards the west grade into shale before wedging out and to the east grade into a thicker coarser detrital sequence (Heckel 1966). Fourth, the disconformity *within* the Tully separating the lower and upper members takes on greater significance when recognized as a sequence stratigraphic boundary. Fifth, the disconformities and their lateral equivalents noted at the base and the top of the Tully, also represent sequence boundaries. Finally, by taking all of the other listed items together, the ultimate question when recognizing a non-carbonate Tully-correlative is where it correlates relative to any of the three Tully Mesosequence boundaries or of a key marker bed.

The correlation of both the Tully and its adjacent units relative to any of the three recognized Tully Mesosequence boundaries is complicated, however, by the apparent combining of any two Tully Mesosequence boundaries into a single disconformity whereby only one or two boundaries are readily recognized at a given section. This condition occurs in western New York as well in southern Pennsylvania. In contrast, where the Tully Mesosequence is especially thick, smaller scale parasequence boundaries may also occur that further complicate this question, and lead Baird and Brett (1998) to suggest a Middle Tully Member.

As noted at the beginning of this chapter and indicated by Figure 2, the general consensus on the use and definition of the term Tully greatly varies among workers (Heckel 1966, 1973). This follows, in part, the earlier biostratigraphic usage of Cooper and Williams (1935) who recognized the Tully based on a unique fauna. However, subsequent workers, in order to comply with the concepts of the stratigraphic code (ACSN 1961, 1983) attempt to emphasize the lithologic aspect and refer to the Tully Limestone (sensu Rickard 1975). Based on this stratigraphic code dilemma that Heckel (1966, 1973) himself recognized, I prefer the use of the term Tully Mesosequence rather than Tully Limestone. This preference is based on the Tully Mesosequence within the Appalachian Basin varying from a limestone to a sandstone, thereby making lithology of secondary importance relative to stratigraphic position.

In summary, the term Tully Mesosequence refers to a stratigraphically unique unit which when predominantly carbonate is commonly referred to as the Tully Limestone. Further, the Tully Mesosequence is characterized by three sequence stratigraphic boundaries plus occasionally yielding a biostratigraphically unique fauna. From a lithologic perspective, the Tully Mesosequence can still be recognized as a formation based on its stratigraphic position. This is due to adjacent units, from a general lithologic perspective, being distinguished both laterally or vertically from the Tully Mesosequence. Where some past confusion has occurred is that the Upper Tully Member may lithologically resemble the Mahantango Formation (Epstein et al. 1974).

I use the term Tully Mesosequence throughout this paper where there has been debate regarding the identification of the rocks in question as being either of the Tully or Mahantango Formations. The term Tully Mesosequence, is in certain ways similar to the use of the term Tully-correlative by Johnson and Friedman (1969). However, their term had more lithologic and genetic implications with the 'thicker and coarser detrital sequence' (Heckel 1966) east of the Tully Limestone. The Tully-correlatives of Johnson and Friedman (1969) are penecontemporaneous, lithologically-distinct, rocks that have a non-marine to marginal marine origin whereas rocks recognized here as part of the Tully Mesosequence are of a marine origin. In this study, I prefer the depositional term sequence rather than the more lithologically oriented term formation. As will be shown, the subtle significance of this is where a Tully contact occurs within shales which would otherwise be lumped together as a single stratigraphic unit. Hopefully, the use of the term sequence will force others to look at the Tully and how it is correlated in a slightly different light.

In summary, Heckel's dilemma was one of terminology which sequence stratigraphic concepts help to clarify. As will be shown, by recognizing the Tully Mesosequence and adjacent Givetian to lowermost Frasnian units as sequences, the completeness of which vary at each locality, lithologic discrepancies become irrelevant. Instead, potential time-stratigraphic and biostratigraphic similarities play a greater role in correlation.

CHAPTER THREE

INVESTIGATIVE METHODOLOGY

This chapter briefly discusses the procedures used in the field and in macrofossil identification. However, the laboratory procedures (summarized in Appendix A) that were used to process microfossils are presented in more detail due to the unusual techniques used.

Field Procedures

All of the exposures of the Tully Mesosequence and Mahantango Formations discussed in this study have been previously described by others. This allowed for field investigation to focus on the gaining of new detail information rather than the preparation of a basic geologic presentation. Reconfirmation of sectional measurements with a Jacob staff and Brunton compass was made to confirm previous published and unpublished section descriptions. This was also done in order to select sampling horizons. Field inspection of each section was performed on a bed-by-bed basis in order to determine the distribution of fossils. In general, macrofossils are scattered throughout the sections studied, but rarely concentrated in distinct beds. Therefore, sampling horizons were selected which showed abundant fossils, distinct lithologic change or a sequence stratigraphic boundary as proposed by Slattery

(1993). Schematic diagrams summarizing field observations on lithology and stratigraphy are presented as figures in Chapter Four. These schematic sections were prepared using a Corel Draw (Version 3.0) computer program. Additional field observations are found in Appendix B.

Sample collection attempted to focus on the more fossiliferous beds. All samples were taken from no greater than a one foot interval or a single bed. At intervals where macrofossils are common, a large bulk sample, weighing ten to twenty kilograms was collected. At intervals sampled only for microfossils, smaller samples of approximately two kilograms were collected. Identification of macrofossils from these smaller size sampled intervals was also attempted, but of more limited use when compared to the bulk sampled horizons. Descriptions of each sample are summarized in Appendix C.

Actual collection entailed the use of a rock hammer and chisel. Most samples broke into chips three to seven centimeters in size, although larger blocks up to twenty or thirty centimeters were also collected. Chips were placed in a labelled sack for transport back to the lab. A total of thirty-seven microfossil samples were collected at the referenced sections.

Macrofossil Identification

An attempt was made to identify up to three hundred individual fossil specimens from each 20 kilogram bulk sample. However, none of the collected samples yielded this quantity of specimens and usually only a hundred fossil specimens were identified in the more fossiliferous rock samples. Tables of fossils identified from bulk samples are summarized in Appendix D. Rock fragments treated for microfossils were also inspected for macrofossils.

Each sample was broken apart with a chisel and rock hammer in order to expose fossils along fractures and bedding surfaces. Individual fossil-bearing rock samples ranged from less than a centimeter to approximately ten centimeters in size. A binocular microscope was used to aid in the identification of individual specimens and also lead to the recognition of many small 1 to 2 mm size specimens: predominantly ostracodes, dacryoconarids, brachiopods and pelecypods.

All observed fossil specimens were labelled with a stick-on tag or circled with a color pencil for subsequent number labelling and species identification. Mold and cast were counted as a single specimen and attempts to cross-check for specimens separated during sample collection and rock breakage were also made. Each fossil-bearing rock was given an individual identification number.

Faunal lists of all identified specimens are presented in Appendix D. An objective of this aspect of the study was to present an 'unbiased' assessment of the relative abundance of faunal elements. The identification of up to three hundred specimens per sample was selected on past recommendations and procedures discussed in Brower and Nye (1991). According to Brower and Nye (1991) the identification of 100 to 300 specimens assures a "95 percent chance of finding at least one specimen of a species that comprises one to three percent, respectively, of the population sampled." However, achievement of the optimal number of 300, or even 100 specimens was difficult due to the overall sparsity of fossils and their commonly poor state of preservation. This lead to the collection of approximately twenty kilograms per bulk sample in order to assure a mode of consistency in the collection of data among samples.

The main references used for specimen identification were Ellison (1965), Linsley (1994) and Grabau (1898-99). All three of these works are substantially based upon initial descriptions made by James Hall (and J. M. Clarke) during the nineteenth century. Only Ellison (1965) uses original figures rather than reproductions of Hall's lithographs. Linsley (1994) does not review ostracodes, coelenterates or echinoderms in his publication. Otherwise Ellison (1965), Linsley (1994) and Grabau (1898-99) are broad based references in their coverage of both common and exotic invertebrate taxa found in the Givetian of Pennsylvania and New York. Deference with regard to taxonomic nomenclature is given to Linsley (1994), whose work, especially for brachiopods, employs currently accepted generic and species names. The Treatise of Invertebrate Paleontology was also used whenever there was uncertainty concerning an generic name in an older reference.

Other works useful in the identification of brachiopods and their biostratigraphy included Dutro (1981), Goldman and Mitchell (1990) and Cooper and Williams (1935). Recent works by Brett et al. (1991) and Brower and Nye (1991) contain useful illustrations and updated taxonomic names for some mollusks. Names listed by Berdan (1981) were checked with the Treatise of Invertebrate Paleontology as well as Smith (1956), Friedman and Lundin (1998), Ellison (1965) and Grabau (1898-99) for the identification of ostracodes. In addition to Linsley (1994), papers by Yochelson (1986), Yochelson and Lindemann (1986) and Lindemann (1994) were used for dacryoconarid identification and paleoecologic interpretation. Conodont identification benefitted from the works of Ziegler et al. (1976), Klapper and Johnson (1980), Klapper (1981), Rogers (1998) and Sparling (1999). The enigmatic *Jinonicella* was identified using Dzik (1994) and Fryda (1999) from less common European papers brought to my attention by John Pojeta of the USGS. Dzik (1994) and Loomis (1903) were useful in tentative identification of other microfossils from sample LH-4 with *Jinonicella*. Additional general references for preliminary and rough identification included Moore et al. (1952) and Hoskins et al. (1983) for invertebrates and Jones (1969) for microfossils.

Identification to the species level was attempted, but was not always possible due to poor specimen preservation. For example, most brachiopods were identifiable to the genus or species level because they are generally well preserved and because they have received wide scrutiny. Ostracodes were more difficult to identify due to their overall poor preservation.

Microfossil Preparation

The initial goal of processing rocks samples for microfossils was targeted towards obtaining conodonts. Processing normally began by mechanical breakdown. Rock chips were reduced to a few square centimeters and then further disaggregated with formic acid. If this procedure was either partially or totally unsuccessful, more radical techniques were used. These additional procedures were alternately performed and included: 1) soaking in Stoddards Solvent, 2) boiling in water, 3) soaking in bleach, and/or 4) heating the rock sample. Some of these techniques were modified from those discussed by Maples and Waters (1990) and Harris and Sweet (1989). In general, this processing is more physical than chemical in nature. All processed samples produced a large amount of fine residue. Further separation of high versus low specific gravity residue using heavy liquid was necessary. For this study, Sodium Metatungstate (SMT) was used. Excessively large quantities of fine residue obtained from several of the processed samples made necessary the application of a modified SMT-liquid separation technique different than described in the published literature (cf. Krukowski 1988, Harris and Sweet 1989, Berdan 1989). Therefore, a detailed discussion of this technique is presented in this chapter.

The main objective of processing these rocks was to obtain conodonts, although other microfossils and microstructures were collected (Brown 1996). The success of processing techniques varied as indicated by the weighed amounts of coarse versus fine residue remaining upon completion (see Table 2). Further details concerning the processing techniques of each sample are presented in Appendix A (Tables 3 through 8). Each of the following subsections reviews a key aspect of the procedures performed in obtaining microfossils.

Initial Disaggregation

The initial mechanical breakdown involved the use of a

TABLE 2
SUMMARY OF PROCESSING RESULTS
(See Appendix A for results of each sample.)

LOCATION	NUMBER OF SAMPLES	TOTAL WEIGH OF SAMPLE			WEIGH OF COARSE RESIDUE			WEIGH OF FINE HIGH SPECIFIC			WEIGH OF FINE LOW SPECIFIC GRAVITY		
		HIGHEST	LOWEST	MEAN	HIGHEST	LOWEST	MEAN	HIGHEST	LOWEST	MEAN	HIGHEST	LOWEST	MEAN
GIRTY'S NOTCH	4	8784	2015	4604.25	5929.0	683.1	2860.58	28.1	3.5	11.78	1013	282.4	604.53
ROCKVILLE	5	7519	1170	2939.40	5365.6	128.2	1975.68	582	1	119.32	508.1	147.5	331.78
LOCK HAVEN	4	2252.3	2000	2090.28	1485.4	358.6	699.15	22	0.8	10.25	467	36	204.73
RIVERSIDE	8	2533	903	1956.85	1905.6	211.1	1574.80	2.9	0.4	1.96	133	25.6	55.61
BOWMANS-TOWN	12	2058	435.5	1676.26	1946.2	392.7	1441.96	29.7	0.10	6.13	139.8	13.4	74.27
PORT JERVIS, NY	3	8455	2822	4915.67	7056.7	2383.6	4162.73	16.7	4.2	8.40	477	98.7	282.77
WATTS	2	2757	2000	2378.50	2515.2	1681.5	2098.35	3	2	2.50	141.6	84	112.80
TOTAL	38												

rock hammer and chisel to create pieces large enough to enter a chip-munk rock crusher. This resulted in individual rock fragments typically less than six centimeters in size. Samples were then weighed with a targeted weight of two thousand grams. Actual weights varied and are listed in Table 2 and Appendix A (Tables 9 through 14). A few of the preliminary samples are less than two-thousand grams.

Formic Acid

In order to assess whether carbonate cement was present, I typically placed a five hundred gram portion of a sample into a dilute solution of formic acid (710 milliliters acid to approximately six liters of tap water) for a minimum of six hours. If no chemical reaction was observed, additional techniques were used to disaggregate this portion and the remainder of the sample. If a reaction occurred, then the total 2000 gram sample was subjected to further soaking with formic acid. Quantities of sample processed with formic acid are found in Appendix A (Tables 9 through 14).

Multiple Soaking

Samples were repeatedly subjected to one or more disaggregation procedures. Summaries of total number of times a particular processing technique was applied are found in Appendix A (Tables 3 through 8). Both the sequence and number of applications to disaggregate each sample varied, although typically at least two soakings using either bleach or Stoddards solvent were performed. No particular application was determined to be superior to any of the others, except for a calcareous sample's reaction to formic acid. Multiple applications were usually necessary to induce disaggregation. A few samples did not show any type of breakdown, despite multiple and extended applications. The length of time an individual samples was soaked in a particular liquid medium varied from a few days or weeks to, in a few cases, months.

Heating

Samples were placed in a drying oven at a temperature of approximately 150 degrees Fahrenheit for four to eight hours prior to the application of Stoddards solvent. In most cases heat was also applied to a sample prior to the use of bleach. For some samples the reaction to heat and quenching in liquid lead to disaggregation along weak fractures similar to results discussed by Pojeta and Balanc (1989) by quenching with cold water.

A cleaned metal container was used to place a sample in a oven. Each container was dedicated to a particular sample in order to avoid cross-contamination. If rust developed on a particular container it was replaced.

Stoddards Solvent

Once properly heated, a sample-bearing container was filled with Stoddards solvent until all rock was immersed. The plastic lid was then placed on top and covered with masking tape to avoid evaporation and accidental spillage. A sample was typically soaked for two days to three weeks. The Stoddards solvent was recycled by pouring the solution through a glass funnel with filter paper to separate the rock sample from most of the solvent. The rock sample was then transferred into a container with water for boiling. Prior to reuse, the Stoddards solvent was filtered a second time.

Theoretically, Stoddards solvent will turn the matrix of a rock sample into a slurry which then can be washed and sieved for non-reactive residue. I did not encounter this condition with any of my samples. Instead, I found some rock, in particular shaly samples, to be softened by the Stoddards solvent rather than then disaggregated. The rock matrix apparently lost some of its initial hardness and developed a tendency to break off into flake-like smaller fragments. With the exception of several samples from the Bowmanstown and Port Jervis sections, most of the green gray to black shale samples reacted well enough to be softened by this method. In addition, several samples from the Rockville section composed of siltstone to fine sand also showed some reaction.

Bleaching

Several different techniques using bleach (sodium hypochlorite) were applied. Unlike Stoddards solvent, where the critical reaction occurs while the rock is still hot, bleach will continue to react as a cold liquid. Therefore, the length of time a sample was left to soak varied from a week to several months and in at least one case for over a year. In several cases bleach was added to unheated rock samples and allowed to soak for extended periods of time.

As with Stoddards solvent, many of the samples were heated prior to being placed in a plastic or glass beaker containing bleach. Sometimes twenty-five grams of lye (sodium hydroxide) was added to the liquid. Only small quantities of lye were applied as in certain situations the lye did not always completely dissolve in the bleach or react to the rock. In such cases where the lye did not react (dissolve), small undissolved particles would appear as a contaminant during heavy liquid separation.

The use of drain cleaner instead of bleach, as discussed by Maples and Waters (1990), was also tested. This procedure gave results similar to the more economical bleach and lye, and therefore was not extensively used.

Results with bleach varied. Many of the finer grained samples showed some degree of reaction to the bleaching, especially when alternated with heating. A color change was observed in nearly every sample, indicating some level of reaction with the bleach. Most samples were medium gray to black in color and after bleaching became light gray with varying shades of light green and brown. Information on the actual color changes encountered from processing is recorded in Appendix A (Tables 9 through 14) under the heading of post-process. For comparative purposes descriptions of fresh and outdoor weathered colors are also presented in Appendix B.

Multiple Boiling

Between each chemical soaking, samples were boiled on a hot plate. This procedure, in combination with bleaching, is discussed by Duffield and Warshaver (1979). The main liquid boiled was tap water combined with bleach or residual Stoddards solvent. Water was added as necessary to avoid air exposure of the sample. In most cases the samples achieved a gentle rather than brisk boil. Exceptions were the coarser grained samples, mainly from Rockville which attained a more rapid boil. Prior to further chemical soaking, samples were typically boiled for three four to eight hours time blocks (the number of boilings per sample are summarized in Appendix A).

The process of boiling helped to both disaggregate and soften a sample after chemical treatment. Only in the cases of a siltstone and a chamosite oolite, both from

Rockville, did any samples appear to show significant disaggregation strictly from boiling.

Sieving

Each sample was sieved multiple times during processing for collection of fine residue. Residue between mesh sizes No. 20 and No. 140 (850 and 106 micrometer, respectively) was retained for microfossils analysis. Most of this residue material was non-desirable matrix as indicated in Appendix A (Tables 9 through 14).

Heavy Separation

Because most of the samples under study are siliciclastic rather than carbonate, excessively large quantities (greater than 25 grams and in some cases over 1000 grams) of fine residue were obtained after processing samples. Such large quantities (see Tables 9 through 14 of Appendix A) lead to the use of a modified SMT-liquid separation technique. The following details the procedures I used and discusses how they digress from published methods (cf. Krukowski 1988, Harris and Sweet 1989, Berdan 1989) that typically process smaller quantities (less than ten grams) of fine residue.

I used a modified gravity-dependent SMT heavy separation technique based on processing methodology discussed by Harris and Sweet (1989) and Krukowski (1988).

Due to the large quantity of residue recovered from each sample, the cryogenic, centrifugal technique discussed by Morrow and Webster (1989) was not feasible. Cylinder-shaped 1000 milliliter plastic beakers approximately 7.5 centimeters in diameter were filled with 250 to 300 milliliters of SMT liquid sufficient for the separation of light from heavy residue. The top of each beaker was covered with a plastic lid to inhibit evaporation. When left to sit for extended periods of time, the beaker and lid were covered with saran wrap secured by a rubber band. While multiple beakers of SMT liquid were available, only the residue from a single sample was processed at any time. This was done in order to avoid any chance of cross-contamination of samples.

A centimeter-size quartz crystal and apatite crystal were used to check specific gravity prior to the use of the SMT liquid. In rare situations it was necessary to double check the specific gravity of the SMT liquid with residue present. The larger size of these crystals made it easy to wash off and collect with filter paper the finer residue particles without worry of sample cross-contamination.

Each SMT run consisted of approximately twenty grams of sample. The upper portion of liquid was stirred every fifteen minutes to half hour on a regular basis for a minimum of three hours. This was done in order to free heavier particles floating on lighter material. The liquid was not stirred during the final half-hour. Usually two distinct layers of floating (light) and bottom (heavy) residues were developed after the SMT had been allow to sit for a half hour.

Once separated, the floating, light residue was poured into a plastic funnel secured within a 1000 milliliter container. The funnel was lined with a circular coffee filter in order to allow the SMT liquid to drain as discussed in Krukowski (1988). A second filtered funnel was used to collect the remaining SMT liquid and to collect the heavy residue. A plastic lid was placed over each funnel top in order to avoid any particle contamination and inhibit evaporation of the SMT. If filtration of liquid was slow or left to sit for an extended period of time, a saran wrap cover secured with a rubber band was place on top. Recovered SMT liquid from the filtration was then transferred to a non-residue bearing container for continued use.

Once all visible SMT liquid had gravity-poured through the filter system, the residue was washed with distilled water. The 1000 milliliter beaker initially used for liquid separation would contain heavy residue, adhering light particles and dried SMT. This material was washed off with distilled water and poured into the funnel with the heavy residue. This method created a bias of light residue from the beaker wall being retained with the heavy residue. Consequently, where this process lead to an excessive final volume, an additional SMT liquid separation of all of the collected heavy residue was performed. Any light (low specific gravity) residue from this extra final separation was retained in a unique light residue container for inspection. Thoroughly washed residues were allowed to air dry. Dried separated residues were transferred to a sample container for later inspection with a stereoscopic microscope.

All SMT-bearing liquid from the distilled water wash was recycled by evaporation. A simple series of plastic beakers was used to concentrate the SMT-bearing liquid over several weeks. This liquid was regularly transferred to a fresh beaker as finer particulates (contaminants) within the liquid settled out. As noted by Krukowski (1988), plastic containers are preferred over glass beakers. However, in order to speed up the evaporation process, glass beakers containing SMT-bearing distilled water were placed in an oven and allowed to partially concentrate the liquid. Aliquots close to proper specific gravity were securely covered when left unattended for extended periods of time in order to avoid excess evaporation. I attempted to avoid complete evaporation of SMT to a solid state based on concerns noted by Krukowski (1988) of incompatible recrystallization. However, any SMT powder (solid) derived from over-evaporation or dried spillage was added to liquid undergoing evaporation. A centimeter size quartz crystal was used to assess when a liquid had evaporated to a specific gravity suitable for continued heavy separation use.

Both the ready-for-use SMT liquid and evaporating SMT-bearing distilled water required regular filtering. This was due to the presence of very fine particles and precipitates in the SMT liquid. These particles are probably derived from a combination of: 1) clay in the rock samples, 2) chemical reaction of carbonates with the SMT, 3) pulp from the filter paper and 4) residue, such as lye, from the chemical processing. Krukowski (1988) noted the first two of these special problems, but did not mention the latter two in his review of SMT liquid separation technique. Some preliminary experiments with dishwashing detergent, suggest that this material did not always completely dissolve despite boiling and sieving of a sample. Filtering was accomplished by a series of containers with filter paper on plastic funnels. The order of filtering was from the most SMT-bearing liquid to the least. Upon completion, this paper was washed with some distilled water, in order to obtain residual SMT, but not so thoroughly as to recycle all of its collected contaminants.

Beakers and funnels were also washed for SMT stains. Minor (and a couple of major) spills were collected by a combination of used filter paper and distilled water. These filter papers were then placed in a funnel and washed with distilled water for the recycling of SMT as noted above prior to being discarded.

Overall the SMT liquid technique used here greatly reduced the amount of residue requiring inspection for potential conodonts and other microfossils. Only in the case of a chamosite oolite sample (R-3) from the Rockville section was there a significant gradation between light and heavy residue. The abundance of chamosite also lead to R-3 being the only sample which had a significantly greater amount of heavy than light residue after the use of the described SMT liquid separation technique.

The advantage of the SMT heavy liquid separation procedure is the use of recyclable, non-toxic material (Krukowski 1988; Harris and Sweet 1989). Two disadvantages are controlling specific gravity and filtering out contaminants. The expense of SMT (approximately $200 per kilogram) necessitates the use of elaborate and tedious recycling procedures.

Additional Comments

Excluding soaking time, at least fourteen days, typically more, were spent in the disaggregation process of a single sample. The results showed varying levels of success. A further three days to three weeks were spent on the use of SMT for heavy separation. As noted, not included are the days to months that a samples would be allowed to soak (typically in bleach with lye). As indicated in Table 2 (see also Appendix A), not one sample was completely broken down and most retained up to 75% of rock residue greater than No. 20 mesh. However, not as clearly indicated in Table 2 is the qualitative observation that several of the shale and claystone samples would continue to disaggregate if the processing techniques were extended for a longer period of time.

CHAPTER FOUR

DESCRIPTIONS OF MEASURED SECTIONS

The following details the stratigraphic, lithologic and paleontologic aspects of each of the sections studied. Comparison of these findings to the observations of previous workers is also presented with each of the sections reviewed in this chapter. Later chapters discuss each section's relationship to the other sections studied as well as correlations to better established subdivisions in New York. General stratigraphic terms used by past workers at the various sections are summarized in Figures 2 and 4 as noted in Chapter Two.

Location of Study

The rock units examined during this study are located in the Appalachian Valley and Ridge Physiographic Province of Pennsylvania and southeast New York (Figure 1). Sections where rock samples were collected for analysis include those located at Girty's Notch ("A" in Figure 1), Rockville ("B"), Lock Haven ("C"), Riverside ("D"), Bowmanstown ("E") and Port Jervis ("F"). Other sections or outcrops reviewed for stratigraphic correlation include Watts ("1" in Figure 1), Dalmatia Quarry ("2"), Raymondskill Creek ("3") and North Weissport ("4"). With the exception of the Lock Haven and Riverside sections, all of these localities were reviewed by Slattery (1993, 1995).

Included within this chapter is a detailed topographic map for each of the six sampled sections reviewed. Summaries of field observations for each section measured is presented in Appendix B. Further information useful in the following descriptions of the sections includes matrix and fossil descriptions of collected samples (Appendices C and D, respectively).

A graphic interpretation of each section studied is presented within this chapter (see Figure 5 for legend). The scale used in these graphic presentations of the sections measured is one inch equal to ten feet (one meter equals approximately 0.83 centimeters). This is a compromise scale adopted in order to achieve a uniform comparison of all of the measured sections. However, this 'compromise' leads to presentation of certain portions of sections with little significant information due to large intervals that are covered or poorly exposed. Further, in an opposite sense, this scale is marginally acceptable for small intervals bearing several significant or thin stratigraphically distinct beds.

The following presents the sections studied from east to west along strike as depicted on Figure 1. As will be shown, the correlative significance of each section greatly

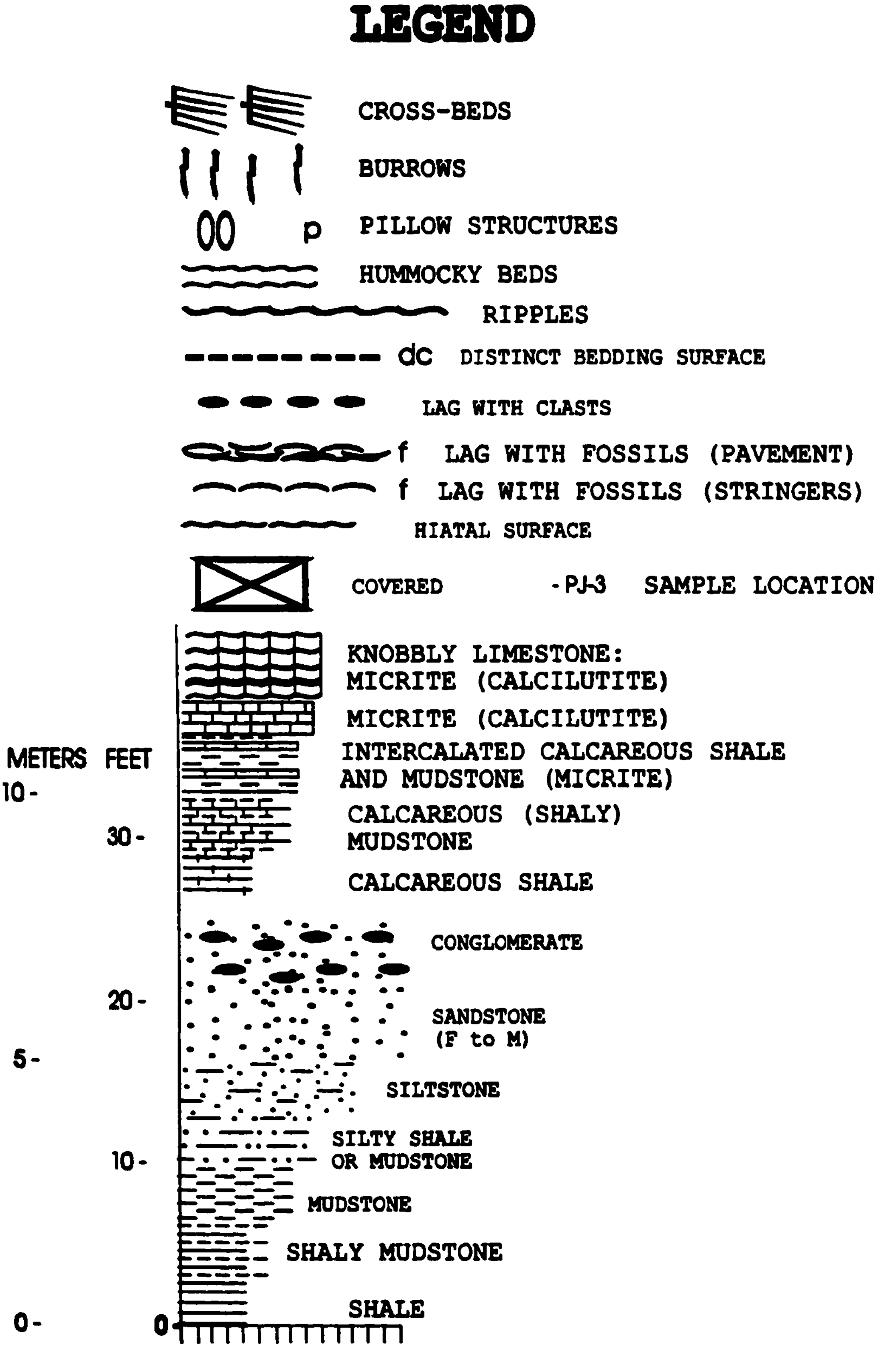


Figure 5 - Legend of symbols for measured sections

varies. Use of an east to west presentation allows the Port Jervis with the least amount of correlative information relative to the other sections to be discussed first. This is followed by the Bowmanstown section which I consider to have the most significant new information.

Port Jervis Section

The Port Jervis, NY section ("F" of Figure 1) is located approximately one-half mile north of the edge of the Town of Port Jervis on the east side of Route 97 along Skyline Road on the eastern edge of Germantown (Figure 6). This section is one of three stratigraphically similar sections reviewed by Slattery (1993, 1995) in the northeast Pennsylvania-southeast New York region. The Port Jervis section was selected over the other two Pennsylvania sections based on accessibility for sample collection. Only the Raymondskill Creek section (locality "3" of Figure 1), in a scenic area on federally protected lands, was also readily accessible for field inspection during this study.

From lowest to highest, stratigraphic units observed in the area are: the Marcellus Formation (Shale); the Lower, Middle and Upper Members of the Mahantango Formation; the Sparrow Bush Formation and the Trimmers Rock Formation (Sloat Brook Member). However, only the Lower Mahantango Formation and the lower portion of the Middle

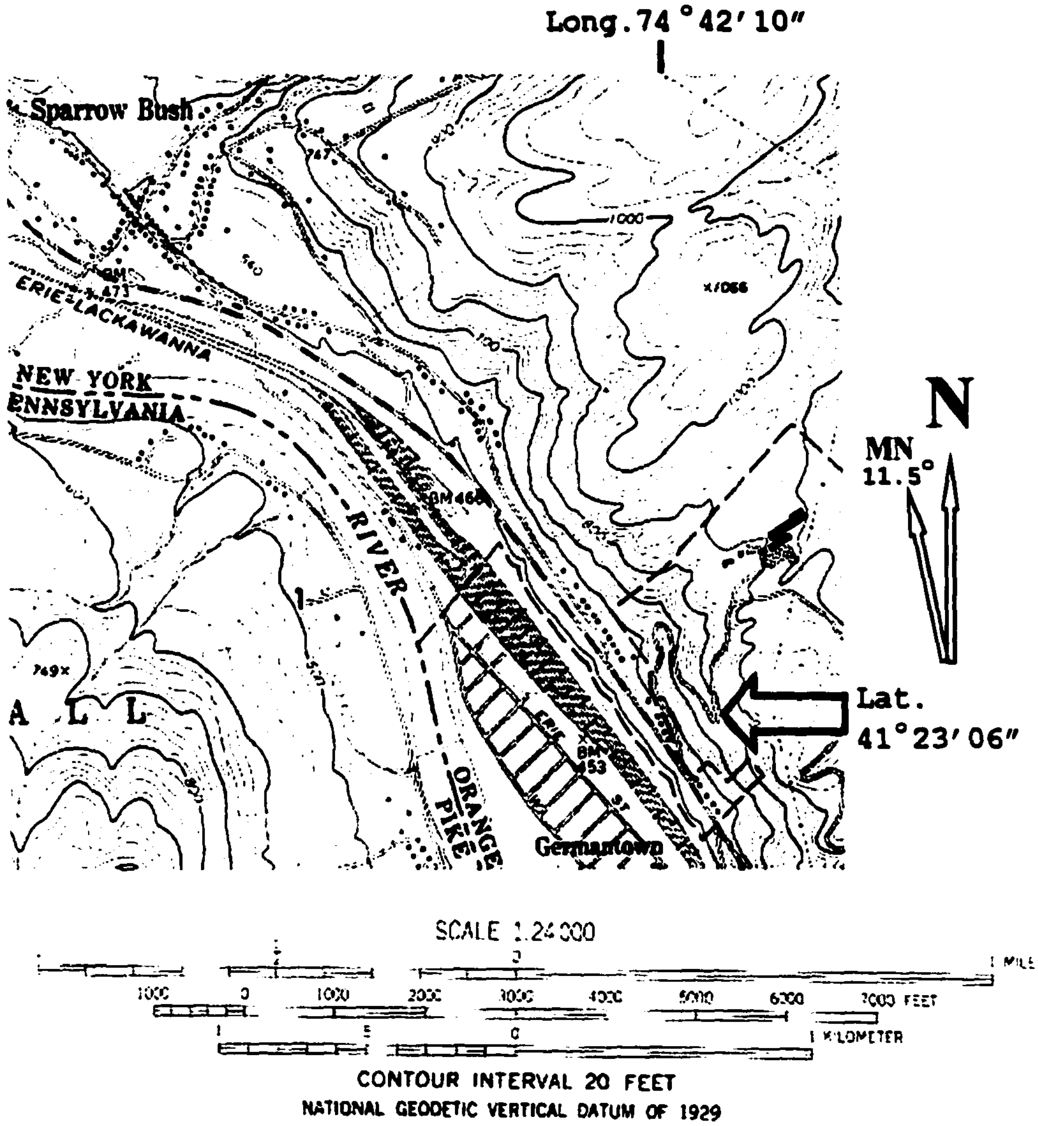


Figure 6 - Map showing location of Port Jervis, NY section. Source: USGS Port Jervis North, NY-PA Quadrangle Map.

Mahantango Formation are equivalent to the section illustrated on Figure 7 as studied by Slattery (1993, 1995). A total of three whole rock samples (labelled PJ-1 through PJ-3) were collected at stratigraphic locations shown on Figure 7.

Lower Mahantango Formation - At the Port Jervis section the uppermost Lower Member of the Mahantango Formation is a distinct dark gray to black fissile shale. Approximately 0.5 meter, representing the uppermost portion of this unit, was measured (Figure 7).

Middle Mahantango Formation - The lower part of the Middle Member of the Mahantango Formation consists of medium to dark gray cyclic beds of shales, claystone and siltstone. These cyclic beds normally occur in three meter thick bed sets. Pillow ('flow-roll') structures are present in some of the siltier beds (Figure 8). Sand to gravel size clasts in the form of brachiopods and mud rip-ups are present. These fine-textured clasts (Figure 9) can be easily overlooked when not weathered to a different color than the matrix. Such beds with "clasts", both similar in color and texture to the matrix, make these mudstone-clast "sandstones, breccias, and conglomerates" difficult to identify. Also fairly common are carbonized to pyritized fragments of plant material that are twig-like in shape. At the 45 meter interval of section measured is a distinct brachiopod-bearing lag with abundant *Fimbrispirifer*. This

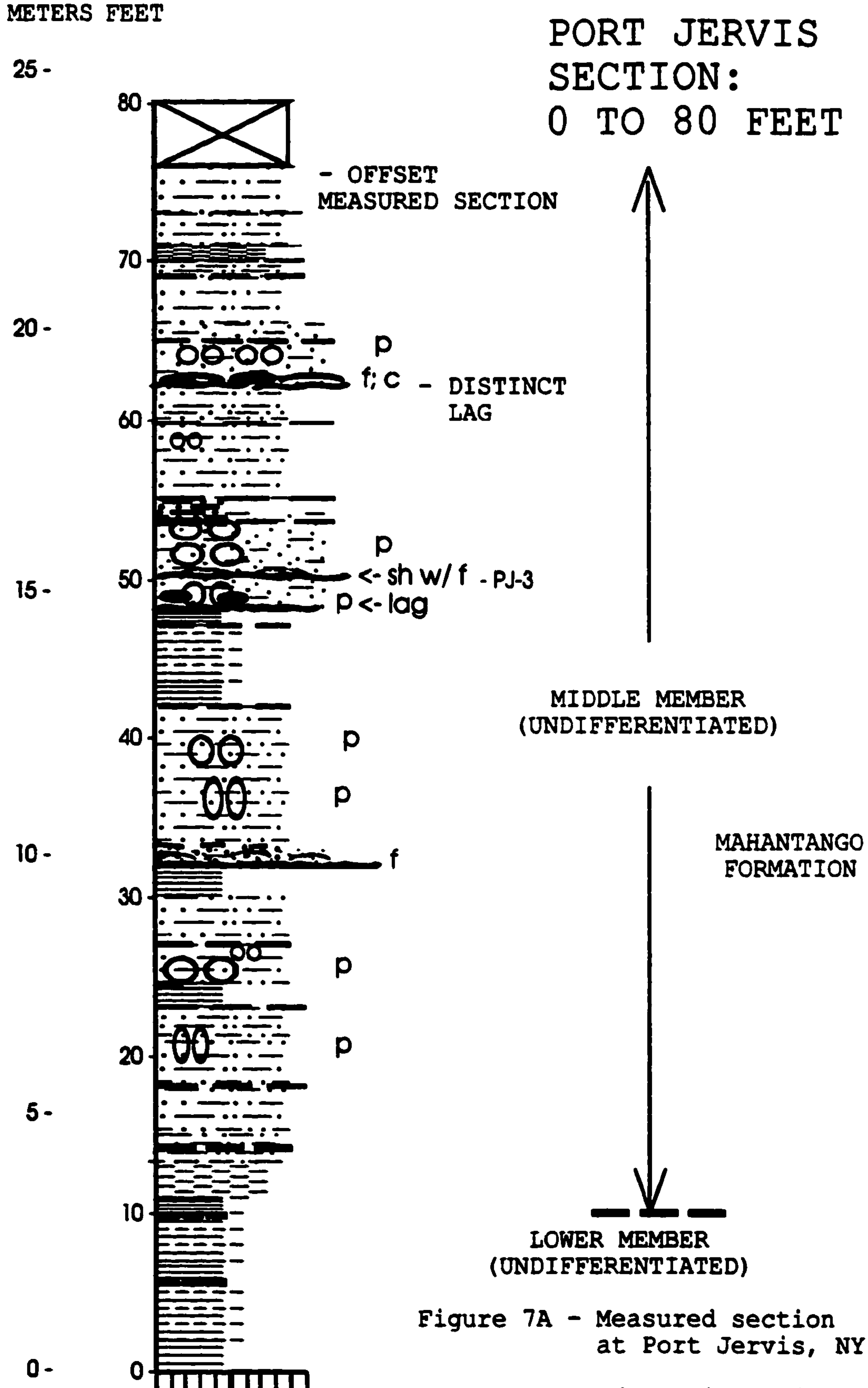


Figure 7A - Measured section at Port Jervis, NY

Legend on Figure 5

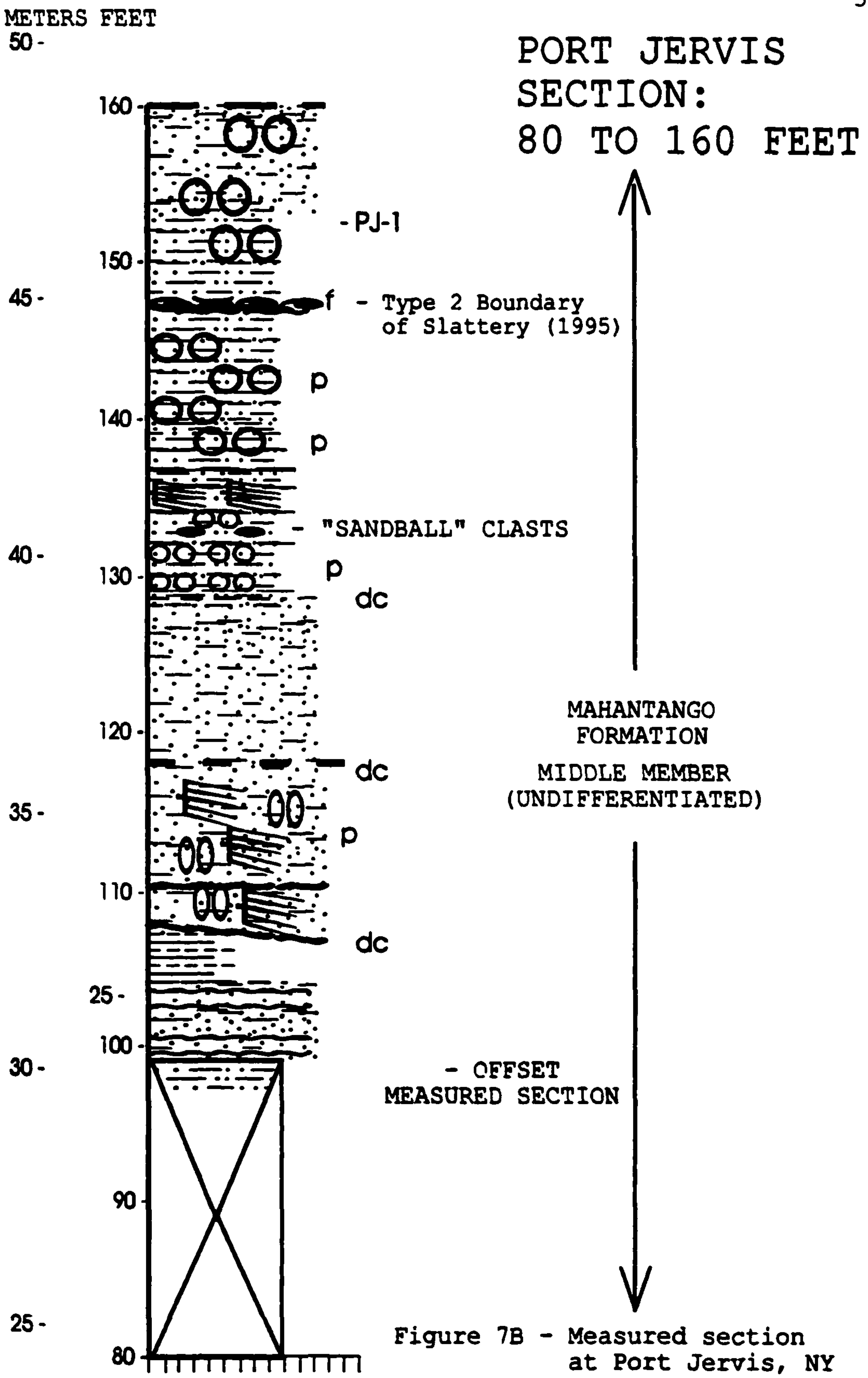


Figure 7B - Measured section at Port Jervis, NY

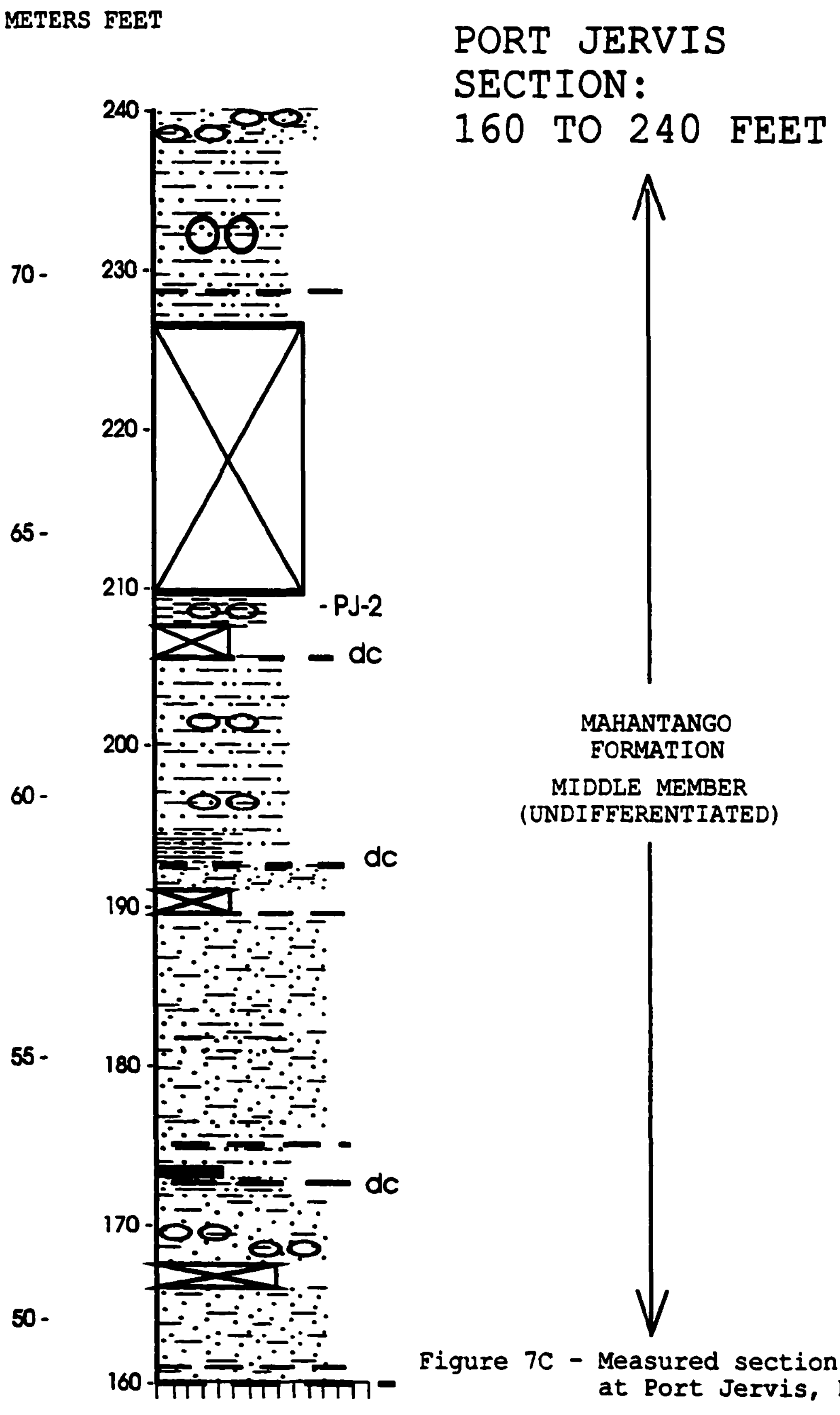


Figure 7C - Measured section at Port Jervis, NY

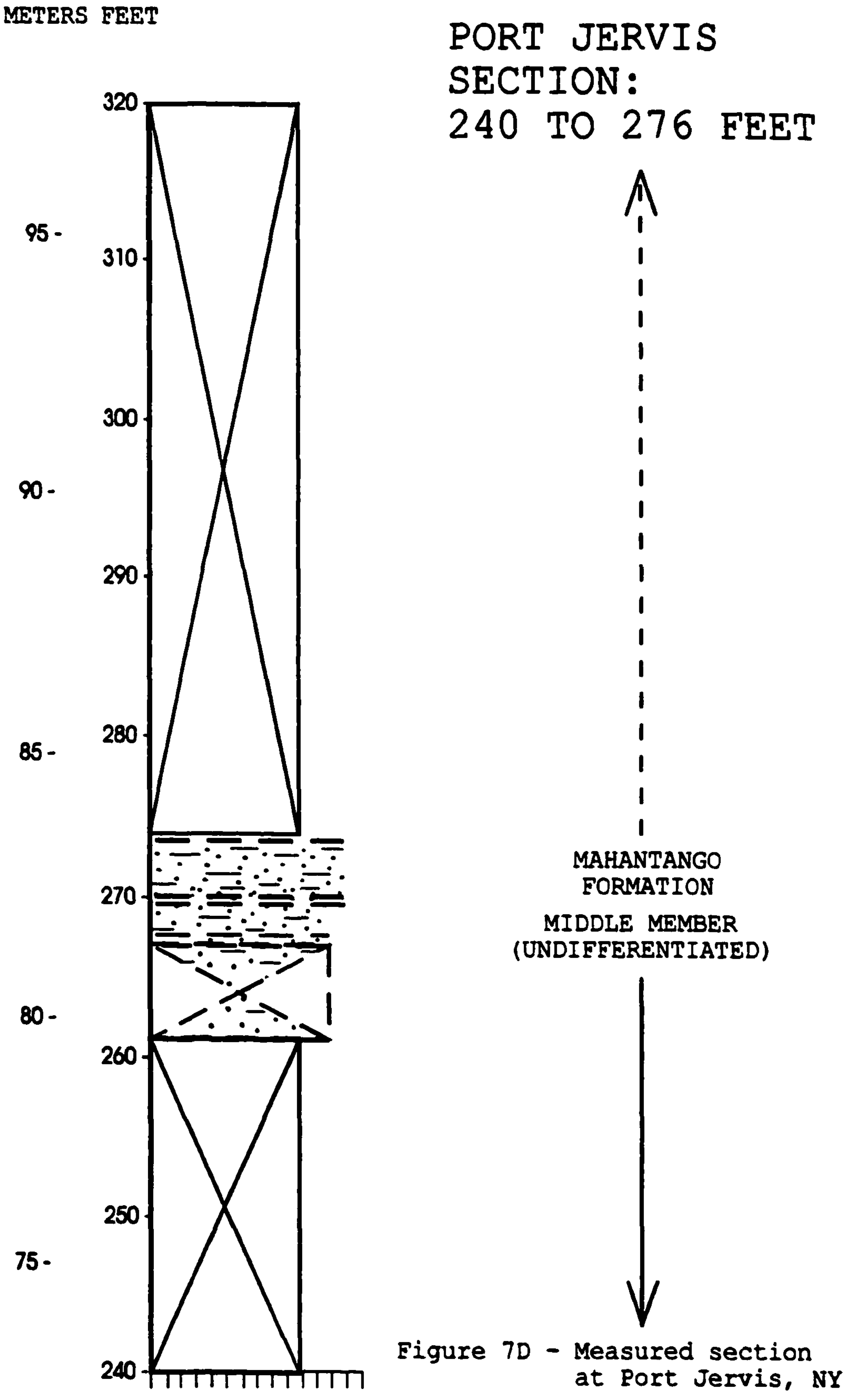


Figure 7D - Measured section at Port Jervis, NY

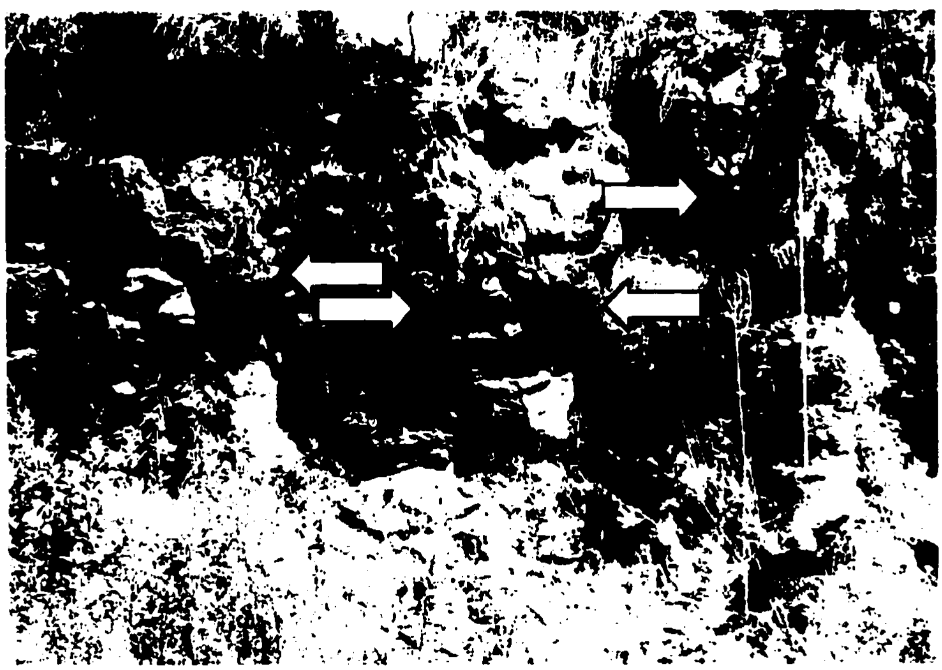


Figure 8 - "Flow roll" structures as indicated by arrows
at Port Jervis, NY.
Six-foot ruler on right side of photograph.

A. Gravel-size mudstone clast showing differential weathering to fine-textured matrix.

B. Opposite side of same specimen, showing smaller clasts.

Figure 9 - Example of fine-textured clasts from Mahantango Formation at Port Jervis, NY.

brachiopod was also observed in sampled horizon PJ-2. The contact with the overlying Upper Member is covered in the immediate area of the studied section (Figures 6 and 7). Therefore, neither the Upper Member of the Mahantango Formation, Sparrow Bush Formation or Sloat Brook Member of the Trimmers Rock Formation, while found elsewhere, are exposed at the studied Port Jervis section. The Sparrow Bush is a sandstone recognized by Fletcher and Woodrow (1970) as a Tully correlative and the Trimmers Rock Formation is a correlative of the Harrell Formation as recognized at the other studied sections.

Comparison to Other Studies - From lowest to highest, stratigraphic units observed in the Port Jervis area (Figure 10) are: the Marcellus Formation (Shale); the Lower, Middle and Upper Members (cf. Fletcher and Woodrow 1970) of the Mahantango Formation; the Sparrow Bush Formation and the Trimmers Rock Formation (Sloat Brook Member). Only portions of the lower and middle members of the Mahantango Formation at Port Jervis were measured for this study (Figure 7) under the initial assumption presented by Slattery (1993) that this section is correlative to the other localities studied (Figure 1). Significant to Slattery's (1993, 1995) study is the detail recognition of facies associations with depositional cycles at the Port Jervis section. Unfortunately, Slattery (1993) did not use an independent datum to assess whether these

REFERENCE:	Fletcher & Woodrow (1970) (PA)	Rickard (1975) (General for SE NY)	*Sevon et al.* (1989) (PA)	*Slattery* (1993, 1995) (PA, NY)	This Study (PA, NY)
UNITS RECOGNIZED	Trimmers Rock Fm. Sloat Brook Member	Genesee Group Tully Fm.	Trimmers Rock Fm.	(Not Discussed)	Trimmers Rock Fm. Sloat Brook Member
	Hamilton Group: Sparrow Bush Fm.	Hamilton Group:	Hamilton Group: "localized" Sparrow Bush strata	Hamilton Group: Sparrow Bush Fm.	Hamilton Group: Sparrow Bush Fm.
	Mahantango Fm. Upper Member	*Panther Mountain Fm* (Undifferentiated)	*Mahantango Fm.* (Undifferentiated: no subdivisions recognized)	*Mahantango Fm.* (Undifferentiated)	*Mahantango Fm.* Upper Member
	Middle Member				Middle Member
	Lower Member		Unnamed Fine-textured Mmbr. (Inferred)	Marcellus Fm. (miscorrelated?)	Lower Member
	Marcellus Fm.	Marcellus Fm.	Marcellus Fm.		Marcellus Fm. (Not Inspected)

Legend:

- ═ Group Boundary
- ─ Formation Boundary
- \- Member Boundary

FIGURE 10 - SUMMARY OF STRATIGRAPHIC UNITS RECOGNIZED IN THE PORT JERVIS, NY AREA

cycles were actually correlative with those of his other studied sections. Instead, the change he observed within the depositional cycles was also used as a datum to indicate his proposed Type II boundary. Basic review of the location of these Mahantango Formation beds relative to the contacts of the underlying Marcellus and overlying Trimmers Rock Formations, indicate that this part of the Mahantango Formation is significantly older than the other studied sections. Review of other studies (in particular Rickard 1975, Fletcher and Woodrow 1970, and Sevon et al. 1989) support this observation regarding the stratigraphic position of the section measured (Figure 7). Another indicator is the presence of *Fimbrispirifer* which is more prevalently found within the lower part of the Mahantango Formation.

Rickard (1975) had reviewed the New York area Devonian units, although the stratigraphic terms he used are not readily recognizable in the Port Jervis area. This is due to significant facies changes northeast of Port Jervis where chronostratigraphic equivalent rocks change from marine to non-marine facies. Therefore, the Port Jervis rocks are more compatible to the Mahantango Formation of Pennsylvania than other southeastern New York state Givetian age rocks (Rickard 1975 as shown by Sevon and Woodrow 1985). In addition, Rickard (1975) shows the Hamilton Group as "undifferentiated". However, at least for the Port Jervis area there is enough lithologic similarity with Pennsylvania to recognize the Marcellus Formation and to subdivide the Mahantango Formation as originally proposed by Fletcher and Woodrow (1970).

The study of Fletcher and Woodrow (1970) concerned Pennsylvania geology, but also reviewed the New York side of the Delaware River and even proposed a new stratigraphic unit, the Sparrow Bush, based on a New York locality. The Mahantango Formation was divided into three unnamed members by Fletcher and Woodrow (1970). However, Fletcher and Woodrow (1970) recognized these subdivisions only in the northeastern most portion of their geologic map of the Pennsylvania sections of the Port Jervis and Milford Quadrangles. Another study in Pennsylvania, was by Sevon et al. (1989) who did not subdivide the Mahantango Formation on their Pike County (PA) map.

Comparison of the Mahantango Formation at the Port Jervis section to northeast Pennsylvania (Raymondskill locality of Figure 1) indicates, these sections to be very similar on a lithologic and sedimentologic basis. This was best demonstrated by Slattery (1993, 1995) and further supports the use of Pennsylvania nomenclature for this area of New York. Slattery's work suggests the feasibility of subdividing the Mahantango Formation in northeastern Pennsylvania and southern New York as originally proposed by Fletcher and Woodrow (1970). As with the Port Jervis section, the portion of the Raymondskill section studied by Slattery (1993, 1995) is correlative to the Lower and Middle Members as recognized by Fletcher and Woodrow (1970). The geologic map of Sevon et al. (1989) also concurs with this stratigraphic placement. However, as previously noted, Slattery (1993, 1995) considered these beds to be stratigraphically higher within the Mahantango Formation than the findings of this study.

Based on its stratigraphic position beneath the Trimmers Rock and at the top of the Hamilton Group, the Sparrow Bush Formation as proposed by Fletcher and Woodrow (1970) is considered to be a detrital equivalent of the Tully Mesosequence. They recognized the best exposures of this formation along the Delaware River in vicinity of Sparrow Bush, New York. Consequentially, Sevon et al. (1989) considered the Sparrow Bush 'Member' as unmappable due to poor exposure away from the river and preferred to include this unit within the Mahantango Formation.

Bowmanstown Section

Approximately a quarter of a mile north of Bowmanstown is a section (locality "E" of Figure 1) along an entrance ramp to PA Route 248 adjacent to the Lehigh River (see Figure 11 for detailed location information). A total of eleven whole rock samples (labelled B-1 through B-4,

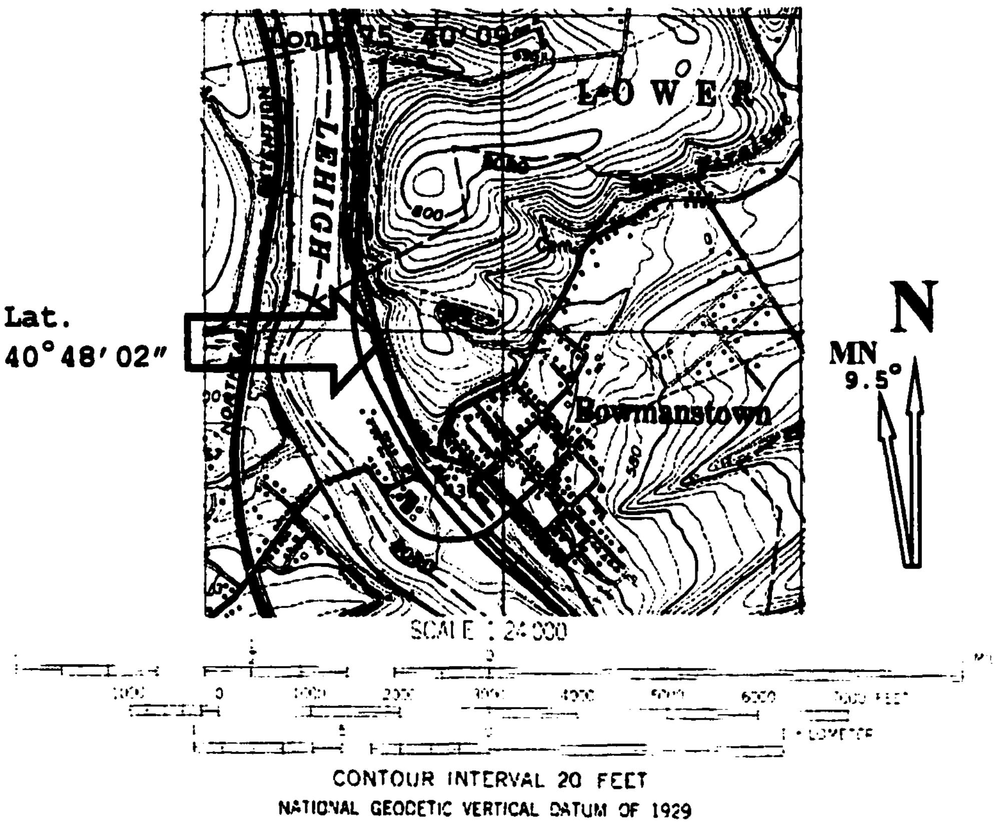


Figure 11 - Map showing location of Bowmanstown, PA section. Source: USGS Leighton, PA Quadrangle Map.

B-1.0', B-80, B-98, B-244, B-411, B-455 and B-490) were collected along this section at stratigraphic locations shown on Figure 12. From oldest to youngest, the stratigraphic units occurring here are: a previously unnamed unit referred to here as the Bowmanstown Shale Member, the Nis Hollow Member, and the Weissport Member, all subdivisions of the Mahantango Formation, the Tully Mesosequence, and the Trimmers Rock Formation. As discussed in Chapter Two, the term mesosequence for the Tully includes rocks that have previously been recognized as part of the Mahantango Formation based on their non-calcareous lithology. A unit referred to as the Centerfield fossil zone was reported and mapped by Epstein et al. (1974) as occurring directly below the Bowmanstown Shale Member. The Centerfield fossil zone is not visible at the Bowmanstown locality due to cover and development.

Bowmanstown Shale Member - The term Bowmanstown Shale Member is here proposed for a previously unnamed section of the Mahantango Formation occurring between the Centerfield fossil zone of Epstein et al. (1974) and the Nis Hollow Member. The uppermost 57 meters (188 feet) of the Bowmanstown Shale Member of the Mahantango consists predominantly of medium to dark gray shales, claystone and some siltstone. The presence of prominent, nearly horizontal fracture cleavage planes makes difficult the recognition of fossils and sedimentary structures within

BOWMANSTOWN SECTION: 0 to 80 FEET

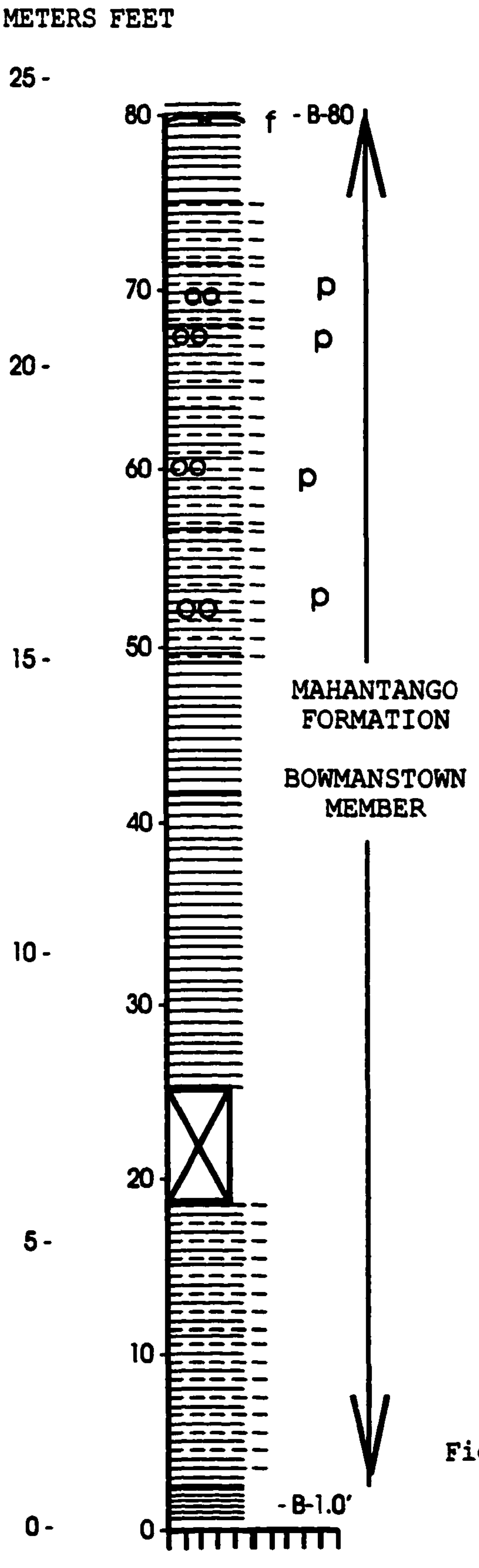


Figure 12A - Measured section at Bowmanstown, PA.

Legend on Figure 5.

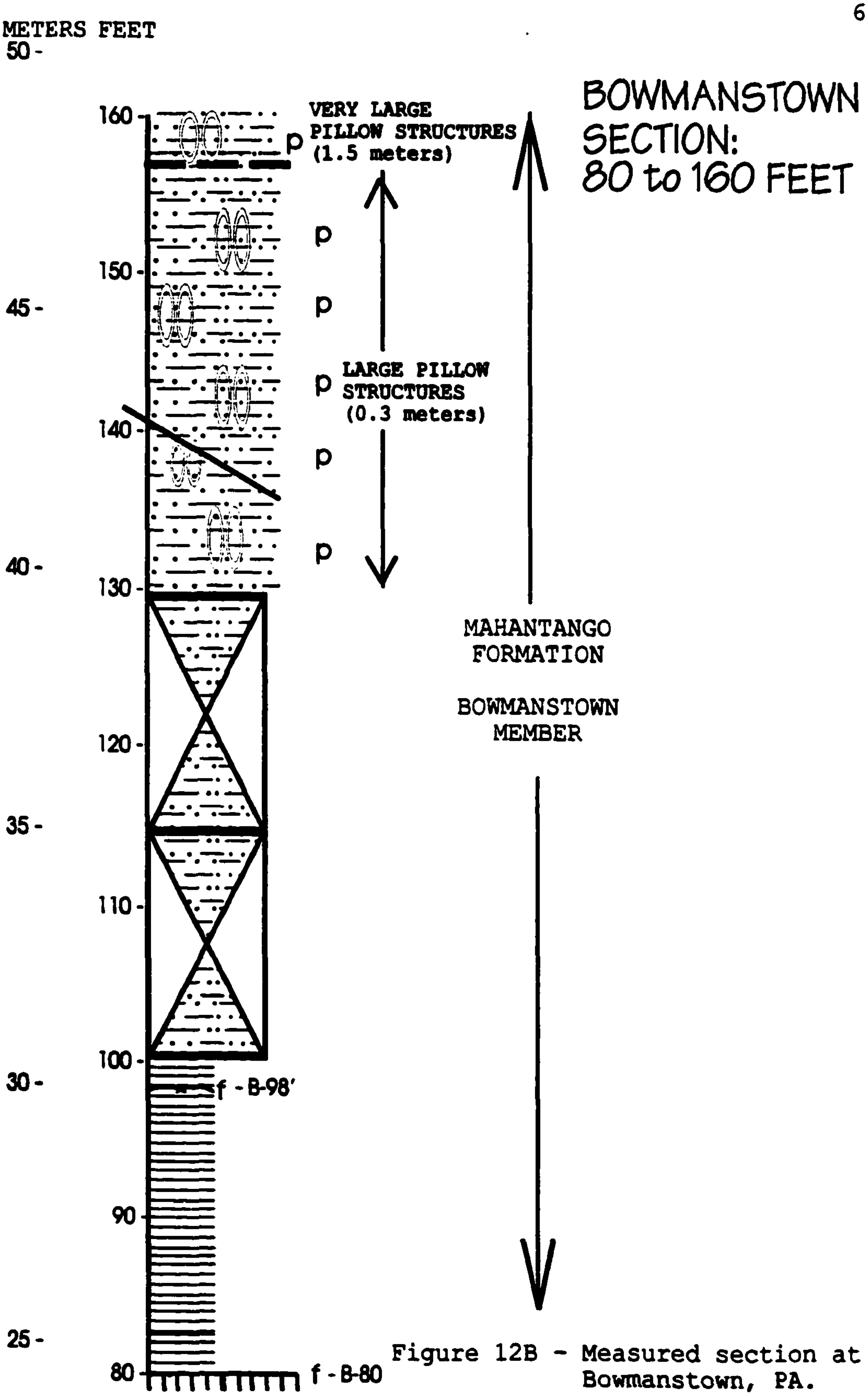


Figure 12B - Measured section at Bowmanstown, PA.

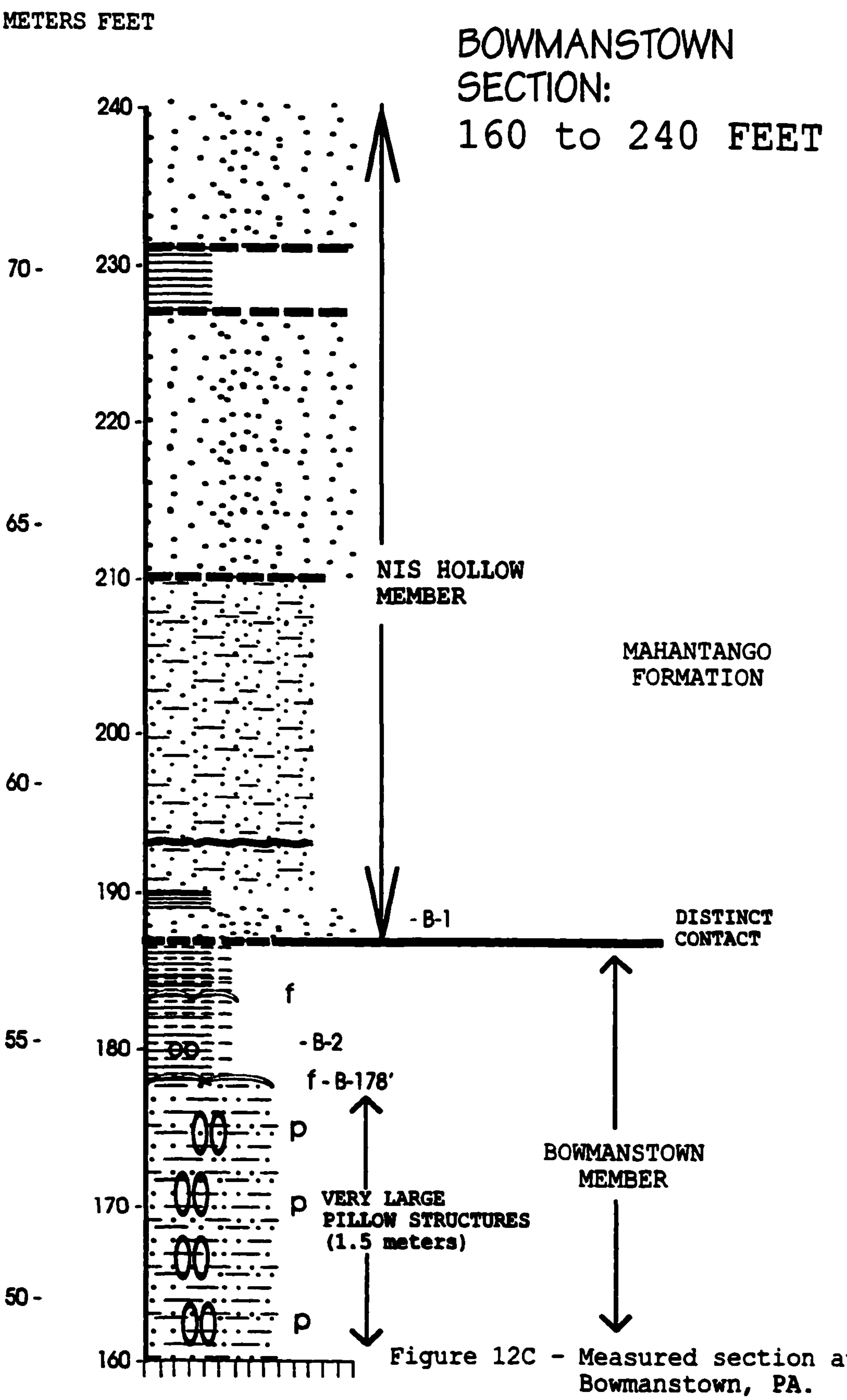


Figure 12C - Measured section at Bowmanstown, PA.

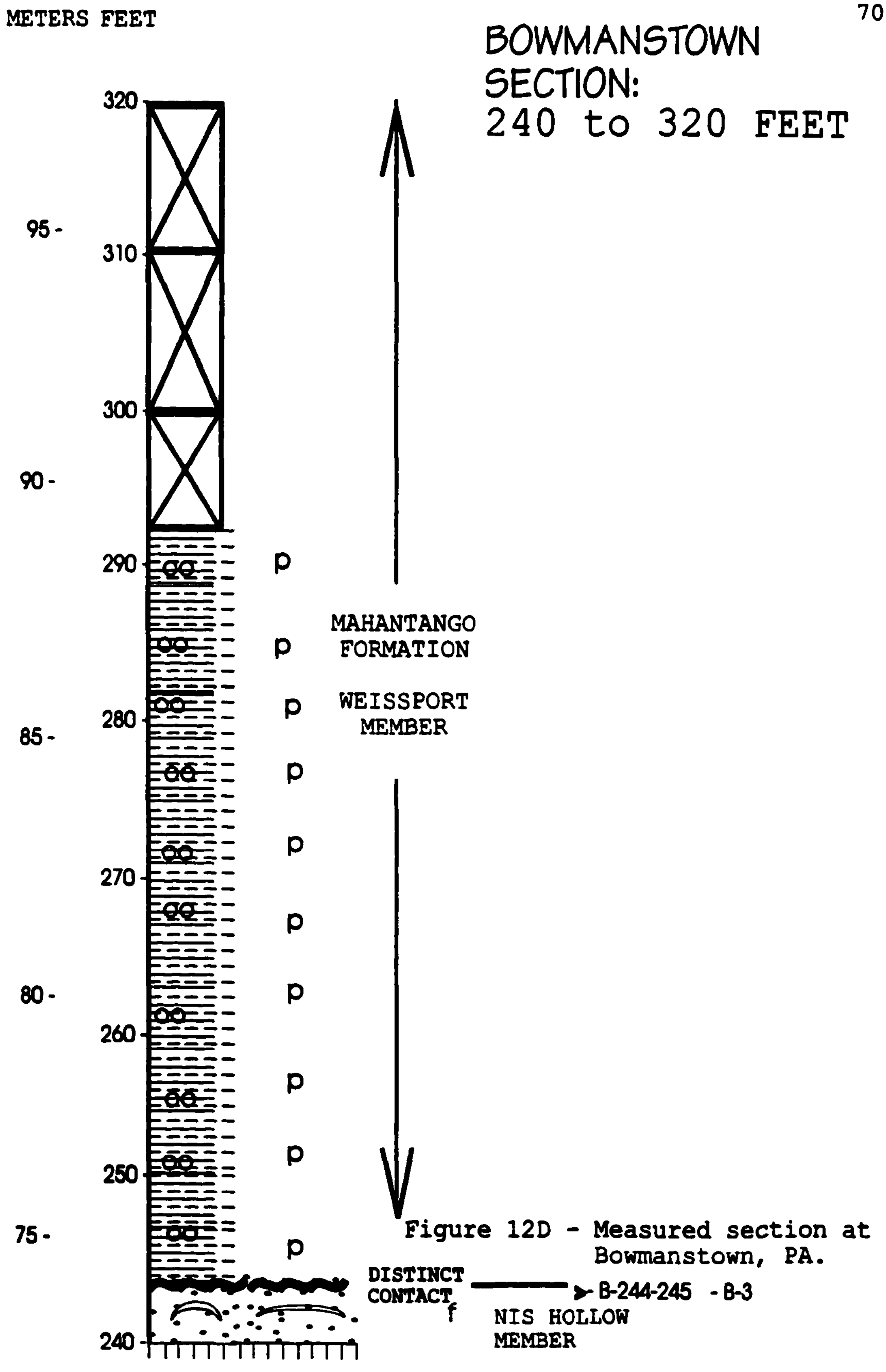


Figure 12D - Measured section at Bowmanstown, PA.

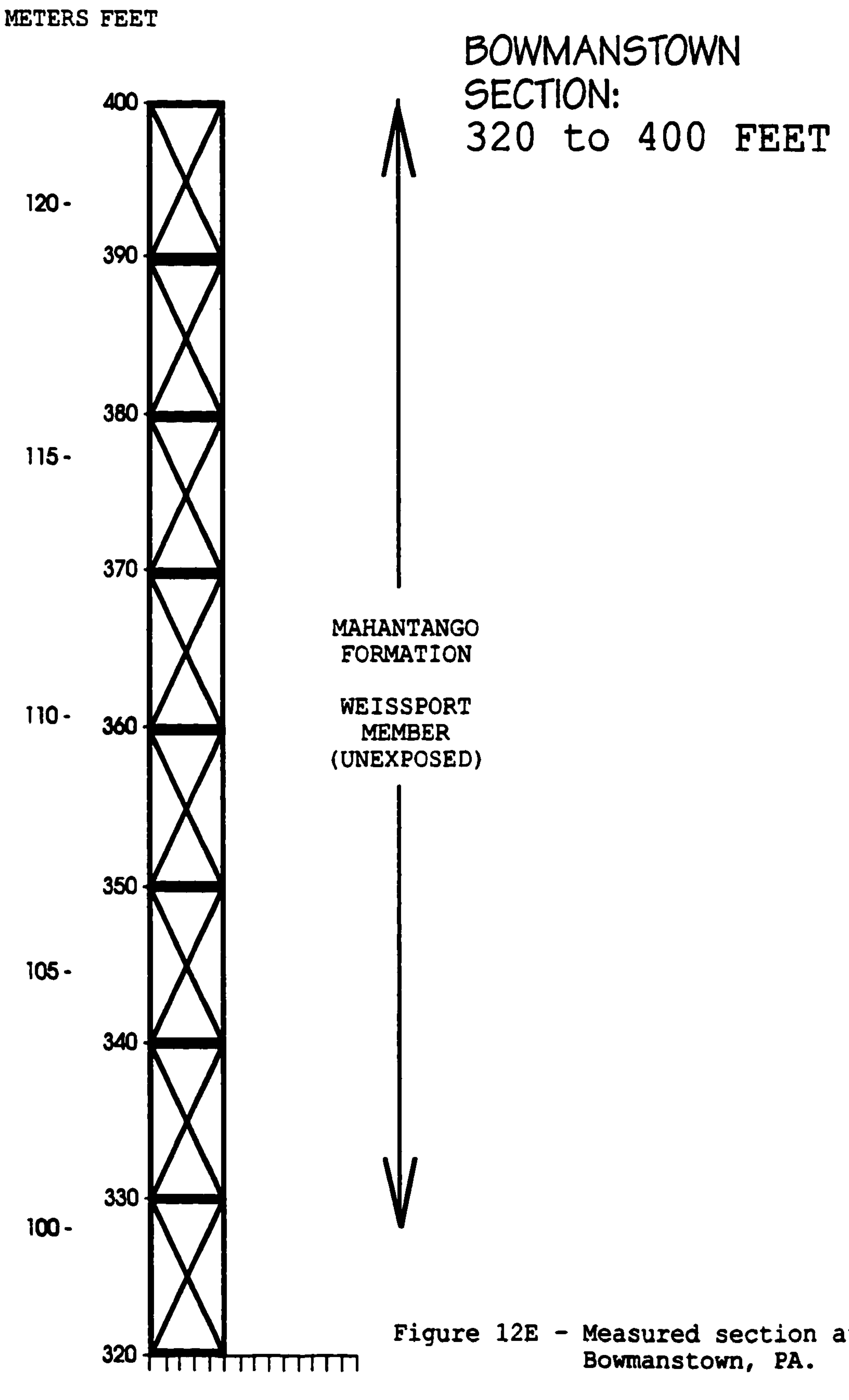


Figure 12E - Measured section at Bowmanstown, PA.

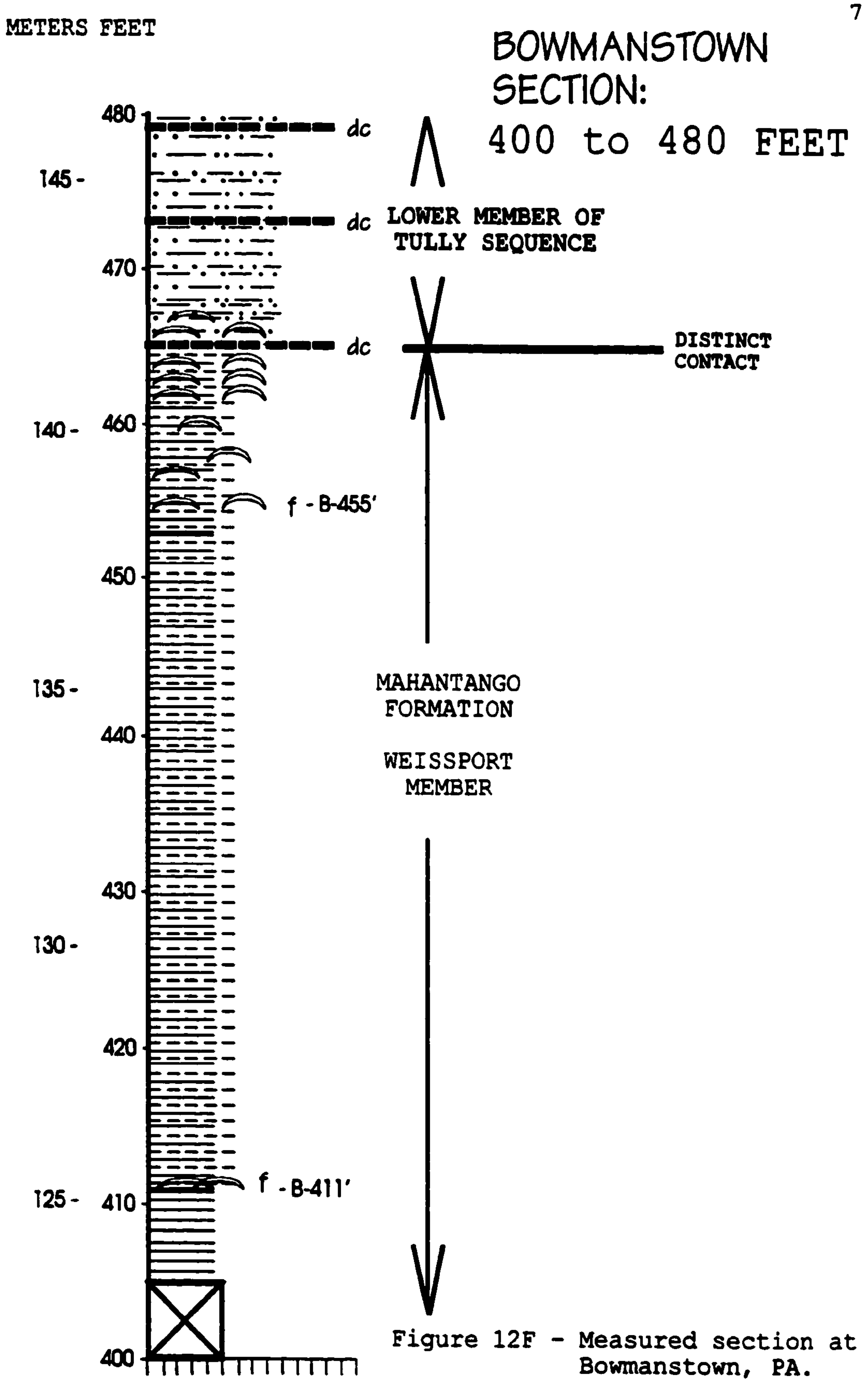


Figure 12F - Measured section at Bowmanstown, PA.

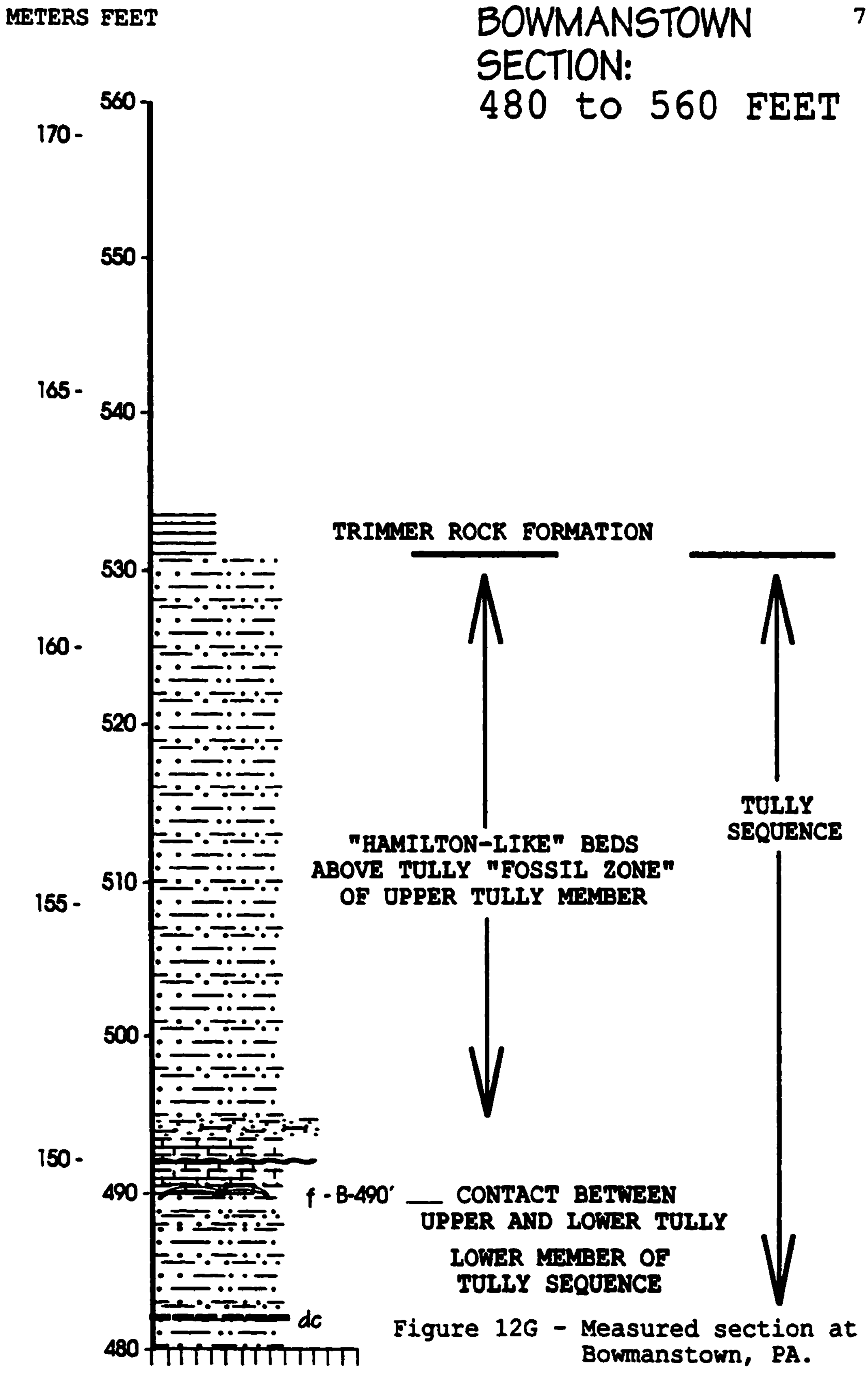


Figure 12G - Measured section at Bowmanstown, PA.

the nearly vertical bedding planes. At least two discontinuous, diagnostically significant fossiliferous lags (B-80 and B-98 in Figure 12) are present within this member. These structurally distorted fossils (Figure 13) are typically leached so that only molds and casts remain. Present within the uppermost portion (18 meters) of the Bowmanstown Shale Member are what I refer to as "pillow structures" (Figure 14). These "ellipsoidal exfoliation-like structures" of Epstein et al. (1974, 136) are recognized by these authors as "weathering features developed by mechanical disintegration along intersecting cleavage, bedding and fracture planes in the shales having prominent cleavage". This assessment is in contrast to Willard (Willard and Cleaves 1933, 763; Willard 1935, 2302) who interpreted these structures as primary sedimentary features and referred to then as "storm rollers". Kramers and Friedman (1986) refer to similar structures lower in the Hamilton Group of New York as "flow rolls". I favor the primary sedimentary hypothesis based on these structures being present at other sections, such as Port Jervis (see Figure 8) and Riverside, where structural deformation is not as pronounced. This origin concurs with Willard's original interpretation of a primary sedimentary feature. This interpretation is similar to that of Kramers and Friedman (1986) and Friedman (1985) for older beds

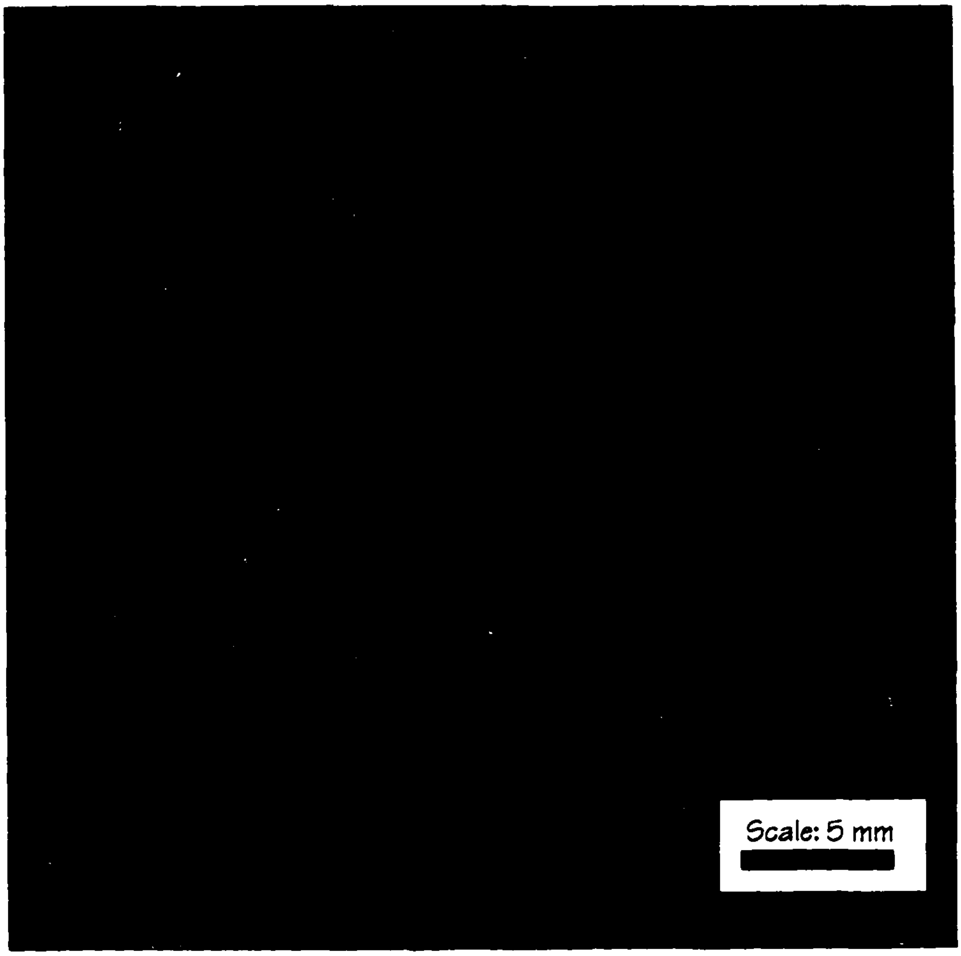


Figure 13 - Examples of leached and distorted brachiopods from sampled horizon B-80 of the Bowmanstown Shale Member at Bowmanstown, PA section.
A. *Spinatrypa spinosa* and B. *Camarotoechia mesacostalis*..

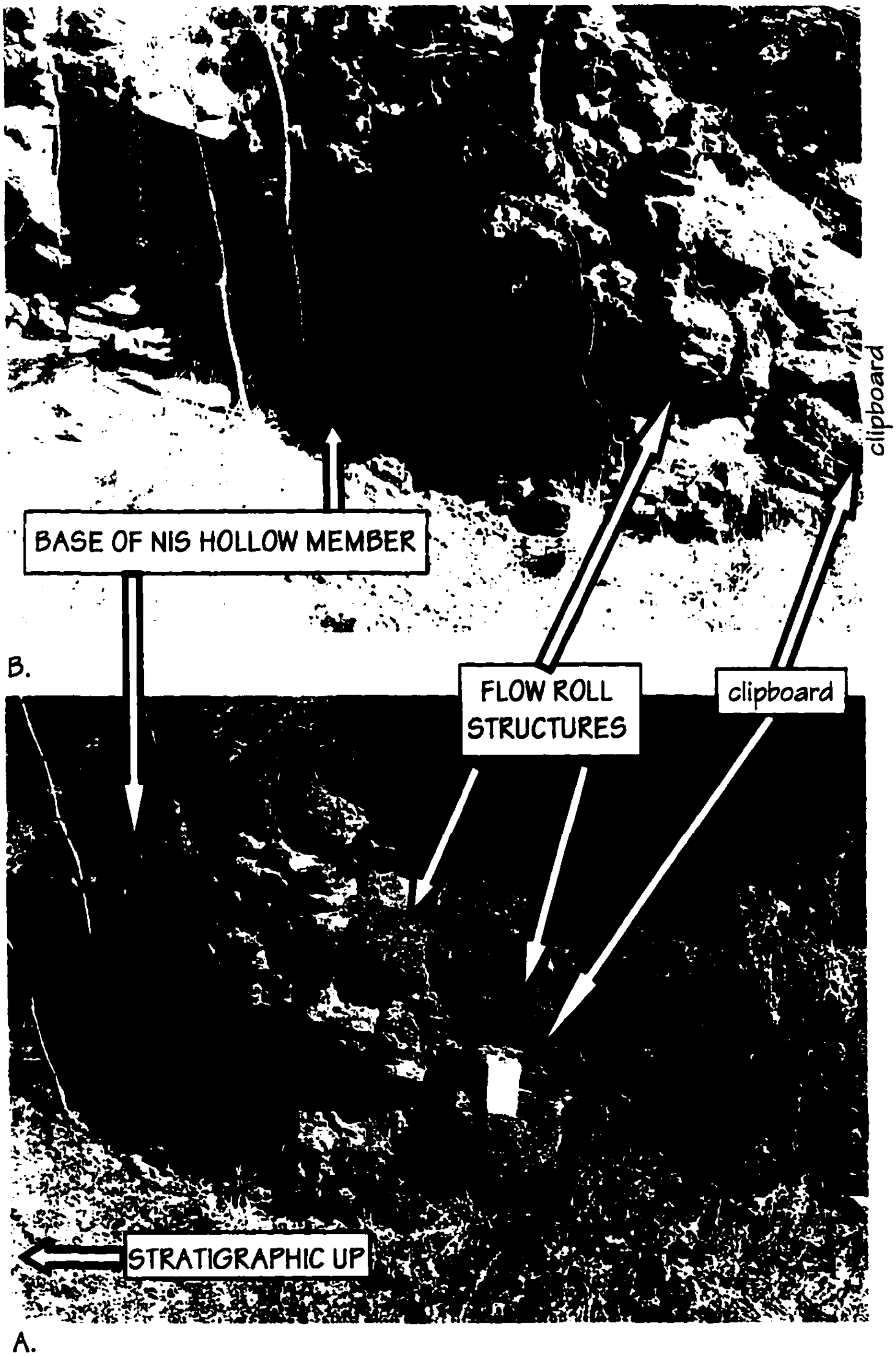


Figure 14 - Contact between Bowmanstown Shale and Nis Hollow Members at Bowmanstown, PA. Beds are nearly vertical. Edge of clipboard (39 cm long) at extreme right in photograph B is in approximately same location as shown on photograph A. Stratigraphic up is to the left side of both photographs.

associated with the Centerfield Member of New York. Close inspection of the pillow structures show that they apparently are coarser-textured, being more silty or with more fine sand than the surrounding finer textured shale matrix. This further suggests a sedimentary rather than tectonic origin. No matter what their origin, as noted by Epstein et al. (1974), the pillow structures are more resistant to weathering than adjacent rock, thereby making them a "structural feature".

Possibly due to the presence of the overlying coarser textured Nis Hollow Member, the uppermost three meters of the Bowmanstown Shale Member is relatively undeformed where bedding features can be readily distinguished (Figure 14). Several fossil lags including sample locations B-2 and B-178), consisting mainly of brachiopods and crinoids (Figure 15) are present.

Nis Hollow Member - The Nis Hollow Member is the only distinctive coarse textured unit at the measured Bowmanstown section. This unit consists of planar beds of siltstone with some fine sandstone beds and a few intrastratified shaly beds. The color of this member varies from a light brown on weathered surfaces to a medium to brownish gray on fresh surfaces. Therefore, the Nis Hollow Member has a lighter color than adjacent units (Figure 14). Beds vary from a few centimeters to nearly a meter in thickness. The Nis Hollow Member is approximately

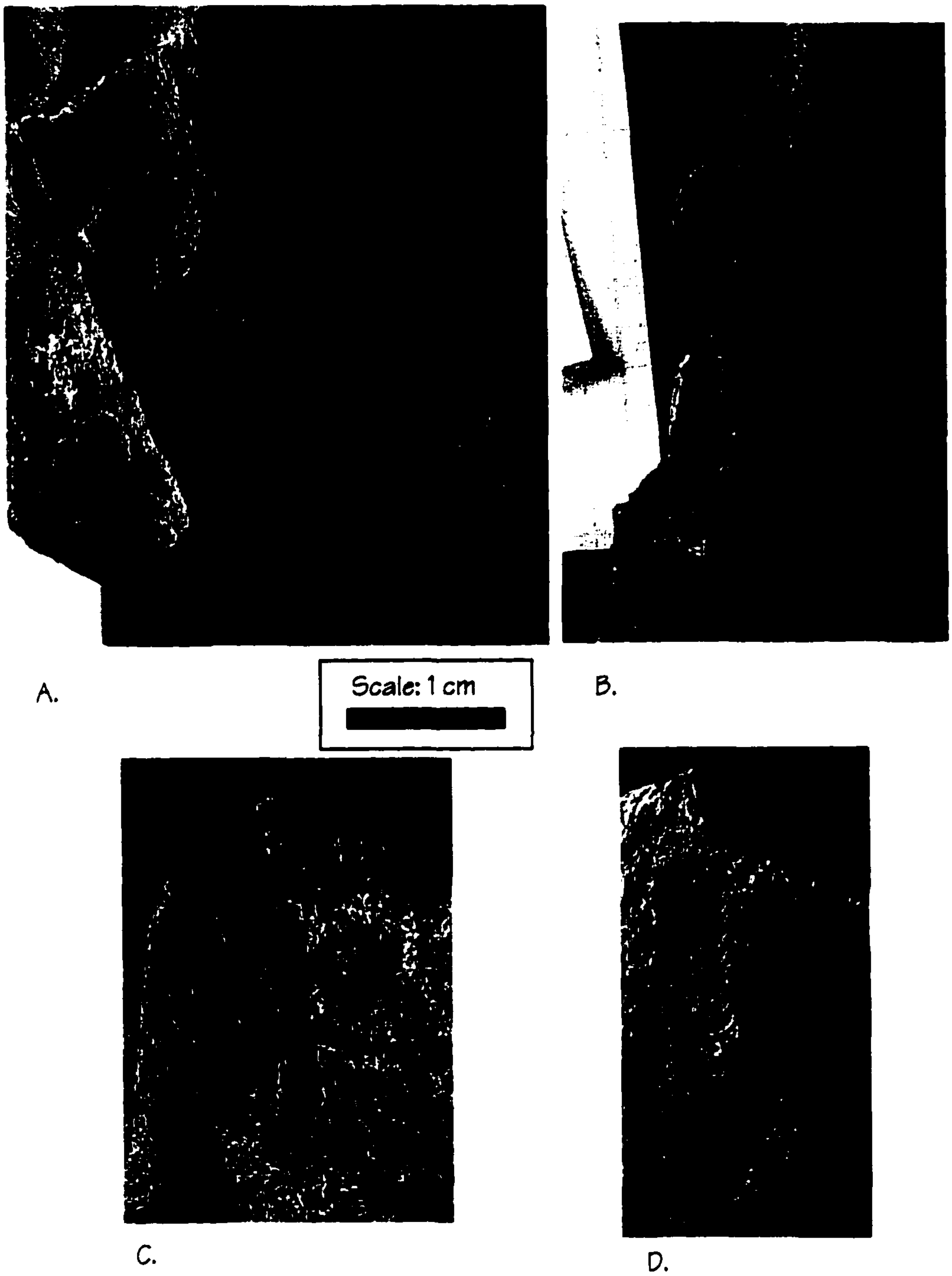
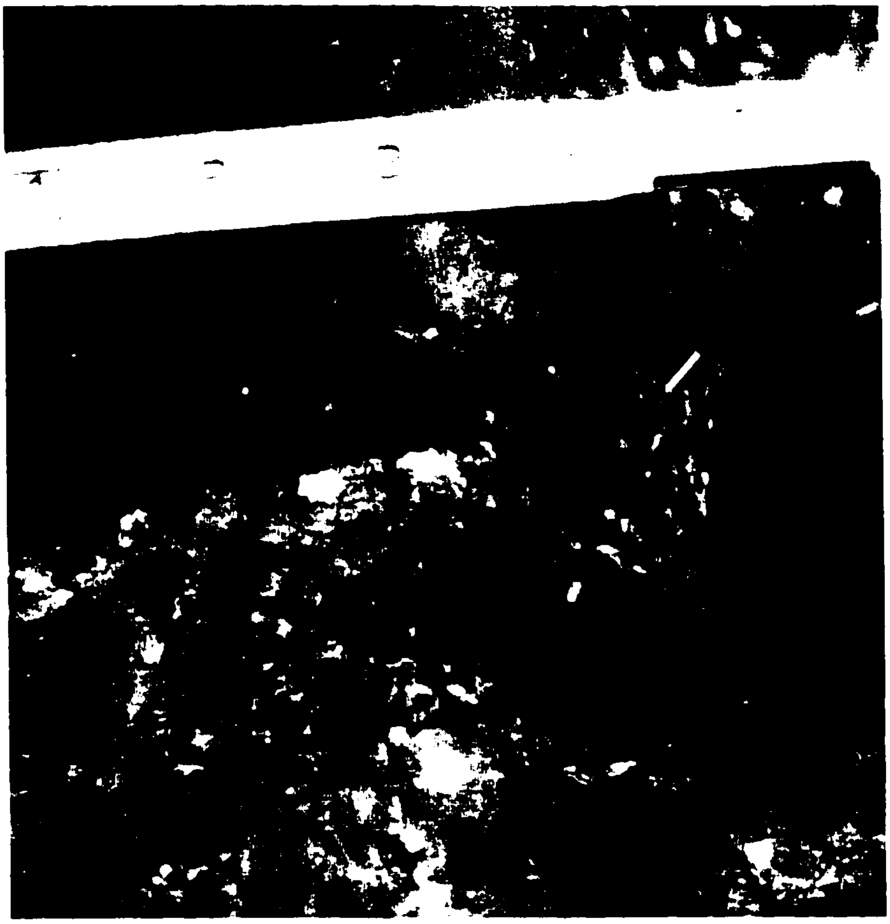


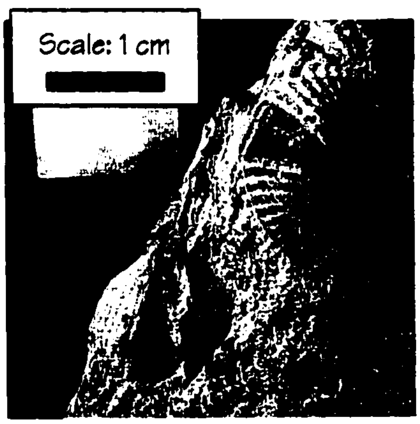
Figure 15 - Articulated crinoid with calyx from sampled horizon B-2 from the Bownmanstown Shale Member at Bowmanstown, PA.

17 meters (56 feet) thick at Bowmanstown starting from the 57 meter interval of measured section shown on Figure 12. This is the same thickness reported by Epstein et al. (1974, 140) and illustrated by Slattery (1995 Figure 3) making the Nis Hollow an excellent marker bed at this locality.

The Nis Hollow Member, when compared to the two stratigraphically adjacent unnamed finer-grained units, has undergone less structural deformation and demonstrates distinct, nearly vertical dipping beds (Figure 14). The coarser beds of the Nis Hollow Member have distinct contacts with both finer-grained adjacent members. Interestingly, both overlying and underlying fine-textured shales and mudstone in immediate contact with the Nis Hollow Member are less deformed and retain recognizable bedding features (Figure 14). A distinct change in texture from shale to sandy siltstone (Figure 14) marks the base of the Nis Hollow Member (57 meter interval of measured section shown on Figure 12). A massive planar bed nearly 1.5 meters thick containing large (three to five centimeter) brachiopods (*Mediospirifer* and smaller *Allanella*) dispersed ("floating") within the matrix (Figure 16) marks the top of this member. These fossils are also not as structurally deformed as those observed in adjacent beds.



A. *Mediospirifer audaculus* (arrow).

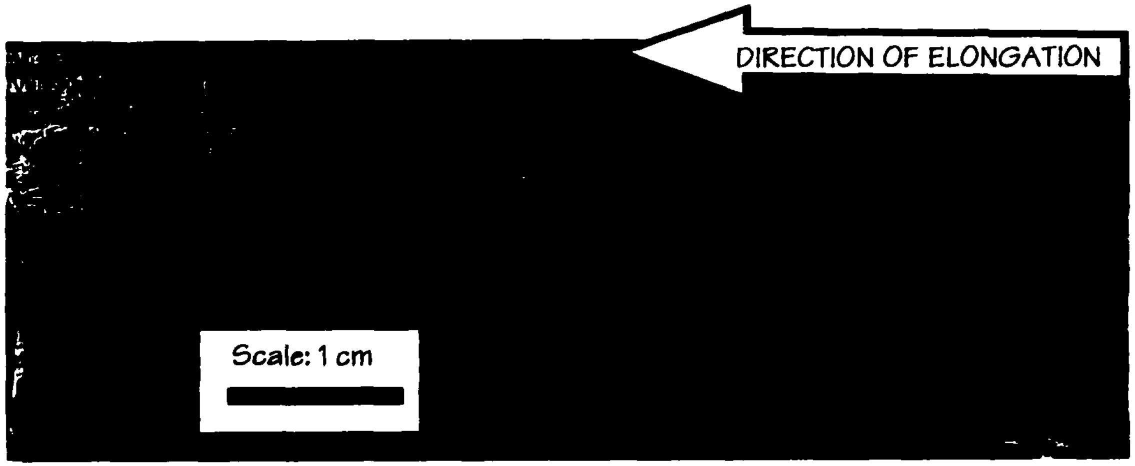


B. *Allanella tullia* (1) and *Spinocyrtia granulosa* (2).

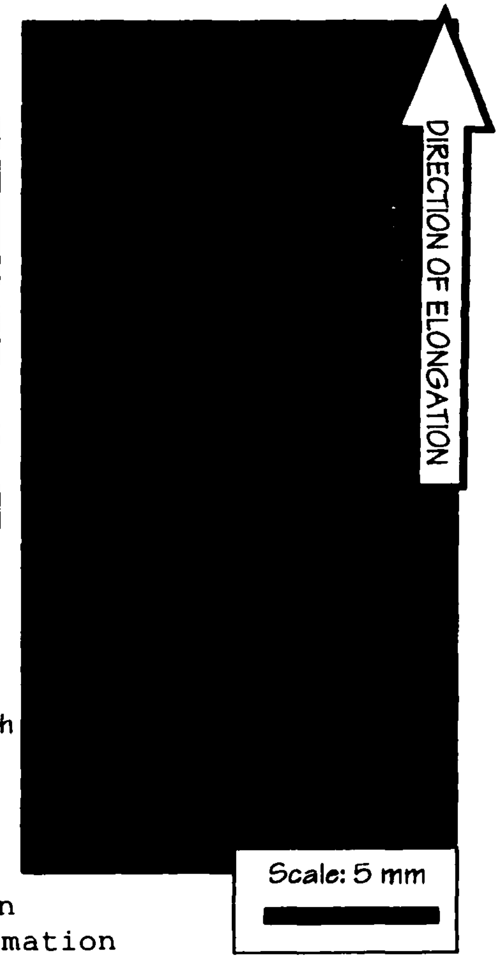
Figure 16 - Large brachiopods from upper Nis Hollow Member at Bowmanstown, PA section.

Weissport Member - The Weissport Member immediately overlies the Nis Hollow Member. The term Weissport was initially proposed by Stevenson and Skinner (1949), but as noted by Heckel (1969), is not formally recognized by the Pennsylvania Geologic Survey. This unit consists of a series of medium to dark gray shales and claystones with relatively good exposure for approximately fifteen meters (fifty feet). The Weissport Member then becomes covered for approximately thirty-five meters. Above this covered interval continues a poorly fossiliferous, dark gray shale for approximately two meters that is similar to the shales found at the base of the Weissport Member. From approximately the 125 meter interval (sample horizon B-411 on Figure 12), the shales and claystones become more fossiliferous (Figure 17). The stratigraphically higher portion contains abundant *Mucrospirifer*. Fossil preservation within the Weissport Member is similar to that observed in the Bowmanstown Shale Member (contrast Figures 13 with 17 and 18) with specimens typically being leached and structurally distorted.

The shaly beds of the Weissport Member have a slightly higher iron content than lower fine-textured beds in the Mahantango Formation. This is indicated by the presence of disseminated pyrite within these rocks. There is also more pyritic (or limonitic) residue present in the two samples (B-411 and B-455) processed for microfossils from this



A. Various distorted fossils.along bedding surface.



B. A distorted leiorhyncid brachiopod showing compression along its width and extension along its height.

Figure 17 - Examples of fossiliferous lag (Sample B-411) in Bowmanstown Shale Member of the Mahantango Formation at Bowmanstown, PA.

B. Close-up of collected sampled showing pelecypod (1) and the brachiopods Mucrospirifer (2) and "Leiorhynchus" (3). Note axial distortion of specimens.

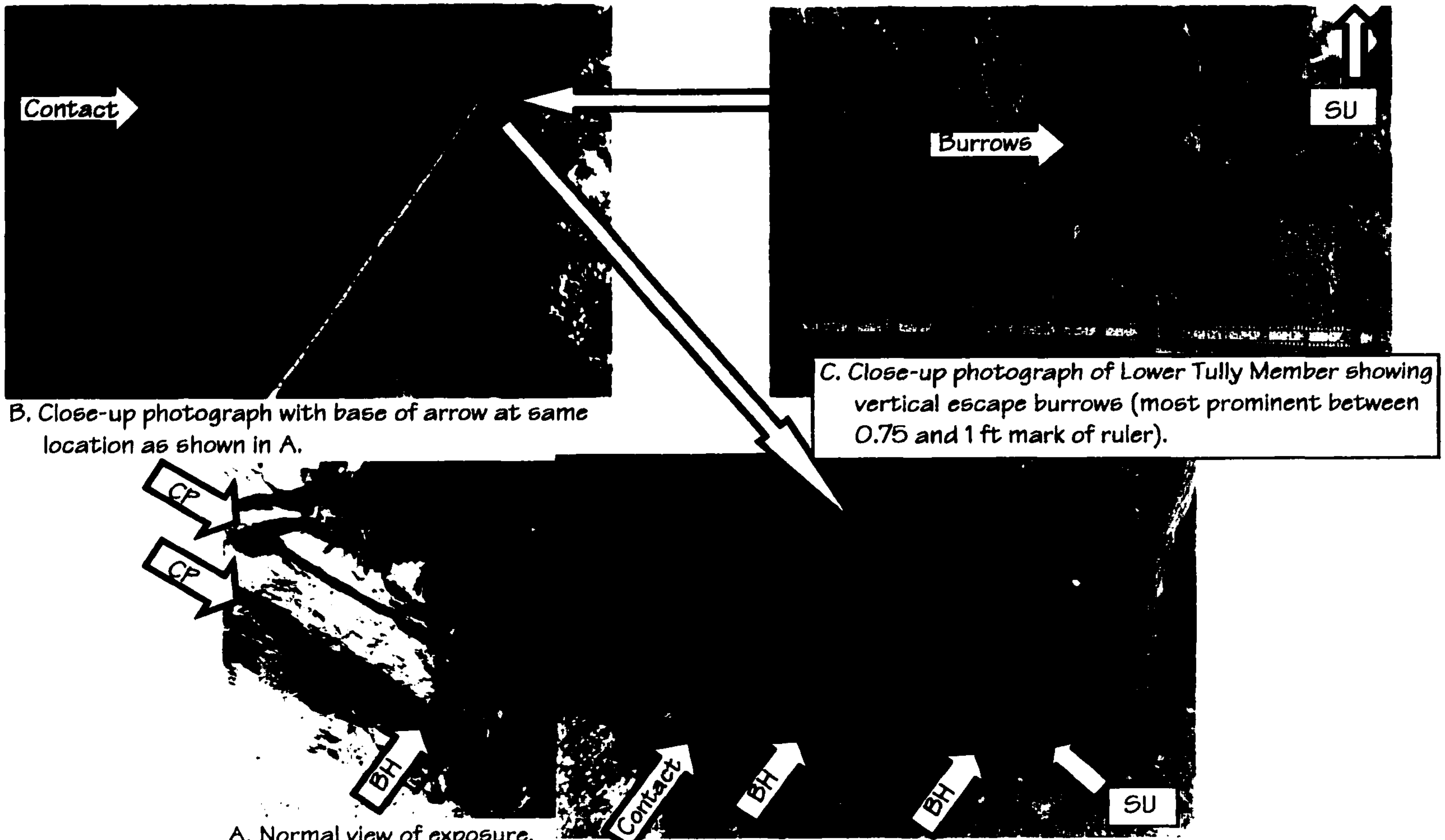
A. Field photograph. Stratigraphic up is to left; topographic up is to top of photograph. Note diagonal (from upper left to lower right corners), deformational cleavage. Last digit of index finger is 2.5 centimeters long.

Figure 18 - Examples of fossiliferous lag (Sample B-455) in Weissport Member of the Mahantango Formation at Bowmanstown, PA.

interval when compared to sampled Mahantango Formation beds lower in the section.

Tully Mesosequence (Lower Member) - The base of the Tully Mesosequence is here recognized as beds of brownish gray siltstone to silty mudstone (Figure 19). A distinct contact is present where fossil lags dominated by spiriferid brachiopods are replaced by less fossiliferous lags containing rhynchonellid brachiopods. *Mucrospirifer*, abundantly present in the underlying Weissport, are distinctly absent in the overlying beds here recognized as representing the base of the Tully Mesosequence. Found within the basal fossiliferous lag are a few poorly preserved specimens of the 'Tully Zone' index fossil *Hypothyridina venustula*. This portion of the Tully Mesosequence (at the 142.5 meter interval of measured section on Figure 12) is approximately 7 meters lower in the section than recognized by Epstein et al. (1974) or illustrated by Heckel (1969 Figure 3). However, this interval is possibly equivalent to the 'Tully Shale' illustrated by Slattery (1995 Figure 3).

Tully Mesosequence (Upper Member) - A distinct hiatal lag of corals, brachiopods and trilobites is present at the 149 meter interval of measured section (Figure 12). This shaly mudstone bed and approximately two meters of similar, less fossiliferous, overlying beds are partly calcareous in contrast to adjacent beds (see summary table of processing



B. Close-up photograph with base of arrow at same location as shown in A.

C. Close-up photograph of Lower Tully Member showing vertical escape burrows (most prominent between 0.75 and 1 ft mark of ruler).

A. Normal view of exposure.

Figure 19 - Contact (C) of Uppermost Mahantango Formation and Tully Mesosequence at Bowmanstown, PA. SU-Stratigraphic Up; BH-Bedding Horizon; CP - Cleavage Plane. Six-foot ruler at center by contact.

techniques in Appendix A). Based on their calcareous nature and fossil content, these beds were referred to as the "Tully fossil Zone (or Member)" by Epstein et al. (1974). This is also the base of the Upper Tully Member as shown by Heckel (1969 Figure 3). As noted here and by Epstein et al. (1974), overlying these beds are another twelve meters of "Hamilton-like" silty shale and mudstone with occasional "Hamilton" fossils. Based on their stratigraphic position beneath the dark gray to black shale of the Trimmers Rock Formation, these beds are included here as part of the Tully Mesosequence. Although poorly exposed, the top of this sequence is distinct from the overlying black shales of the Trimmers Rock Formation and appears to be hiatal.

Fossiliferous and Sampled Beds

Bowmanstown Shale Member - Possibly one of the most significant findings of this study is the recognition of several fossiliferous beds within the Mahantango fine-textured members that had not been observed or emphasized by Epstein et al. (1974) or Slattery (1993, 1995). Due to structural deformation at this locality (see Figures 13, 14, 17 and 18), these beds are not readily apparent and the fossils themselves are, at times, difficult to identify. Sample B-1.0' (not to be confused with B-1) was collected at the lower foot of the measured section (Figure 12) and contained, sparse fossils (nuculoid pelecypods). In contrast, the other sampled beds from the Bowmanstown Shale Member (B-80', B-98', B-178' and B-2) consist of discontinuous to continuous fossiliferous lags (Figure 13). Pelecypods (Figure 20) predominate in the lower beds (B-80' and B-98') and include *Carydium bellistriatum*, *Nuculoidea* spp., and *Paracyclas* sp. Brachiopods (Figure 13) include *Nucleospira concinna*, *Spinatrypa spinosa*, *Emanuella* sp. and "*Leiorhynchus*" spp. (mostly *Camarotechia mesacostalis*). Sampled horizon B-98' also contained a well-preserved specimen of the colonial rugose coral *Pleurodictyum* with apparent symbiotic gastropods (Figure 21). The uppermost part of the Bowmanstown Shale Member, immediately below the Nis Hollow, is dominated by brachiopods and pelmatozoans (Figures 13 and 15) in contrast to mollusks.

Nis Hollow Member - Sample B-1 is from the base of the Nis Hollow Member. It does not contain noticeable fossils. As previously noted, the uppermost Nis Hollow Member (sample location of B-3 and B-244-45') has large brachiopods (Figure 16) including *Mediospirifer* and smaller *Allanella* up to five centimeters in size. Immediately above the Nis Hollow Member, sample B-2 from the base of the Weissport Member also contains noticeable fossils, mainly small ambocoelid brachiopods.

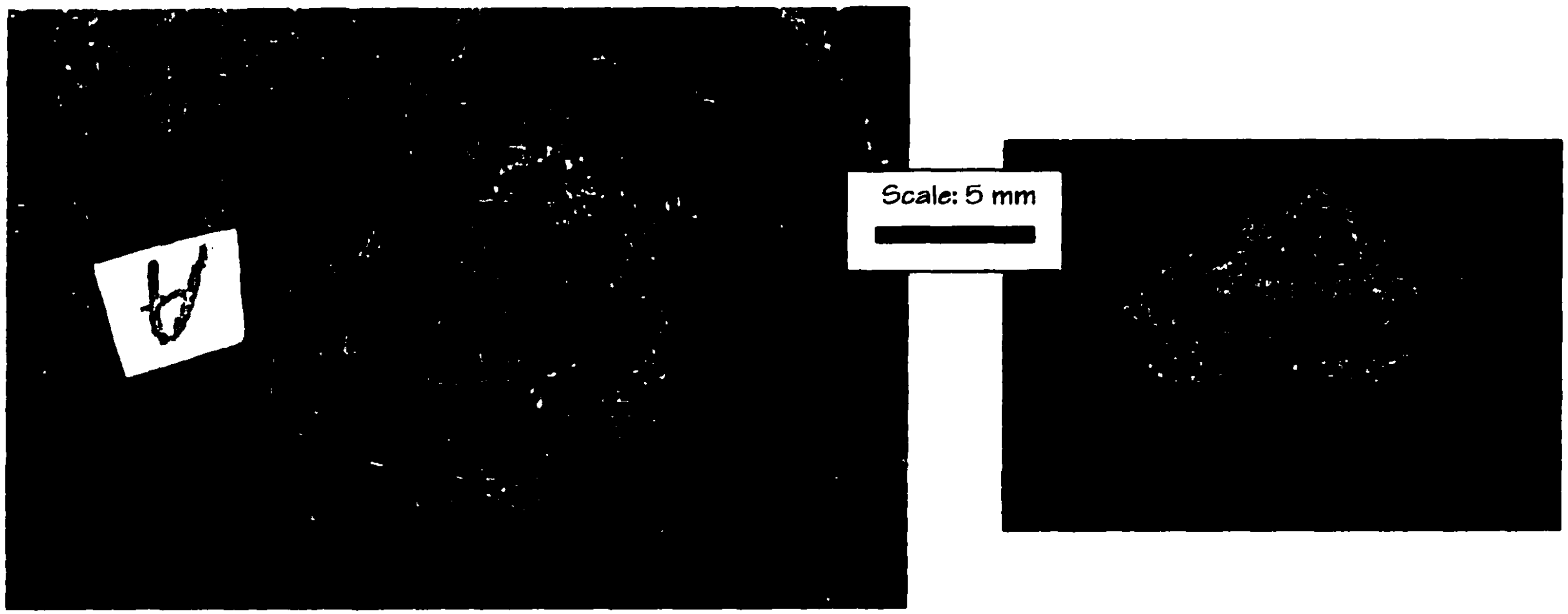
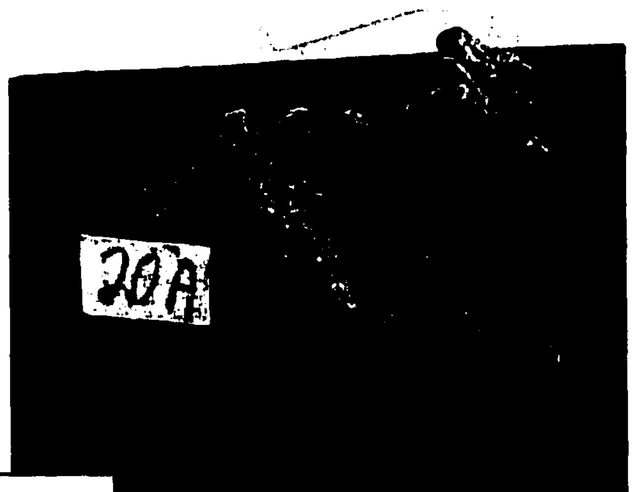


Figure 20 - External mold (A) and cast (B) of *Nuculoidea* from sample horizon B-80 at Bowmanstown, PA.

A. Arrow points to gastropod associated with polyps.



Scale: 5 mm

B. Side view of polyps.

C. Interior view showing apparent spherical nature of colony.

Figure 21 - Specimen of *Pleurodictyum* from the Bowmanstown Shale Member (sampled horizon B-98) at Bowmanstown, PA.

Weissport Member - Diminutive specimens of ambocoelid brachiopods are present in the lower part of Weissport Member at Bowmanstown. Other fossils observed just before this unit becomes covered include the pelecypod *Grammysoidea* and the straight nautiloid *Spyroceras* (Figure 22). However, these specimens were not found in what could be called distinct fossiliferous beds. Unfortunately, a potentially critical portion of section at Bowmanstown is covered (89 to 123 meter of measured interval of Figure 12) which at a nearby section in North Weissport, Pennsylvania (Locality "4" of Figure 1) yields abundant lags of rhynchonellid (formerly referred to as "*Leioryhnchus*") brachiopods (Figure 23).

A fossiliferous lag at Sample location B-411' contains rhynchonellid brachiopods (Figure 17) and might be equivalent to the upper portion of better exposed beds at North Weissport, Pennsylvania. A second fossiliferous lag, present at B-455' within the Weissport Member, contains spiriferid brachiopods (Figure 18). Additional fossiliferous lags with common to abundant specimens of *Mucrospirifer* are present up to the overlying contact with the Tully Mesosequence.

Tully Mesosequence Beds - The 'Tully Zone' brachiopod *Hypothyridina venustula* is present at the 142.5 meter interval (Figure 12). Also present within the basalmost bed are nearly foot-long, vertical structures approximately

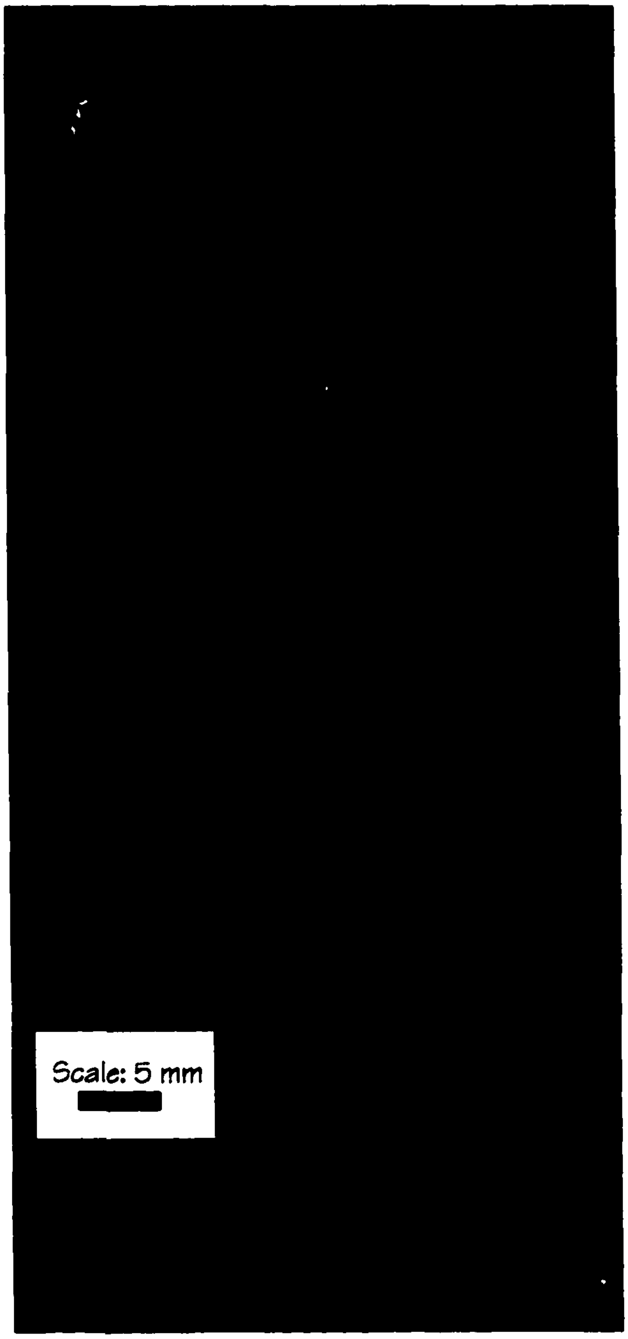


Figure 22 - Straight cephalopod, Spyroceras from the Weissport Member at 91 meter interval of measured section at Bowmanstown, PA.

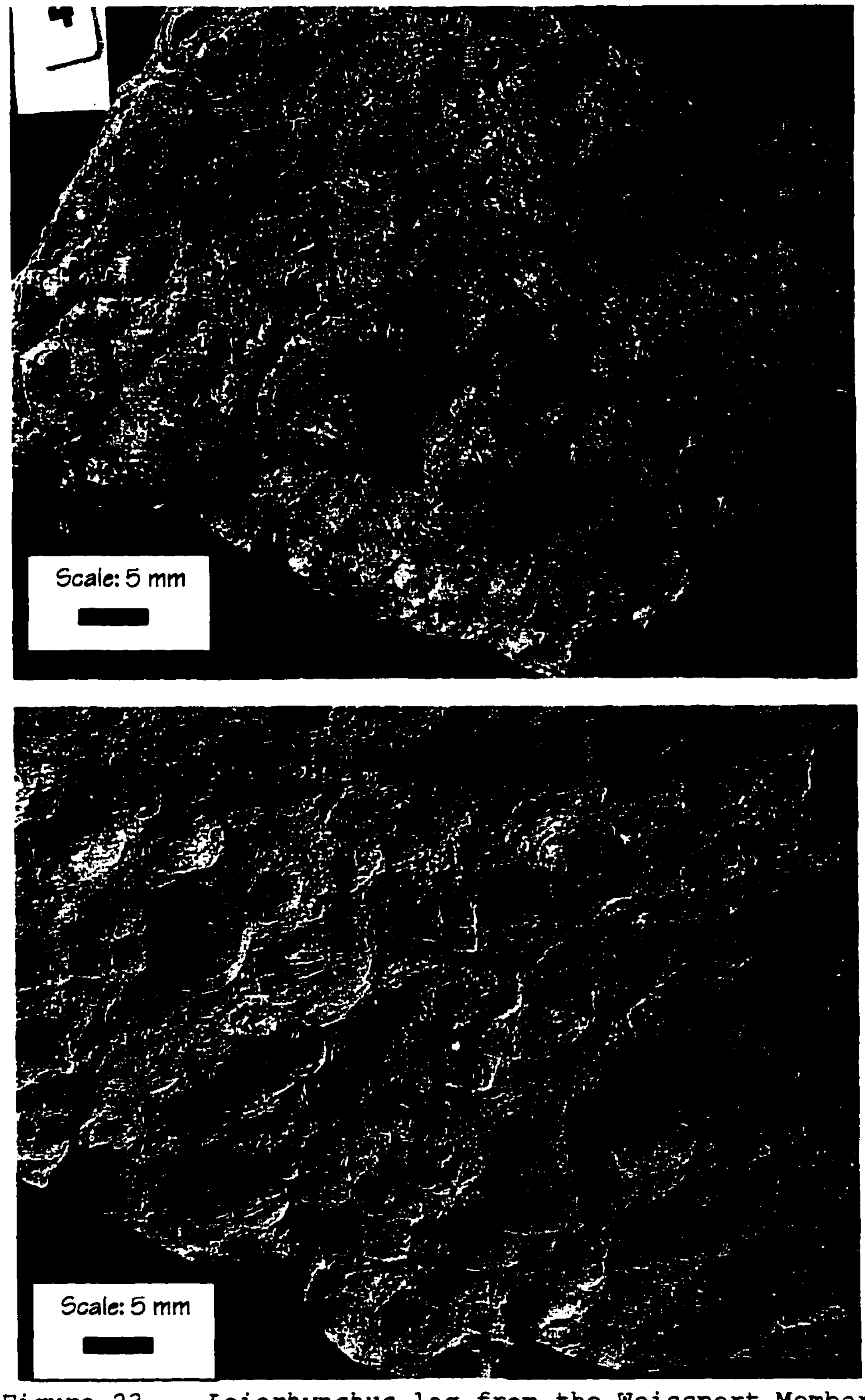


Figure 23 - *Leiorhynchus* lag from the Weissport Member of the upper Mahantango Formation at North Weissport, PA.

one centimeter wide that appear to be burrows. The Lower Tully Member basically becomes non-fossiliferous about a half meter above its contact with the Mahantango Formation. The recognition of these beds extends the Tully Mesosequence lower within the Bowmanstown section than previously suggested by either Heckel (1969, 1973) or Epstein et al. (1974). A fauna consisting of coral, trilobites, and brachiopods is present at sampled horizon B-490'. Based on these fossils, hiatal base and stratigraphic position, this bed represents the base of the Upper Tully Member.

Comparison to Other Studies - From oldest to youngest, the stratigraphic units occurring here are: the Bowmanstown Shale Member, the Nis Hollow Member, and the Weissport Member, all of the Mahantango Formation, the Tully Mesosequence and the Trimmers Rock Formation (Figure 24). The names Bowmanstown Shale and Weissport Members have not been previously used at this section. The Bowmanstown Member is newly proposed to recognize a previously unnamed interval above the 'Centerfield Fossil Zone' of Epstein et al. (1974) and below the Nis Hollow Member. The Weissport Member has been previously used by Stevenson and Skinner (1949) at North Weissport (Locality 4 of Figure 1). The other names of units recognized here (Figure 24) concur with Heckel (1969, 1973), Epstein et al. (1974) and Slattery (1993, 1995). The studied portion of the

REFERENCE:	Heckel (1969, 1973)	Epstein et al. (1974)	Slattery (1993, 1995)	This Study
UNITS RECOGNIZED	Harrell Fm. Burket Shale Member	Trimmers Rock Fm.	(Not Discussed)	Trimmers Rock Fm.
	Hamilton Group: Tully Fm. Upper Member	Hamilton Group: Mahantango Fm.: Tully fossil Zone	Hamilton Group: Black Shale (?) of Tully Member (Fm.)	Hamilton Group: Tully Mesosequence Upper Member
	Lower Member?		- - ? - - ? - - ? - - ? - -	Lower Member
	Mahantango Fm. (Undifferentiated)	Unnamed Fine-textured Member (Inferred)	Mahantango Fm. Unnamed Fine-textured Member (Inferred)	Mahantango Fm. Weissport Member
	(Lower part of section not reviewed)	Nis Hollow Member	Nis Hollow Member	Nis Hollow Member
		Unnamed Fine-textured Member (Inferred)	Unnamed Fine-textured Member (Inferred)	Bowmanstown Shale Memb.
		Centerfield and Additional fossil Zones	Centerfield Member	Centerfield Member (Not Inspected)
		Marcellus Fm.	Marcellus Fm.	Marcellus Fm. (Not Inspected)

Legend:

═ Group Boundary

— Formation Boundary

- - Member Boundary

FIGURE 24 - SUMMARY OF STRATIGRAPHIC UNITS RECOGNIZED AT BOWMANSTOWN, PA

Mahantango Formation can easily be subdivided at this section by the coarse-textured Nis Hollow Member. In addition, this section has Tully Mesosequence beds that are divisible into Lower and Upper Members (Heckel 1969, 1973).

Prior to Slattery (1993, 1995), the Bowmanstown section was studied by Heckel (1969, 1973) and Epstein et al. (1974). In general, these studies recognize the units in this area to be poorly fossiliferous except for some beds representing the Tully Mesosequence (sample horizon B-490') and the uppermost part of the Nis Hollow Member (sample horizon B-244-45'). However, after thorough searching of this section, I was able to locate numerous additional continuous and discontinuous, macrofossil-bearing lags within both of the unnamed fine-textured members of the Mahantango Fm.

The Bowmanstown Shale Member is estimated to be approximately 500 feet thick based on mapping information presented by Epstein et al. (1974) that shows the location of the adjacent Nis Hollow and Centerfield Members. At a section measured by W. D. Sevon in Weissport, Pa (Epstein et al 1974, 406-407), the Bowmanstown Shale Member is approximately 420 feet thick. The Bowmanstown Shale Member consists predominantly of medium to dark gray shales, claystone and siltstone. Slattery (1993, 1995) measured approximately 40 meters of this unit showing it all to represent a similar facies association. However, as indicated in Figure 14 several subtle differences are present within the uppermost part of this unit. This includes a slightly coarser texture, more fossils and distinct sedimentary structures in the form of flow rolls. Due to the structural deformation present at the Bowmanstown locality, these features are difficult to recognize. The nearly vertical bedding planes of the Bowmanstown Shale Member are much less distinct than the more prominent nearly horizontal cleavage planes. Fossils in this and other finer textured units at this section are typically leached so that only molds and casts remain. Fossils are also structurally distorted along the direction of cleavage (Figure 13). This distortion complicated macrofossil identification of many specimens.

The unit referred to here as the Weissport Member would be recognized as typical fine-textured beds of the Mahantango Formation with little debate. However, Epstein et al. (1974) noted additional "pre-Tully" Mahantango Formation that would extend the upper boundary of this unit to their "Tully fossil Zone" (sample horizon B-490'). As already noted, the base of the Tully Mesosequence is here recognized by a fossiliferous lag at the 142.5 meter of section measured based on the 'Tully Zone' brachiopod *Hypothyridina venustula*. Heckel (1969) did not discuss the Weissport Member at Bowmanstown, but did note this unit as being equivalent to the 'Leiorhynchus'-bearing beds of the

New Lisbon Member in new York State.

As noted here and by Epstein et al. (1974, 142), the upper ten meters (from approximately the 142.5 to 149 meter of section measured on Figure 12) of the Lower Member of the Tully Mesosequence consists of "thin, very coarse textured siltstone beds up to 6 inches thick sometimes occur 10 to 30 feet below the base of the (Tully fossil) zone". Not emphasized by Epstein et al. (1974) is that these siltstones are interstratified with shales. These alternating shales and siltstones show a "cyclic pattern" that is also observed in the Lower Tully Mesosequence at the Lock Haven section.

These observations only add to the debate of previous workers (in particular Epstein et al. 1974, Heckel 1969, 1973, Slattery 1995) regarding the Bowmanstown section. These authors reach no consensus as to the thickness and the contacts of the Tully 'Formation'. For example, Epstein et al. (1974) classified the Tully as a "fossil zone" member of the Mahantango Formation the top of which for mapping purposes represented the top of the Hamilton Group. However, above the top of the Tully Member, they (p 142) noted an additional "45 feet of shales identical to those of the Mahantango Formation" that "grade upward into material mapped as the Trimmers Rock Formation". More difficult to decipher is Slattery (1995 Fig. 3) who illustrates a "Black Shales of Tully Member" to be present at the Bowmanstown section. However, the exact location of this and other stratigraphic boundaries, such as the Nis Hollow Member, are not clearly shown (Slattery 1995, Fig. 3).

Heckel (1969, Fig. 2) recognized the Tully as 30 feet (9.1 meters) thick, although in the text he referred to the entire unit as 40 feet thick. In contrast, Epstein et al. (1974, 142) stated the Tully fossil zone to be 64 feet thick. This thickness includes the approximately 40 feet of Mahantango-like sedimentary rocks between the Trimmers Rock Formation the "Tully Fossil Zone" (Epstein et al. 1974). All of the Tully Mesosequence as recognized by Epstein et al. (1974) is equivalent to the Upper Tully Member as recognized by this study and by Heckel (1969, 1973).

The Trimmers Rock Formation, a black fissile shale, is referred to as the Burket Shale by Heckel (1969). Heckel (1969) stated the upper Tully contact to be gradational with this overlying darker shale. In contrast, both this study and that of Epstein et al. (1974) recognized a distinctive contact between gray silty shales and dark gray shales.

In summary, Heckel (1969) recognized the "Tully detrital equivalent", what is here referred to as the Tully Mesosequence, to be present at Bowmanstown rather than the lithologic "Tully Limestone". The predominant lithology noted by Heckel (1969) was "hard silty shale" where the carbonate content of these rocks was over 90 percent non-reactive to acid. Instead of lithology, the key basis for recognizing the Tully Mesosequence at Bowmanstown by Heckel (1969, 1973) is the fauna encountered in these rocks. The observations of this study concur with Heckel's assessment. However, I extend the Tully to include more distinct (hiatal?) upper and lower boundaries whereby the stratigraphic interval representing the Tully Mesosequence has a total thickness at Bowmanstown of approximately 20 meters as depicted on Figure 12. The basis for this lower boundary is the "Tully" fossil assemblage found at the 142.5 meter interval. The upper boundary is extended relative to Heckel's early observation based on boundary of the Trimmers Rock Formation.

Rockville Section

The Rockville section ("B" of Figure 1) is located along PA Routes 322 & 22 adjacent to the east side of the Susquehanna River (Figure 25 for detailed information). From oldest to youngest, the stratigraphic units exposed at this locality are: the Fisher Ridge, Montebello and Sherman Ridge Members of the Mahantango Formation of the Hamilton Group. Neither the overlying Tully or Harrell Formation are exposed at this section. A total of six whole rock

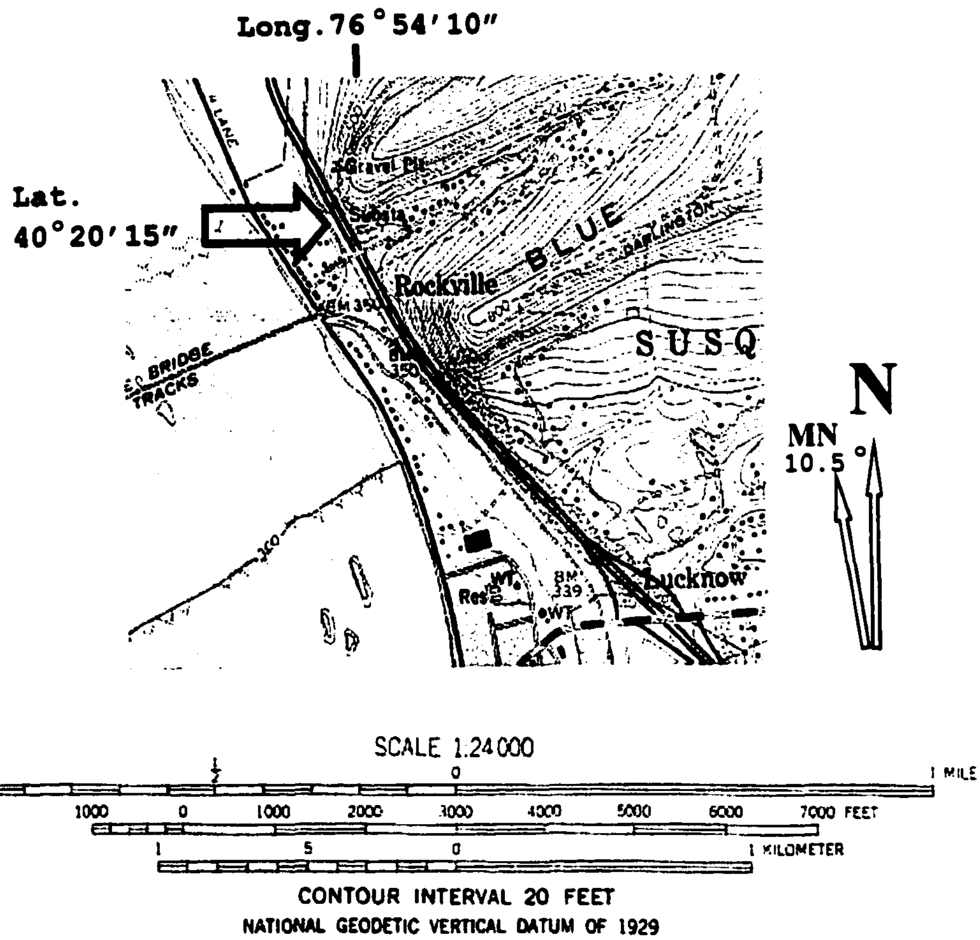


Figure 25 - Map showing location of Rockville, PA section. Source: USGS Harrisburg West, PA Quadrangle Map.

samples (labelled R-1 through R-6) were collected at stratigraphic locations shown on Figure 26.

Fisher Ridge Member - The measured section shown on Figure 26, starts with 16.8 meters recognized as the upper part of the Fisher Ridge Member. The sequence of rock in question consists predominantly of shale and siltstone beds. Distinctive, coarser sandy siltstone to silty sandstone of the Montebello Member overlie this interval of beds (Figure 26).

Montebello Member - Except for some of its lower portion, the Montebello Member is fairly well exposed and is approximately 183 meters (600 feet) thick at the Rockville locality. Typical for the Harrisburg area, the Montebello Member varies both in color and grain-size at the Rockville locality. The most distinguishable beds are the conglomeratic sandstones and conglomerates up to a meter thick. However, the most predominant beds consist of medium gray fine-textured sandstones (Figure 27). The sandstone beds are commonly cross-bedded and locally fossiliferous with thick-shelled brachiopods such as *Spinocyrtia* (Figure 28).

Sherman Ridge Member - A chamosite oolite (Figure 29 and sample location R-3 on Figure 26) is present at the base of the Sherman Ridge Member at Girty's Notch. For the interval approximately six meter(s) above R-3, is a calcareous, brachiopod-bearing fine sandy siltstone. The

ROCKVILLE SECTION: 0 to 80 FEET

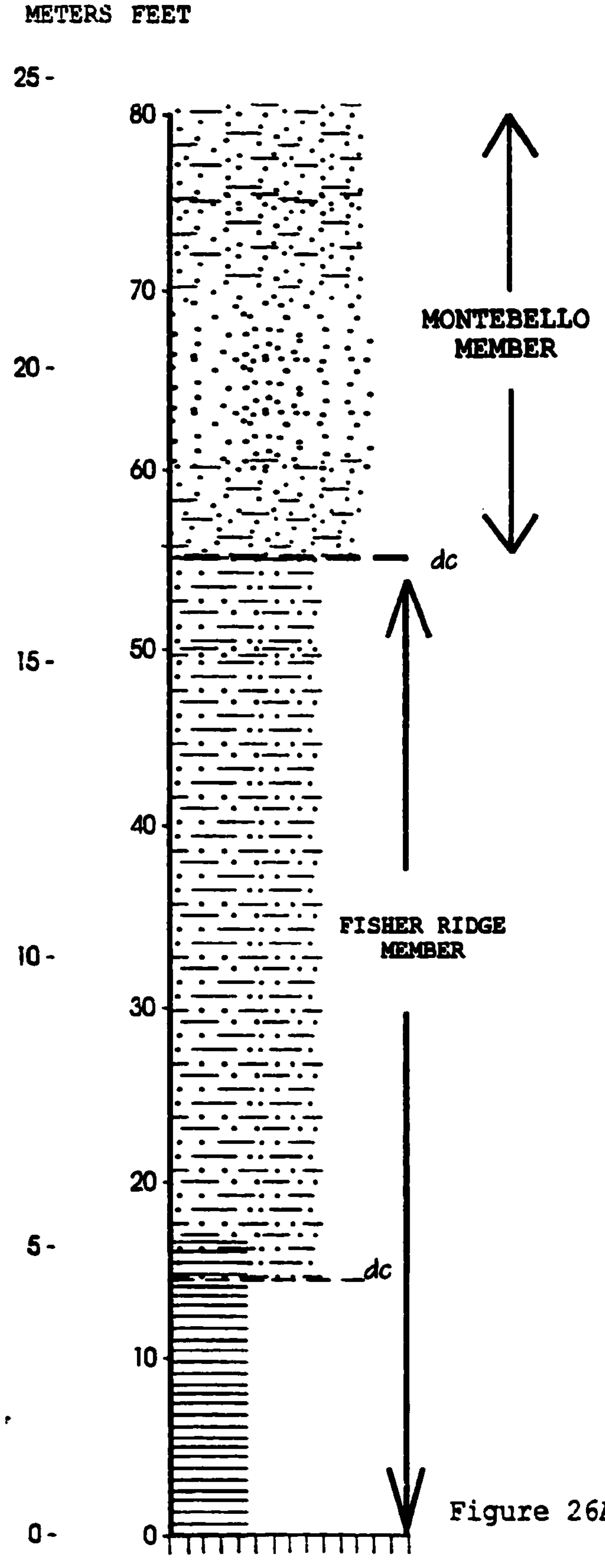


Figure 26A - Measured section at Rockville, PA.

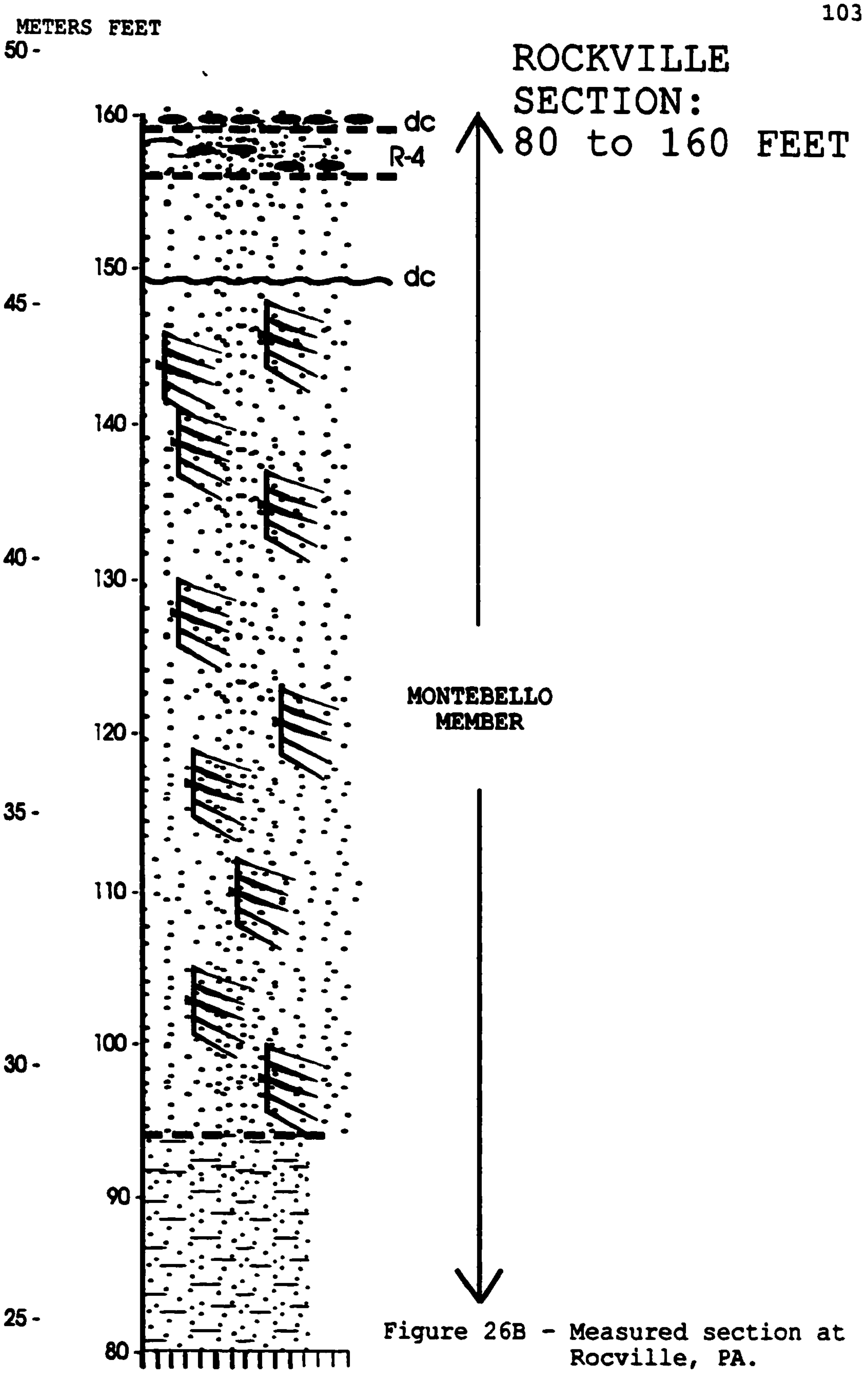


Figure 26B - Measured section at Rocville, PA.

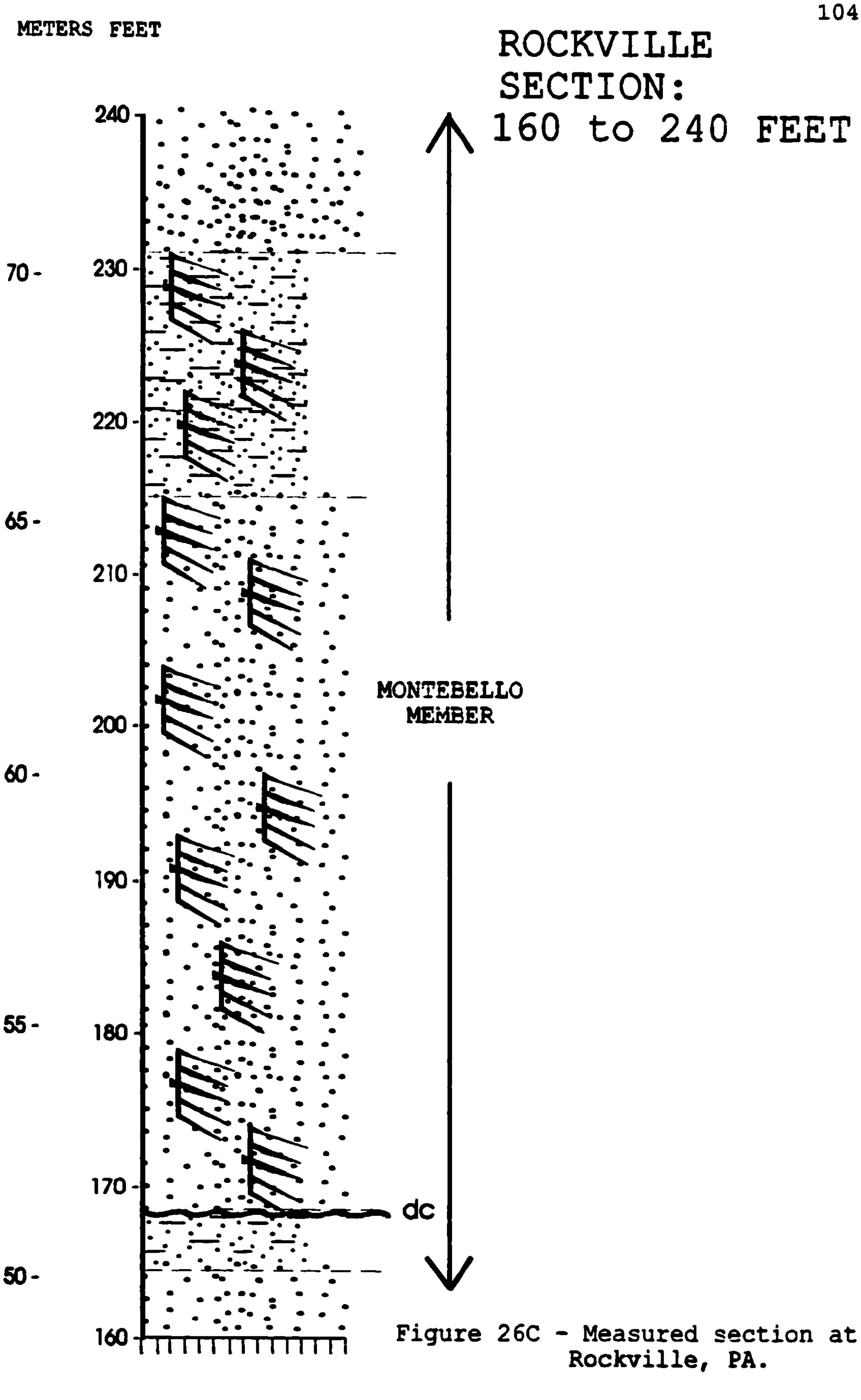


Figure 26C - Measured section at Rockville, PA.

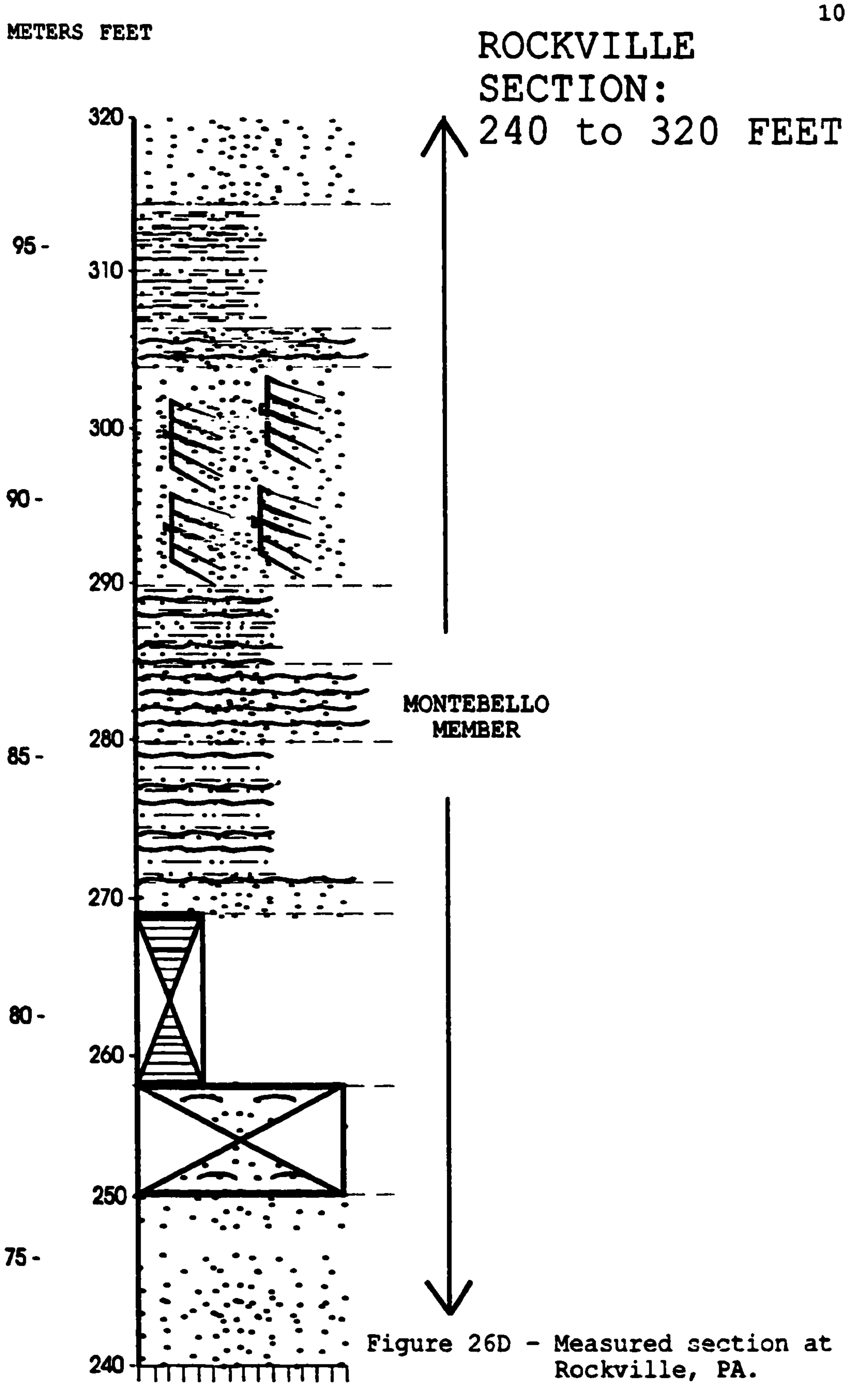


Figure 26D - Measured section at Rockville, PA.

ROCKVILLE SECTION: 320 to 400 FEET

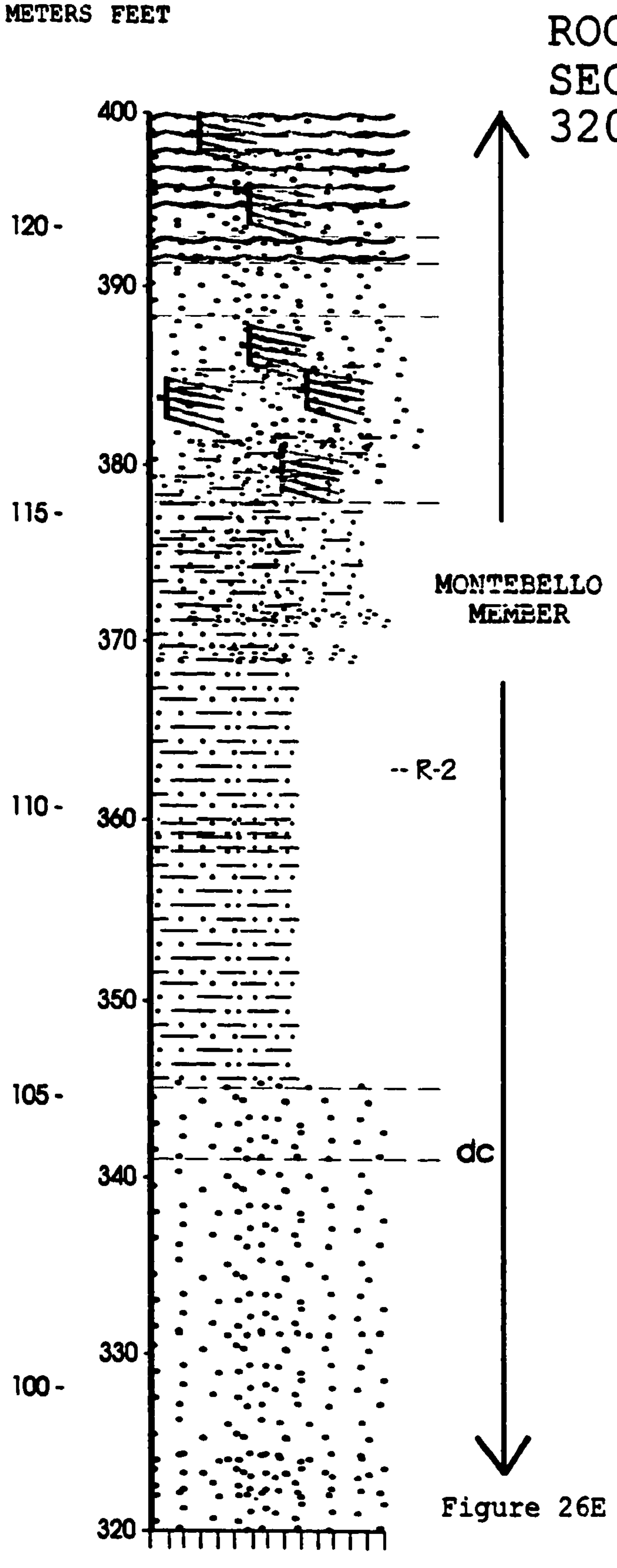


Figure 26E - Measured section at Rockville, PA.

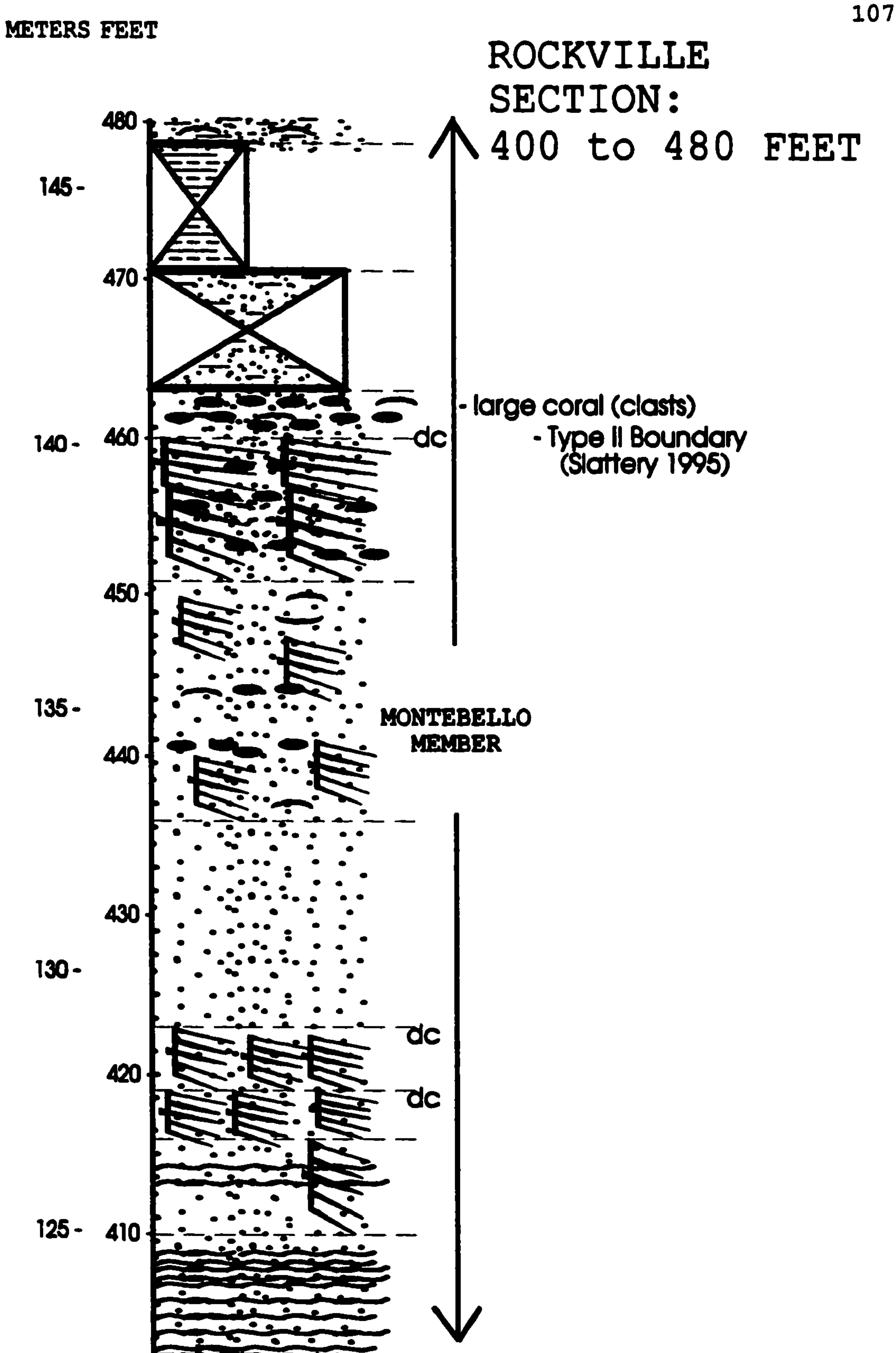


Figure 26F - Measured section at Rockville, PA.

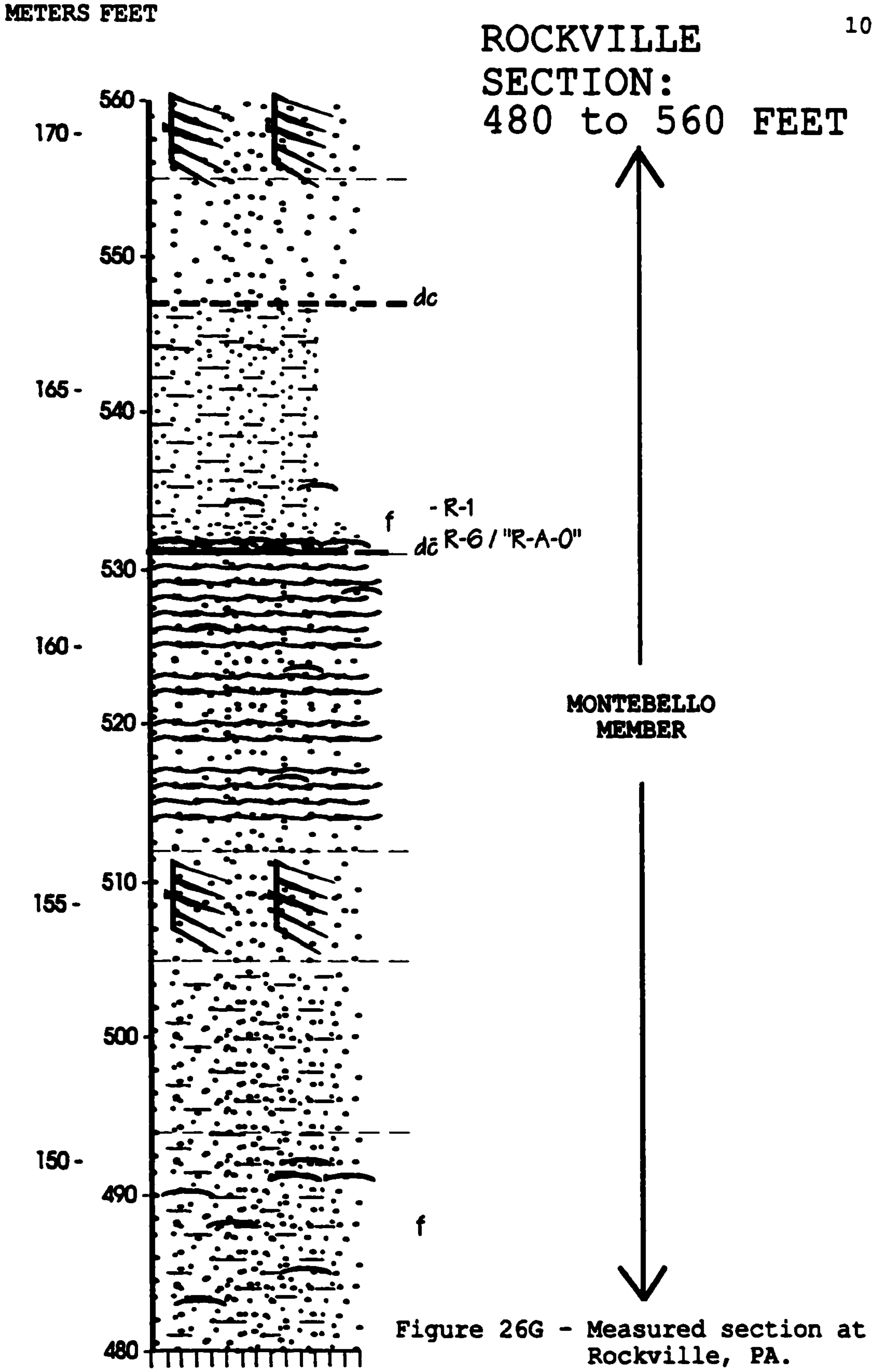


Figure 26G - Measured section at Rockville, PA.

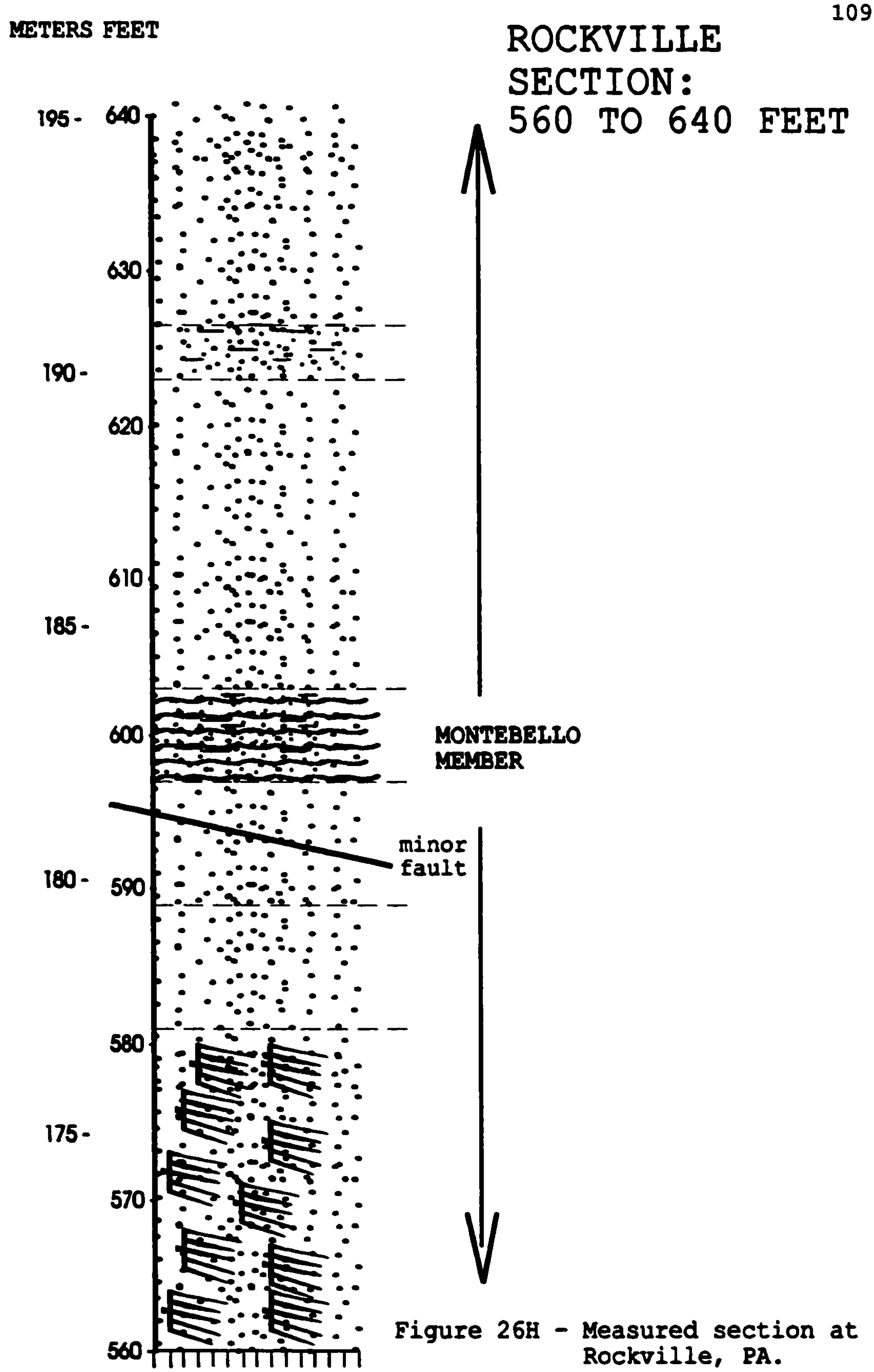


Figure 26H - Measured section at Rockville, PA.

ROCKVILLE SECTION: 640 to 720 FEET

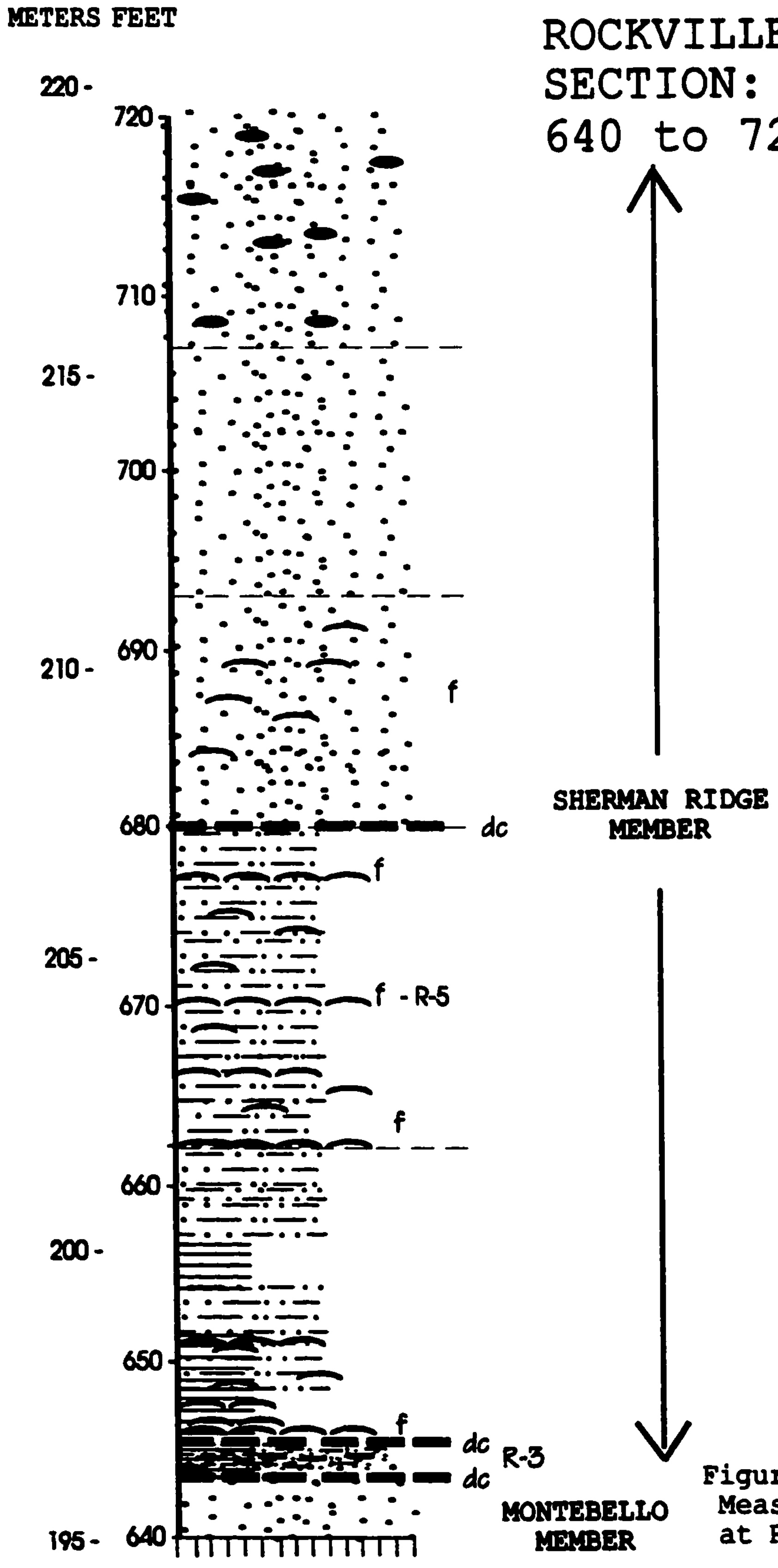


Figure 26I - Measured section at Rockville, PA.

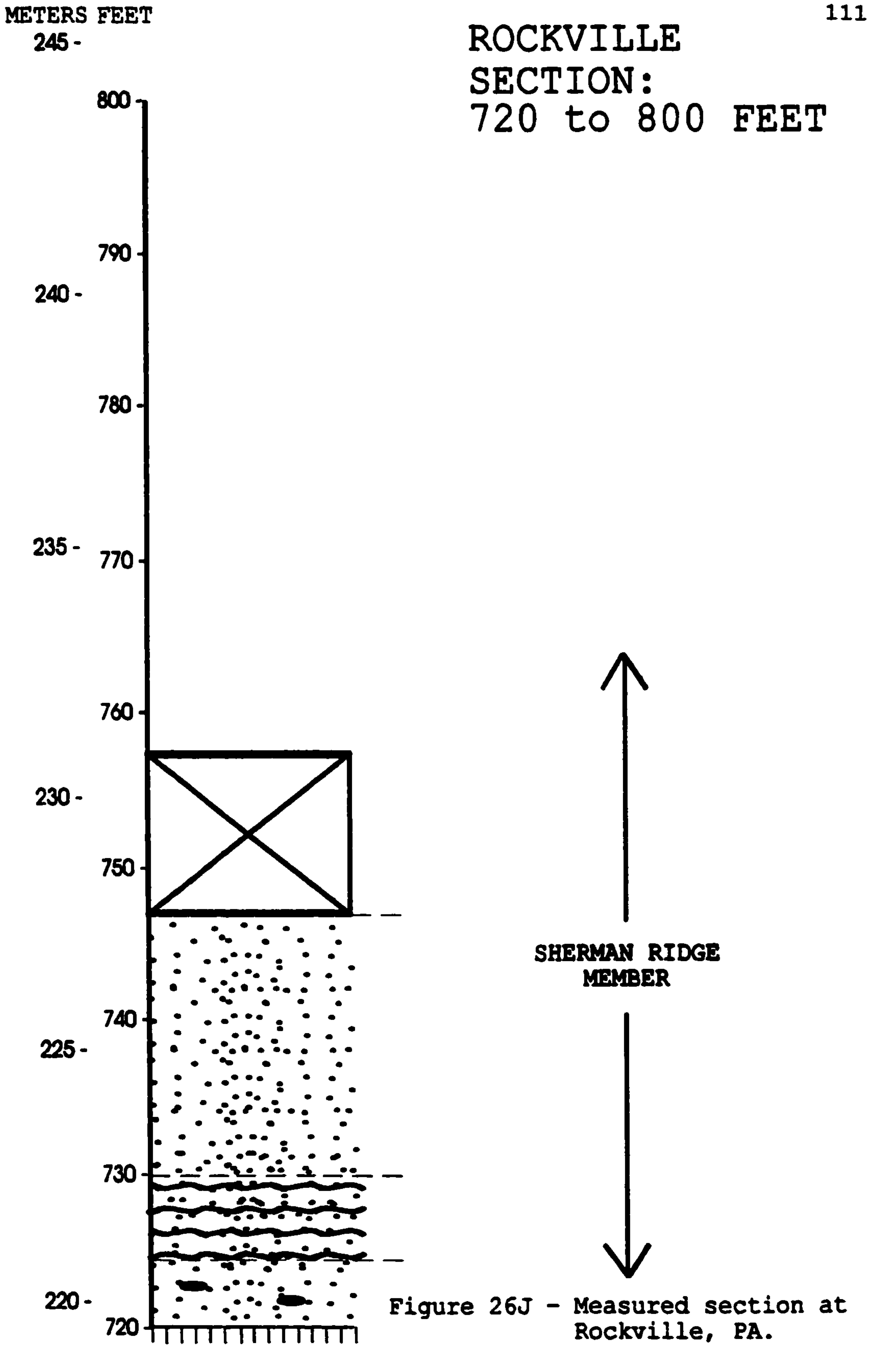


Figure 26J - Measured section at Rockville, PA.

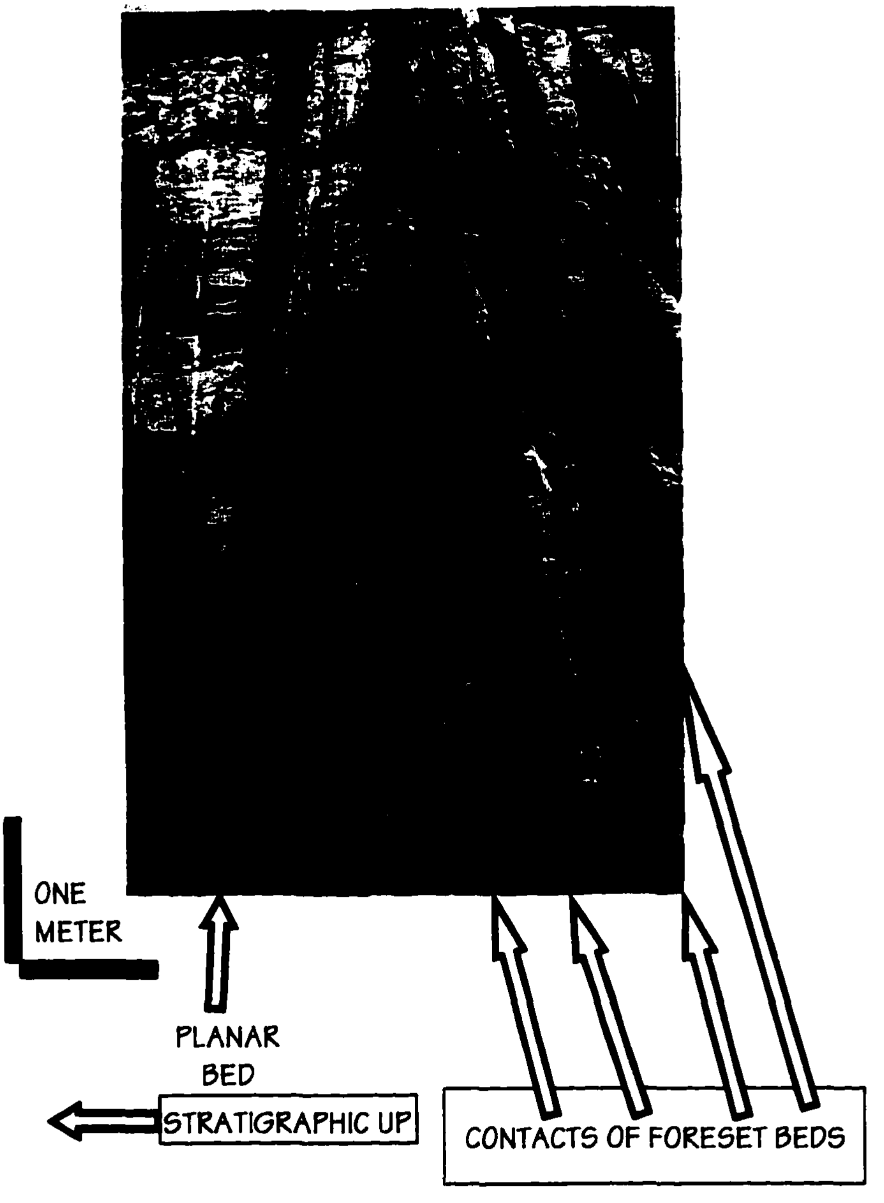


Figure 27 - Roadcut photograph of Rockville Section showing large cross-beds of lower Montebello Member.

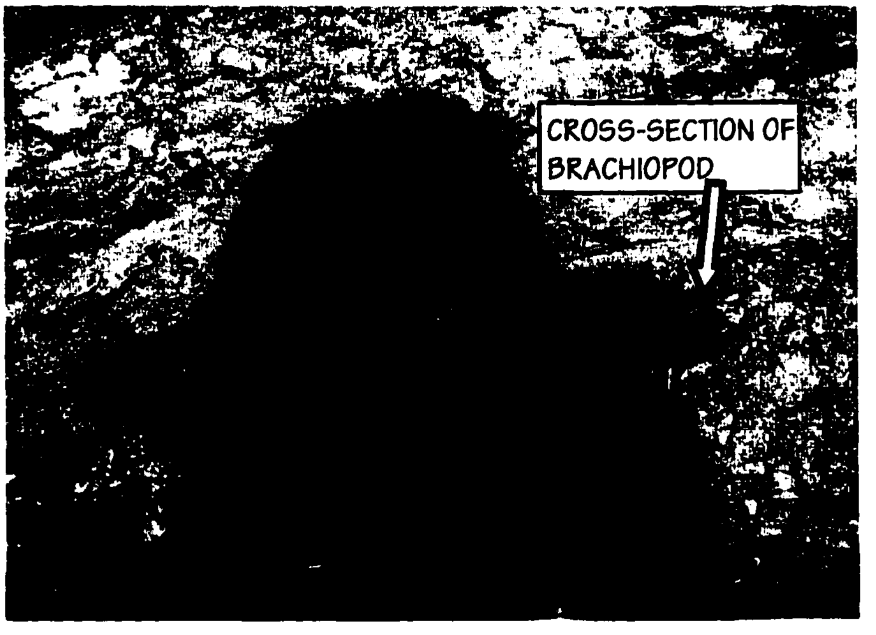
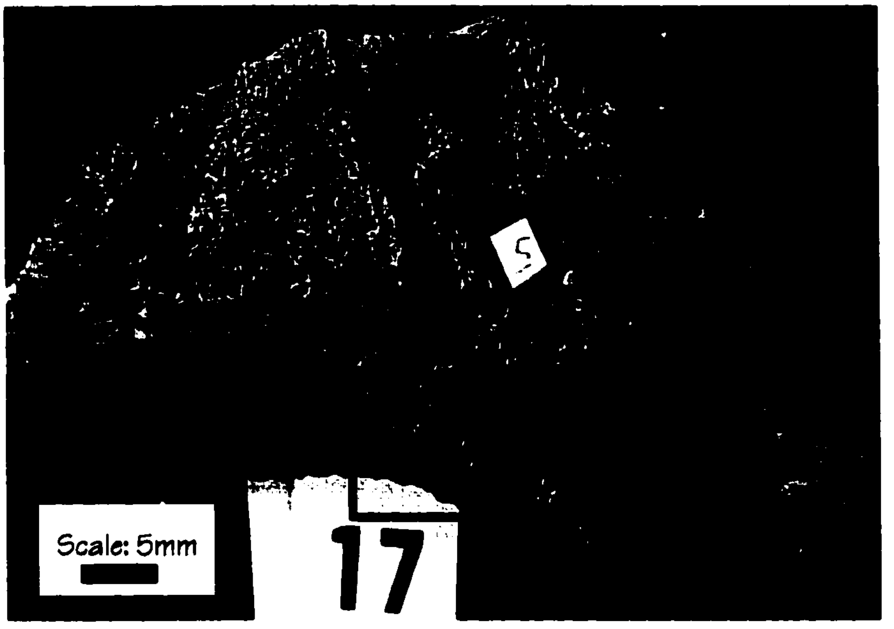
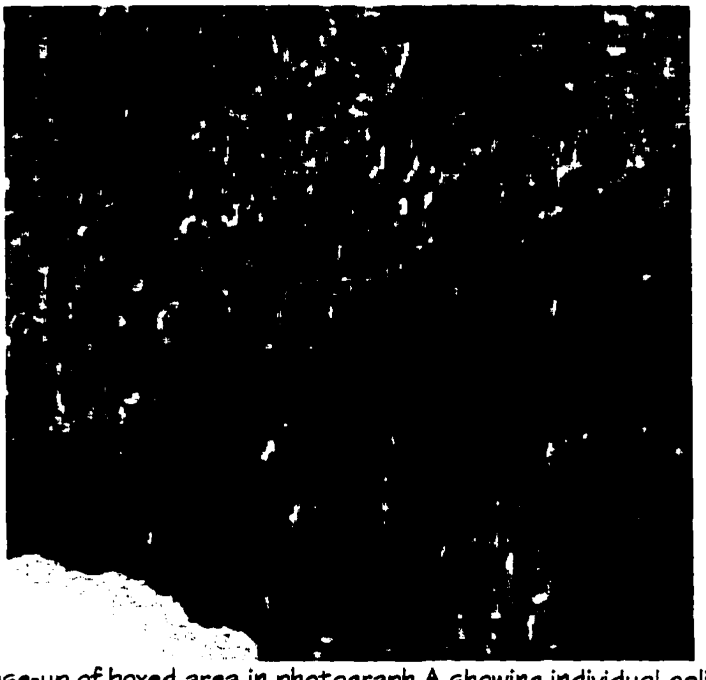


Figure 28 - Fossiliferous lag at sampled horizon
R-6/"R-A-O", Rockville, PA.
Chisel 18.5 cm long.



A - Typical hand specimen.



B. - Close-up of boxed area in photograph A showing individual oolites.

Figure 29 - Examples of chamosite oolite from base of Sherman Ridge Member, Rockville, PA (sampled horizon R-3).

unit becomes a less fossiliferous siltstone and silty fine sandstone higher up section. The upper portion of the Sherman Ridge Member is poorly exposed. Both the overlying Tully and Harrell Formation are not exposed at the section studied, but were both reported by Ellison (1965) in a nearby quarry.

Fossiliferous and Sampled Beds - In general, distinct fossiliferous beds are uncommon at the Rockville locality. Sparse articulated pelmatazoan columns are present in the fine-textured Fisher Ridge Member. As at Girty's Notch, the lower part of the Montebello Member contains cross-bedded sandstone and coarse siltstone beds with large brachiopod clasts such as *Spinocyrtia* (Figure 28). Large 'clasts' of *Favosites* corals were also observed within a conglomeratic sandstone at the 140 meter interval of measured section (Figure 26). Some exposed fossils have been weathered to the point where the calcite shell has been dissolved (Figure 28). Conodont bearing Sample R-4 (Figure 30) from the lower part of the Montebello Member contained some brachiopod clasts (see Figure 26 for retrieval intervals of each sample). In contrast, sample R-2, also from the lower part of this member, did not contain conodonts or many fossils. Sample R-1 is immediately above the uppermost brachiopod bed (sample R-6 of Figure 26) in the lower part of the Montebello Member. Sample R-1 is more silty and sparsely fossiliferous with

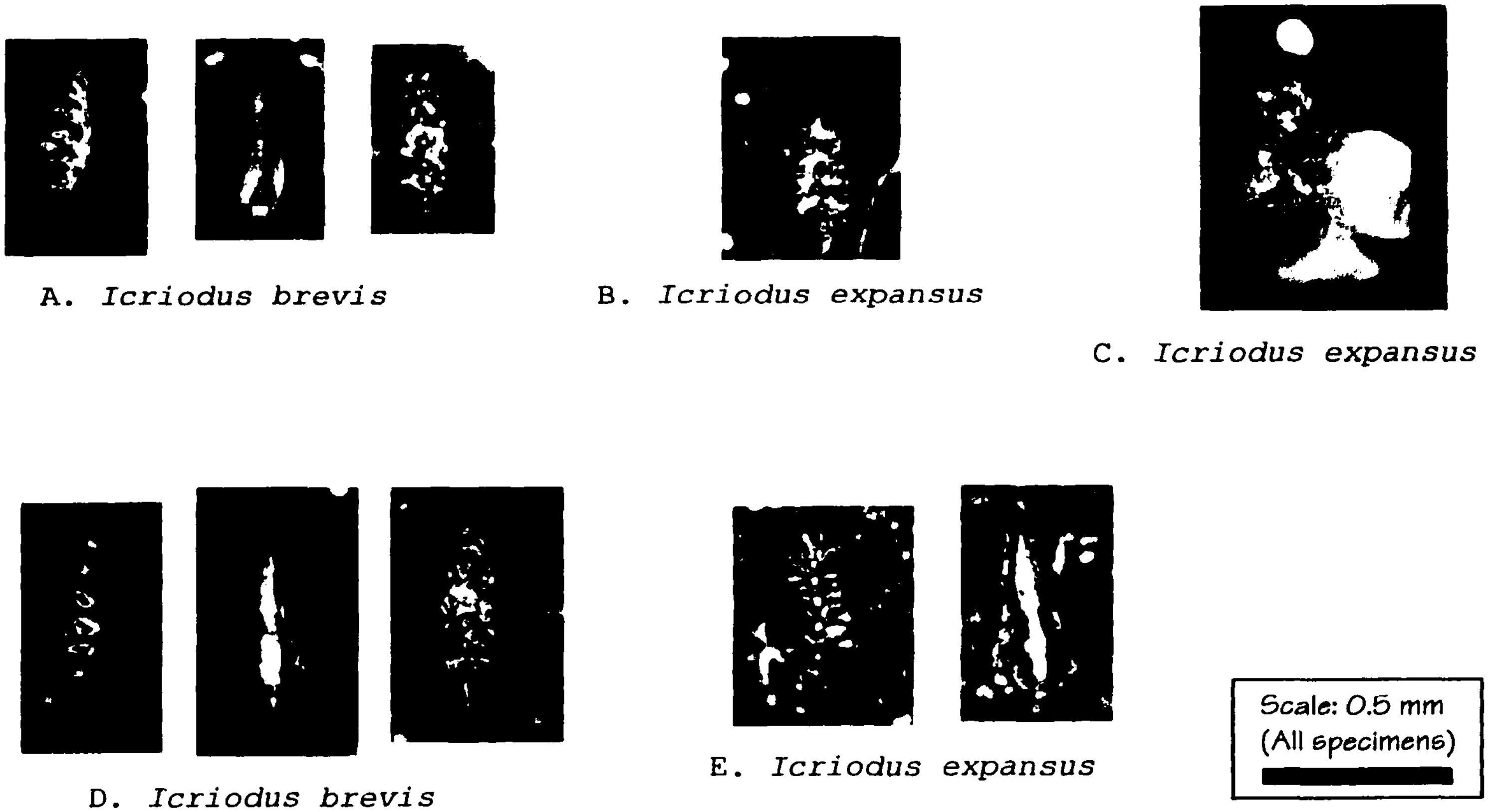
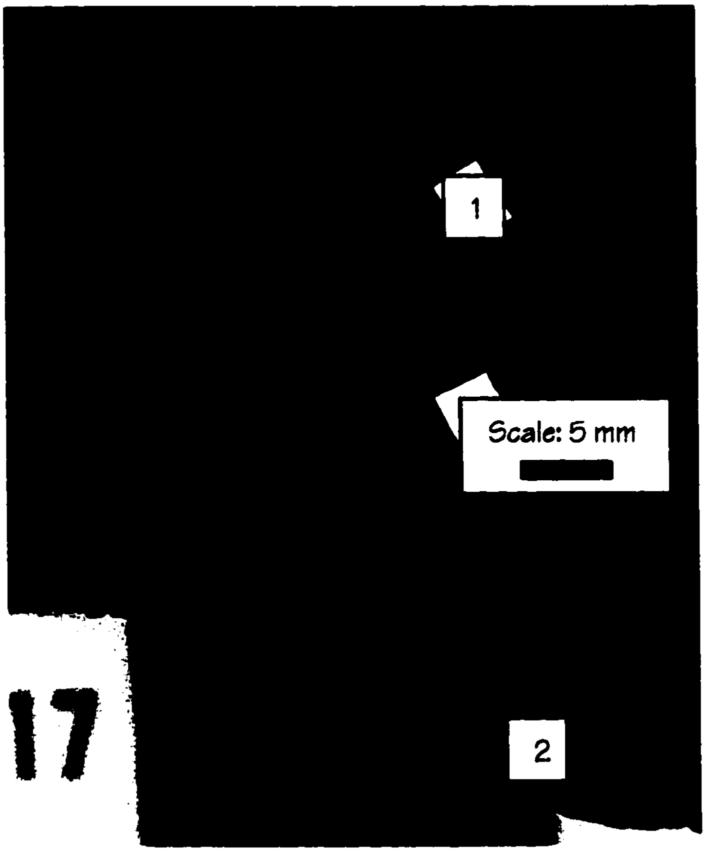


Figure 30 - Photographs of conodonts Sample R-4, Montebello Member at Rockville, PA section.

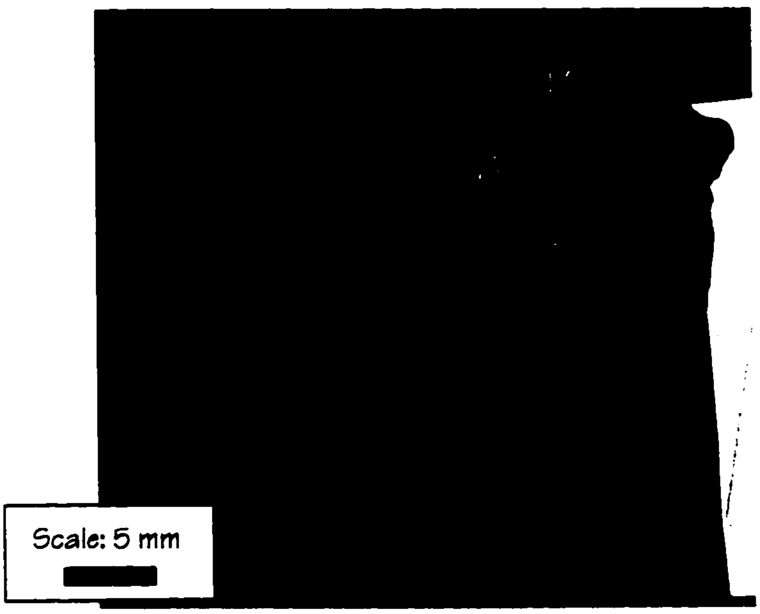
only a few fragments of bryozoans, but appears to be a part of the same brachiopod clast tempestite deposit of sample R-6. Sample R-3 is a chamosite oolite at the base of the Sherman Ridge Member. Sparse large macrofossils (Figure 31), such as *Mediospirifer*, *Spinocyrtia*, and *Megastrophia* are present. About five meters above sampled horizon R-3 is sampled location R-5 (Figure 26) containing small corals and brachiopods. This interval is one of the most fossiliferous parts of the section measured at Rockville.

Comparison to Other Studies - The stratigraphic units observed at Rockville are: the Fisher Ridge, Montebello, and Sherman Ridge Members of the Mahantango Formation (Figure 32). Other units recognized in the Rockville area are also presented on Figure 32. With the exception noted below, the recognized units basically concur with those noted by previous workers (Figure 32).

One question regarding the Rockville locality concerns the Fisher Ridge Member not being readily recognized by Faill et al. (1978). This is based on their uncertainty of the identity of a 39 meter thick dark-gray shale underlying the Montebello Member. The portion of section recognized in this study as the Fisher Ridge Member is presented by Faill et al. (1978) with contrary interpretations (Plate 1 versus p 14 of cited reference). Faill et al. (1978) recognized this interval as either the Fisher Ridge Member (p 14 interpretation) or Turkey Ridge Member (their Plate 1



B. - *Spinocytria* (1) and *Mediospirifer* (2).



A - *Megastrophia*

Figure 31 - Examples of fossils from base of Sherman Ridge Member, Rockville, PA (sample location R-3).

REFERENCE	Ellison (1965)	Faill et al. (1978)	Prave & Duke (1991 Figure 10)	Slattery (1993, 1995)	This Study
UNITS RECOGNIZED	Harrell Fm. Burket Member - - - - - - - - - - - Tully Memb.	Harrell Fm.	Burket Black Shale	(Not Discussed)	Harrell Fm.
	Hamilton Group: Mahantango Fm.: Upper Shale Memb. - - - - - - - - - - - Montebello Memb. - - - - - - - - - - - Lower Shale Member	Hamilton Group: Mahantango Fm.: Tully Memb. - - - - - - - - - - - Sherman Ridge Memb. Montebello Memb. - - - - - - - - - - - Fisher Ridge Member? - - - - - - - - - - - Dalmatia Member? - - - - - - - - - - - Turkey Ridge Member	Hamilton Group: (Tully Unit Not Discussed) Mahantango Fm.: Sherman Ridge Memb. - - - - - - - - - - - Montebello Memb. or Fisher Ridge Member - - - - - - - - - - - Dalmatia Member or Turkey Ridge Member	Hamilton Group: Tully Fm. Mahantango Fm.: Sherman Ridge Memb. - - - - - - - - - - - Montebello Memb. or? Fisher Ridge Member - - - - - - - - - - - Dalmatia Member or? Turkey Ridge Member	Hamilton Group: Tully Mesosequence (Inferred) Mahantango Fm.: Sherman Ridge Memb. - - - - - - - - - - - Montebello Memb. - - - - - - - - - - - Fisher Ridge Member - - - - - - - - - - - Dalmatia Member? - - - - - - - - - - - Turkey Ridge Member?
	Marcellus Fm.	Marcellus Fm.	Marcellus Black Shale	Marcellus Fm.	Marcellus Fm.

Legend:

═ Group Boundary
— Formation Boundary
- - Member Boundary

FIGURE 32 - SUMMARY OF STRATIGRAPHIC UNITS RECOGNIZED AT ROCKVILLE, PA

interpretation) at Rockville. Faill et al. (1978) recognized this dark gray shale to be equivalent to the Fisher Ridge Member on one page (p 14), but also showed it to be equivalent to the lower (shaly) part of the Dalmatia Member elsewhere (p 11; Plate 1) within their report.

I suspect the unusual thickness of the sandstone beds of the lower part of the Montebello Member at Rockville lead Faill et al. (1978) to these different interpretations. I recognized these beds as having the ability to thin out over very short distances (as best exemplified at the Girty's Notch section). However, a second interpretation would be of two sets of sandstone beds originally representing two different members being combined whereby the intercalated, fine-textured beds of the Fisher Ridge Member are not preserved. This discrepancy possibly explains the misinterpretation of this unit as the older Marcellus Formation by Slattery (1993) as summarized here on Figure 32. In this study, however, these fine-textured beds are recognized as the Fisher Ridge Member. Other correlations with regard to the other sections studied are discussed in Chapter Five.

Girty's Notch Section

The Girty's Notch section ("A" of Figure 1) is located approximately 1.5 miles northeast of Halifax, PA along

Routes 11 and 15 adjacent to the west side of the Susquehanna River (see Figure 33 for detail location information). After preliminary field reconnaissance and collection of samples in 1993, this locality became inaccessible due to road work expansion and was not revisited until 1998. The newly exposed outcrop shows significantly better exposure of sedimentary features not readily apparent in the earlier studies of Prave and Duke (1991) and Slattery (1993, 1995). In particular, are large-scale cross-beds channel features (Figure 34). A total of four rock samples (G-1, G-2, G-3, G-64) were collected at stratigraphic locations shown on Figure 35. The observed stratigraphic units from lowest to highest exposed at Girty's Notch are: the Fisher Ridge, Montebello, and Sherman Ridge Members of the Mahantango Formation, and the Harrell Formation.

Fisher Ridge Member. At the Girty's Notch section the Fisher Ridge Member is predominantly a green gray (olive) colored siltstone to claystone. The upper 14 meters of this member measured for this study (0 to 14 meter interval of Figure 35) is not very fossiliferous. Exceptions to this are two similar fossiliferous lags approximately a half foot (15 cm) thick that have a coarser, silty texture than adjacent mudstone beds. The upper contact of the Fisher Ridge Member with the overlying Montebello Member is abrupt and appears hiatal.

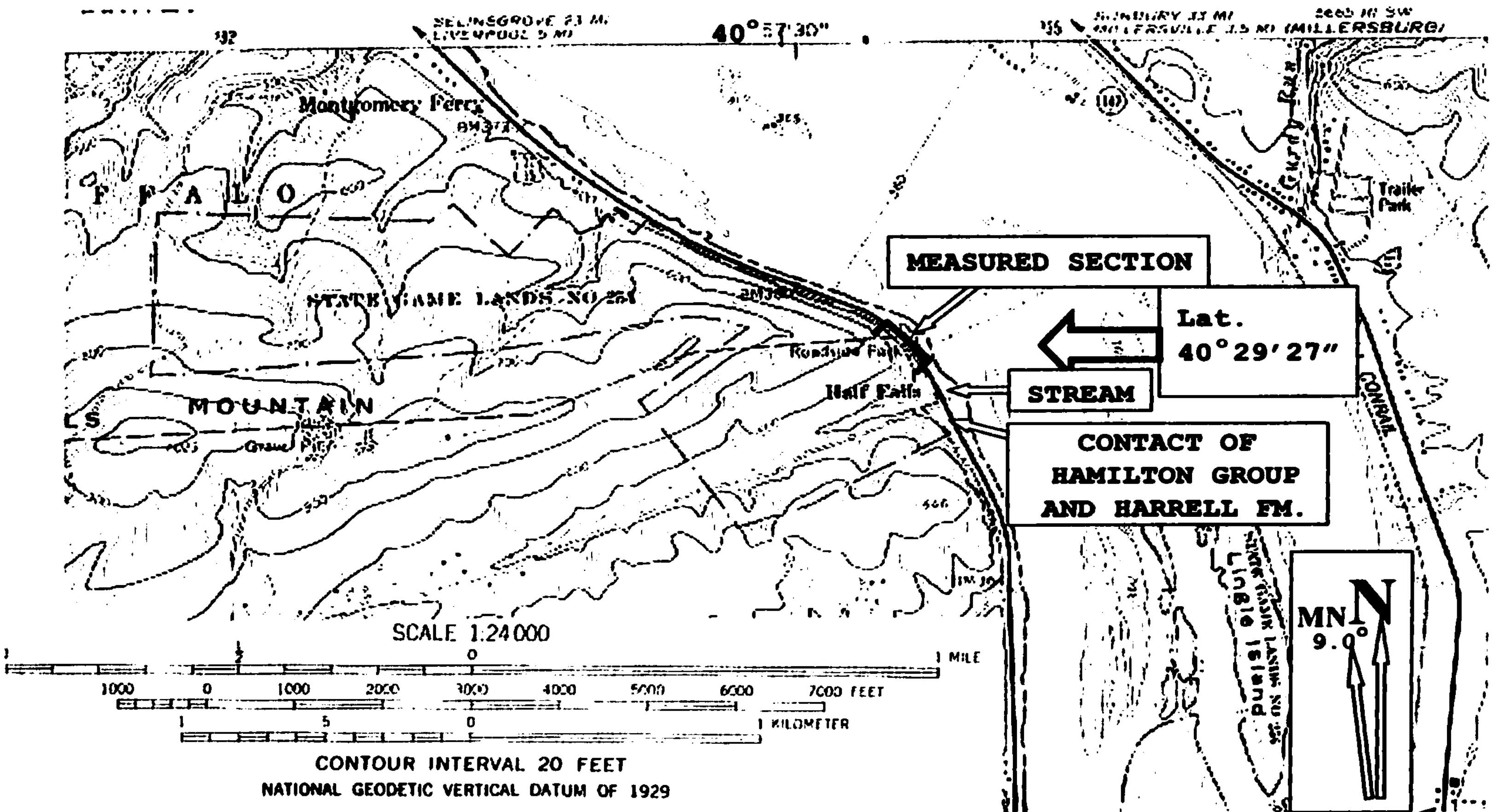


Figure 33 - Map showing location of Girty's Notch, PA section. Source: USGS Halifax, PA Quadrangle Map.

Figure 34 - Roadcut photograph of Montebello Member at Girty's Notch Section showing large cross-beds.

GIRTY'S NOTCH SECTION: 0 to 80 FEET

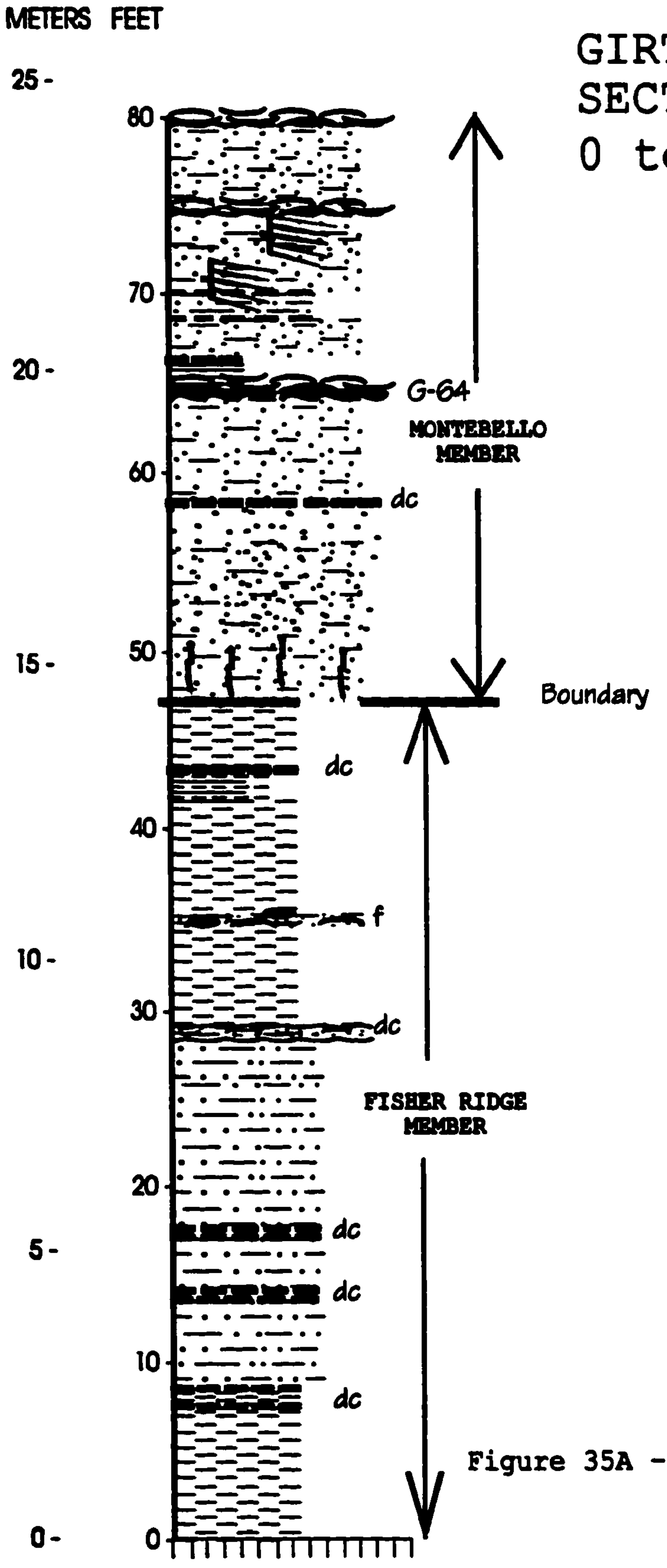


Figure 35A - Measured section at Girty's Notch, PA.

Legend on Figure 5

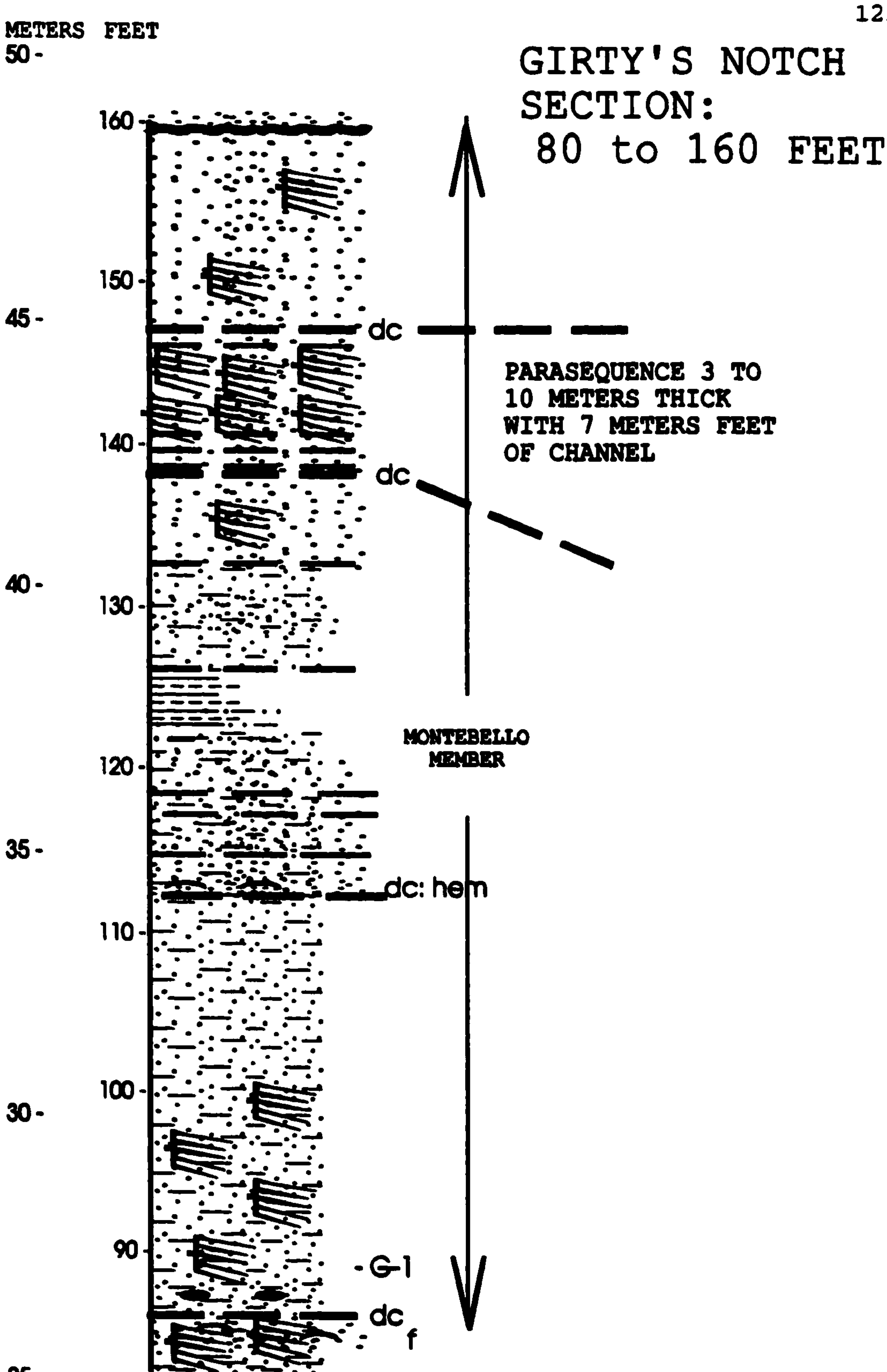


Figure 35B - Measured section at Girty's Notch, PA.

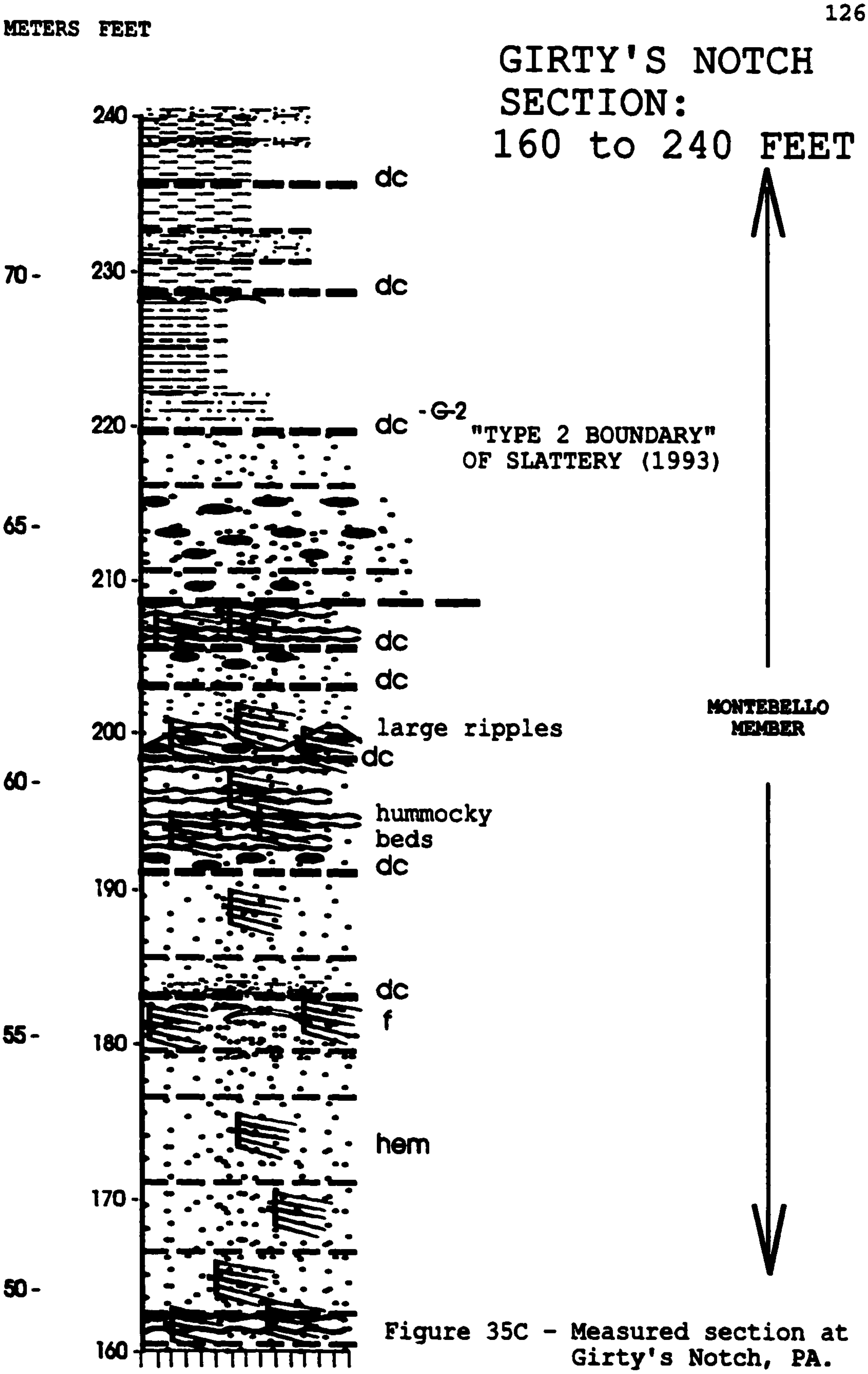


Figure 35C - Measured section at Girty's Notch, PA.

GIRTY'S NOTCH SECTION: 240 to 320 FEET

Figure 35D - Measured section at Girty's Notch, PA.

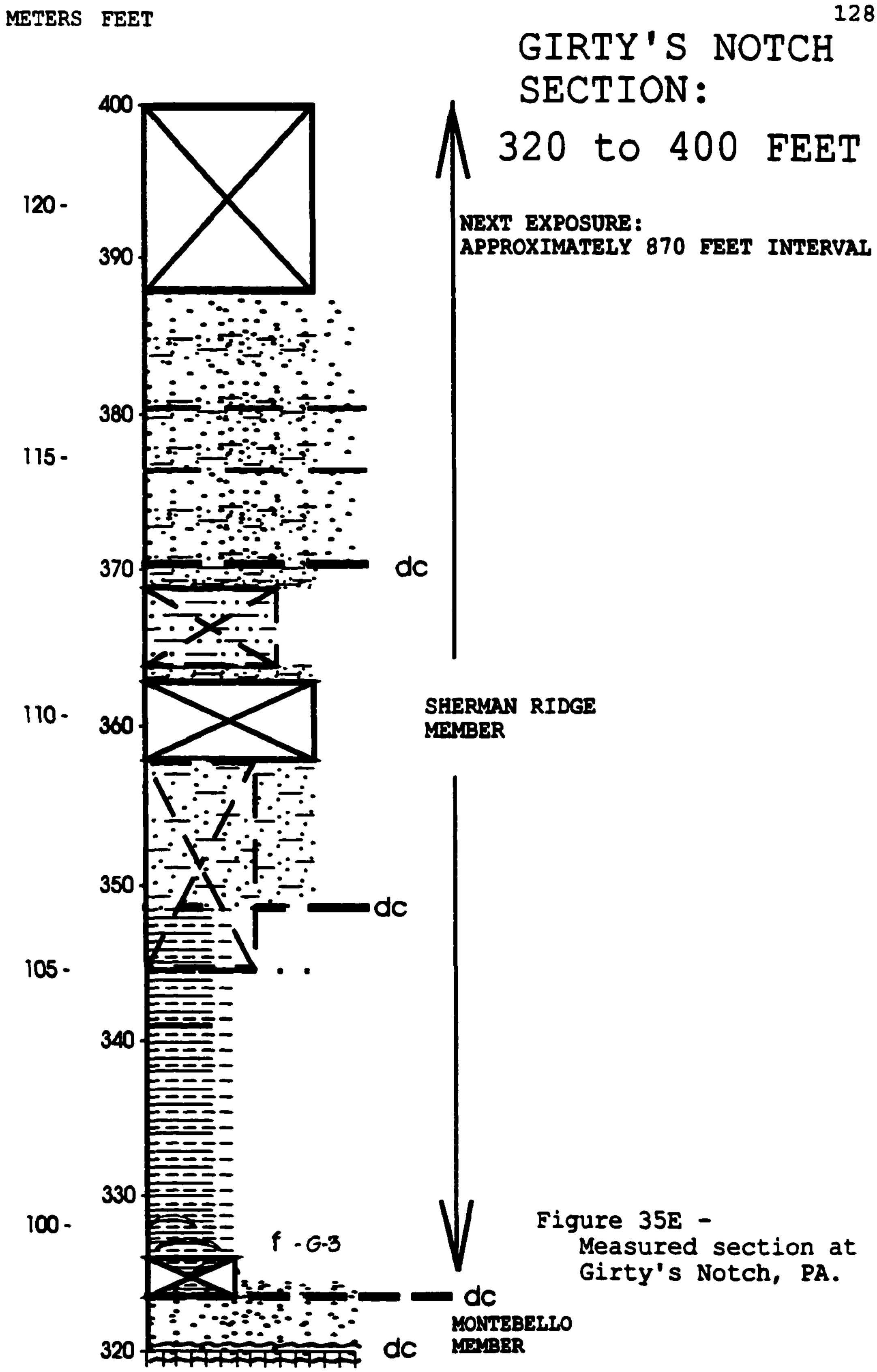


Figure 35E - Measured section at Girty's Notch, PA.

Montebello Member - The Montebello Member at the Girty's Notch section totals about 84 meters (275 feet) in thickness. The lower boundary of this unit appears to be hiatal and the lowermost beds have common vertical ichnofossils (Figure 35). The member varies both in color and texture, but is predominantly a greenish gray fine-textured sandstone. The most distinctive beds of the Montebello Member at Girty's Notch, however, are conglomeratic sandstones and conglomerates up to a meter thick. The sandstone beds in the lower part of the Montebello are locally fossiliferous with the thick-shelled brachiopod *Spinocyrtia*, as well as *Mediospirifer* (Figure 36), and contain large meter-size cross-beds. The new exposure at Girty's Notch shows one sequence of cross-beds thinning from approximately 8 to 3 meters within this portion of the member (right side of Figure 34).

The upper part of the Montebello Member lacks thick (greater than a meter) conglomeratic beds from approximately the 67.5 meter (220 feet) of measured interval on Figure 35. A distinct hiatal contact occurs here and, based on it representing a depositional cycle change, was identified as the Type II boundary (Figure 35) by Slattery (1993). Most of the upper beds consist of a sequence of cyclic beds that alternate between a distinct claystone or siltstone bed and shaly bed(s). Green gray quartz sandstones as well as a distinct hematitic sandstone

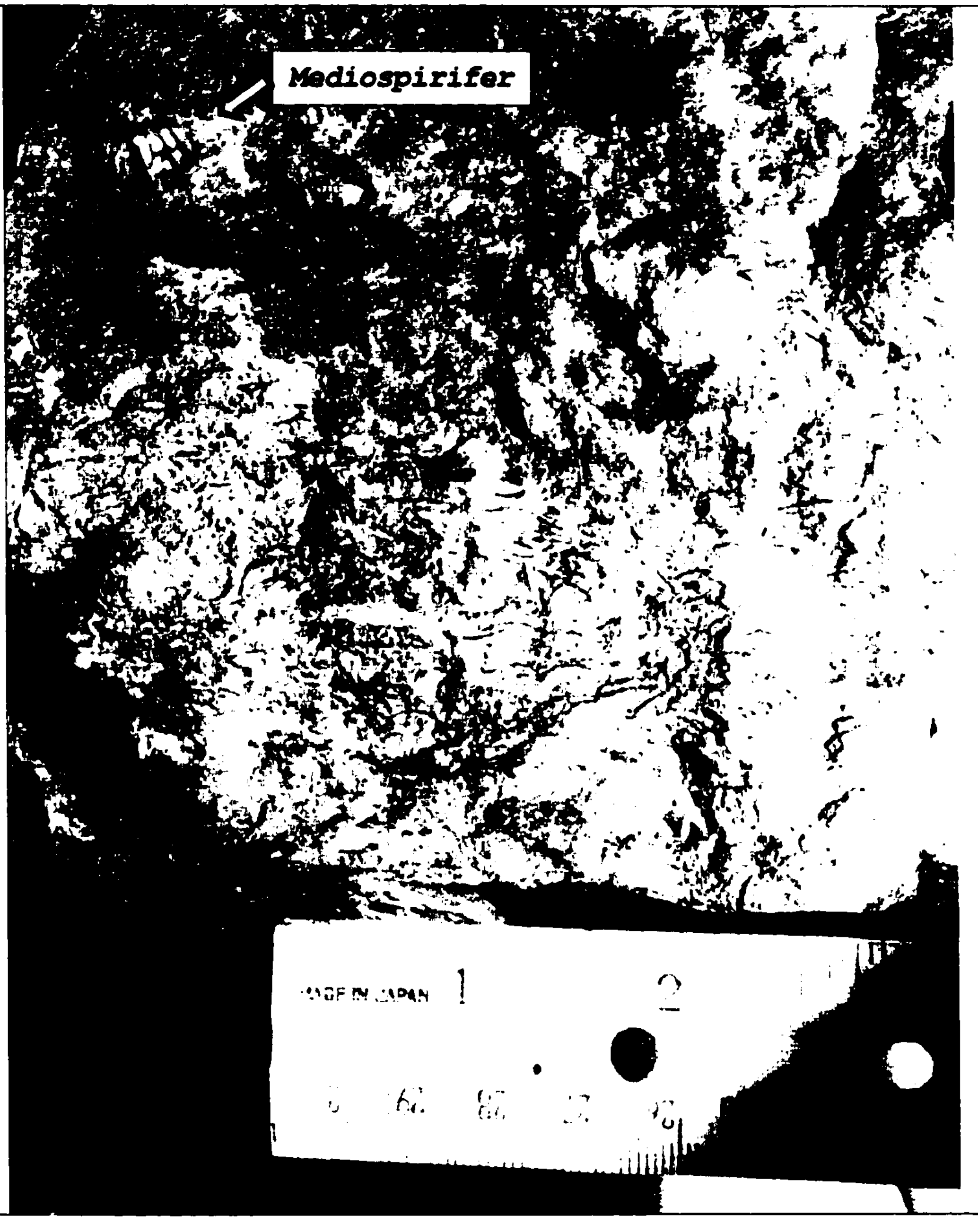
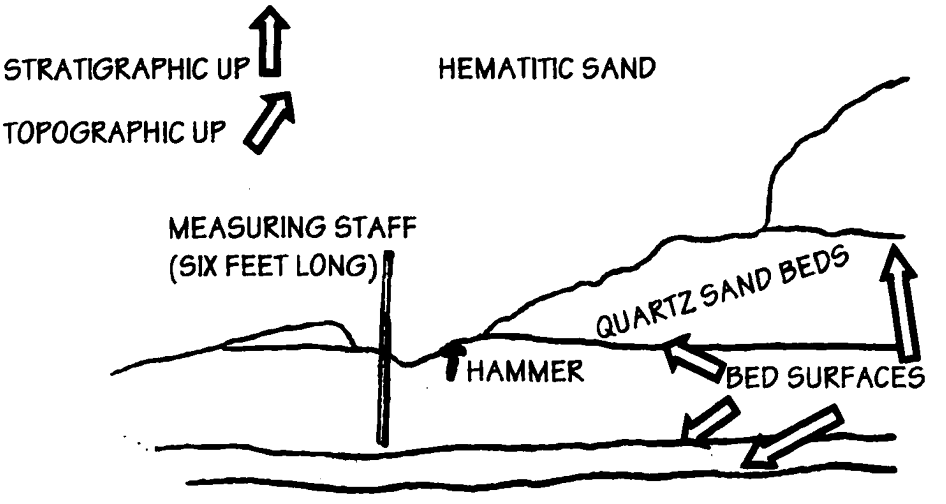


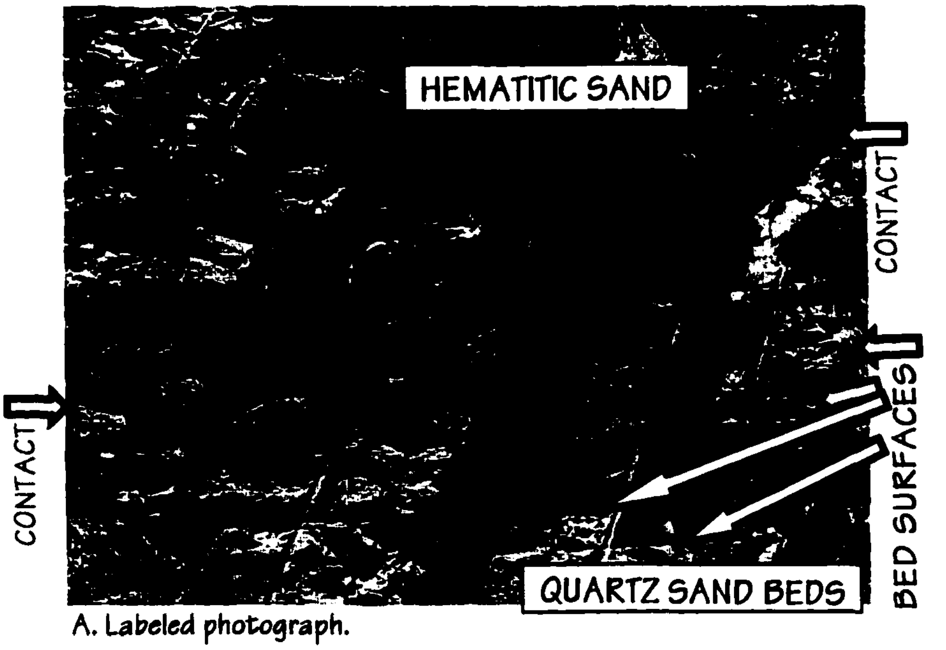
Figure 36 - Brachiopod coquina from lower Montebello Member at Girty's Notch, PA (Sampled horizon G-64).

are also present within this interval which continues up to 98 meter of measured section (Figure 35). Due to the dominance of fine-textured beds, this was referred to as the 'upper shale portion' of the Montebello Member by Faill et al. (1978).

In the upper part of the Montebello Member is a ruby-red, well-sorted hematitic sand containing weak cross-beds approximately a meter apart (Figure 37). (The existence of this bed only became apparent after completion of the road work, prior to which this portion of the section was covered.) Despite its ruby red color, this sandstone is over 95 per cent quartz with only about three per cent hematite and other heavy minerals (John Puffer, personal commun., 1998). The exposed portion of this hematitic sand has an steep erosional contact with the underlying more typical green-gray quartz-dominated fine sandstone. This contact suggests a channel where the exposed hematitic sandstone has a thickness that varies between one and 3.5 meters. Further, the uppermost part of the hematitic sand "channel" bed has a gradational contact, suggesting reworking with the overlying green-gray quartz sandstone. Both the underlying and overlying green-gray sandstones are lithologically the same and dominated by a fine-textured quartz similar to that of the hematitic bed. The greenish-gray sandstone beds would be recognized as a single bed set if not for the intermediate hematitic sand channel. The



B - Line drawing of A.



A. Labeled photograph.

Figure 37 - Hematitic sand channel (93 to 96 meter of measured interval) at Girty's Notch, PA.

upper green-gray fine-texture sandstone bed is about a meter thick and truncated by a hiatal contact marking the top of the Montebello Member (Figure 35). Therefore, the hematitic sand channel is recognized as a unusual local sedimentary feature. The unusual nature is that while both chamositic and hematitic beds are commonly reported within the Montebello Member, I am unaware of a channel-filling origin being noted for any of these beds (cf. Faill et al. 1978, Ellison 1965, Sheppard and Hunter 1960).

Sherman Ridge Member - The base of the Sherman Ridge Member is a green-gray fossiliferous shaly claystone (sample G-3 location on Figure 35) consisting of a decimeter thick chamosite oolite. The oolite has a hiatal base and grades upward into the fossiliferous claystone. Notable fossils include *Mucrospirifer* (Figure 38A) and *Paracylas* (Figure 38B). These fossils are fairly common over a 1.5 meter interval. Above this initial 1.5 meter interval brachiopods decrease in abundance and pelecypods become more common. The claystone also becomes less fossiliferous to poorly fossiliferous within its uppermost six meters.

Above the shaly claystone base of the Sherman Ridge Member are gray to brown color beds consisting of claystone intercalated with laminated siltstone. These beds represent the lower 25 meters of the Sherman Ridge Member which is fairly well exposed. However, the remainder of the Sherman Ridge Member at the Girty's Notch section is poorly exposed or covered and therefore not shown as part of Figure 35.

Contact of the Hamilton Group and Harrell Formation - A question that is unclear at the Girty's Notch section due to poor exposure is the stratigraphic location of the Tully Mesosequence. This is indicated at a nearby roadcut that is stratigraphically above the measured section illustrated on Figure 35 (see arrows on Figure 33). I consider the contact between the Harrell Formation and the Hamilton Group (Figure 39) to occur here based on a moderately well exposed hiatal contact. Above this contact, the Harrell Formation is fairly well exposed and is readily recognized as a dark gray to black fissile shale (Figure 39A) characteristic of this unit. However, the approximately 15 meters of the underlying Hamilton rocks are poorly exposed as part of a graded surface (Figure 39B). These underlying Hamilton rocks consist of lighter gray shale and siltstone that contains pyrite, but did not yield diagnostic fossils and have a lithology more characteristic of the Sherman Ridge Member. I suspect a situation exists here, similar to the Bowmanstown section, where typical Mahantango fine-textured rocks (in this case similar to the Sherman Ridge Member) reoccur above the fossiliferous interval that is recognized as the Tully Member by Ellison (1965). However, another possibility is that all three sequence boundaries of the Tully Mesosequence occur at this hiatal contact.

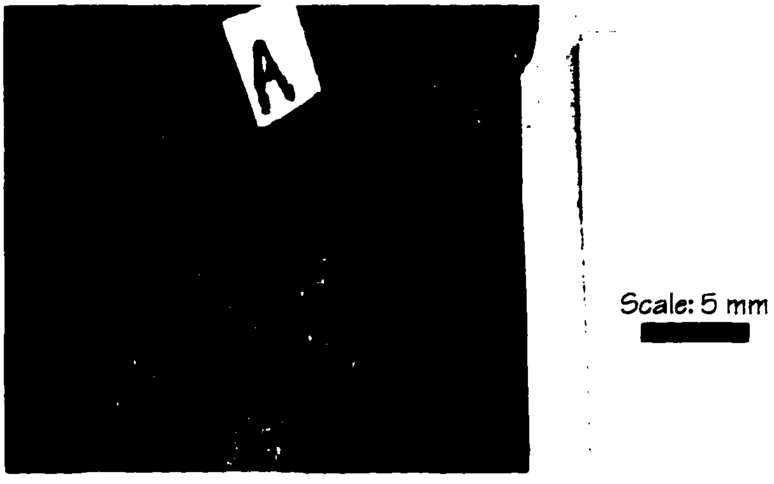


Figure 38A - Mucrospirifer from base of Sherman Ridge Member, Girty's Notch, PA (sample location G-3).

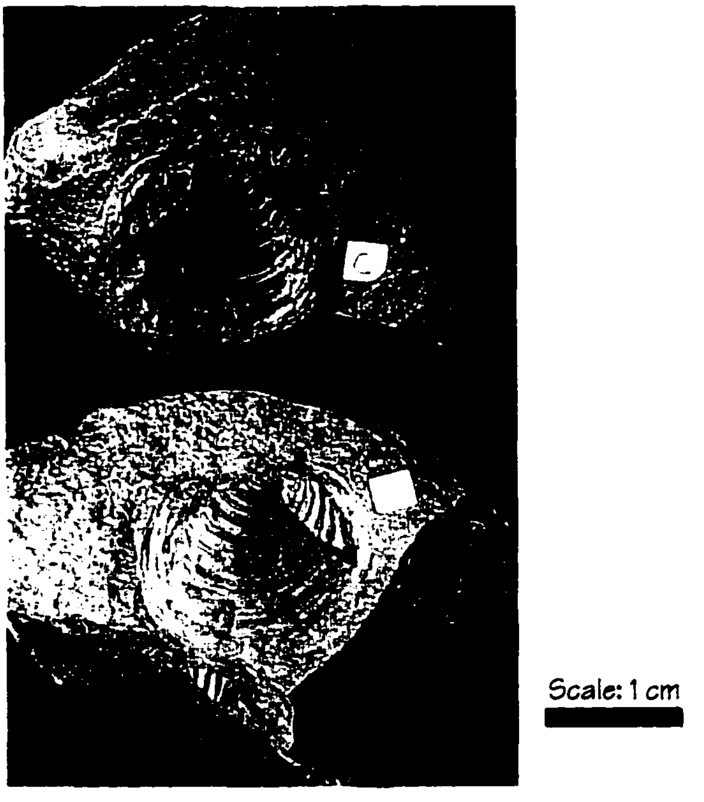
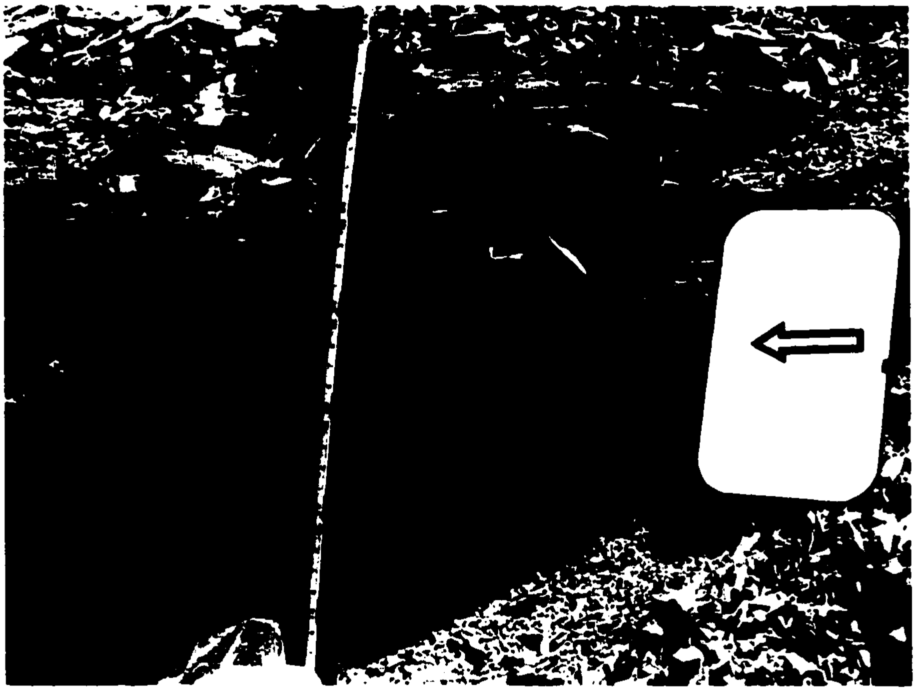
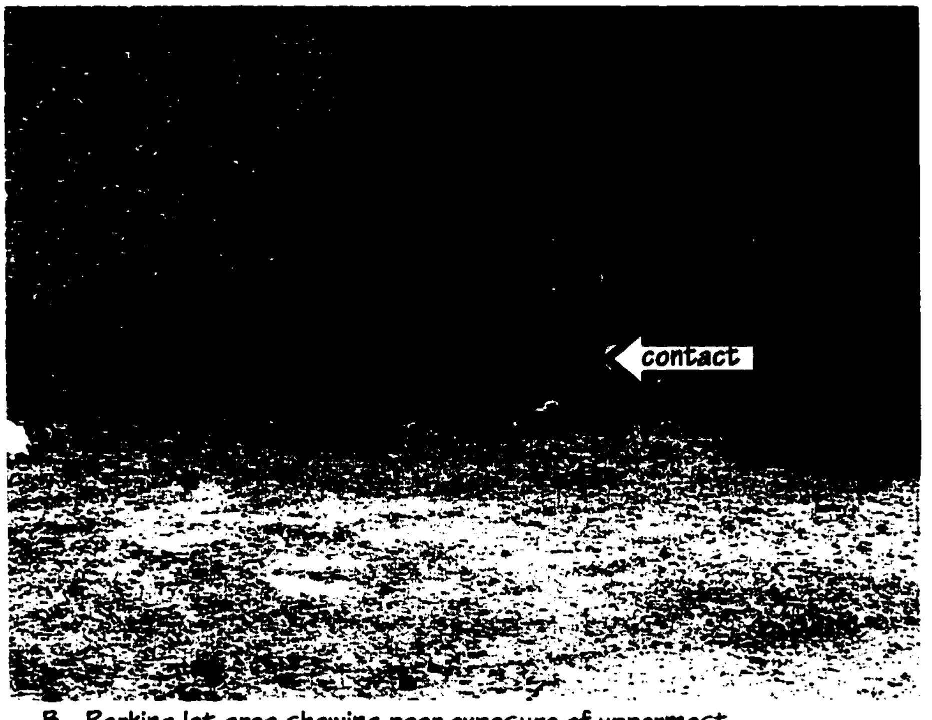


Figure 38B - Paracyclas from base of Sherman Ridge Member, Girty's Notch, PA (sample location G-3).



A - Close-up of contact indicated by arrow.



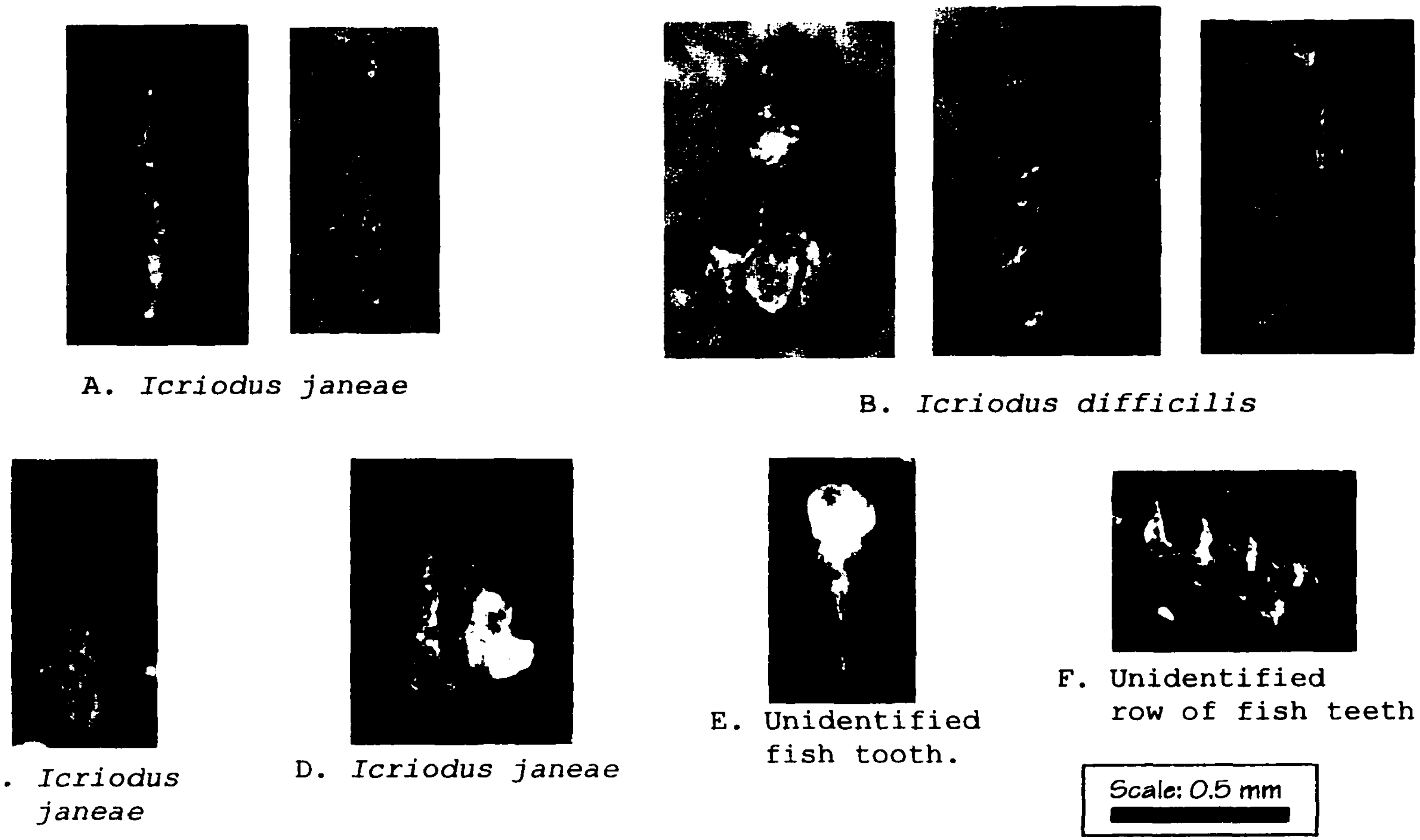
B - Parking lot area showing poor exposure of uppermost Hamilton Group immediately below contact.

Figure 39 - Contact between the Burket Member of Harrell Shale and uppermost Hamilton Group at Girty's Notch, PA.

Approximately 100 meters away in a stratigraphically lower location at the base of a unnamed stream between the roadcut and measured exposure (middle arrow on Figure 33) is a moderately fossiliferous, slightly calcareous, medium gray claystone. The possibility exists that this calcareous unit was previously recognized on a regional basis as the Tully Limestone Member of the Harrell Formation by Ellison (1965). If so, these rocks, along with the overlying beds that are characteristic of the Sherman Ridge Member, were recognized by Ellison (1965) as being part of the Harrell Formation. Further uncertainty is derived from Ellison (1965) showing the stratigraphic position of the Tully 'Member' at Girty's Notch to be covered. As noted, the recent roadwork has significantly changed the physiography of this area since Ellison's visit. Unfortunately, the existing, but poor, exposure has not yielded any fossils diagnostic of the Tully Mesosequence.

Fossiliferous and Sampled Beds - In general, distinct fossiliferous beds are uncommon at the Girty's Notch locality. An exception is the lower part of the Montebello Member which contains cross-bedded sandstone and coarse siltstone beds with large disarticulated brachiopods (Figure 36). The juxtaposed positions and disarticulated shells of the fossils suggest deposition as clasts. Fish and conodont-bearing sample G-64 (Figure 40) is representative of these beds and was collected from a fresh (post-road-cut) exposure where calcareous shells are still preserved. Higher up section, the Montebello Member only occasionally yields body fossils intermixed with the conglomeratic beds and ichnofossils within the fine-textured beds (Figure 41). Samples G-1 and G-2 were collected for microfossil analysis based on their respective stratigraphic locations relative to the Type II Boundary of Slattery (1993). Sample G-3 was targeted on it being a fossiliferous shale (Figure 38) located at the base of the Sherman Ridge Member. Another fossiliferous bed bearing corals, trilobites and atrypid brachiopods is present in the unnamed stream to the south of the measured exposure (Figure 33). This a moderately fossiliferous, calcareous, medium gray claystone both in fossil content and physical appearance resembles the Windom Shale of New York (and is in a similar stratigraphic position relative to the top of the Hamilton Group).

Comparison to Other Studies - The stratigraphic units readily observed at Girty's Notch by this writer are: the Fisher Ridge, Montebello, and Sherman Ridge Members of the Mahantango Formation, and the Harrell Formation (Figure 42). A tentative identification of the Tully Mesosequence is also proposed. Historically, there has been some ambiguity concerning the contact between the Hamilton Group



A. *Icriodus janeae*

B. *Icriodus difficilis*

C. *Icriodus janeae*

D. *Icriodus janeae*

E. Unidentified fish tooth.

F. Unidentified row of fish teeth.

Figure 40 - Photographs of conodonts and fish teeth from Sample G-64, Montebello Member at Girty's Notch section.

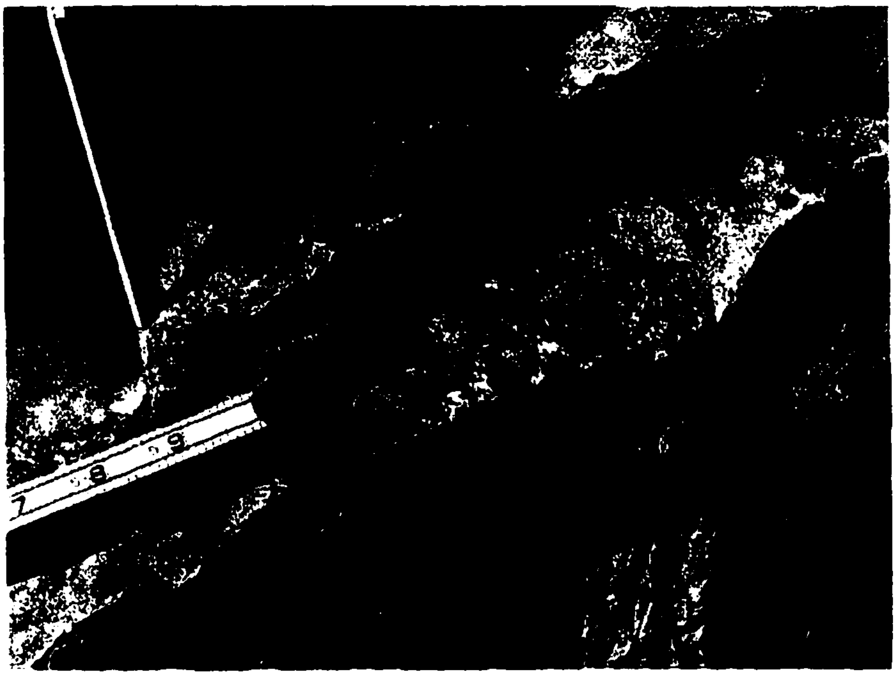


Figure 41 - *Cruziana* trails in Montebellow Member (55 meter measured interval) at Girty's Notch, PA. Lufkin Ruler in hundreds of a foot.

REFERENCE:	Ellison (1965)	Faill et al. (1978)	Prave & Duke (1991 Figure 10)	Slattery (1993, 1995)	This Study
UNITS RECOGNIZED	Harrell Fm. Burket Member - - - - - - - - - Tully Memb.	Harrell Fm.	Burket Black Shale	(Not Discussed)	Harrell Fm.
	Hamilton Group:	Hamilton Group:	Hamilton Group: (Tully Unit Not Discussed)	Hamilton Group: Tully Fm.	Hamilton Group: Tully Mesosequence
	Mahantango Fm.:	Mahantango Fm.: Tully Memb.	Mahantango Fm.:	Mahantango Fm.:	Mahantango Fm.:
	Upper Shale Memb.	Sherman Ridge Memb.	Sherman Ridge Memb.	Sherman Ridge Memb.	Sherman Ridge Memb.
	Montebello Memb.	Montebello Memb.	Montebello Memb. or Fisher Ridge Member	Montebello Memb. or? Fisher Ridge Member	Montebello Memb.
	Lower Shale Member	Fisher Ridge Member?			Fisher Ridge Member
		Dalmatia Member?	Dalmatia Member or Turkey Ridge Member	Dalmatia Member or? Turkey Ridge Member	Dalmatia Member?
		Turkey Ridge Member			Turkey Ridge Member?
	Marcellus Fm.	Marcellus Fm.	Marcellus Black Shale	Marcellus Fm.	Marcellus Fm.

Legend:

═══ Group Boundary

─── Formation Boundary

- - Member Boundary

FIGURE 42 - SUMMARY OF STRATIGRAPHIC UNITS RECOGNIZED AT GIRTY'S NOTCH, PA

and Harrell Formation and the placement of the Tully Member. My field observations do not settle this question, but rather add fuel to the fire. Faill et al. (1978) placed the Tully as a member of the Mahantango Formation. In contrast, earlier studies such as Ellison (1965) placed the Tully as a Member of the Harrell Formation (see Figure 42). Based on the hiatal nature of the Tully Mesosequence boundaries as well as it having an upper lithology and fauna similar to the older beds, I concur with Faill et al. (1978) placement of the Tully within the Hamilton Group.

I have placed the contact between the Hamilton Group and Harrell Formation at a distinct hiatal contact (Figure 39). Above the contact are dark shales typical of the Harrell Formation (Figure 39). Underlying this contact are poorly exposed non-calcareous, fine-textured beds, typical of the Hamilton. As discussed in Chapter Two, there are three sequence stratigraphic boundaries associated with the Tully Mesosequence. I consider this hiatal contact to be equivalent to one or more of these sequence boundaries. Therefore as based on stratigraphic location, the underlying non-calcareous beds at this contact are recognized as part of the Tully Mesosequence. Unfortunately, I did not observe among these poorly to non-exposed beds any additional indicators that would further substantiate these beds as part of Tully Mesosequence. A poorly exposed calcareous fossiliferous interval, at a significantly lower stratigraphic position (the stream location indicated on Figure 33), has a fauna of trilobites, corals and brachiopods that is similar to both the upper Tully Member and older New York Windom Shale. Therefore, while indicating the upper Hamilton, these beds do not help to further resolve where the lower Tully boundary may be.

As shown on Figure 42, both of the units adjacent to the Montebello Member are unnamed by Ellison (1965). On a regional scale, the Montebello Member as recognized by Ellison (1965, Plate 3) apparently includes sandstone beds of the upper Dalmatia Member and the entire Fisher Ridge Member as recognized by this author and Faill et al. (1978, Plate 1).

With these notable exceptions, the names and stratigraphic listings of this study as summarized in Figure 42 basically concur with the studies of Faill et al. (1978), Prave and Duke (1991), Slattery (1995) and Ellison (1965).

Riverside (Danville) Section

The Riverside section (locality "D" in Figure 1) is located along Route 54 parallel to the south side of the East Branch of the Susquehanna River (see Figure 43 for detail location information). This section, located in

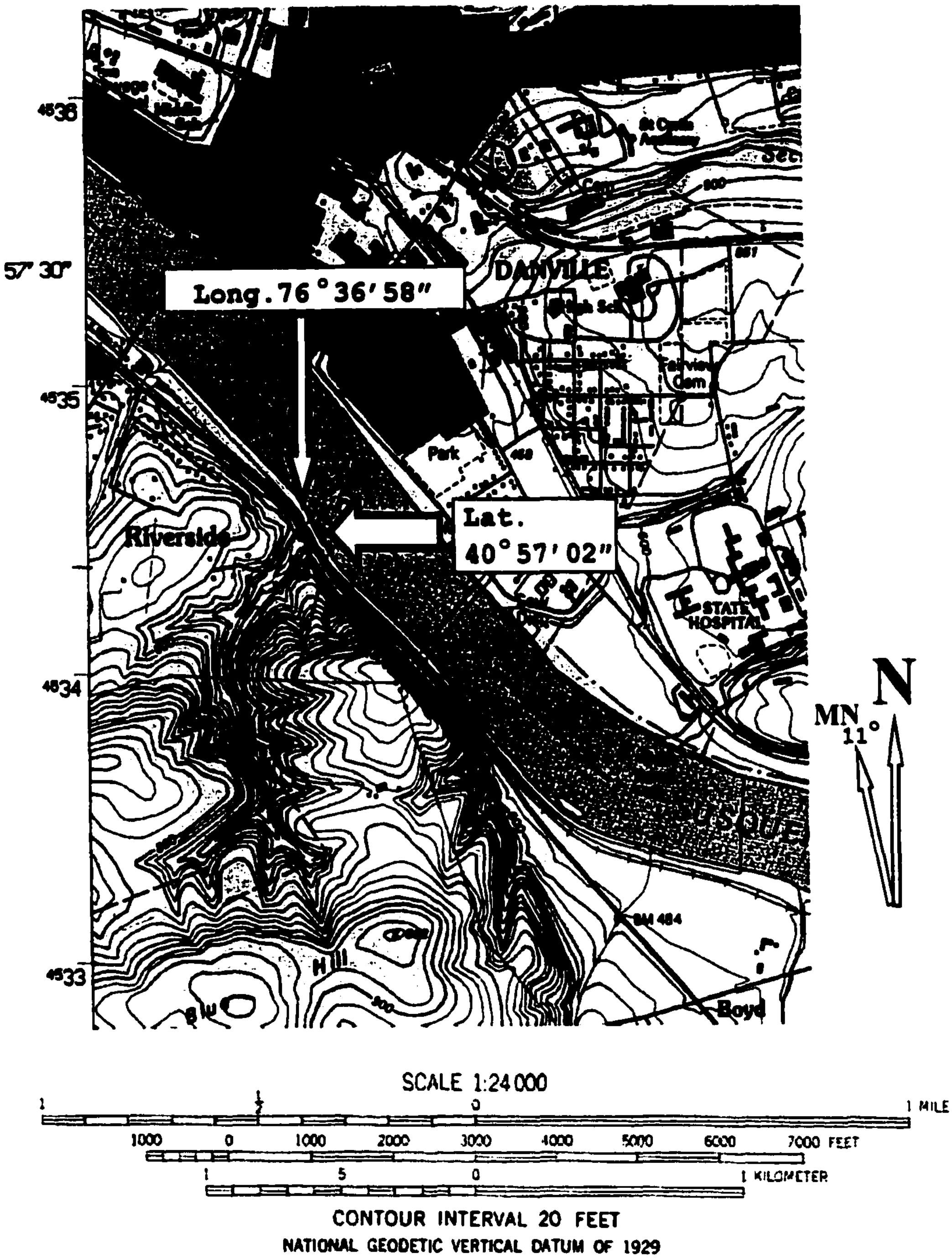


Figure 43 - Map showing location of Riverside, PA section. Source: USGS Danville, PA Quadrangle Map.

Northumberland County, has also been referred to as the "Danville section" (Heckel 1969, 1973) and "South Danville section" by Willard (1939) in reference to the more recognizable Columbia County town on the opposite side of the river. This section has fair to good exposure except near Hower Road (Figure 44). A total of nine whole rock samples (labelled Ri-1 through Ri-9) were collected at stratigraphic locations shown on Figure 44. From oldest to youngest, stratigraphic units occurring here are: the Mahantango Formation, the Tully Mesosequence and the Harrell Formation. The Mahantango Formation is further subdivided into four units with proposed names of the Lower South Danville Shale, Riverside Siltstone, Middle South Danville Shale and Upper South Danville Shale. Both Lower and Upper Members of the Tully Mesosequence are recognized at this section.

Mahantango Formation

Previous investigation at the Riverside section shows the Mahantango Formation as undifferentiated (Willard 1939). It is proposed here that four informal units are present, namely: the Lower South Danville Shale consisting predominantly of fine-textured beds; the Riverside Siltstone composed of a basal siltstone and overlying silty shales; the Middle South Danville Shale consisting predominantly of fine-textured beds; and the Upper South

RIVERSIDE SECTION: 0 to 80 FEET

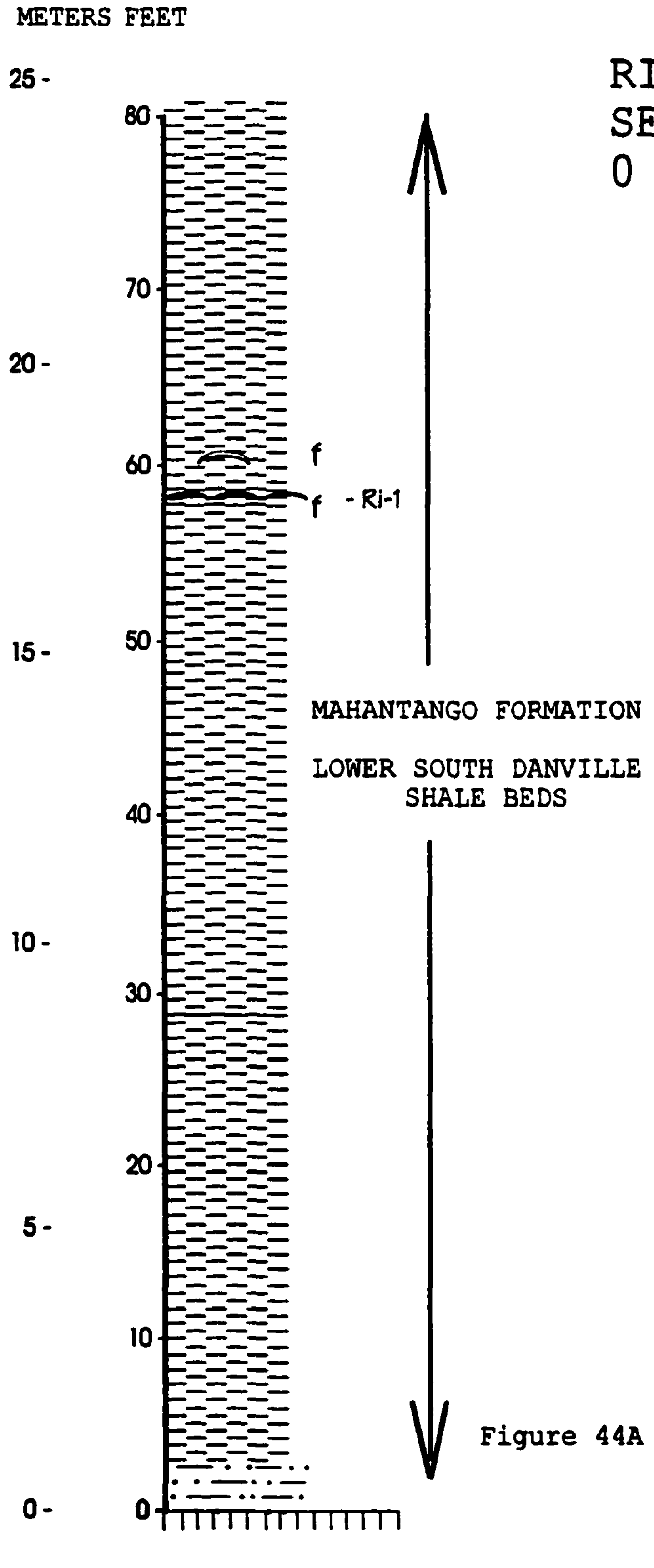


Figure 44A - Measured section at Riverside, PA.

Legend on Figure 5.

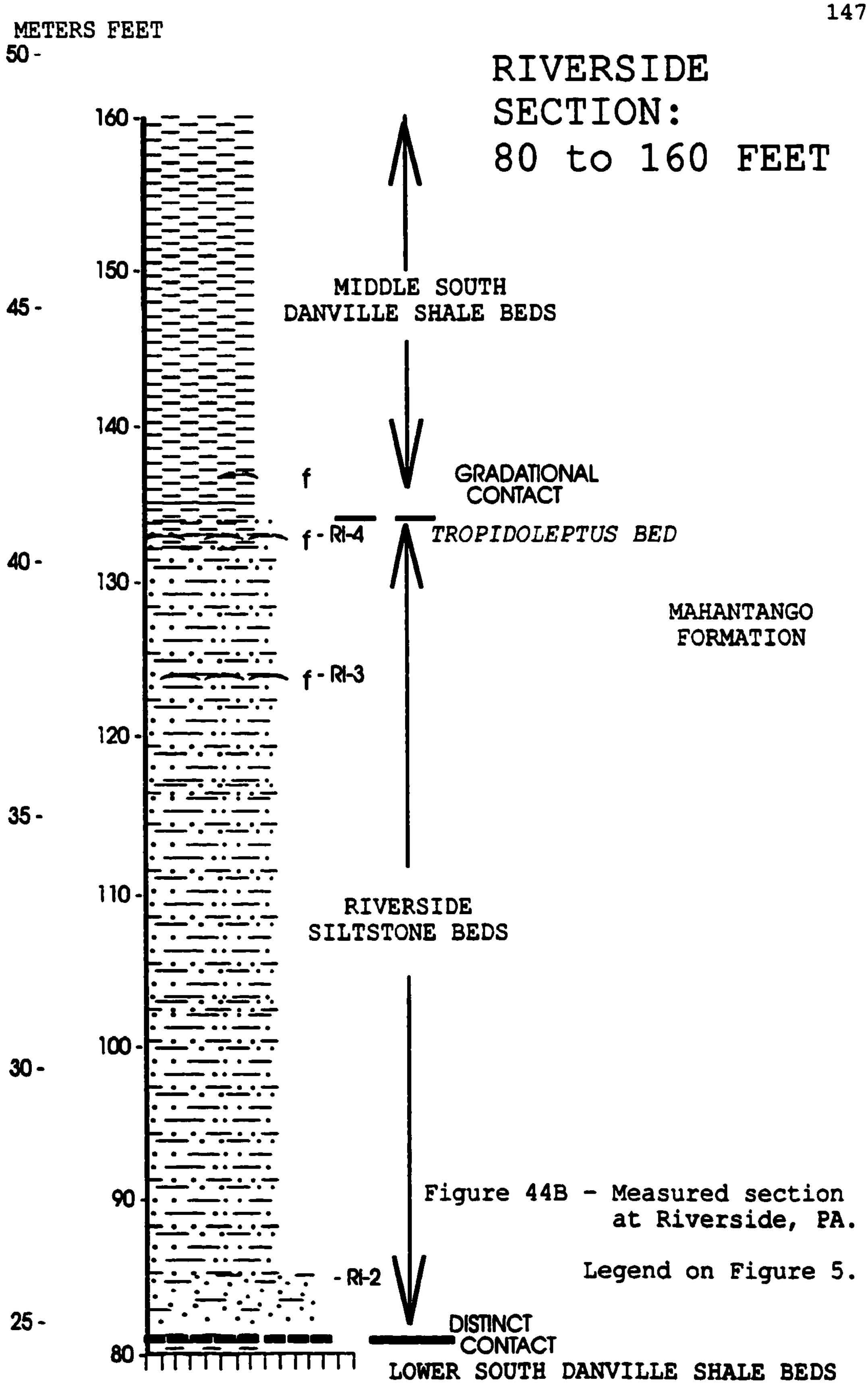


Figure 44B - Measured section at Riverside, PA.

Legend on Figure 5.

RIVERSIDE SECTION: 160 to 240 FEET

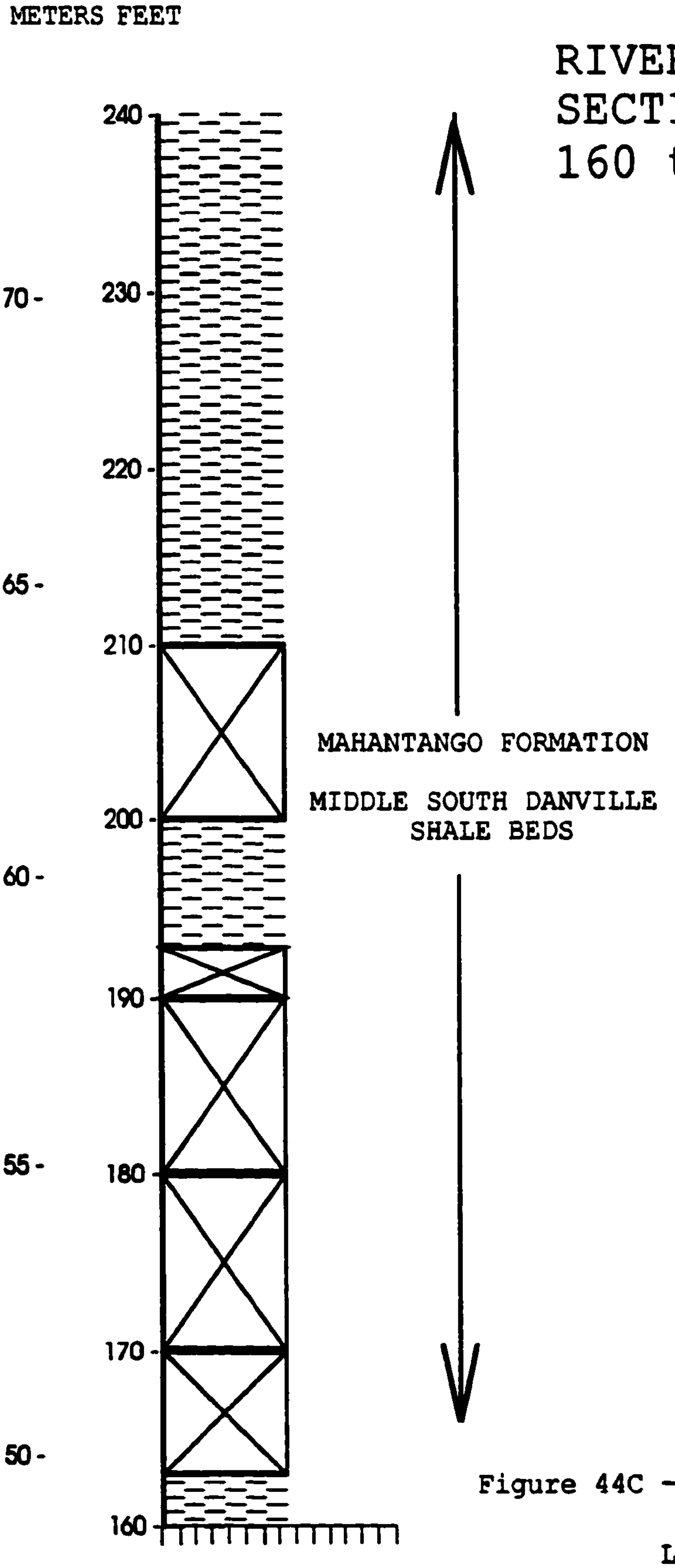


Figure 44C - Measured section at Riverside, PA.

Legend on Figure 5.

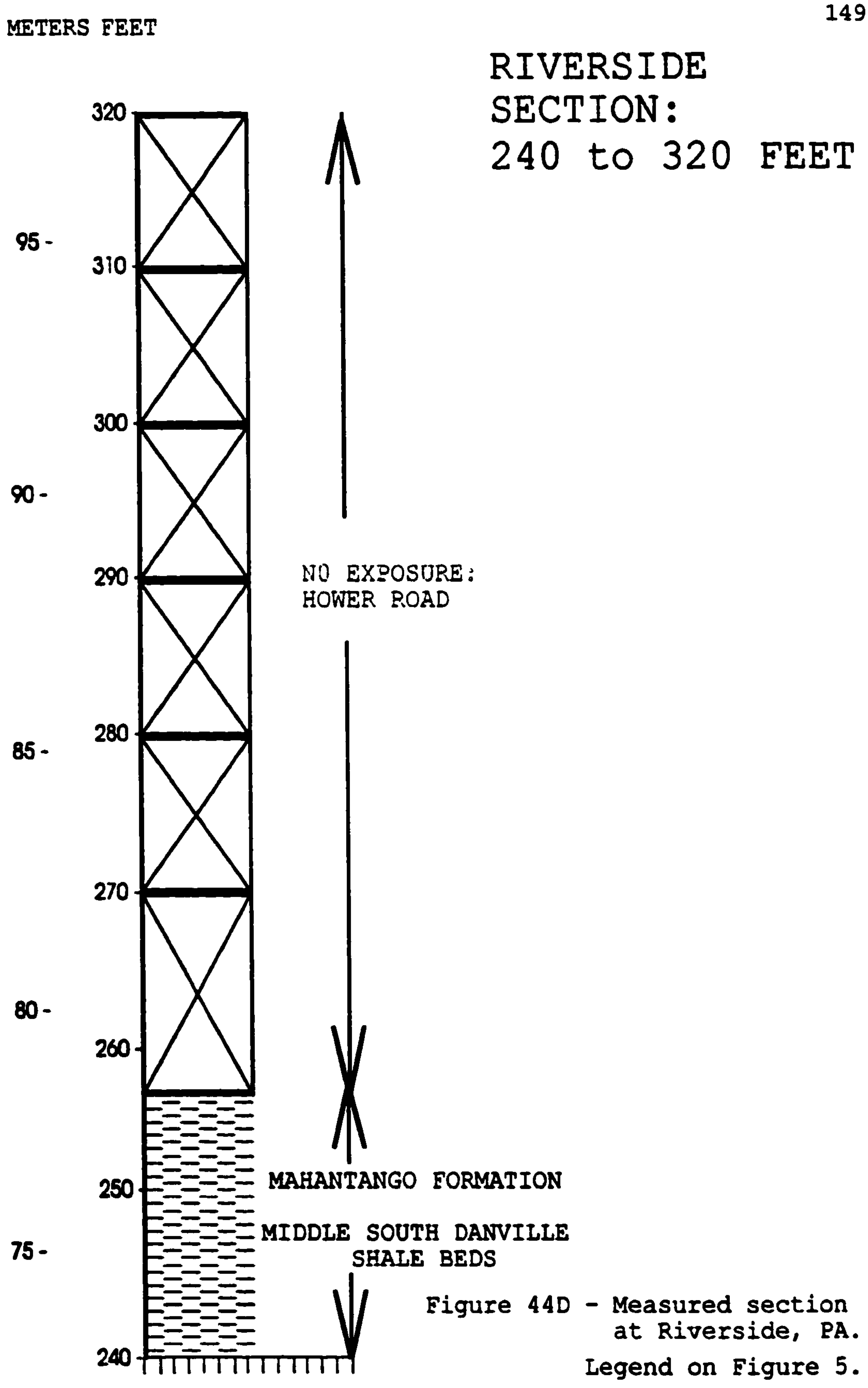


Figure 44D - Measured section at Riverside, PA. Legend on Figure 5.

RIVERSIDE SECTION: 320 to 400 FEET

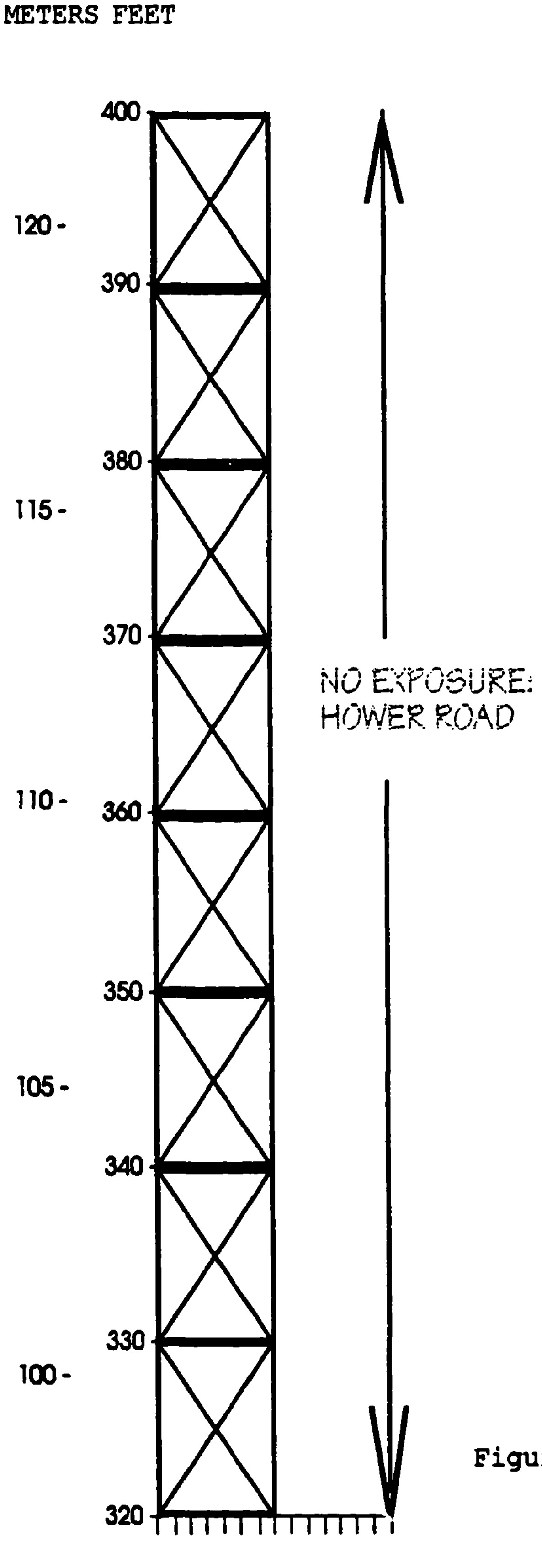


Figure 44E - Measured section at Riverside, PA.

Legend on Figure 5.

RIVERSIDE SECTION: 400 to 480 FEET

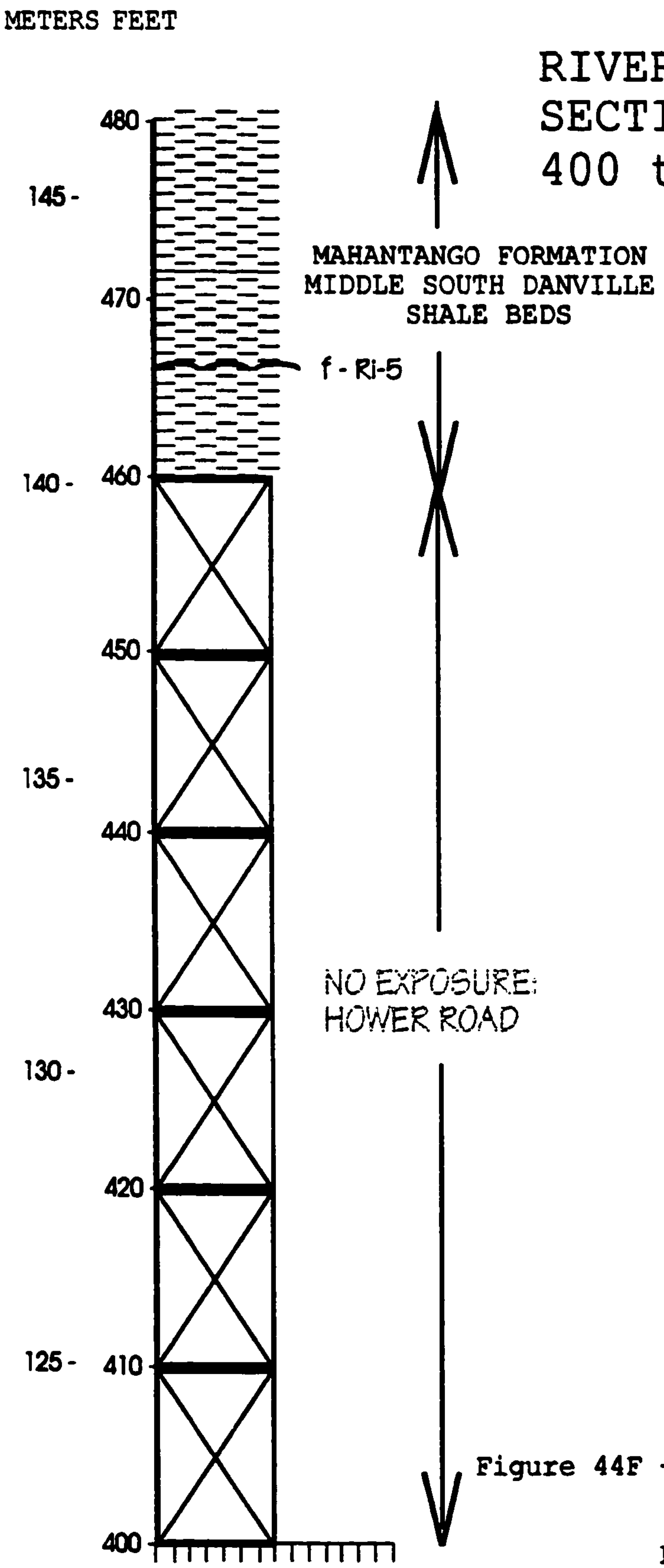


Figure 44F - Measured section at Riverside, PA.

Legend on Figure 5.

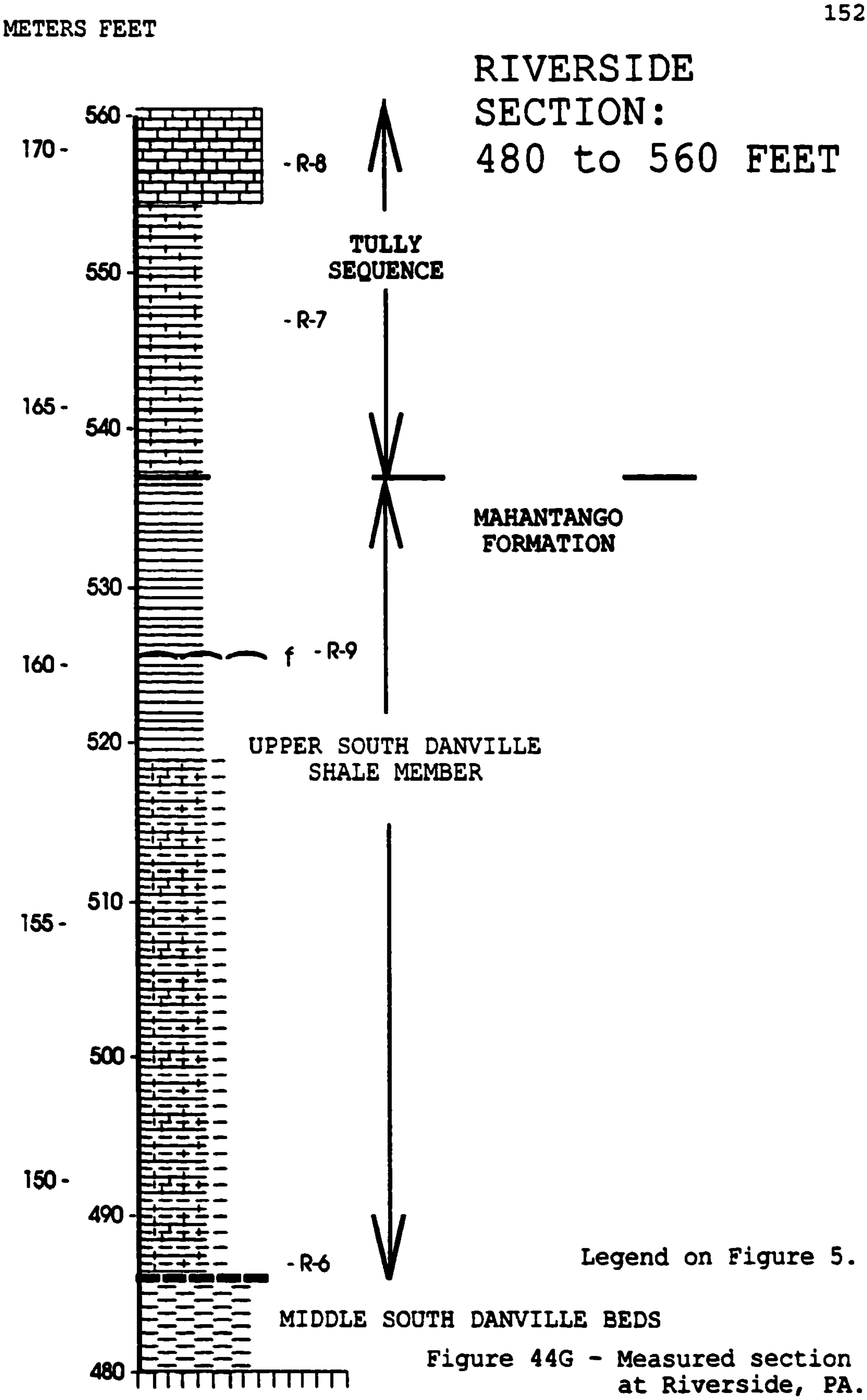


Figure 44G - Measured section at Riverside, PA.

Danville Shale composed of calcareous fine-textured beds. The geographic (mappable) usefulness of these names has yet to be tested. However, the major purpose these names serve in this study is as an easy to use representative stratigraphic term. Both "South Danville" and "Riverside" are geographic names indicating the studied section as the type locality. The term "South Danville" is incorporated into three of the proposed unit names due to their having similar lithologies. Outside of the type area this term can be used to identify the upper Mahantango Formation when the precise stratigraphic position is initially unclear.

Lower South Danville Shale Beds - The Lower South Danville Shale Beds consist predominantly of medium to dark gray shales and claystone (mudstone). Bedding planes are difficult to differentiate due to deformation, but suggest wedge-shaped beds with typical thicknesses that vary from 10 to 40 centimeters. Small flow-roll structures (barely distinguishable on the right side of Figure 45) occur in the uppermost part of the Lower South Danville Shale Beds beneath the overlying Riverside Siltstone Beds. Weakly defined cross-beds are also present. The lowermost meter of the Lower South Danville Shale Beds is a silty mudstone and may actual represent a different subdivision. Otherwise the Lower South Danville Shale unit occurs up to 24.5 interval of measured section and has a distinct (hiatal?) contact with the overlying Riverside Siltstone

Beds (Figure 44).

Riverside Siltstone Interval - An approximately 1.5 meter thick sequence consisting of siltstone and very fine sandstone (Figure 45) readily marks the base of the Riverside Siltstone Beds (24.5 to 26 meter interval of section measured on Figure 44). These are the coarsest textured beds present within this part of the Mahantango Formation studied at Riverside. Overlying the distinct 1.5 meter interval is another fifteen meters of silty mudstone and shale that is also recognized as part of the Riverside Siltstone Unit based on its coarser texture when compared to overlying beds. In general, these beds, especially the lower 1.5 meter interval, resemble the Nis Hollow at the Bowmanstown, but based on fossil content are correlative with older beds (see Chapter Five). The top of the Riverside Siltstone beds are marked by a distinct *Tropidoleptus* bed (Figure 46).

Middle South Danville Shale Unit - Dark gray shale and mudstone beds occur above the *Tropidoleptus* bed (sample Ri-4 on Figure 44) and are recognized as the lower part of the Middle South Danville Shale interval. Most of the Middle South Danville Shale unit is covered by Hower Road (78 to 140 meter interval of measured section on Figure 44) where it may be possible that the Mahantango Formation can be further subdivided at this locality. However, the upper exposure resembles the lower part and is therefore

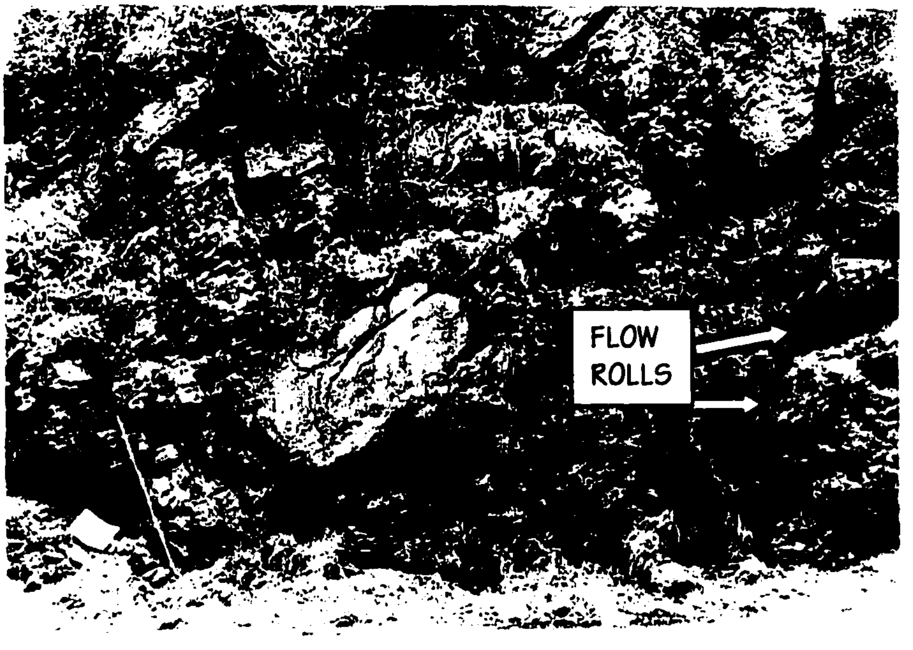
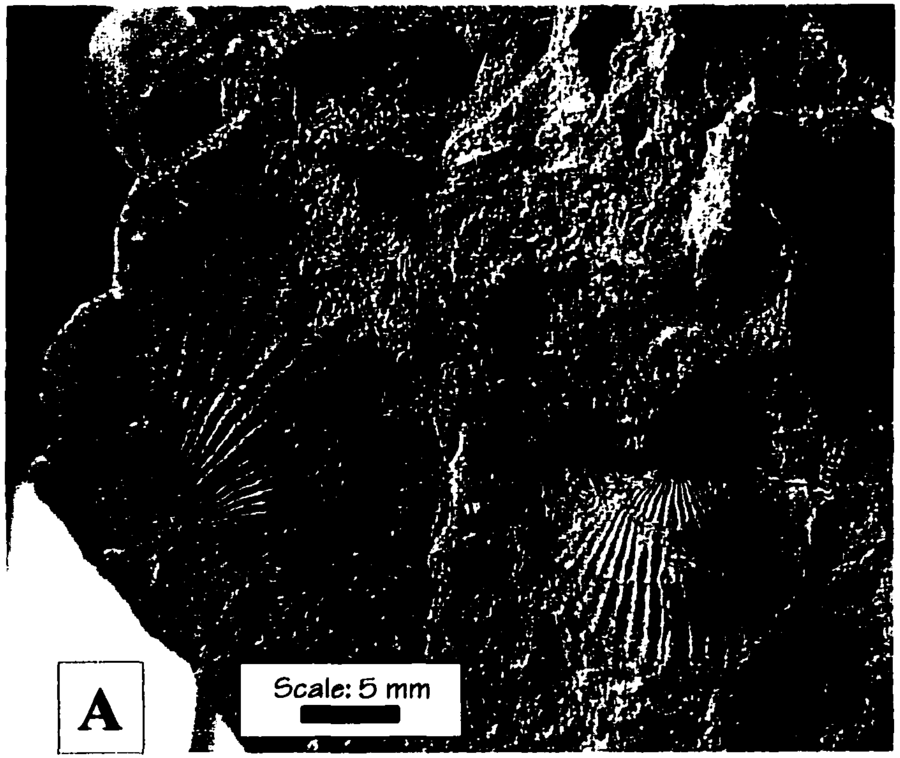


Figure 45 - Mahantango Formation at Riverside, PA.
The paper bag and five-foot ruler are at the base of the Riverside Member (sample horizon Ri-2) consisting of siltstone and silty shale.
Arrows show flow rolls in underlying beds.



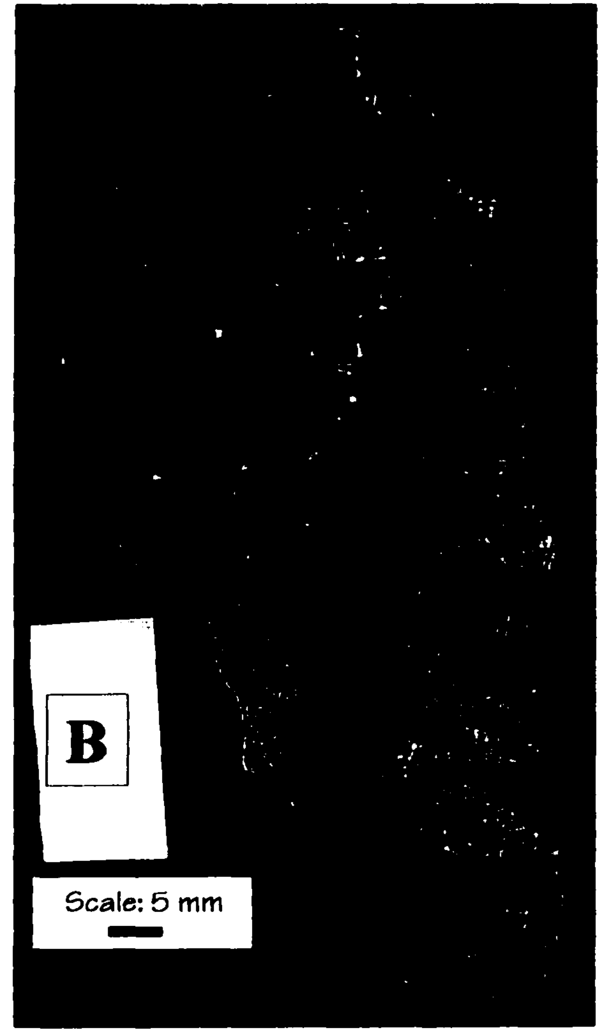


Figure 46 - Examples of *Tropidoleptus carinatus* bed (sample horizon Ri-4) of Mahantango Formation at Riverside, PA.

recognized as a single unit. Based on these considerations, the total thickness of the Middle South Danville Shale is approximately 108 meters (41 to 148 meter of measured interval on Figure 44). Overall this unit is poorly fossiliferous where exposed with only one discontinuous fossil lag (sampled horizon Ri-5) having been located.

Upper South Danville Shale Unit - A distinct color change at Ri-6 (Figures 44 and 47) and slightly calcareous condition, lead to the preliminary suspicion of this being the contact between the Mahantango Formation and Tully Mesosequence. However, the "pre-Tully" megafauna containing the upper Mahantango index brachiopod *Pustulatia postulosa* (Figure 48) located approximately eleven meters higher up section (sample horizon Ri-9 of Figure 44), indicates this interval to be part of the Mahantango Formation. What is here referred to as the Upper South Danville Shale Unit occurs from the 148 to 163 meter of measured section as depicted on Figure 44. The first ten meters is a light gray calcareous shale. The upper five meters is mostly noncalcareous shale with some interbedded micrites. This upper portion includes a fossiliferous bed with *Pustulatia postulosa* (sample Ri-9).

Contact between Mahantango Formation and Tully Mesosequence -Based on the stratigraphic location of *Pustulatia postulosa* (sample Ri-9), the contact between the Mahantango

Figure 47 - Color change of shale beds within upper Mahantango Formation at Riverside, PA marking the contact between the Middle and Upper South Danville Members.

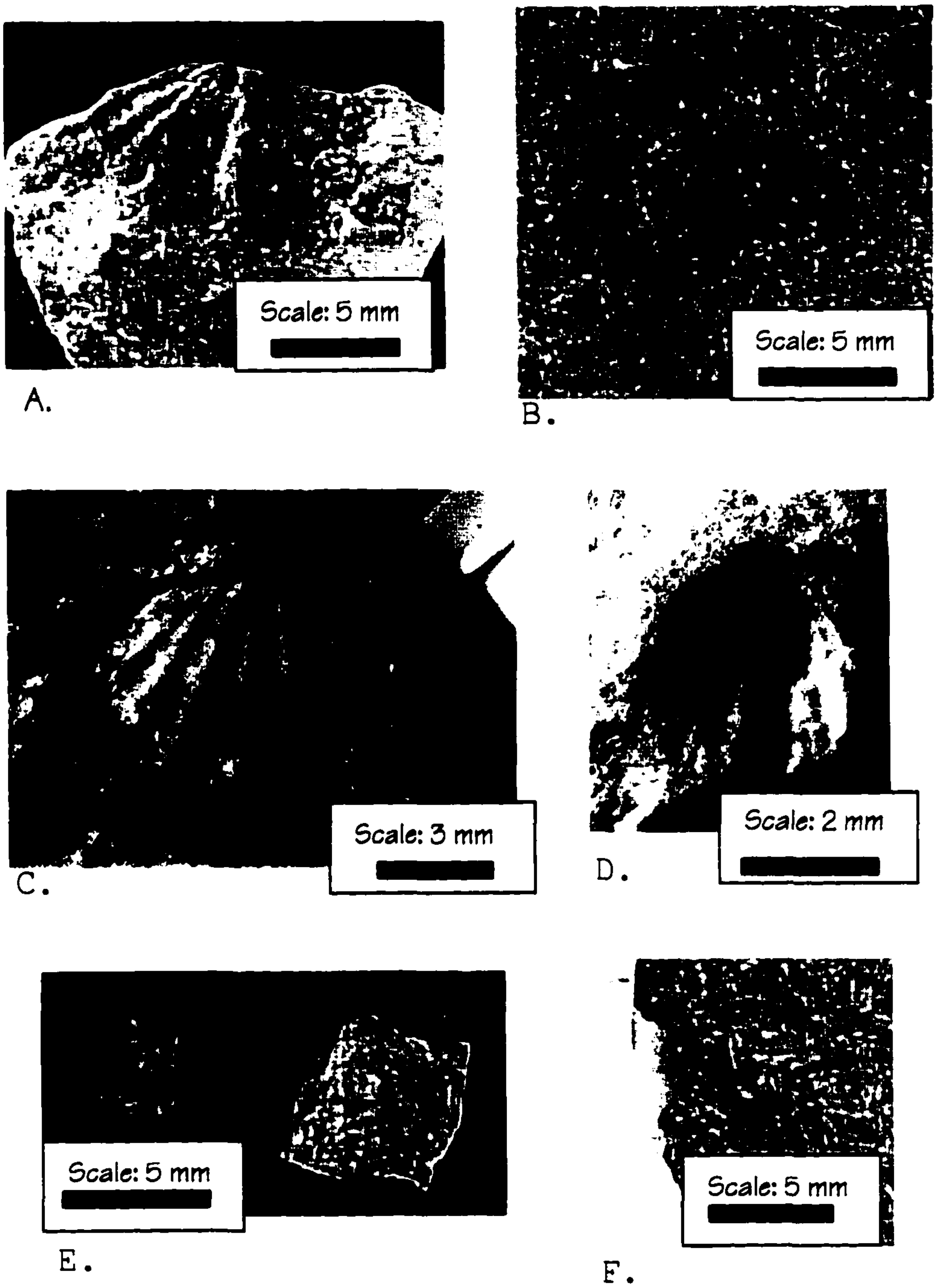


Figure 48 - Examples of the brachiopods *Pustulatia pustulosa* (a-c) and *Allanella tullia* (d-f) from sampled horizon Ri-9 of the Upper South Danville Member of the Mahantango Formation, Riverside, PA.

Formation and Tully Mesosequence appears to be gradational at the Riverside section. Therefore, the presence of a change from non-calcareous to calcareous shale at the 164 meter interval of measured section is here recognized as the contact between these two units as shown on Figure 44.

Tully Mesosequence - The total thickness of the Tully is estimated (due to poor exposure) as approximately 15 meters thick at the Riverside section. The Lower Tully Member consists of calcareous shale as well as calcilutite. The basal contact of the Tully Mesosequence with the underlying Mahantango is not readily distinguishable. Instead an arbitrary placement of the contact between the Mahantango Formation and Tully Mesosequence is indicated by a transition of non-calcareous to calcareous shale (as depicted on Figure 44). The upper portion of the Tully Mesosequence has become poorly exposed since the previous studies of Willard (1939) and Heckel (1969). The contact indicated by Heckel (1969, Figure 3) between the Lower and Upper Tully Members based on the presence of fossiliferous lag with a fauna similar to that at Lock Haven was not located during this study. The overlying contact of the Tully Mesosequence was also not found, although dark gray to black fissile shale representing the Harrell Formation is found approximately 50 meters further along Route 54 at this exposure.

Fossiliferous and Sampled Beds

Mahantango Formation - Of the seven (Ri-1 through R-6 and Ri-9) sampled locations from the Mahantango Formation at Riverside (see Figure 44), five are fossiliferous beds having either brachiopods, mollusks or echinoderms. The other two (samples Ri-2 and Ri-6) represent sparse to non-fossiliferous intervals. Most of the beds have some fossils with calcitic shell still preserved, although most are typically leached of original shell material so that only molds and casts remain. For example, sample Ri-1 (17.5 meter interval of measured section on Figure 44), contains calcareous crinoid columnals (Figure 49). Likewise, sample Ri-3 (37.75 meter interval of measured section on Figure 44), is a discontinuous lag with calcitic shell gastropods of the genus *Ptychospirina* (Figure 50). Other fossils from Ri-3, including spiriferid brachiopods (Figure 51A) and disarticulated pelmatazoan columnals, also have calcitic shell or are leached. Sampled horizon Ri-4 marks the top of the Riverside Siltstone Beds and consists of a shaly siltstone containing *Tropidoleptus carinatus* (Figure 46). This species makes up approximately 75 percent of the fossils identified (refer to Appendix D).

Unlike the bed at sample location Ri-4, fossils (Figures 51 and 52) from the bed of sample Ri-5 has a mixed grouping of brachiopods, mollusks and echinoderms. The

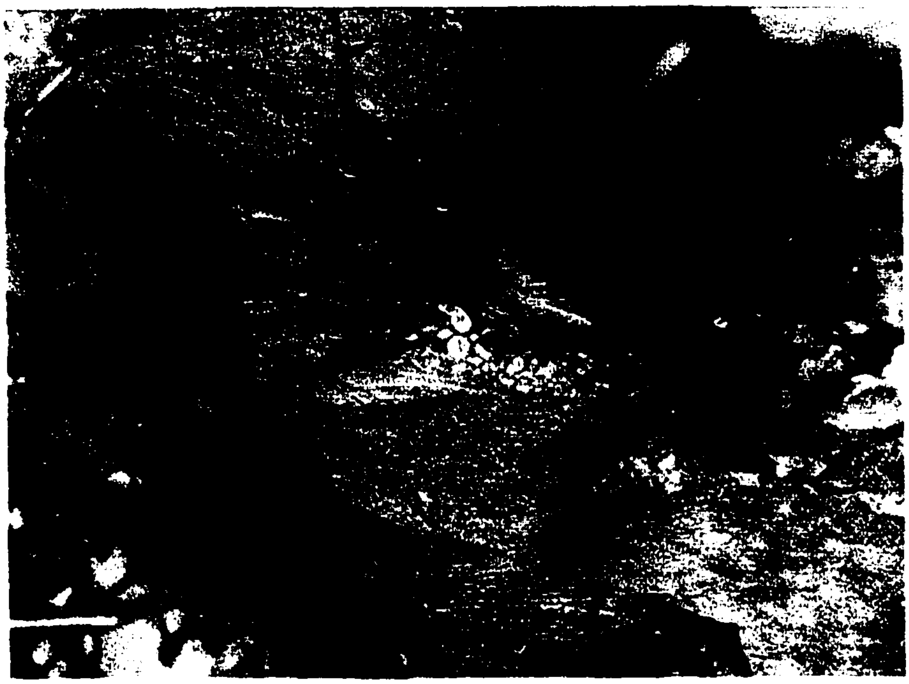
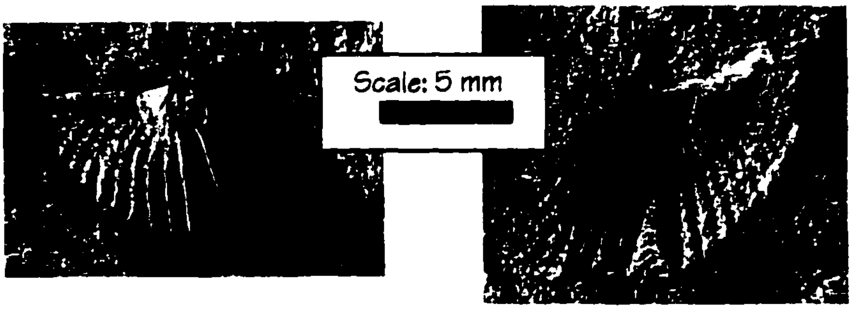
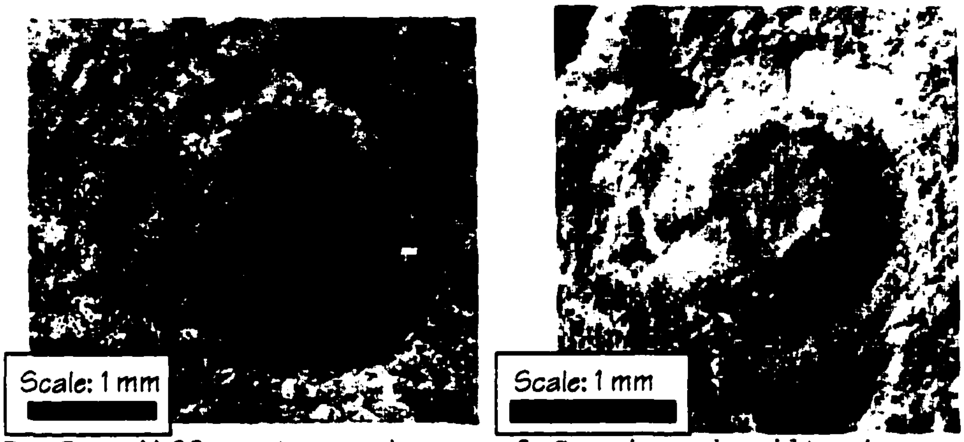


Figure 49 - Discontinuous lag of calcareous pelmatazoan columna. Sampled horizon Ri-1 (Lower South Danville Member of Mahantango Formation) at Riverside, PA.

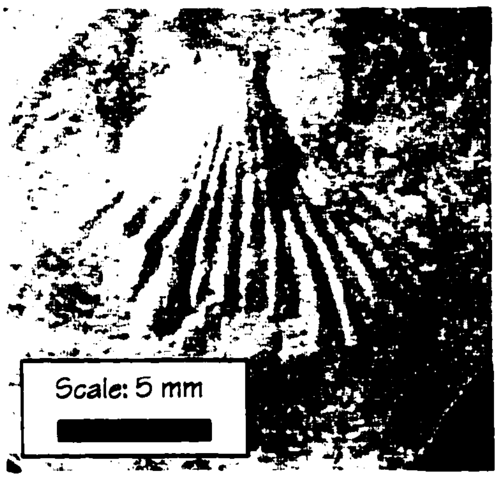
Figure 50 - Discontinuous lag of gastropod (arrows). Sampled horizon Ri-3 (Riverside Member of Mahantango Formation at Riverside, PA.



A. Spiriferid brachiopod from sampled horizon Ri-3.



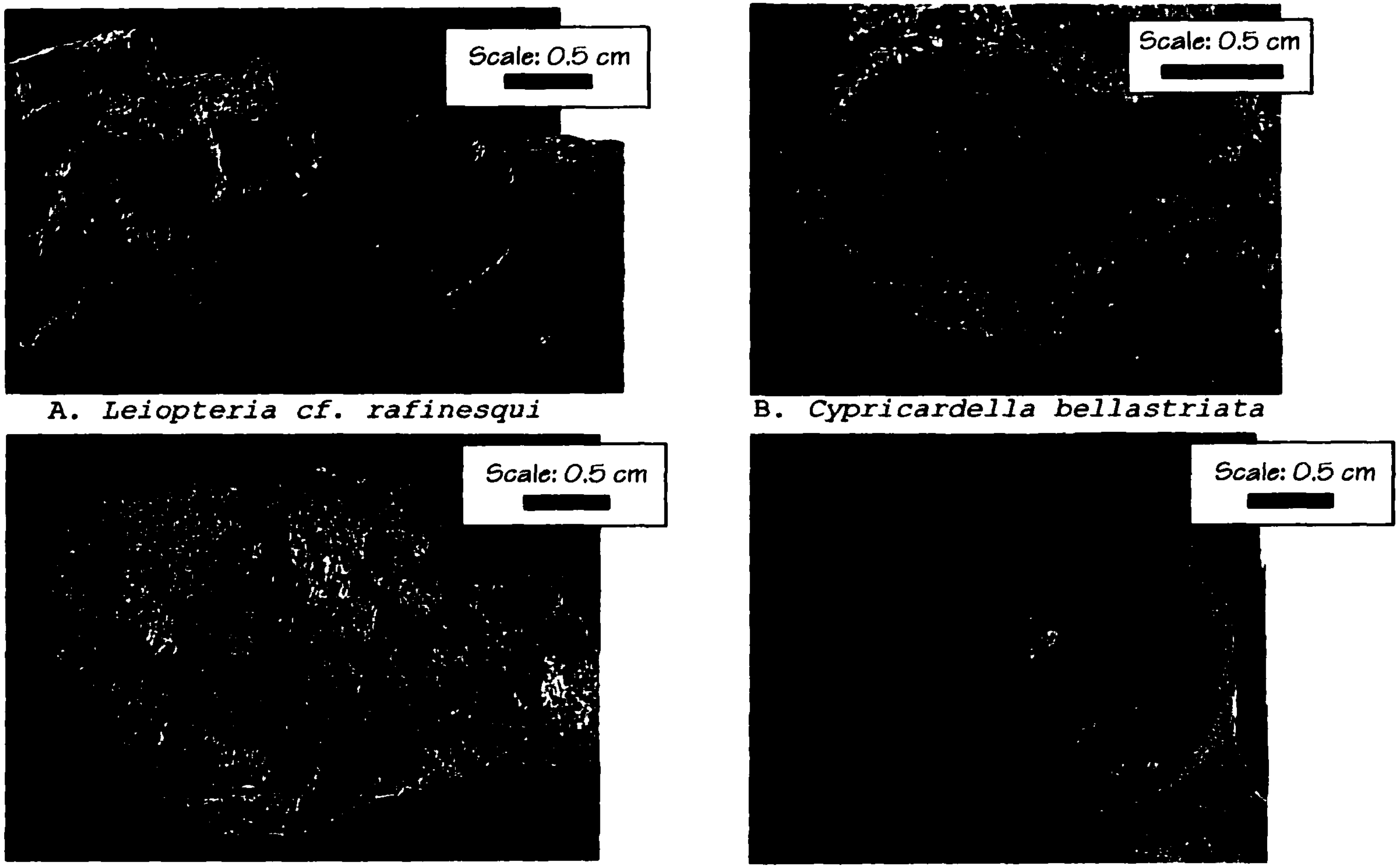
B. Two different specimens of *Craniops hamiltoniae* (inarticulate brachiopod) from sampled horizon Ri-5.



D. *Ponderodictya punctulifera* (ostracode) from sampled horizon Ri-7.

C. *Cupularostrum sappho* (rhynchonellid brachiopod from sampled horizon Ri-4.

Figure 51 - Examples of fossils from the Mahantango Formation (A-C) and Tully Mesosequence (D) at Riverside, PA.



A. *Leiopteria cf. rafinesqui*   B. *Cypricardella bellastriata*

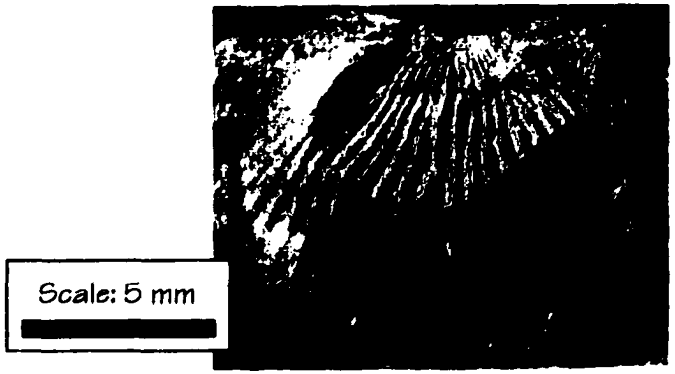
C. *Mediospirifer audaculus*   D. *Rhipidomella sp.*

Figure 52 - Examples of fossils from sampled horizon Ri-5, Mahantango Formation, Riverside, PA.

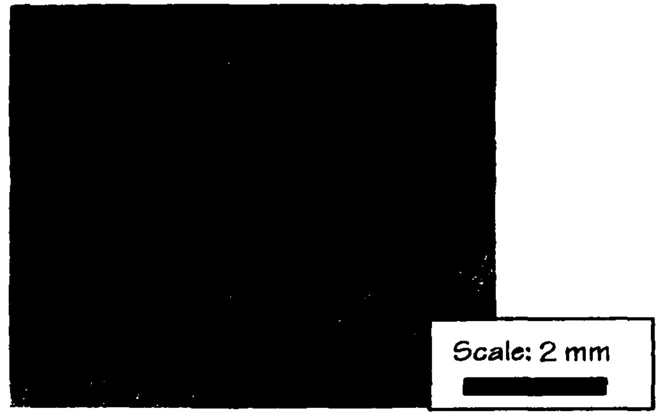
most common brachiopod found is *Athyris spiriferoides* in various sizes and states of preservation. Other brachiopods present are typically disarticulated and include a diminutive form of *Allanella tullia*, *Rhipidomella* sp. (Figure 52), *Mediospirifer audaculus* (Figure 52), and *Tropidoleptus carinatus*. More common pelecypods from the lag at sample location Ri-5 include *Cypricardinea indenta*, poorly preserved specimens of *Leiopteria* cf. *rafinesqui* (Figure 52), and *Carydium bellistriatum* (Figure 52).

Sampled horizon Ri-9 is dominated by brachiopods and includes the biostratigraphically significant *Pustulatia postulosa* (Figure 48) indicating the upper assemblage zone of this name and that this horizon is still within the Mahantango Formation (sensu Heckel 1973 and Cooper and Williams 1935). Two other common brachiopods are *Allanella tullia* (Figure 48) and *Tropidoleptus carinatus* (Figure 53). Ichnofossils are also present (Figure 53). In summary, the presence of fossiliferous beds within the upper Mahantango Formation at Riverside is similar to the Bowmanstown section. The types of brachiopods present though are different. At Bowmanstown *Mucrospirifer* and "*Leiorhynchus*" are more dominant than the genera found at Riverside.

<u>Tully Mesosequence</u> - The two samples from of the Tully Mesosequence (Ri-7 and Ri-8) do not have many shelly fossils. The calcareous shaly mudstone (calcilutite) bed of Sample Ri-7 contains three millimeter wide horizon



A. *Tropidoleptus carinatus:* brachial valve.



B. *Tropidoleptus carinatus*:pedicle valve.

C. Horizontal burrow.

Figure 53 - Examples of fossils from sampled horizon Ri-9, uppermost Mahantango Formation, Riverside, PA.

burrows and some microfossils (Figure 51D). These burrows, some of which are weathered limonite, resemble those associated with sample LH-2 at the Lock Haven. Sample Ri-8 is similar to Ri-7, but with small (one millimeter to one centimeter) pyritic concretions and burrows. No distinct fossiliferous horizons are readily apparent in the Lower Tully, although occasional fossils, including corals are found higher up section.

Comparison to Other Studies - From oldest to youngest, stratigraphic units observed by this writer at the Riverside section are: the Mahantango Formation, the Tully Mesosequence, and the Burket Shale (Member) of the Harrell Formation. As indicated in Figure 54, these units concur with those noted by Willard (1935a,b, 1939) and Heckel (1969, 1973). As with this study, both of these authors subdivided the Tully into Lower and Upper Members. This study further subdivides the Mahantango Formation into four informal subunits which appear to basically concur with the general log description of Willard (1939, p 352). Unit 2 of Willard (1939) appears to be in the same stratigraphic interval as the Lower South Danville Shale Beds. Unit 3 of Willard (1939) equals the Riverside Siltstone Beds. Units 4, 5 (the latter being concealed) and probably the lower portion of 6 of Willard (1939) equal the Middle South Danville Beds (which includes the unexposed interval of Hower Road). The remainder of Unit 6 (also referred to as the "Moscow fauna facies" by Willard 1939) is equivalent to the Upper South Danville Shale Beds.

The most distinct unit at the Riverside section is the Riverside Siltstone Beds which is characterized at its base by a distinct 1.5 meter thick siltstone and has the equally distinct *Tropidoleptus* bed (Figure 46) at its top. Willard's (1939) general description of Unit 3 notes the presence of "sandstone" (recognized as siltstone in this study) and "abundant *Tropidoleptus*", but does not refer to any key beds. The basalmost 1.5 meter thick bed of the Riverside Siltstone Interval resembles the Nis Hollow Member found at Bowmanstown (contrast Figure 45 with Figure 14). However, based on fossils found in overlying beds (and discussed in more detail in Chapter Five) this unit is recognized as being older than the Nis Hollow Member observed at Bowmanstown despite its lithologic resemblance. The Riverside Siltstone Beds are in a stratigraphically lower portion of the section than that reviewed by Heckel (1969, 1973).

The boundary between the Mahantango Formation and Tully Mesosequence is located at meter 164 meter of the measured section (Figure 44). While the contact appears to be gradational at the Riverside section, an identifying change from non-calcareous to calcareous shale at the 164 meter of measured section (Figure 44) basically concurs with the previous studies of Heckel (1969, 1973) and

REFERENCE:	Willard (1935, 1939)	Heckel (1969, 1973)	This Study
UNITS RECOGNIZED	Harrell Fm. Trimmers Rock Member (Unit 11) - - - - - - - - Burket Shale Member (Units 9 and 10)	Harrell Fm. Burket Shale Member	Harrell Fm. Burket Shale Member
	Hamilton Group: Tully Fm. (Unit 8) - - - - - - - - (Unit 7)	Hamilton Group: Tully Fm. Upper Member - - - - - - - - Lower Member	Hamilton Group: Tully Mesosequence Upper Member - - - - - - - - Lower Member
	Mahantango Fm. (Upper part of Unit 6) - - - - - - - - (Units 4, 5 and 6) - - - - - - - - (Unit 3) - - - - - - - - (Unit 2)	Mahantango Fm. (Undifferentiated)	Mahantango Fm. Upper South Danville Shale Member - - - - - - - - Middle South Danville Shale Member - - - - - - - - Riverside Siltstone Member - - - - - - - - Lower South Danville Shale Member

Legend:

Group Boundary (double line)
Formation Boundary (single line)
Member Boundary (- -)

FIGURE 54 - SUMMARY OF STRATIGRAPHIC UNITS RECOGNIZED AT RIVERSIDE, PA

Willard (1939). These earlier studies relied on the stratigraphic location of the *Pustulatia postulosa* brachiopod Zone initially used by Cooper (1934) for New York. This brachiopod (Figure 48) is present at sampled horizon Ri-9 at the 160.5 meter of the measured section (Figure 44).

The upper portion of the Tully Mesosequence has become more poorly exposed since the previous studies of Willard (1939) and Heckel (1969). The contact indicated by Heckel (1969, Figure 3) between the Lower and Upper Tully Members based on the presence of fossiliferous lag with a fauna similar to that at Lock Haven was not located during this study and appears to be no longer exposed.

The Riverside is a pivotal section (see Figure 1) sharing various features with the Lock Haven to the northwest, the Harrisburg sections to the southwest and the Bowmanstown to the southeast. The Mahantango Formation has not previously been differentiated in terms of formal subunits at the Riverside section. However, as with the Bowmanstown section, several lithologic and fossiliferous beds help in subdividing the Mahantango Formation. As will be discussed, both of these sections contrast to the Lock Haven exposure where overall no such subdivisions appear feasible.

Lock Haven (Lockport) Section

The Lock Haven section ("C" of Figure 1) is located in Woodward Township at the foot of the Route 664 Bridge on the "Lockport" (north) side of the West Branch of the Susquehanna River (see Figure 55 for detail location information). This exposure has been referred to as the 'Lock Haven section' (Willard 1939; Heckel 1969, 1973) because of its location directly across the river from this city. Six whole rock samples (labelled LH-1 through LH-6) were collected at stratigraphic locations shown on Figure 56. From oldest to youngest, the stratigraphic units occurring here are: the Mahantango Formation, the Lower and Upper Members of the Tully Mesosequence and the Burket Member of the Harrell Shale. Most of the Tully at this location can be recognized by its formational name of Limestone rather than Mesosequence. This is due to most of the Tully being readily identified from its lithology rather than its sequence stratigraphic or paleontologic characteristics. However, I continue to use the term "Mesosequence" because the lower boundary at this section is not as lithologically distinct as one would like for a lithologic unit.

Mahantango Formation - The Mahantango Formation is predominantly a black to dark gray, shale to silty shale at Lock Haven with poor to fair exposure. These beds weather

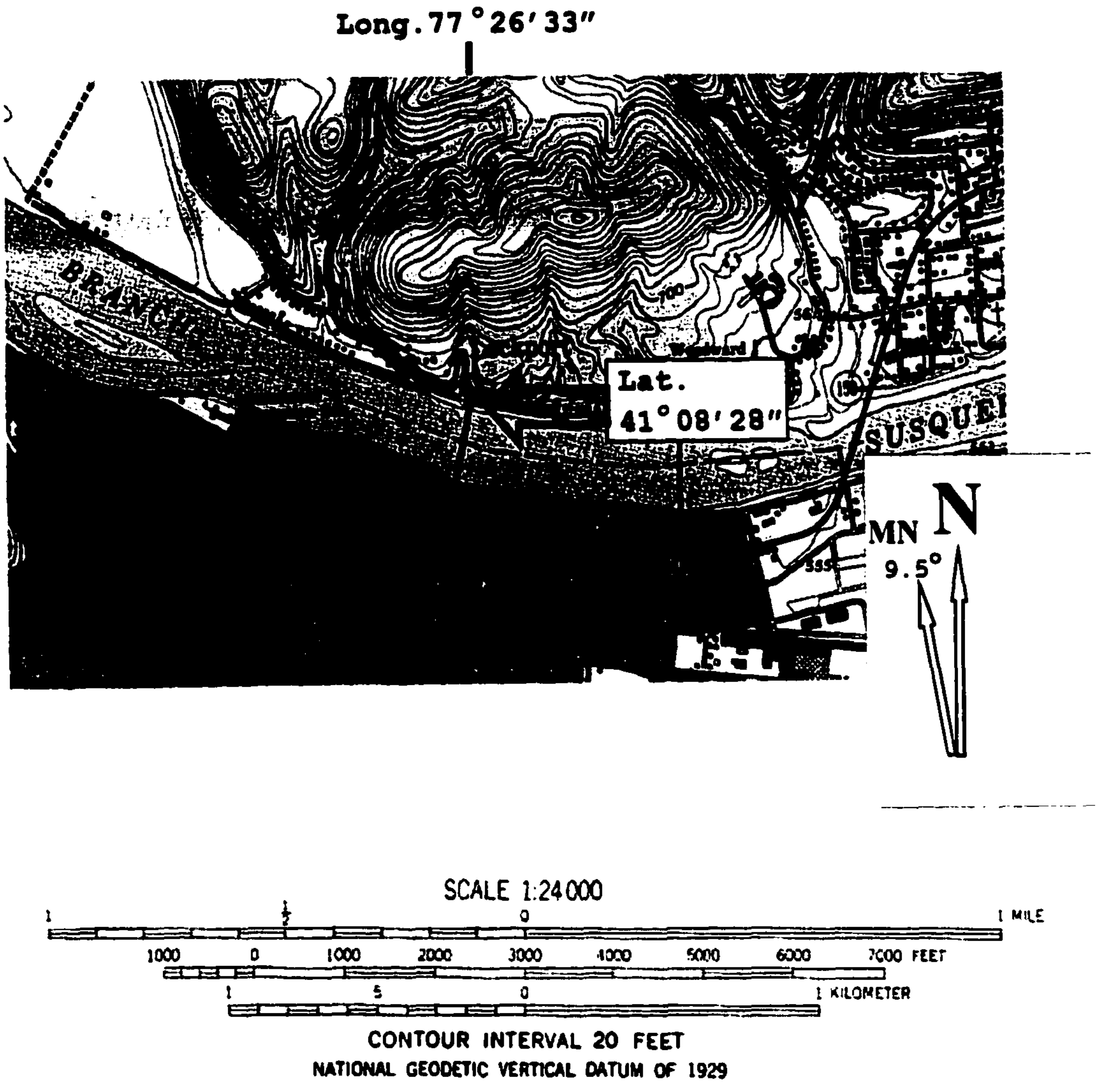


Figure 55 - Map showing location of Lock Haven, PA section.
Source: USGS Lock Haven, PA Quadrangle Map.

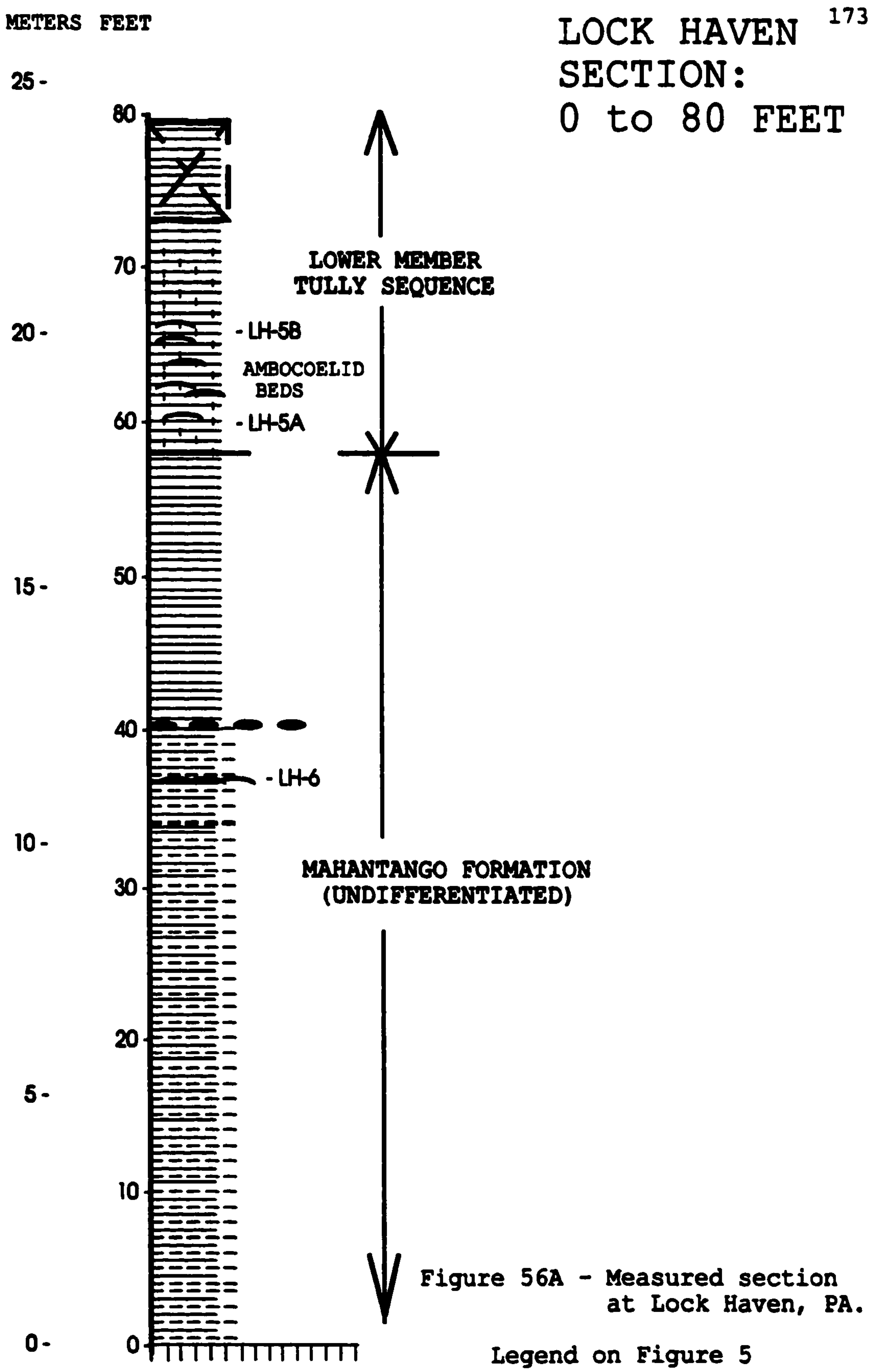


Figure 56A - Measured section at Lock Haven, PA.

Legend on Figure 5

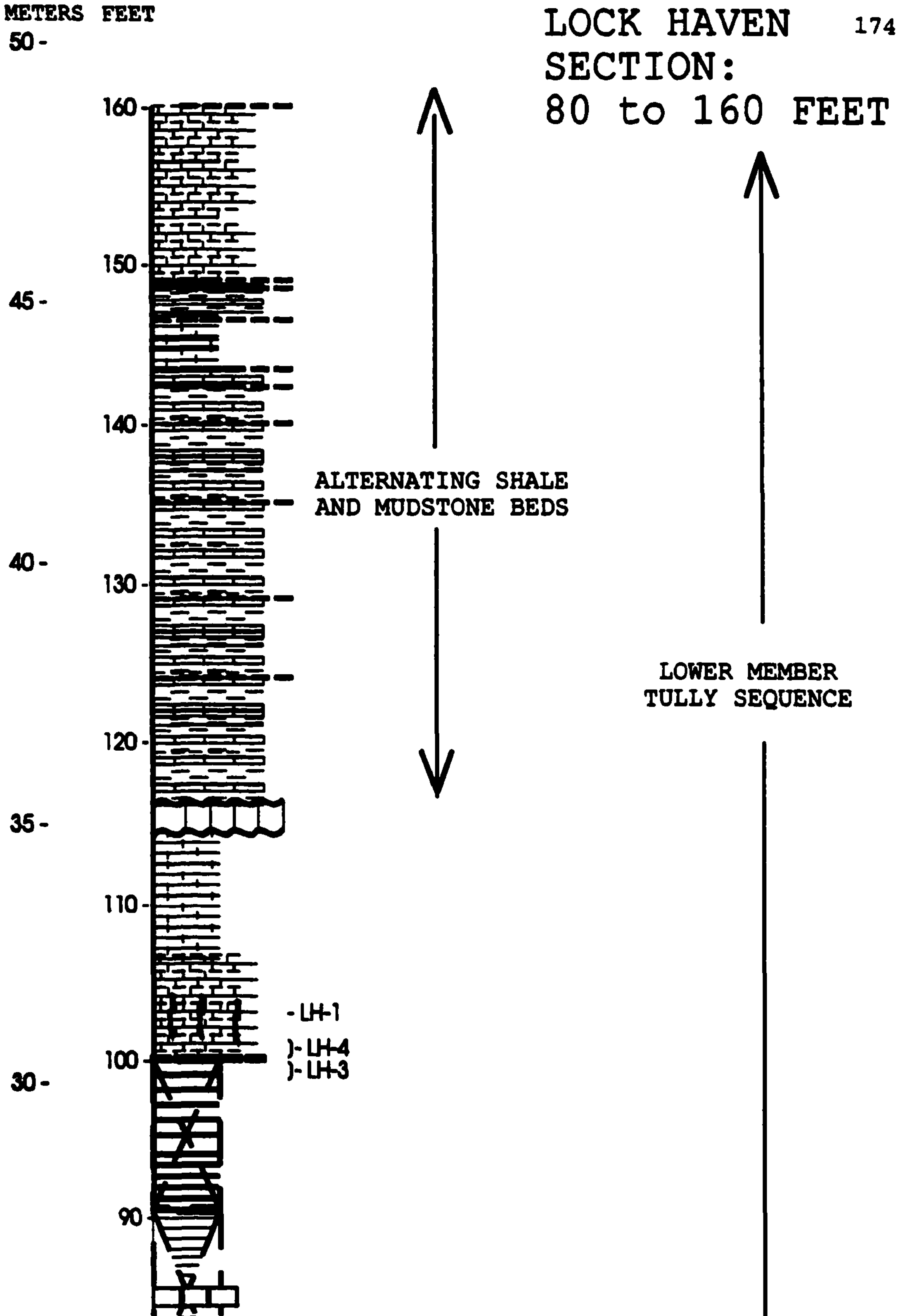


Figure 56B - Measured section at Lock Haven, PA.

Legend on Figure 5

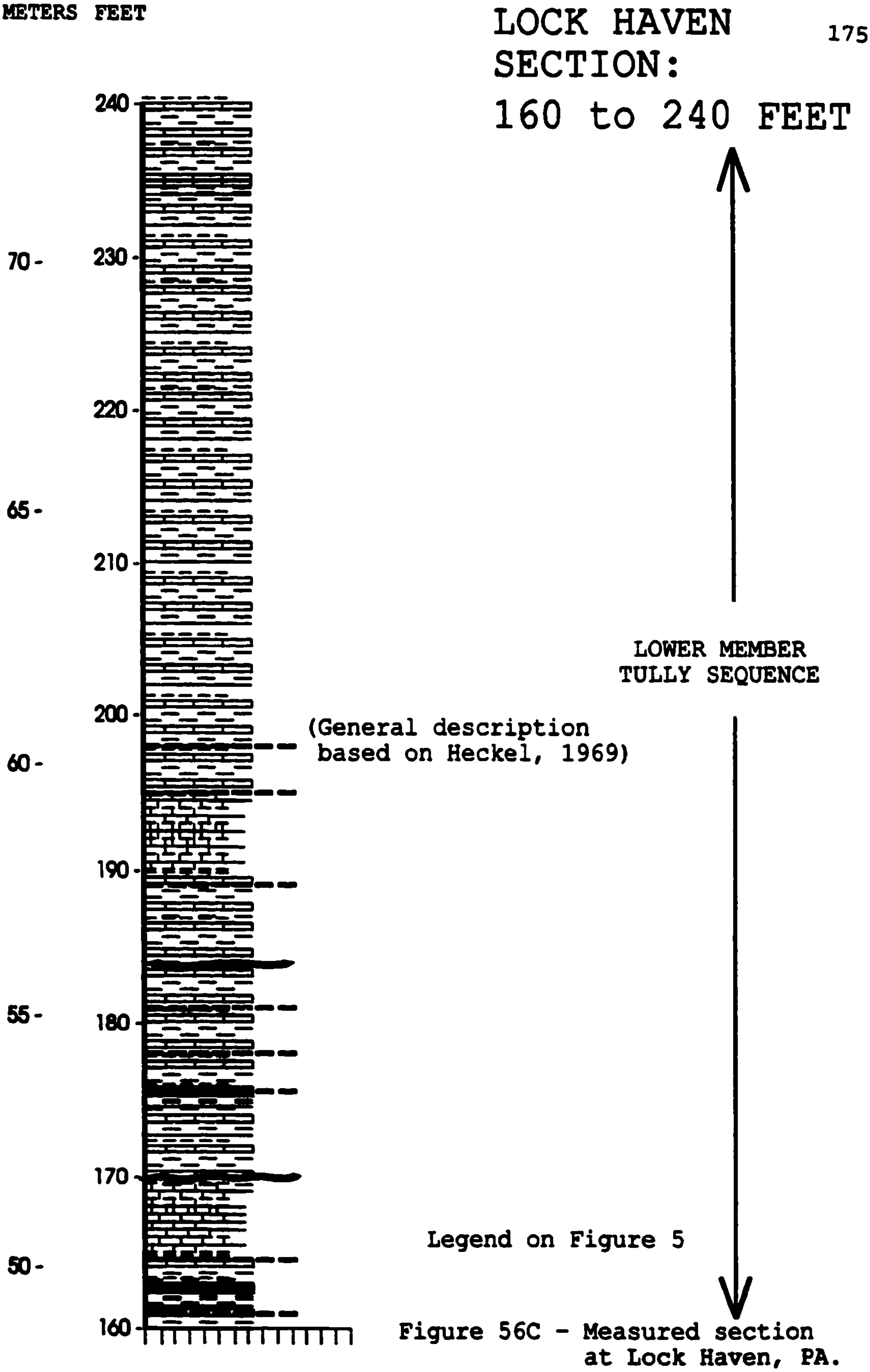


Figure 56C - Measured section at Lock Haven, PA.

LOCK HAVEN SECTION: 240 to 320 FEET

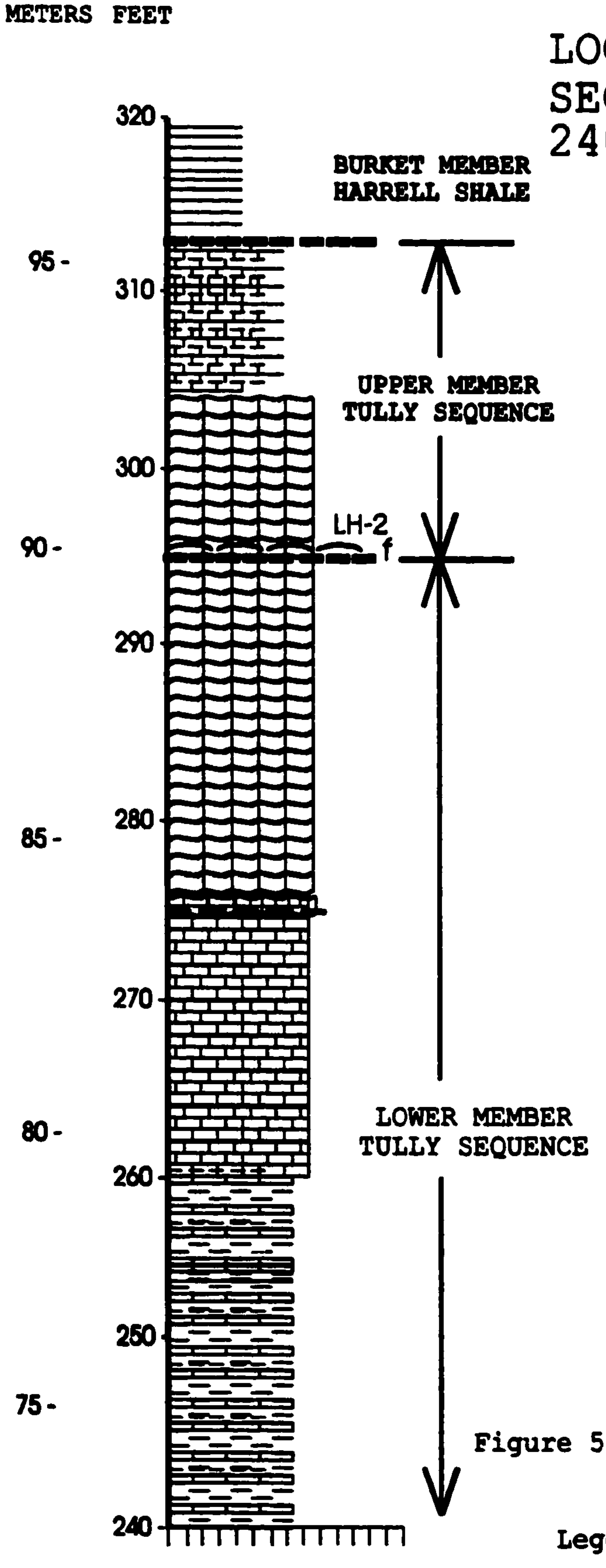


Figure 56D - Measured section at Lock Haven, PA.

Legend on Figure 5

a brownish gray. Approximately 30 meters of the uppermost Mahantango Formation was field measured (Figure 56) with additional lower section visually inspected. For the most part this field inspection was unsuccessful in locating any distinct fossiliferous or lithologic beds similar to those found at the other studied sections. Besides the apparent lack of fossils, sedimentary structures are difficult to recognize among the nearly vertical bedding planes and because of prominent fracture cleavage planes running approximately perpendicular to the beds.

Two exceptional beds within the Mahantango Formation are a discontinuous fossiliferous lag (sample location LH-6) and a concretion horizon (approximate eleven to twelve meter interval of measured section on Figure 56). The concretions are ovoid shape (Figure 57) with typical dimensions of 3 by 5 by 10 centimeters. Both the fossil lag and concretion horizons are near the overlying contact with the Tully Mesosequence.

Mahantango-Tully Contact - The contact between the Mahantango Formation and Tully Mesosequence is not immediately apparent without close field inspection. This is due to both units consisting of shales. The contact is recognized where black to dark gray shales change from non-calcareous to calcareous (Figures 56 and 57). Approximately a half meter above this contact are sporadic bedding surfaces yielding abundant minute (2 to 5

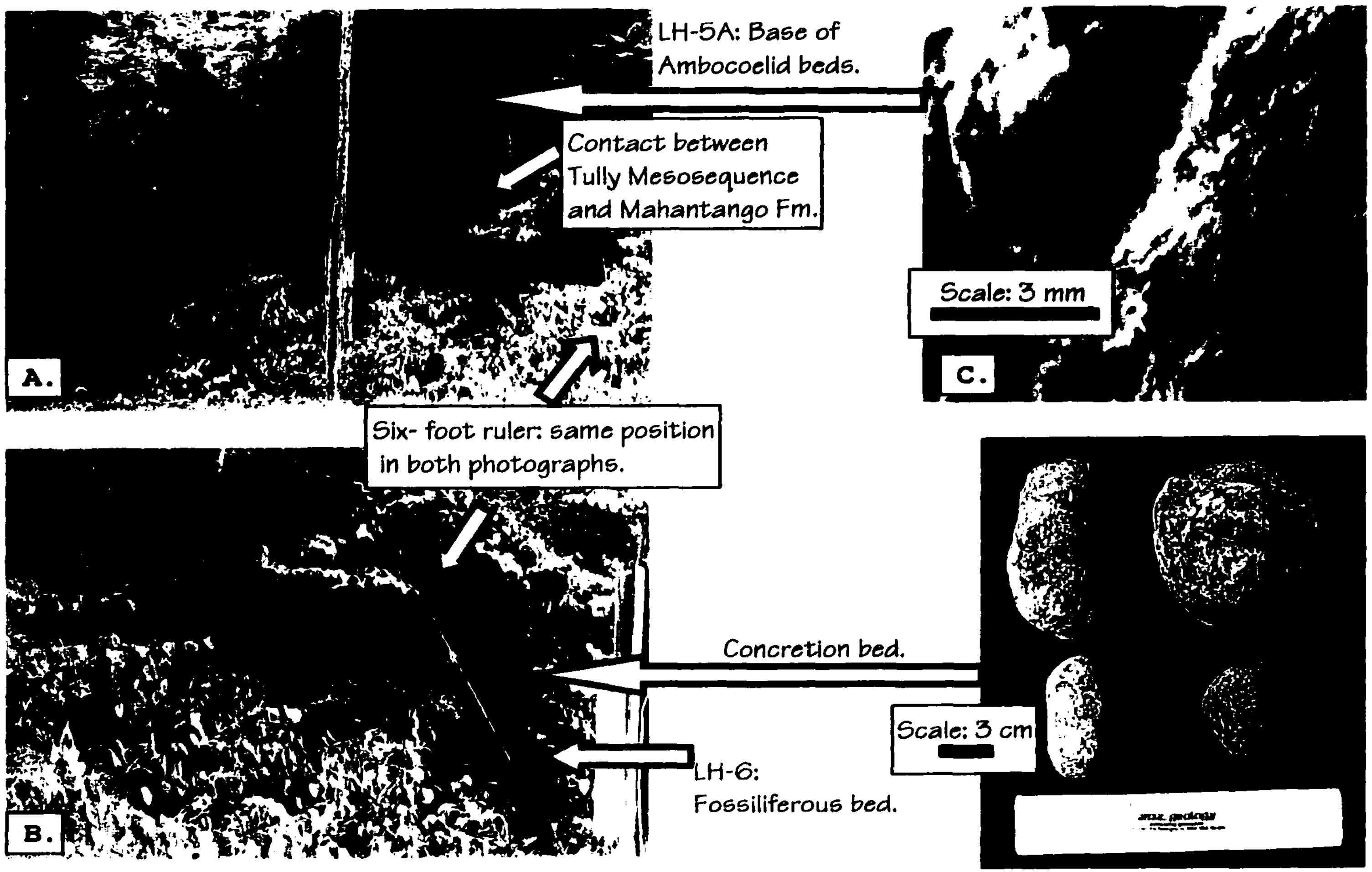


Figure 57 - Contact between Upper Mahantango Formation and Tully Mesosequence at Lock Haven, PA.

millimeter) ambocoelid brachiopods *Emanuella* cf. *subumbona* (the 18 to 20 meter interval of measured depicted on Figure 57). Above this fossiliferous interval the Tully Mesosequence remains shaly, but becomes less calcareous to non-calcareous. Also within this interval (from the 20 to 30.5 meter section depicted on Figure 56) are rare, poorly exposed five to ten centimeter thick micrite (calcilutite) beds. The first distinct calcilutite bed, representing typical Tully Limestone, is located at sample horizon LH-4 which overlies a non-calcareous shale (sample horizon LH-3 on Figure 56). During initial field inspection at Lock Haven, sample LH-3, was collected with the idea that it represents the top of the Mahantango Formation. This contact is misreported by Brown et al. (1998) and is possibly shown by Heckel (1969, Figure 3) as the lower Tully contact as suggested by the lack of shale beds being illustrated in Heckel's diagram.

Lower Tully Member - The surface exposure of the basalmost Tully Mesosequence at Lock Haven is poorly exposed (Figure 57) and, as already noted, dominated by shale. The remaining portion of the Lower Tully Member consists of a distinct sequence of alternating beds of medium gray, calcareous shales and micrite (calcilutites) ranging in thickness from a centimeter to 10 centimeters (Figure 58). Macrofossils are not common in this unit, although burrows and small dacryoconarids (*Styliolina* and *Viriatellina*) are

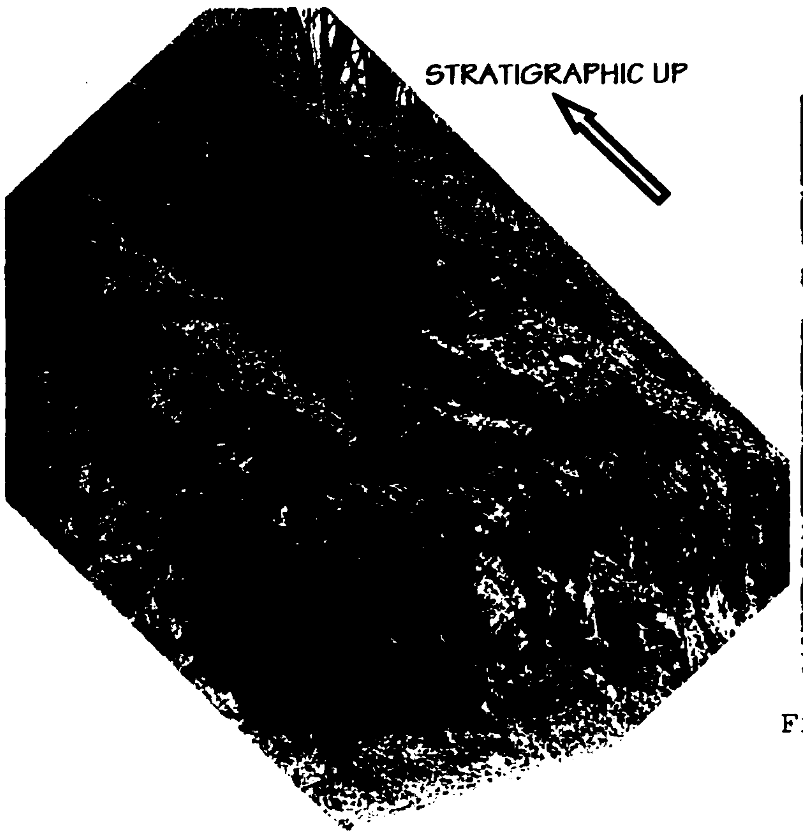


Figure 58A - Typical sequence of intercalated beds of the Lower Tully Member at Lock Haven, PA. Stratigraphic up is to the left.

Figure 58B - Detail of right side of Figure 58A showing intercalated beds of the Lower Tully Member at Lock Haven, PA. Rock hammer and six foot long ruler for scale.

common to abundant at some horizons. Also present at the LH-4 horizon (Figure 59) is a "shelly microfauna" (see Figures 60 through 68 for SEM photographic examples) containing juvenile specimens of gastropods (Figure 66), pelecypods (Figure 64) and other enigmatic microfossils. Brown et al. (1998) used the term 'microfauna' rather than shelly fauna since some of the pyritized specimens may be of soft-bodied or chitinous origin (see Figures 60, 61 and 68 for examples).

More typical Lower Tully Member beds for the Lock Haven section begin above the burrowed calcilutite bed from which sample LH-4 was obtained. These dacryoconarid-bearing beds had been previously observed by Heckel (1969, 1973), although the microfauna at LH-4 had not (Heckel, personal commun. 1998). Above sampled horizon LH-4, the lower part of the Lower Tully Member has a sequence of cyclic beds that alternate between distinct micrite beds and calcareous shale (Figure 58). These are referred to as the "platy" beds by Willard (1935, 1939). These beds become less shaly ("platy") and with thicker micritic (calcilutite) beds within the uppermost twenty meters of the Lower Tully Member.

The shelly microfauna from LH-4, although dominated by pyritized fossils, has a fauna similar to phosphate-dominated shelly fauna observed throughout the Paleozoic and into the lower Mesozoic (Dzik 1994). Many of these

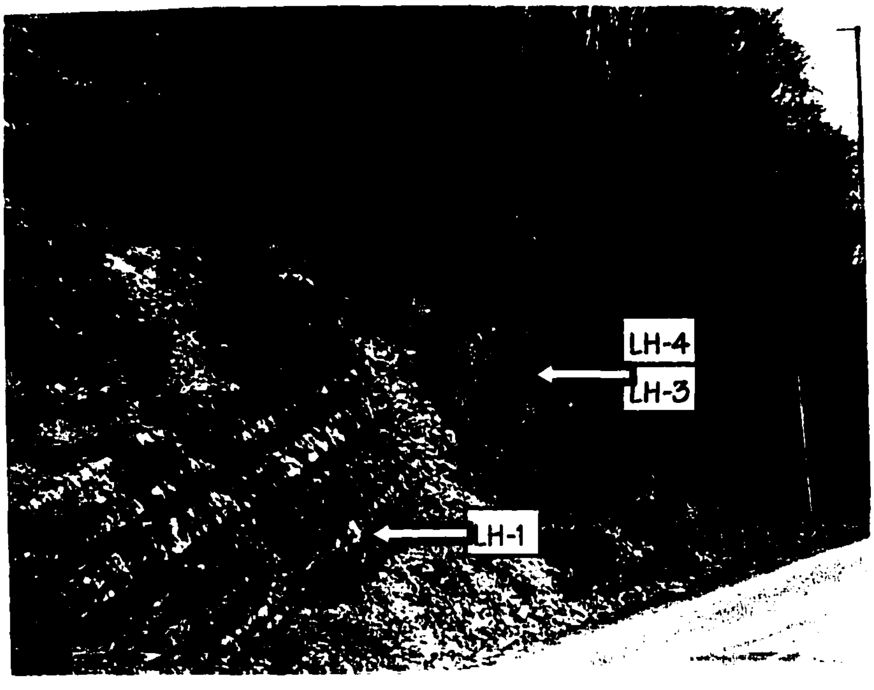
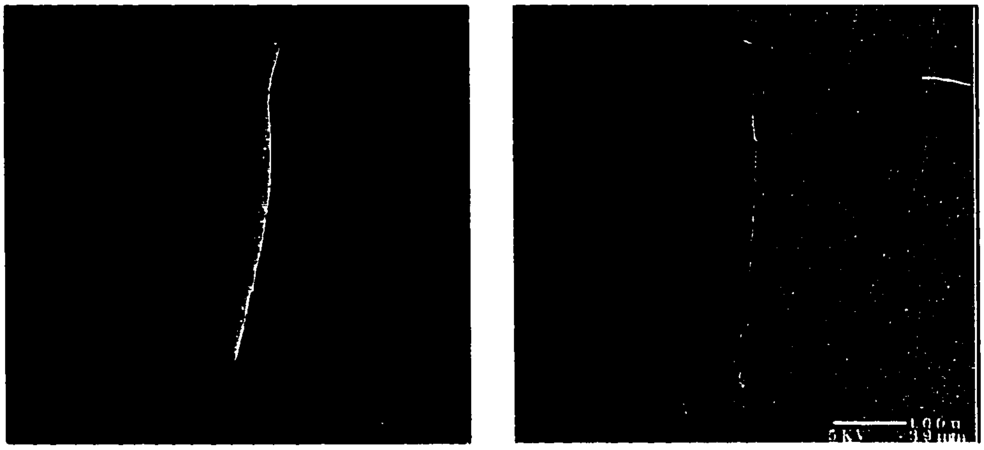
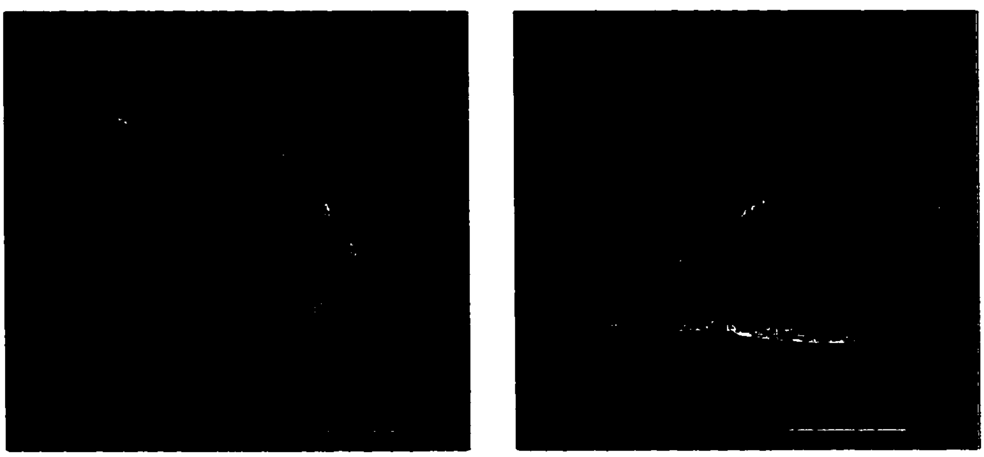


Figure 59 - Roadcut photograph of Lower Tully Member at Lock Haven.
Rock hammer and six foot long ruler for scale.
Sample location LH-1 by hammer. Samples LH-3 and LH-4 collected higher up hill at one meter lower stratigraphic interval.



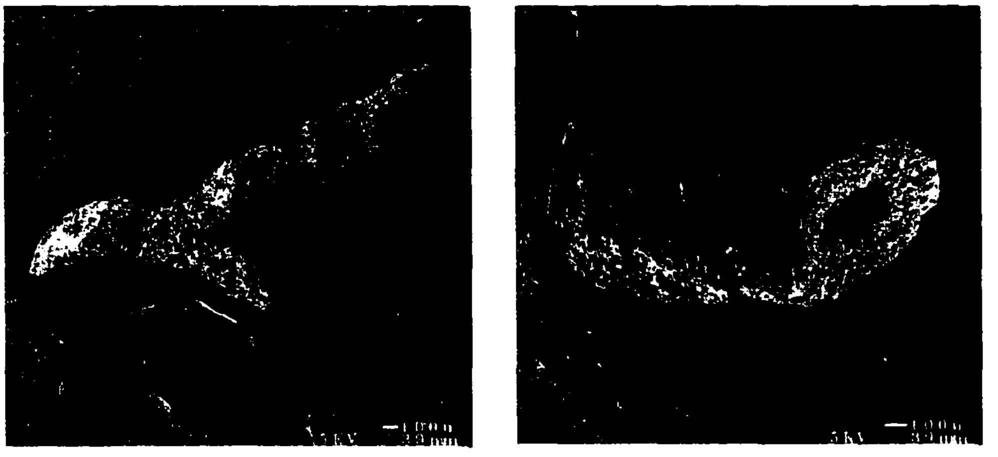
A. B.

Figure 60 - SEM photographs of *Jinonicella* from Sample LH-4.



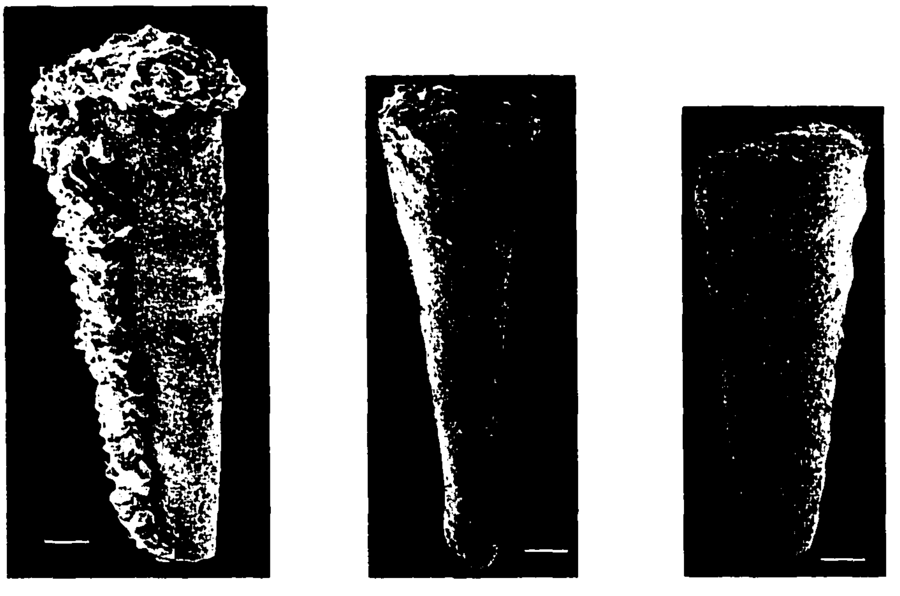
A - Lateral view. B - Lateral view.

Figure 61 - SEM photographs of possible ctenostome bryozoan from Sample LH-4.



A B

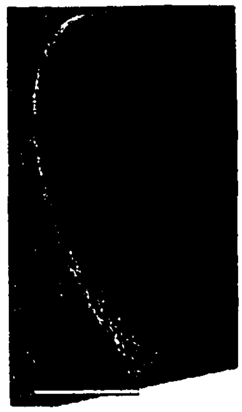
Figure 62 - SEM photographs of pyritized burrows from Sample LH-4.



A B C

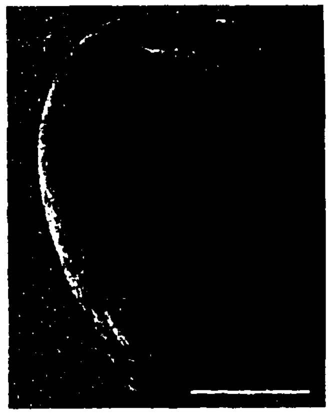
Figure 63 - SEM photographs of *Viriatellina gracilistriata* from Sample LH-4.

A - Dorsal view showing hinge.



B - Anterior lateral view.

C - Right valve.

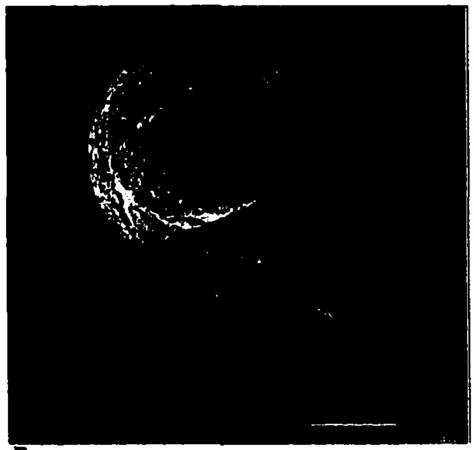


D - Ventral anterior lateral view.

Figure 64 - SEM photographs of pelecypods from Sample LH-4.

Figure 65 - SEM photograph of possible cephalopod from Sample LH-4.

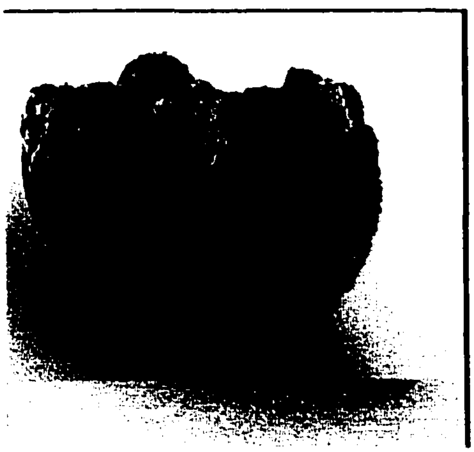
A.



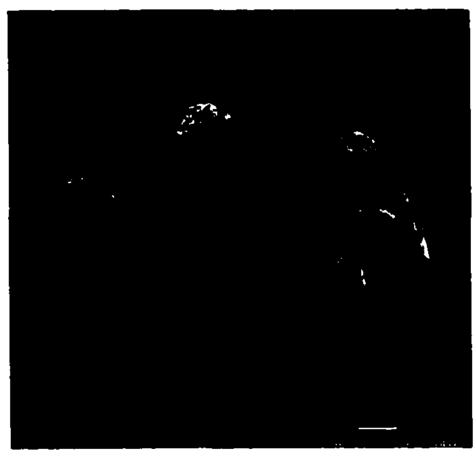
B.

C.

Figure 66 - SEM photographs of indeterminable gastropods from Sample LH-4.
All specimens dextral apertural view.



A - Right valve.



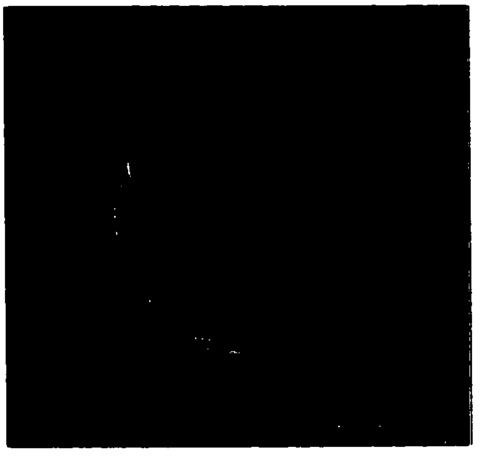
B - Dorsal view.

Figure 67 - SEM photographs of ostracode (cf. *Hollina*) from Sample LH-4.

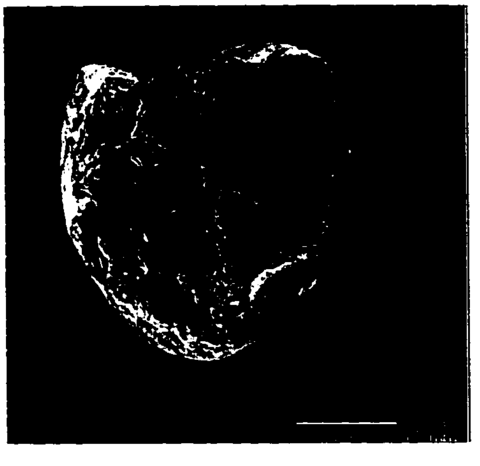
A - Deflated sphere.

B - Rough surface

C - Smooth surface.



D - Smooth surface with minor ornament.



E - Flatted sphere or disk.

Figure 68 - SEM photographs of small round organic structures replaced by pyrite from Sample LH-4.

lagerstatten microfaunas have been considered by Dzik (1994) to represent a maximum flooding surface. A further indication of a 'deep' water environment for the Lower Tully at Lock Haven, at least relative to the rest of the Appalachian Basin at this time, is the abundance of dacryoconarids (or styliolines) which are considered to have been planktonic (Yochelson and Lindemann 1986) and potentially comparable with extant pteropods. Subsequently, the calcitic dacryoconarids (Lindemann and Yochelson 1984) may have served as a carbonate source in a similar fashion as pteropods do under deep-sea conditions (Friedman 1965). The rhythmic nature of the shale and carbonate beds within the Lower Tully Member (Figures 58 and 59) show a similar type of preservation as limestone-shale cycle beds produced within an anaerobic environment (Raiswell 1988). This type of environment may further explain the overall paucity of macrofossils observed within the Lower Tully Member at Lock Haven.

The Lower Tully Member represents nearly 80 percent of the predominantly carbonate unit representing the Tully Mesosequence ("Limestone" in the classic lithologic sense) at the Lock Haven section. Similar carbonate buildups have been observed elsewhere within the Givetian (see Kaufmann and Wendt 2000 for an example from Algeria). This is significant as Lock Haven is recognized as the thickest surface exposure of the Tully 'Limestone' in either

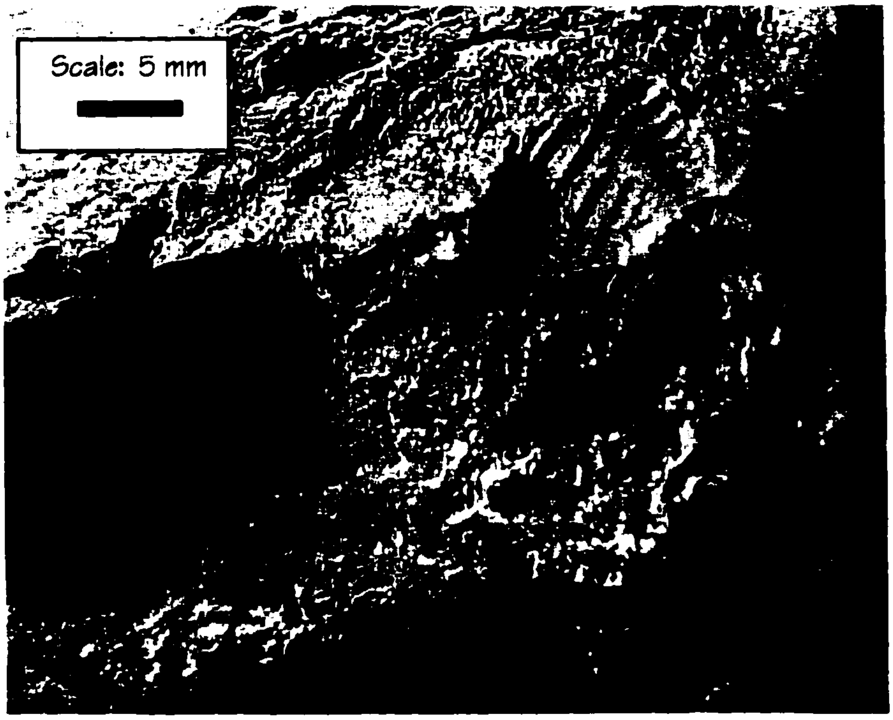
Pennsylvania or New York (Heckel 1969, 1973).

The contact between the Lower and Upper Tully Members is also distinct at the Lock Haven section. It is marked by a hiatal fossiliferous lag. This last observation concurs with the interpretations of Heckel (1969, 1973).

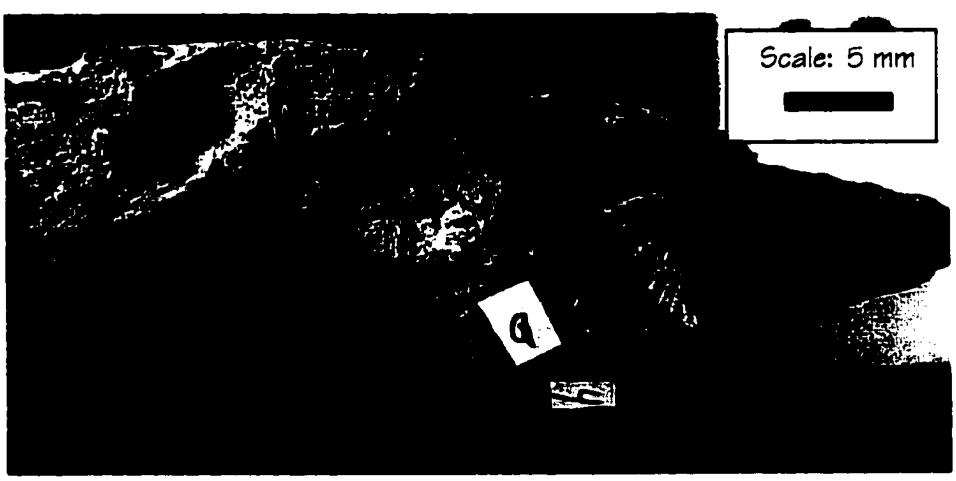
Upper Tully Member - The base of the Upper Tully Member at the Lock Haven section is readily recognized by a fossiliferous lag overlying a hiatal contact (Figure 56). Fossils (see Figure 69) include brachiopods, corals, trilobites, pelmatozoan columnals and bryozoans. The Upper Tully Member lacks the shaly beds common in the Lower Tully and is a knobby limestone (calcarenite). Beds range in thickness from one to two centimeters to ten centimeters. Abraded macrofossils (Figure 69) are abundant at the hiatal base of this unit. However, fossils are less common higher up section. The top of the Tully Mesosequence is marked by a distinct (hiatal?) contact of dark gray and black fissile shale representing the Harrell Formation.

Fossiliferous and Sampled Beds

Mahantango Formation - The Mahantango Formation is not very fossiliferous at the Lock Haven section and only a single horizon (sample location LH-6) had fossils forming a discontinuous lag. Specimens collected include straight nautiloids, '*Leiorhynchus*' brachiopods and nuculoid



A. Trilobite pygidium.



B. Spiriferid brachiopod.

Figure 69 - Fossiliferous lag at base of Upper Tully Member (sampled horizon LH-2) at Loch Haven, PA.

pelecypods.

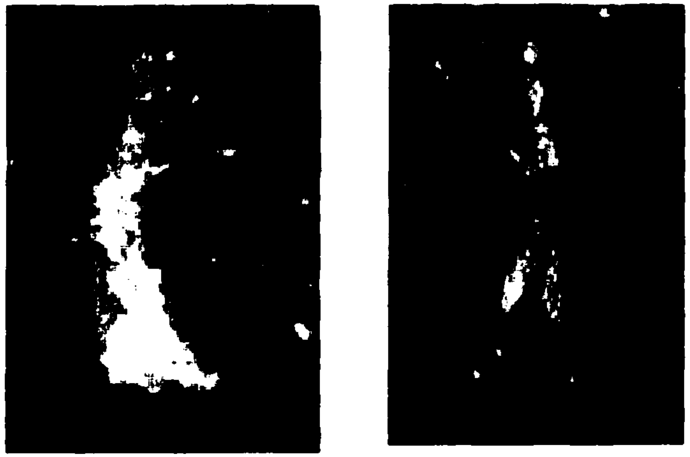
Tully Mesosequence - Distinct macrofossil beds at the Lock Haven locality are not common or readily apparent. For example, the beds containing ambocoelid brachiopod *Emanuella* (Figure 57) consist of small, approximately one centimeter or less macrofossils. These small brachiopods are locally abundant within calcareous shales occurring between the eighteen and twenty meter interval of measured section depicted in Figure 56 (sampled horizons of LH-5). The preservation of these shells is unique in that some have a pearly luster and appear to be composed of "original" calcite. However, these shell are severely deformed due to flattening. The only other readily recognized large fossils within the Lower Tully Member are burrows of varying orientations and lengths with widths up to a centimeter. Another abundant fossil are one to two millimeter-wide dacryoconarids. Heckel (1969, 1973) also observed such horizons with burrows or dacryoconarids (the latter he referred to as styliolines), although the microfauna at LH-4 is a new discovery (Heckel, personal commun. 1998).

As indicated on Figure 56, samples LH-3, LH-4 and LH-1 were all collected within a short stratigraphic interval. During initial field inspection at Lock Haven, sample LH-3 was collected with the idea that this shaly bed represents the top of the Mahantango Formation (as misreported by

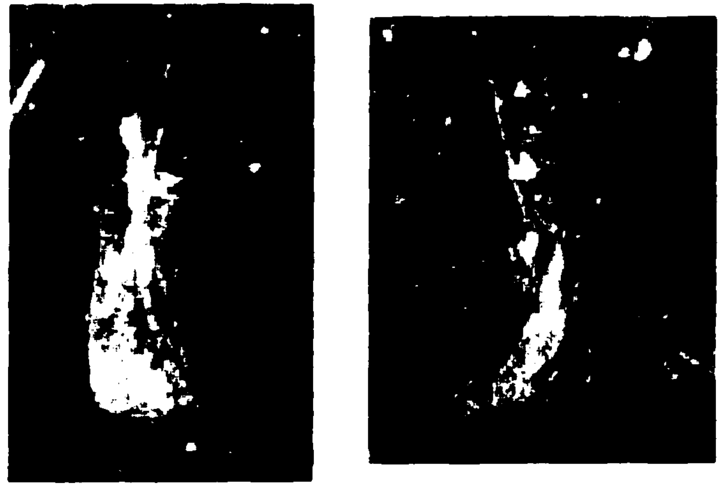
Brown et al. 1998). Sample LH-3 is from the horizon immediately below that of LH-4, while sampled horizon LH-1 is approximately a meter above (see Figures 56 and 59). Sampled horizons LH-3 and LH-1 are both useful in showing the limited vertical distribution of the unique microfauna (Figures 60 through 68) found in sampled horizon LH-4. Except for a rare dacryoconarid, sample LH-1 lacks any microfossils. In contrast, the higher horizon represented by LH-1 contains conodonts (Figure 70), burrows, and dacryoconarids. These fossils are also found in the more diverse sample LH-4 (see Figure 71 for examples of conodonts). However, sample LH-1 lacks any micro-mollusks such as found in LH-4. Some of the calcilutite beds above LH-1 and LH-4 also contain abundant dacryoconarids as well as distinct, pyritized and calcareous, vertical to horizontal, millimeter to centimeter thick burrows.

A calcarenite with a fauna consisting of coral, trilobites, pelmatozoan columnals and bryozoans is present at sampled horizon LH-2 (Figures 56 and 69). The diverse fauna and preservation is similar to that of sampled horizon B-490 (refer to Figure 12) from the Bowmanstown section. Based on these fossils, hiatal base and stratigraphic position this bed represents the base of the Upper Tully Member.

Comparison to Other Studies - Stratigraphic units, from oldest to youngest, observed at the Lock Haven section by



A. *Polygnathus linguiformis linguiformis gamma* morphotype.

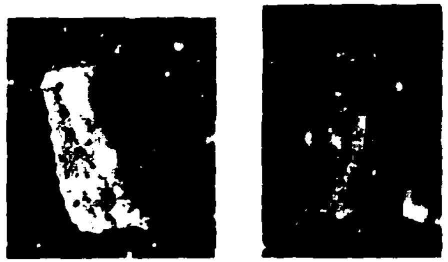


B. *Polygnathus parawebbi.*

C. *Polygnathus parawebbi.*

D. Lateral view of S element of *Polygnathus.*

Figure 70 - Photographs of conodonts from Sample LH-1, Lower Tully Member at Lock Haven, PA.



A. *Polygnathus linguiformis linguiformis gamma* morphotype

B. *Polygnathus linguiformis linguiformis gamma* morphotype

C. Lateral view of O element of *Polygnathus.*

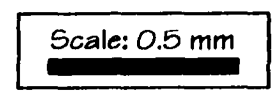


Figure 71 - Photographs of conodonts from Sample LH-4, Lower Tully Member at Lock Haven, PA.

this writer are: the Mahantango Formation, Lower Tully Member, Upper Tully Member and Burket Shale (Member) of the Harrell Formation. As indicated in Figure 72, these units basically concur with the interpretations of Willard (1939) and Heckel (1969, 1973).

The exposed upper Mahantango Formation at the Lock Haven section does not have any distinct coarser-textured or fossiliferous beds. This is especially problematic when attempting to subdivide this formation or compare it to the other areas studied. Inability to subdivide the Mahantango Formation at Lock Haven leads to little new insight relative to the earlier studies of Willard and Heckel. Exceptions are beds in the uppermost Mahantango Formation consisting of a distinct discontinuous fossiliferous lag (sample location LH-6) and a concretion horizon (both approximately at the eleven to twelve meter interval of measured section on Figure 56). The potential significance on a regional basis of these Mahantango beds is reviewed in the following chapters. In addition, the location marking the top of the Mahantango Formation is better defined based on the discovery of ambocoelid brachiopods within the basal Tully Mesosequence indicating a slightly lower stratigraphic position than suggested by Heckel (1969, Figure 3).

In contrast to the Mahantango Formation, the Tully Mesosequence has several features that facilitate at least

REFERENCE:	Willard (1939)	Heckel (1969, 1973)	This Study
UNITS RECOGNIZED	Harrell Fm. Burket Shale Member	Harrell Fm. Burket Shale Member	Harrell Fm. Burket Shale Member
	Hamilton Group: Tully Fm. Upper Member - - - - - - - - "Platy Facies"	Hamilton Group: Tully Fm. Upper Member - - - - - - - - Lower Member	Hamilton Group: Tully Mesosequence Upper Member - - - - - - - - Lower Member
	Mahantango Fm. (Undifferentiated)	Mahantango Fm. (Undifferentiated)	Mahantango Fm. (Upper portiion: Undifferentiated)

Legend:

═══ Group Boundary
─── Formation Boundary
- - Member Boundary

FIGURE 72 - SUMMARY OF STRATIGRAPHIC UNITS RECOGNIZED AT LOCK HAVEN, PA

five subdivisions. The first is the noted ambocoelid beds. A second subunit consists of the calcilutite bed bearing the unique microfauna (LH-4) and overlain by additional beds bearing dacryconarids and burrows. Above this is a third interval of distinct cyclic beds of alternating shales and calcilutites. A fourth interval within the Lower Tully Member are the predominantly micritic beds between the cyclic beds and the hiatal lower contact of the Upper Tully Member. The Upper Tully Member is the fifth major subdivision. With the exception of the LH-4 microfauna and the ambocoelid brachiopod beds, these subdivisions are similar to Heckel's (1969, 1973) review of the Lock Haven section.

CHAPTER FIVE

DISCUSSION OF FINDINGS: PROPOSED REGIONAL CORRELATIONS

This chapter attempts to use the various lithologic and paleontologic observations discussed in Chapter Four for the correlation among the sections studied relative to recognized stratigraphic units within both Pennsylvania and the rest of the Appalachian Basin. In particular, comparisons to those established stratigraphic units recognized from the Group to marker bed level for New York state are made.

Two traditional problems with subdividing the Hamilton Group have been:

1. A thick sequence of sediments dominated by fine-textured sediments, and
2. A fauna that does not drastically change over a nearly eight million year period (Brett 1995, Brett and Baird 1995).

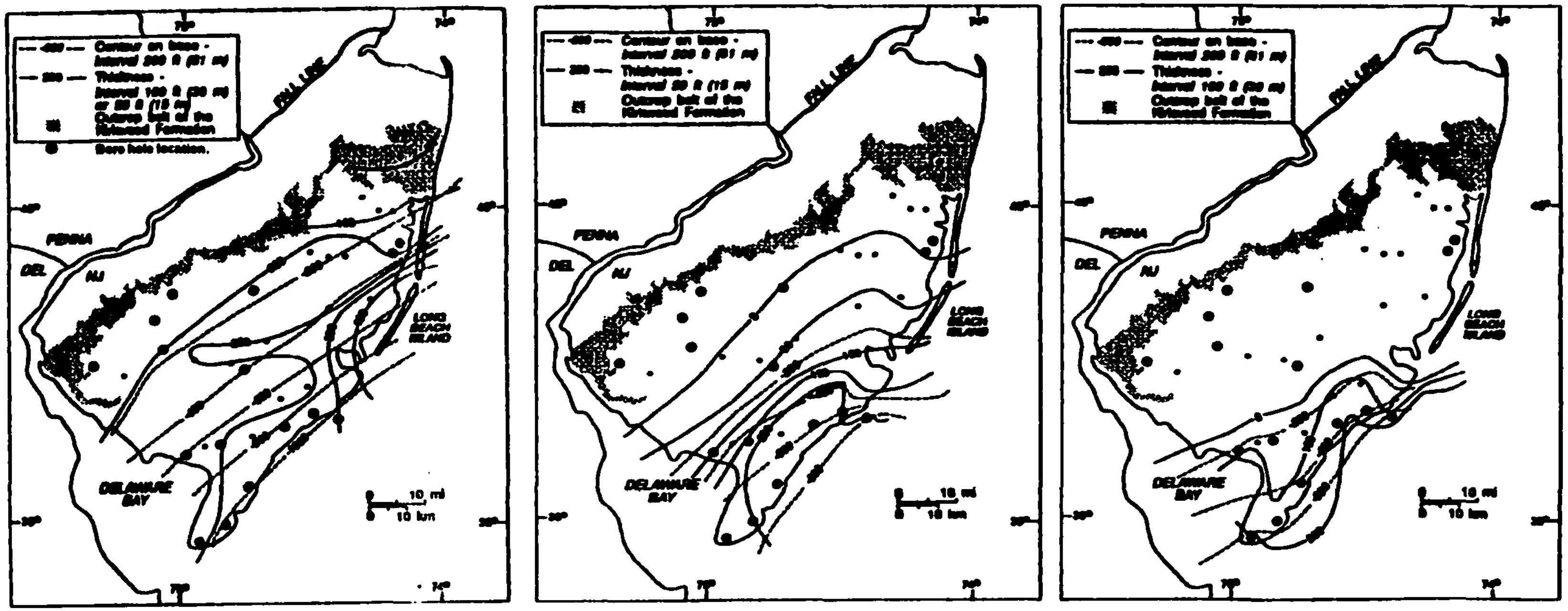
In Pennsylvania this has lead to most of the Hamilton Group being lumped into the Mahantango Formation. Recent studies in New York (Brett and Baird 1994, Landing and Brett 1991), however, have shown deposition and paleoecologic patterns within fine-textured sediments of New York that are applicable for subdividing the Mahantango Formation of Pennsylvania. These patterns are thought to be derived from storm-generated disturbances that create unique beds or bedsets with distributions over tens and hundreds of kilometers (Miller et al. 1988). These patterns share bedding surfaces or occur within a group of bed sets per the concepts of Campbell (1967). However, they do not always abide by conventional lithostratigraphic correlations of a mappable lithofacies or biostratigraphic correlations based on new taxa. These biofacies represent epiboles as either a unique taphofacies or ecofacies (sensu Brett et al. 1990) which are traceable over large distances. Beds representing these biofacies are not necessarily continuous nor single event phenomena, but rather occur within bed sets (parasequences) that have a penecontemporaneous occurrence. This temporal nature, therefore is not always spontaneous, although it has occurred within a short geologic time-frame (Kidwell 1993, Kidwell and Behrensmeyer 1993). Ironically, these patterns have long been noted (for example Grabau 1898-99, Cooper 1930 a,b, 1933, 1934, Cooper and Williams 1935, Willard 1935b, 1939), but were difficult to resolve with the development of conventional stratigraphic correlations which attempt to adhere strictly to the American Code of Stratigraphic Nomenclature (ACSN 1961, 1983).

These problems faced in the Hamilton Group in terms of stratigraphic interpretation and emphasis are not unique. Therefore, I present the following analogy of the Miocene

Kirkwood Formation of New Jersey as an example, where the seismic stratigraphic component of sequence stratigraphy has helped to alleviate questions similar to those found within the Hamilton Group.

As with the Hamilton Group, the Kirkwood Formation is a formal stratigraphic unit which is fine-textured dominated (Sugarman et al. 1993, Sugarman and Miller 1997). Here sequence stratigraphic methods have been used to indicate that what appears to be a single penecontemporaneous lithologic unit of consistent thickness is actually three similar lithologic cycles of slightly different age. The depo-center of each of these lithologic cycles is located farther south than the prior one (Figure 73). Cyclic boundaries were recognized by a combination of seismic and biostratigraphic information. The recognition of these cycles (sequence stratigraphic units) helps to explain why the Kirkwood Formation exposed to the northwest is younger than its subsurface counterpart of similar thickness and lithology located to the southeast (Figure 73).

This situation also occurs in the Hamilton Group where widely dispersed, predominantly fine-textured sediments of apparent uniform thickness actually have varied depo-centers over time. Miller et al. (1988) show this for the Hamilton Group at a smaller scale (Figure 74) than the cited Kirkwood Formation example. The study of Miller et

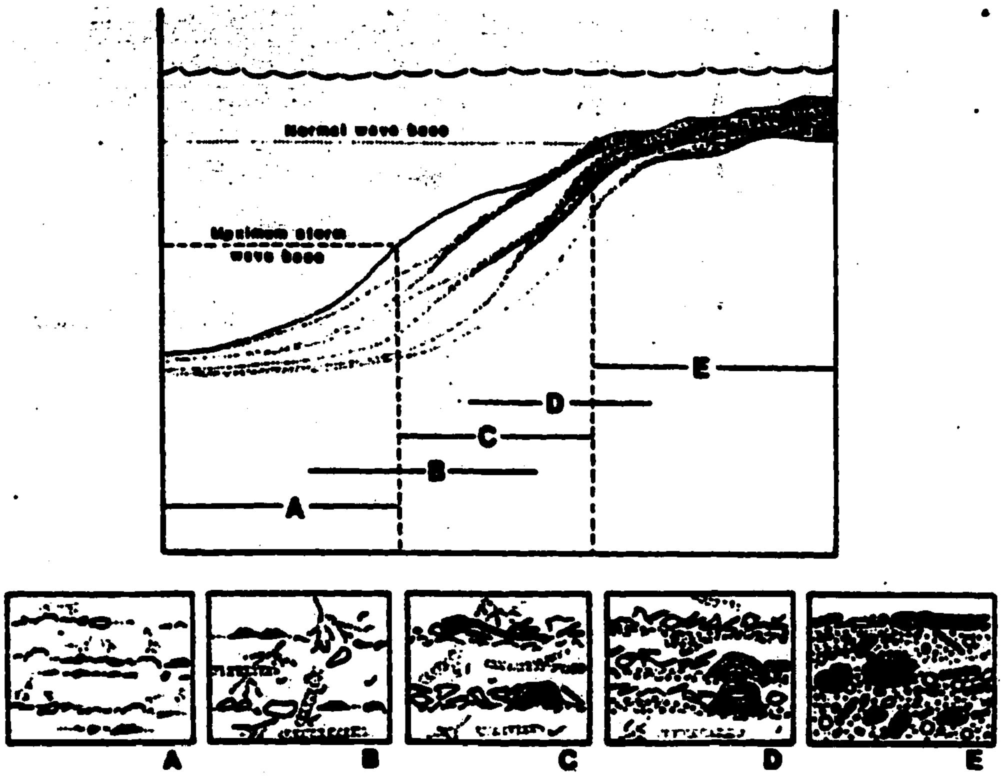


A. Early Kirkwood Formation time.

B. Middle Kirkwood Formation time.

C. Late Kirkwood Formation time.

Figure 73 - Isopach map examples of varying depocenters over time within the Kirkwood Formation of southern New Jersey. Source: Sugarman et al. (1993), Figure 3.



A) Nondepostional surfaces smothered by thin distal mud layers.

B) Colonized soft-bottom surfaces buried by upslope winnowed muds.

C) Colonized winnowed pavements buried by thick layers of redeposited near-shore muds.

D) Rewinnowed and amalgamated shell beds smothered by thick mud layers.

E) Winnowed crinoidal grainstones with a few subtle internal burial horizons.

Figure 74 - Cross-section showing superposition of successive event deposits produced by storms of varying intensity. Lettered bars show expected depth ranges of different shell layer types.
Source: Miller et al. (1988, Figure 6).

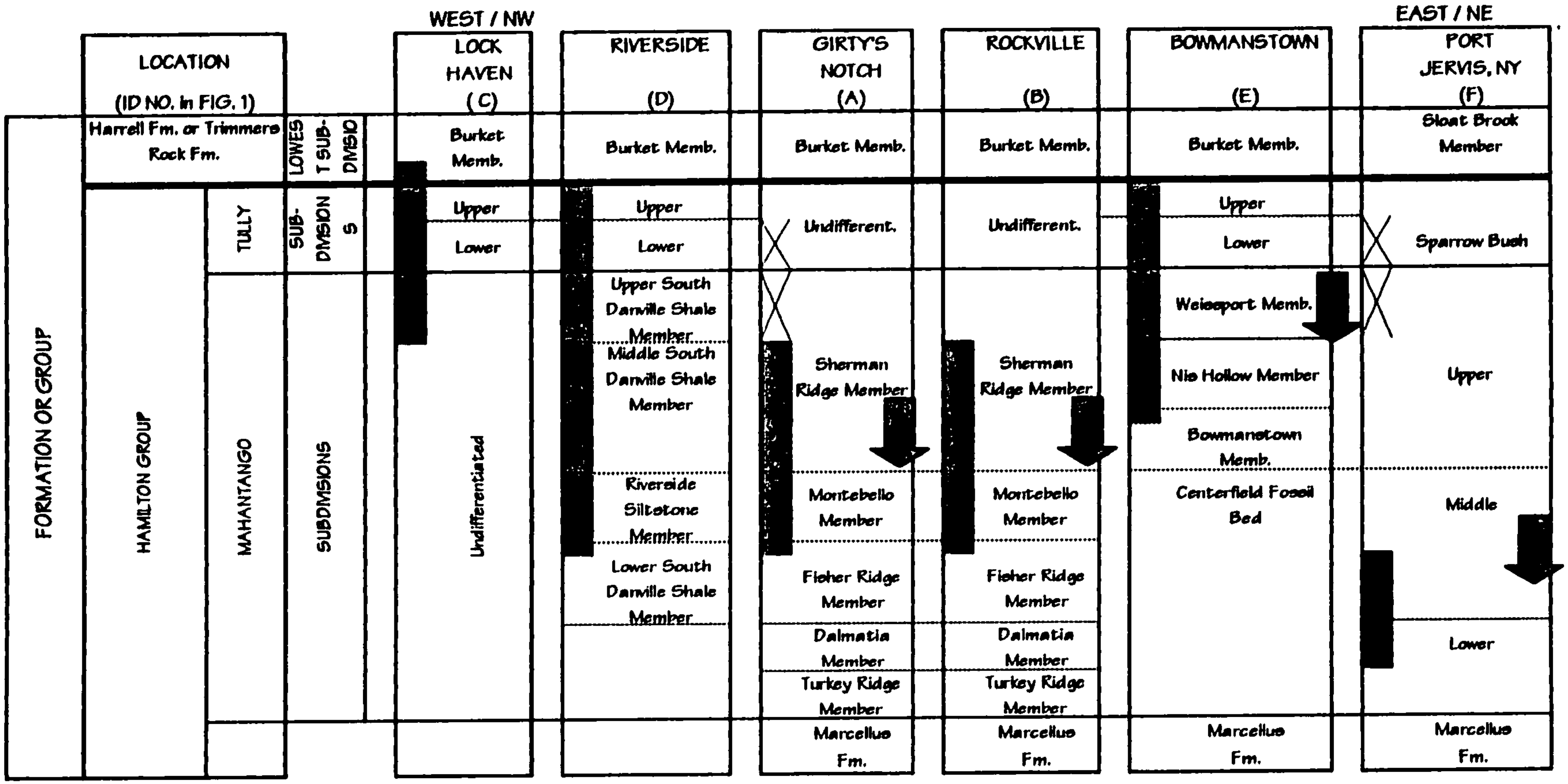
al. (1988) correlates storm-derived taphofacies assemblages that are traceable among beds of varying thicknesses. Such beds typically thin away from the storm-wave base whereby taphofacies converge (Figure 74). As the depo-center changes, so does the storm wave-base and the types of fossils characteristic of the taphofacies, thereby allowing a temporal correlation.

In addition to storm-derived beds, other types of individual beds or bed sets characterized by distinct lithofacies or biofacies have been recognized within the Hamilton Group by Heckel (1973), Gray (1991) and Brett and Baird (1985) which are also useful in the temporal correlations that indicate the change of depo-center location. Consequentially, the correlations based on the unique beds or beds sets presented within this study may have more than one source of origin either as storm-generated, sea level change, progradation, or relict hard bottom community. Regardless of their origin, such beds when distributed over a wide area have the potential of being chronostratigraphic markers (Kidwell 1993, Kidwell and Behrensmeyer 1993).

General Correlations

The above considerations have had only limited success when attempting correlations *strictly* among the sections studied. This is based in part on the geographic distance allowing for less of a chance of the co-occurrence of a distinct bed or bed set occurring at two or more sections. Further complications include structural distortion combined with the dominance of thick poorly fossiliferous intervals. However, additional, potentially useful correlations with New York State beds at each of the sections make it possible to reassess correlations among the sections studied. A review of the general correlations as summarized on Figure 75 observed among the various sections to each other is presented below. This is followed with more detailed correlations based on the above concepts using the better defined stratigraphy of New York state.

Port Jervis Section - The section studied at Port Jervis is recognized as being older than suggested by Slattery (1995) and equivalent to the Lower and Middle Members of the Mahantango Formation (Figure 5) as proposed by Fletcher and Woodrow (1970). This is based on the section's stratigraphic location within the Mahantango Formation relative to the underlying Marcellus and Sparrow Bush Formations. All of the other studied sections are located higher within the Hamilton relative to the Tully Mesosequence (Figure 75) which is equivalent to the Sparrow Bush Formation (Fletcher and Woodrow 1970) found in the Port Jervis area.



Notes:

1) *Only stratigraphic names recognized at each section are listed: no statement of unit thickness or absolute boundary correlation are shown.*

2) Refer to Figure 1 for locations. 3) *Shaded area denotes section measured in this study.* ╳ 4) Field inspected, but not measured.

5) Approximate location of Type II Boundary as proposed by Slattery (1993, 1995).

Figure 75 - General Correlations Between Sections Studied

Bowmanstown Section - The Tully Mesosequence is readily recognized at the Bowmanstown section allowing the correlation of this section with both the Riverside and Lock Haven sections as previously recognized by Heckel (1969, 1973). However, within the Tully only the contact between the Lower and Upper Members at Lock Haven can be further correlated. Three subdivisions of the Mahantango Formation are recognized at Bowmanstown (Figure 75), but none of these contacts are considered correlative with the subdivisions recognized at the two Harrisburg sections or at the Riverside section. The presence of the brachiopod *Pustulatia postulosa* in the upper part of the Weissport Member at Bowmanstown and within the Upper South Danville Shale at Riverside suggests these units to be correlative to some degree. *Allanella tullia* and other spiriferid brachiopods found in the upper Nis Hollow Member at Bowmanstown are also correlative with either the Middle or Upper South Danville Members, but not with the Riverside Member of the Riverside section. This is noteworthy because the Riverside Member and Nis Hollow Member are the coarsest-textured units at their respective localities. This condition is also true for the Harrisburg sections where the Nis Hollow and overlying units appear to be best correlative with the Sherman Ridge Member based on fossil content.

Harrisburg Area Sections - Unlike most of the other sections studied, the two Harrisburg area localities share fairly similar litho- and chronostratigraphic characteristics. The following reviews these similarities along with key differences that help to show the variability of facies on a local level.

Possibly, the most notable change between the two Harrisburg sections concerns the sandstone beds of the basal Montebello Member which at Rockville are thicker than at Girty's Notch (Figure 76). This leads to an additional thickness of 100 meters at the Rockville section. These sandstone beds have a tendency within the lower Montebello Member to have individual half meter foresets which change thickness from two to ten meters over very short distances. These radical lateral and vertical changes are best exposed at the Girty's Notch section (Figure 34). The existence of such radical changes in thicknesses among bed sets representing a similar depositional cycle explains why the total thickness of the lower portion of the Montebello Member can vary so much between Rockville and Girty's Notch as indicated on Figure 76. In contrast, the upper portion of the Montebello Member at both sections are similar in thickness: 40 meters at Girty's Notch versus 45 meters at Rockville.

These differences become less dramatic, despite the twelve mile lineal distance between the Girty's Notch and

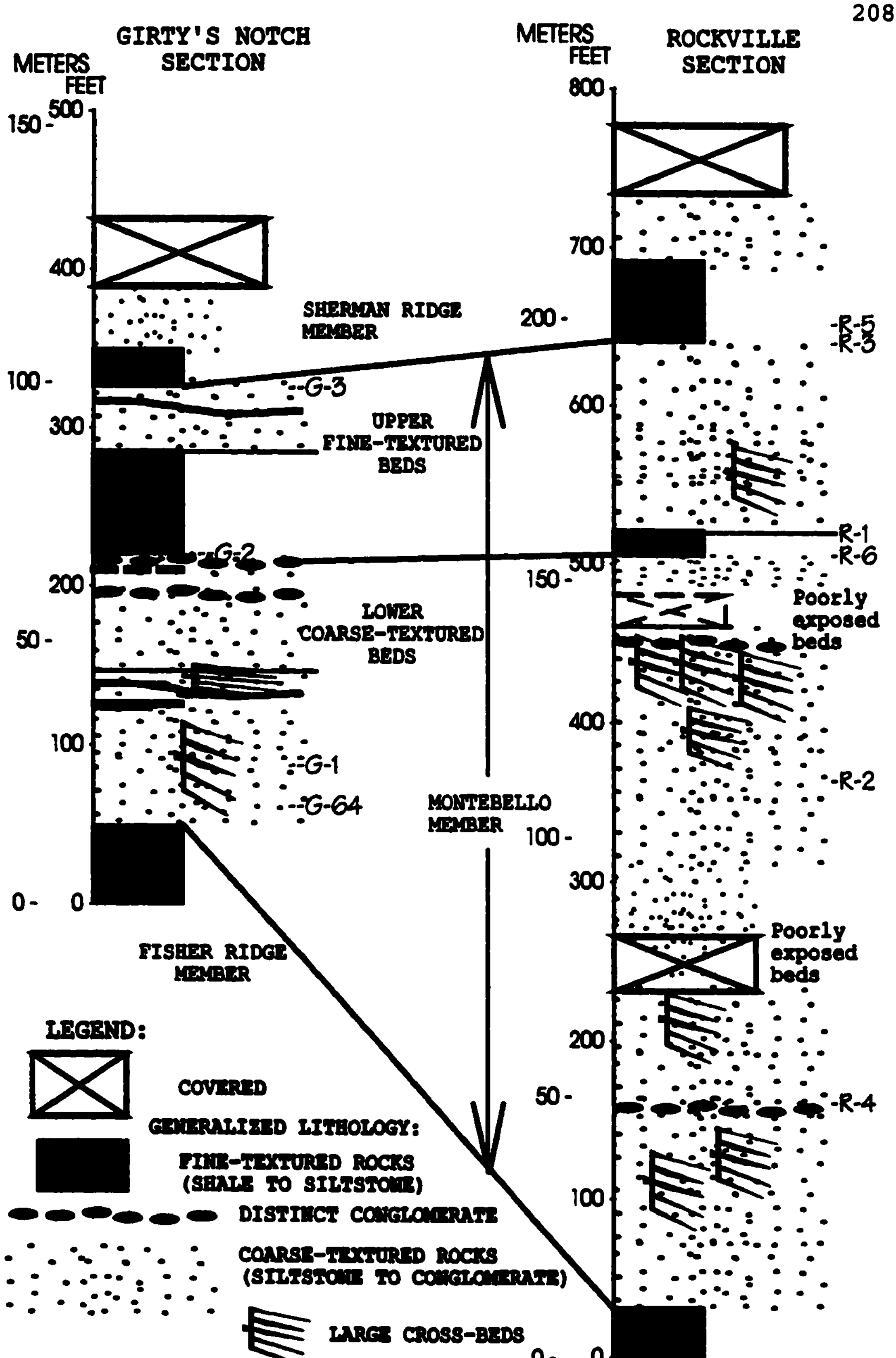


Figure 76 -
General Correlation of Key Measured Intervals
Between Girty's Notch and Rockville, PA Sections

Rockville localities, because along strike the actual distance is approximately fifty miles between the two exposures. This strike distance is indicated by folding shown on the geologic map of Faill et al. (1978).

The exposure at Rockville shows one sequence of cross-beds thinning from approximately 5 to 2 meters (Figure 27) that is similar to stratigraphically equivalent beds at Girty's Notch. The sandstone sequences of the basal Montebello Member at Rockville are thicker than at Girty's Notch. This leads to the total thickness of the unit being 100 meters thicker. In contrast, the upper, finer textured portion of the Montebello Member at both sections are similar in thickness: 40 meters at Girty's Notch versus 45 meters at Rockville. The abrupt thickness change of the lower, storm-dominated portion of the Montebello Member (from approximate thicknesses of 53 to 165 meters at the two measured sections) occurs over a distance of just twelve miles. However, the actual depositional (paleogeographic) distance is probably fifty miles when consideration is made of strike and folding of the Mahantango Formation as indicated on Plate 1 of Faill et al. (1978).

No hematitic sand channel similar to the one found at Girty's Notch was observed in the upper portion of the Montebello Member. However, a chamosite oolite (Figure 29 and sample location R-3 on Figure 26), similar to the weathered oolite at the base of the Sherman Ridge Member at Girty's Notch is present.

A problem with the Harrisburg area sections is that the Tully Mesosequence is not well exposed. Potentially, it is completely absent. This limits the ability to use the Tully as "datum" for comparison of Mahantango Formation correlations at the other studied sections. When compared to the Montebello Member the Sherman Ridge Member is a fine-texture unit. However, the Sherman Ridge Member contains beds that are as coarse or coarser than those of either the Riverside Member of the Riverside section or the Nis Hollow Member at Bowmanstown. Therefore, correlations based on lithology are of limited use.

Riverside Section - The Tully Mesosequence at Riverside is the most lithologically similar to the 'typical' Tully Limestone found at the Lock Haven section. Unlike the other sections, four subdivisions are recognized with the upper Mahantango Formation (although the Harrisburg sections could readily be further subdivided) based on general lithologic aspects. Other correlative aspects of the Mahantango Formation at the Riverside section with the Harrisburg area and Bowmanstown sections have already been noted.

Lock Haven - Despite the unusually large thickness of the Tully Mesosequence at Lock Haven, no distinctive feature, besides the contact of the Lower and Upper Members is readily correlative with any of the other sections. In the opposite sense, the Mahantango is fairly well exposed (for at least an additional 50 meters than that depicted on Figure 56), but lacks any unique bedding features. Two exceptions to this are the concretion and fossil-bearing beds located near the top of the Mahantango's contact with the Tully Mesosequence. Neither of these beds are readily correlative with any of the beds observed at the other sections, but as will be shown in the following discussion may have New York correlatives that can then be extrapolated back to the other studied sections.

Proposed Regional Correlations

The following reviews how subunits observed within the Mahantango and Tully units correlate to those recognized in New York State. These proposed correlations rely in particular on Brett and Baird's (1994) summary of recognized subunits within the upper Hamilton Group of New York. A composite summary section for New York state is presented on Figure 77. Information presented on Figure 77 includes formal and informal stratigraphic units recognized by Brett and Baird (1994) for western and central New York, the subdivisions of the Tully Mesosequence (Figure 4) noted by Heckel (1973) and select subdivisions of the upper Hamilton Group for eastern New York used by Cooper (1933, 1934). As with New York, the criteria that characterizes a

Formation or Member (a)	Sedimentary Sequence (or Cycle) (b)	Bed or Bed Sets (c)
Geneseo Shale:		
Leicaster Pyrite Mb.	6	
Tully Mesosequence.:	6 (4)	Fillmore Glen
Upper Member		Moravia
		Bellona Coral
	(4)	West Brook
(Middle)	(3)	Taughannock Falls
	(3)	Smyrna
Lower Member	(2)	Carpenter Falls
	(1)	Vesper
		Tully Valley
		Meeker Hill
		Fabius
		Cuyler
	(1)	Deruyter
Moscow Fm.:	5 (4)	New Lisbon Mb. of east NY
Windom Shale		post-Gage Gully
Member		Gage Gully
	(4)	Simpson Creek lag
	(3)	Spezzano Gully
		Upper Taunton
		So. Lansing Coral
		Lower Taunton
		Fall Brook
		Fisher Gully
		Bear Swamp
		Smoke Creek
		Bay View Coral Beds
		Devonochonetes Beds
		Ambocoeilia
	(3)	Little Beards Creek

Formation or Member (a)	Sedimentary Sequence or Cycle (b)	Bed or Bed Sets (c)
Moscow Fm.:	(2)	Geer Road
Unnamed		Longispina-Mucrospirifer
Member	(2)	Curtice Road
	(1)	Megastrophia
	(1)	Barnes Gully
Moscow Fm.:	(2)	
Kashong Shale:		
Upper Kashong		Tropidoleptus
Middle Kashong		Concretion Zone
		Tracyhypora-Taenopora
		Rhipidomella-Centr.
Lower Kashong		
Menteth Ls.	(2)	
Deep Run Shale	(1)	
Tichenor Ls./Portland Pt. Ls.	(1)	
Ludlowville Fm.:	4	
Jaycox Shale		Cottage City Coral
		Hills Gulch Ls./Owasco Stst.
Spafford Sh. Member		Spafford Barren Sh.
		Limerick Road Ls.
Wanakah Shale		Ivy Point Siltst.
		Pleurodictyum
Ledyard Shale		
Centerfield Member		
Skaneatales Fm.	3	
Butternut Member		
Pompey Member		
Levanna Member		
Delphi Memmber		
Stafford / Mottville Members		
Marcellus Fm.	2	

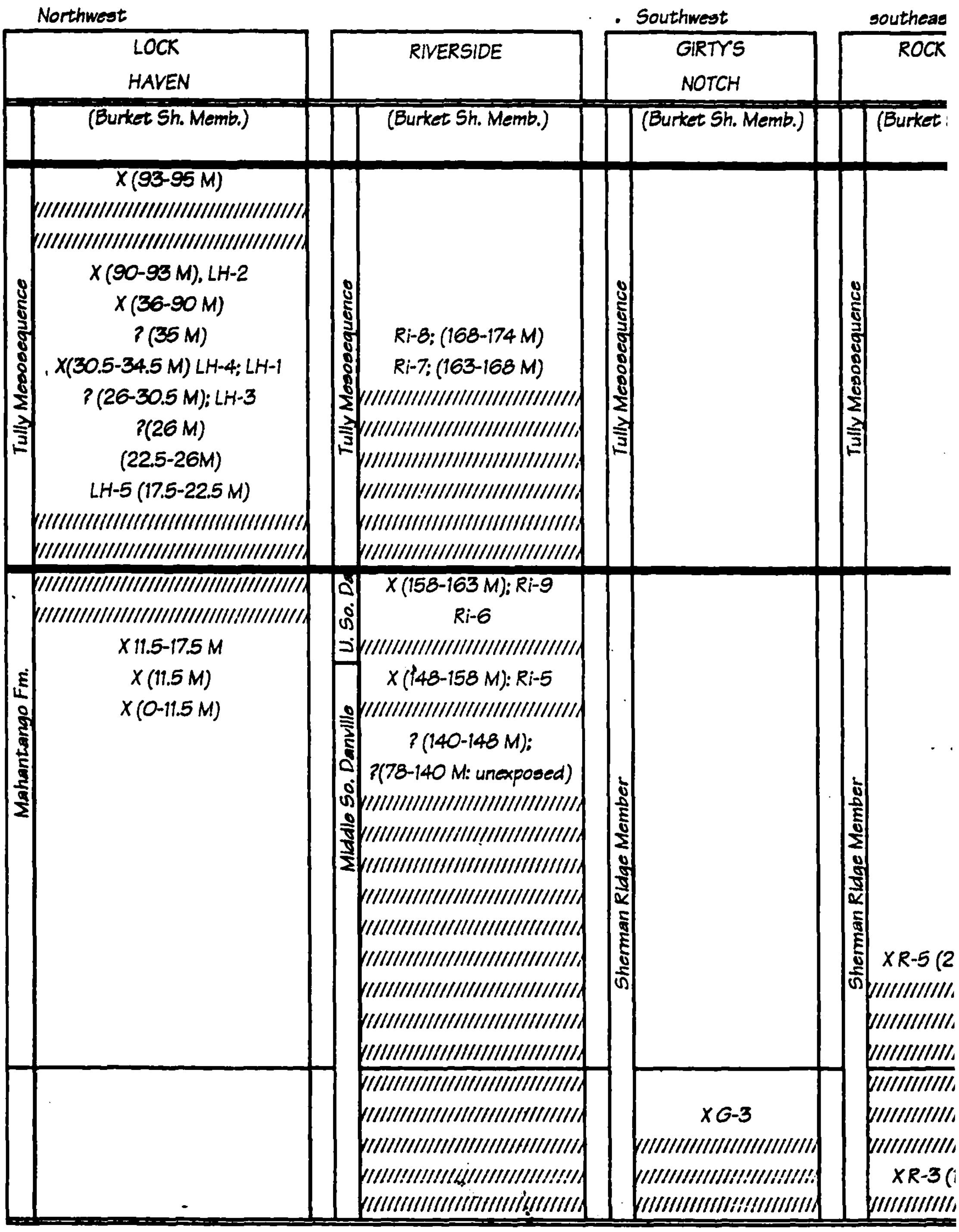
Notes: a) Standard units per Rickard (1975) and Sevon and Woodow (1985), except for Middle Tully.
b) Numbered cycles are modified from Brett and Baird (1994).
c) Tully units based on Heckel (1973); other units derived from Brett and Baird (1994).

Figure 77 - Summary of Hamilton Group Subdivisions of New York State

key marker bed varies in scale of significance. For example, the Nis Hollow Member is best recognized from its lithology and sedimentary structures, while the bed sets of the *Pustulatia postulosa* brachiopod assemblage are best recognized from their paleontologic content. An allostratigraphic unit would be sediments within the boundaries of the Upper Tully Member as best recognized in this study by its basal contact. However, most beds, including these examples, are rarely defined by a single facies criterion.

Graphic Correlation Chart

Based on the cited conditions of key beds or bed sets, the following reviews each of the sections studied with regard to potentially correlative beds, members or formations located in northwest New York. A graphic correlation chart summarizing these findings is presented on Figure 78. This chart is slightly unconventional in being a composite of subdivisions (see Figure 77) outside the actual area of study. A further difference is that the established New York units are mostly correlated to individual sample horizons or measured intervals rather than to informal or formal stratigraphic names. For the most part I have avoided the introduction of new litho- or bio- stratigraphic names for the Pennsylvania localities, which a more conventional correlation chart normally shows.



LEGEND:

//////////////////////	- Interval either not exposed or does not have a b
X (26-30.5M)	- Measured interval in meters (See Appendix B for
X Ri-4	- Sampled horizon (See Appendix C for details).

southeast ROCKVILLE (unit)	southeast ROCKVILLE	Northeast BOWMANSTOWN (unit)	Northeast BOWMANSTOWN	Northeast PORT JERVIS, NY (unit)	Northeast PORT JERVIS, NY	NEW YORK UNITS (Brett and Baird 1994) FM/MEMBR.	SEQ. (CYCLE)	Bed or Bed Sets
	(Burket Sh. Memb.)		(Burket Sh. Memb.)			Geneseo Shale:		
			//////////////////////////			Leicaster Pyrite Mb.	6	
Tully Mesosequence		Tully Mesosequence	//////////////////////////	Tully Mesosequence		Tully Fm.:	6 (4)	Fillmore Glen
			X (150 M)			Upper Member		Moravia
			//////////////////////////					Bellona Coral
			B-490				(4)	West Brook
			//////////////////////////			(Middle)	(3)	Taughannock Falls
			//////////////////////////				(3)	Smyrna
			//////////////////////////			Lower Member	(2)	Carpenter Falls
			//////////////////////////				(1)	Vesper
			//////////////////////////					Tully Valley
			//////////////////////////					Meeker Hill
			//////////////////////////					Fabius
			//////////////////////////					Cuyler
			X (142.5 to 149 M)				(1)	Deruyter
Sherman Ridge Member		Weissport Mem	X (129-142.5 M); B-455	Upper		Moscow Fm.:	5 (4)	New Lisbon Mb. of eas
			B-411			Windom Shale		post-Gage Gully
			?(90-125M)			Member		Gage Gully
			B-293				(4)	Simpson Creek lag
			? (74-89 M); B-293				(3)	Spezzano Gully
		Nis Hollow	(74 M): B-244; B-3					Upper Taunton
			//////////////////////////					So. Lansing Coral
			(58 M)					Lower Taunton
		Bowmanstown Memb.	B-178; B-2					Fall Brook
			B-80, B-98					Fisher Gully
			B-1.0'; (0-15 M)					Bear Swamp
								Smoke Creek
	X R-5 (204-211 M)							Bay View Coral Beds
	//////////////////////////							Devonochonetes Beds
	//////////////////////////							Ambocoeilia
	//////////////////////////						(3)	Little Beards Creek
	//////////////////////////					Unnamed	(2)	Geer Road
	//////////////////////////					Member		Longispina-Mucrospi
	//////////////////////////						(2)	Curtice Road
	X R-3 (196.5 M)						(1)	Megastrophia
	//////////////////////////						(1)	Barnes Gully

not have a bed or bed sets with a New York equivalent at measured section.
endix B for details).
details). ? - Tentative correlation.

FIGURE 78A - GRAPHIC CORRELATION CHART OF STUDIED SECTIONS

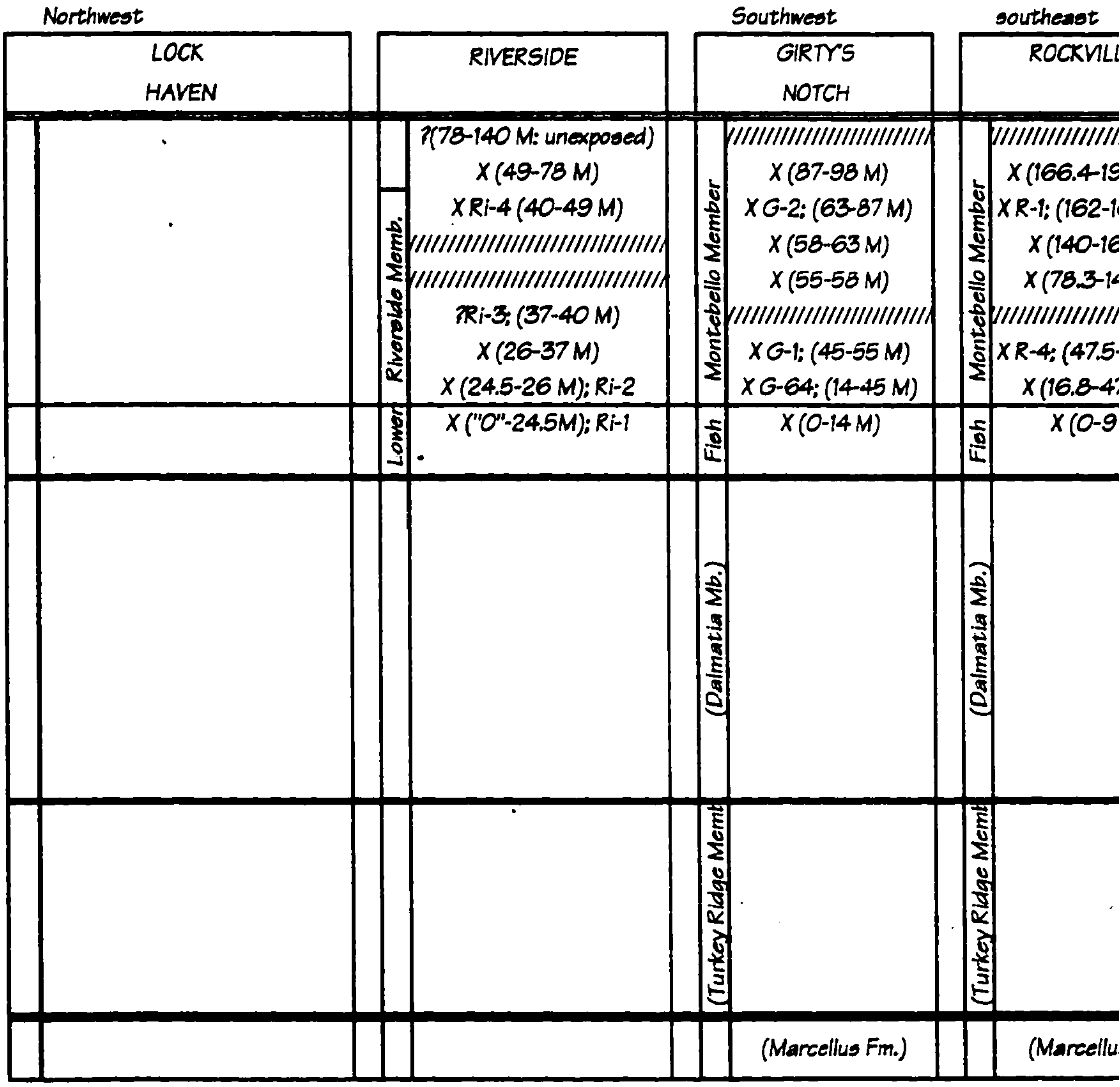
	Northeast		Northeast		NEW YORK UNITS (Brett and Baird 1994)		
		BOWMANSTOWN		PORT JERVIS, NY	FM/MEMBR.	SEQ. (CYCLE)	Bed or Bed Sets
ib.)		(Burket Sh. Memb.)			Geneseo Shale:		
		//////////////////////////////			Leicester Pyrite Mb.	6	
	Tully Mesosequence	//////////////////////////////	Tully Mesosequence		Tully Fm.:	6 (4)	Fillmore Glen
		X (150 M)			Upper Member		Moravia
		//////////////////////////////					Bellona Coral
		B-490				(4)	West Brook
		//////////////////////////////			(Middle)	(3)	Taughannock Falls
		//////////////////////////////				(3)	Smyrna
		//////////////////////////////			Lower Member	(2)	Carpenter Falls
		//////////////////////////////				(1)	Vesper
		//////////////////////////////					Tully Valley
		//////////////////////////////					Meeker Hill
		//////////////////////////////					Fabius
		//////////////////////////////					Cuyler
		X (142.5 to 149 M)				(1)	Deruyter
	Weissport Mem	X (129-142.5 M); B-455	Upper		Moscow Fm.:	5 (4)	New Lisbon Mb. of east NY
		B-411			Windom Shale		post-Gage Gully
		?(90-125M)			Member		Gage Gully
		B-293				(4)	Simpson Creek lag
		? (74-89 M); B-293				(3)	Spezzano Gully
	Nis Hollow	(74 M): B-244; B-3					Upper Taunton
		//////////////////////////					So. Lansing Coral
		(58 M)					Lower Taunton
	Bowmanstown Memb.	B-178; B-2					Fall Brook
		B-80, B-98					Fisher Gully
		B-1.0'; (0-15 M)					Bear Swamp
							Smoke Creek
1 M)							Bay View Coral Beds
///////							Devonochonetes Beds
///////							Ambocoeilia
///////						(3)	Little Beards Creek
///////					Unnamed	(2)	Geer Road
///////					Member		Longispina-Mucrospir.
///////						(2)	Curtice Road
M)						(1)	Megastrophia
///////						(1)	Barnes Gully

r bed sets with a New York equivalent at measured section.

ils).

Tentative correlation.

FIGURE 78A - GRAPHIC CORRELATION CHART OF STUDIED SECTIONS



LEGEND:

////////////////////// - Interval either not exposed or does not have a bed o

X (26-30.5M) - Measured interval in meters (See Appendix B for deta

X Ri-4 - Sampled horizon (See Appendix C for details). ? -

References Used: Brett and Baird (1994), Heckel (1973), Sevon and Woodrow (198 Rickard (1975), Cooper (1930a,b, 1933, 1934), Ellison (1965) Faill et al. (197 et al. (1974), Sevon et al. (1989), Fletcher and Woodward (1970).

t	Northeast	Northeast		NEW YORK UNITS (Brett and Baird 1994)		
VILLE	BOWMANSTOWN		PORT JERVIS, NY	FM/MEMBR.	SEQ. (CYCLE)	Bed or Bed Sets
//////////////				Kashong Shale:	(2)	
‑196.5 M)				Upper Kashong		
2-166.4 M)				Middle Kashong		Tropidoleptus
?-162 M)						Concretion Zone
3-140 M)						Tracyhypora-Taenopora
//////////////						Rhipidomella-Centr.
7.5-78.3 M)				Lower Kashong		
3-47.5 M)				Menteth Ls.	(2)	
?-9 M)				Deep Run Shale	(1)	
		Middle		Tichenor Ls./ Portland Pt. Ls.	(1)	
				Ludlowville Fm.:	4	
				Jaycox Shale		Cottage City Coral
						Hills Gulch Ls./Owasco Stst.
				Spafford Sh. Member		Spafford Barren Sh.
						Limerick Road Ls.
				Wanakah Shale		Ivy Point Siltst.
						Pleurodictyum
			? (45-84.5 M)	Ledyard Shale		
	(Centerfield Bed)		? (3-45 M)	Centerfield Member		
			(0-3 M)	Skaneatales Fm.	3	
				Butternut Member		
		Lower		Pompey Member		
				Levanna Member		
				Delphi Memmber		
				Stafford / Mottville Members		
cellus Fm.)	(Marcellus Fm.)		(Marcellus Fm.)	Marcellus Fm.	2	

d or bed sets with a New York equivalent at measured section.
ietails).
? - Tentative correlation.

(1985),
(1978) Epstein

FIGURE 78B - GRAPHIC CORRELATION CHART OF STUDIED SECTIONS

Such beds await further study whereby individual beds are proven or disproven to be unique to the Mahantango Formation of Pennsylvania. In addition, some of the established New York nomenclature for widely dispersed marker beds may also serve for the identification of equivalent beds in Pennsylvania. This should limit the need for additional names.

The concept of the Graphic Correlation Chart shown on Figure 78 is similar to that of Shaw (1964) for a composite biostratigraphic chart that assumes chronologic occurrence. Similar to Shaw's (1964) chart, the overall emphasis of this study has focused on the paleontology of the study rocks. However, as already noted, the key criteria used to recognized a particular unit vary in emphasis. A major difference between the synthetic graphs of Figure 78 and a composite biostratigraphic chart is Shaw's (1964) use of first and last occurrences of taxa. In contrast, the synthetic graphic correlation chart presented on Figure 78 is solely based on chronostratigraphic position. Unique beds may not always be everywhere at their noted stratigraphic position due to either nondeposition, erosion or condensation. Such beds are indicated by cross-bars (Figure 78). Similarly, negative data are found in Shaw's chart in the form of fossil taxa being absent at a particular locality.

The listing of better established New York sedimentary subdivisions from New York is mainly derived from Brett and Baird (1994). As shown on Figure 78, such units are used as a basis to correlate:

1) a measured stratigraphic interval of this study;

2) a horizon sampled; or

3) a nomenclaturally established stratigraphic unit within Pennsylvania.

Proposed Correlations

In general, I recognize portions of five of the six sections studied as being correlative at least in part with each other. The exception, as previously discussed, is the Port Jervis section which appears to be slightly older than the other sections studied and therefore not further discussed in the context of this chapter.

The last three columns ("New York Units") of the chart in Figure 78 refer to central New York state correlations. The first of these columns lists lithologic units at the formation and member level as found in New York State. The second column indicates sequences and depositional cycles of the New York Givetian as proposed by Brett and Baird (1994) and inferred from Heckel (1973). The third column details beds based on lithologic, paleontologic, and/or other depositional characteristics that are useful for correlation in central New York state. The other columns of Figure 78 list one of the sections studied and includes either lithologic units, measured sectional intervals or sample identification numbers recognized as correlative with the listed New York units. As discussed below, these correlations are based on paleontology, lithology, depositional patterns (Facies Associations of Slattery 1995), sequence boundaries or general stratigraphic position.

The stratigraphic location of some of the listed members among the New York state formations shown in Figure 78 vary from those summarized by Rickard (1975). In particular, the Tichenor Limestone, Deep Run Shale and Menteth Limestone are included within the Moscow Formation rather than in the underlying Ludlowville Formation as based on (Brett and Baird 1994 Figure 2a). Further, Rickard (1975) correlates the Portland Point Limestone of eastern New York with the Tichenor of western New York. However, Baird (1979) was able to recognize individual limestone members within the Portland Point that are correlative with the Menteth and Tichenor Limestone Members.

Information presented on Figure 78 refers to sample locations and stratigraphic intervals as summarized in Chapter Three. The following discusses aspects and observations that lead to the proposed correlations found on Figure 78:

Harrisburg Area Sections

Any attempt at correlation between New York State and the Harrisburg sections must deal with the question of stratigraphic scale that can vary locally on a dramatic basis. The best example of this problem is the lower portion of the Montebello Member. This problem is made especially apparent by a "cycle" of storm-derived sediments approximately 90 meters thick at Rockville (16.8 to approximately 140 meter of measured interval on Figures 26 and 27) versus equivalent beds at Girty's Notch being approximately forty meters thick (14 to 45 meter of measured interval on Figures 34 and 35). This dramatic change in bedding thickness is best illustrated in Figure 34 which shows how over a relatively short distance giant foresets thin out at Girty's Notch. As indicated on Figure 78, this portion of the Montebello Member is shown as equivalent to the Menteth Limestone and lower Kashong Member. These two units combined are only one to 3.5 meters thick in New York state (Brett and Baird 1994). My basis for this correlation is the presence of occasional beds containing abundant abraded "clasts" of the brachiopod *Spinocyrtia* similar to those found in New York equivalents. The Harrisburg area sediments, like their New York counterparts, are recognized as having been deposited in storm-dominated environment (Slattery 1993, 1995; Prave and Duke 1991; Brett and Baird 1994). The New York beds are considered to be lowstand for the Menteth Limestone with a highstand below wave-base for the Kashong Member (Brett and Baird 1994).

Several lines of paleontologic evidence suggest the Middle Kashong Member to be correlative with a series of coarser sandstone to conglomeratic beds within the middle to upper portion of the Montebello Member. This is significant because the proposed Type II boundary (Slattery 1995) location within the Harrisburg area basically occurs within these conglomeratic sandstone beds. As indicated on Figure 78, these beds are shown as potentially equivalent to the "concretion zone" of the Middle Kashong Member, based on the presence of *Tropidoleptus* in overlying beds as noted by myself and Ellison (1965) and therefore correlative with the *Tropidoleptus* mudstone facies of the upper part of the Middle Kashong of Brett and Baird (1994). Other paleontologic data from adjacent beds also appears to concur with this correlation. For example, the presence of *Spinocyrtia* as well as the occurrence of silty beds (sample R-1) at Rockville containing *Sulcoretepora* and possible *Taeniopora* are potentially equivalent to the *Thamnoptychia-Taeniopora* beds of the Middle Kashong Member of New York as described by Brett and Baird (1994).

As indicated on Figure 78, an interval within the upper portion of the Montebello Member representing the 87 to 98 measured meter interval at Girty's Notch and the 164 to 196.5 measured meter interval at Rockville, I have placed as correlative with the Upper Kashong Member. This is based solely on the stratigraphic position of these intervals between the noted conglomeratic sandstones of the middle Montebello and below the Sherman Ridge Member. Unlike their New York equivalents, these two measured intervals are dominated by sandstone beds rather than mudstone facies. In addition, this interval at Girty's Notch has the hematitic channel bed (Figures 35 and 37) which as previously noted grades up into a green-gray quartz dominated sandstone that can not be differentiated from bevelled sandstone forming the channel boundaries. Therefore, from a lateral perspective these beds would be recognized as a single cyclic unit if this hematitic sand is elsewhere not encountered or readily detected. The question then becomes whether to view hematitic channel as representing a local versus regional geologic phenomenon. Based on the lack of a correlative bed at the Rockville section relative to the chamositic oolite which defines the base of the Sherman Ridge Member (cf. Faill et al. 1978), the hematitic channel bed at Girty's Notch is recognized here as a local sedimentary phenomenon.

The base of the Sherman Ridge Member is based on the presence of an oolitic chamosite bed encountered at both the Girty's Notch and Rockville sections. As indicated on Figure 78, I have located this bed as correlative with the disconformity at the base of the Barnes Gully phosphatic bed of the "Unnamed Member" of Moscow Formation of New York (Brett and Baird 1994). A second candidate would be the Little Beards Creek Beds considered by Brett and Baird (1994 Figure 7) to represent the base of the Windom Member and which they had previously mis-correlated as equivalent to the Barnes Gully prior to their recognizing this "Unnamed Member". There are subtle biofacies variations between the beds overlying the chamosite oolite at the two measured Harrisburg sections as well as those inspected at the Watts section which concur with facies variations noted by Brett and Baird (1994) for the "Unnamed Member" of New York. At the Rockville section both *Mediospirifer*, *Megastrophia*, and *Spinocytria* (see Figure 31) are present in the oolitic and overlying beds, which are elements also present within the "Unnamed Member". Further fossil evidence for supporting this correlation with the Unnamed Member includes the present of a *Longispina-Mucrospirifer* dominated facies at Girty's Notch (sample G-3). This facies is not found at Rockville, but is present at the Watt's section (location 1 of Figure 1).

Sample R-5 is correlated with the Bayview Beds (Figure 78) based on the presence of small rugose corals. With this exception, no definite correlations with the Windom Shale are apparent at either of the measured portions of the two Harrisburg area sections. However, Brett and Baird

(1994 p. 536) suggested that the South Lansing Coral bed is correlative with the coral-bearing beds observed by Ellison (1965) in what is now recognized as the Sherman Ridge Member. Correlatives to these beds were not observed at either the Girty's Notch or Rockville sections and are considered to lie within covered parts of both of these locations based on review of illustrated sections in Ellison (1965). A slightly calcareous *Phacops*-bearing bed in the tributary at Girty's Notch (not shown and stratigraphically above the measured section illustrated on Figure 35) also has a Windom-like aspect.

In summary, based on the above observations, most of the sections studied at Girty's Notch and Rockville are here recognized as equivalent to the Kashong Shale of the Moscow Formation of central New York (Figure 78). This is in contrast to Slattery (1995), who indicated correlations with the Deep Run Shale which, when not eroded, immediately overlies the Tichenor Limestone (Figure 78). Consequentially, the measured sections in the Harrisburg area are here recognized to be slightly younger than originally suggested by Slattery (1995). This means that the Type II boundary for this area is not correlative with the Tichenor Limestone as proposed by Slattery (1995).

Based on the observed correlations established for overlying beds, I believe the Fisher Ridge Member of Pennsylvania is equivalent to the Deep Run Shale of New

York (Figure 78). If such a correlation is correct, it suggests that the stratigraphic position of the Dalmatia Member might be equivalent to the Tichenor Limestone and/or portions of the Ludlowville Formation of New York State as proposed on Figure 78.

Bowmanstown Section

In contrast to the Harrisburg sections, all of the measured section at Bowmanstown is recognized as correlative with the Windom Shale of the Moscow Formation and Tully Mesosequence (Figure 78).

Bowmanstown Member - The basal part of the measured Bowmanstown section (Figure 12) which is considered to be within the central part of the proposed Bowmanstown Member is correlative with the sparsely fossiliferous Bear Swamp Beds of New York (Figure 78). This is based on a dark shale lithology and the occasional presence of *Ambocoelia* within this interval that represents the first 15 meters of section measured at Bowmanstown (Figure 78). Although dominated by pelecypods (Figure 20) the fossiliferous lens (sample horizon B-80) contains common "*Leiorhynchus*" brachiopods (Figure 13) along with *Ambocoelia praeumbona* indicating these beds to be correlative with the Fisher Gully Beds of New York (Figure 78). Approximately six meters above is a mollusk-bearing (mainly *Carydium bellistratum*) lentil (B-98) that appears to be equivalent to the eastern New York Fall Brook Bed (rather than the coral bed of western New York). Less common in this lentil are *Mediospirifer* and *Tropidoleptus* in addition to a well-preserved specimen of the tabulate *Pleurodictyum* (Figure 21).

Nis Hollow Member - A predominantly *Zoophycos*-burrowed mudstone to siltstone referred to as the Taunton Beds of New York by Brett and Baird (1994) appears to be equivalent to the Nis Hollow Member of eastern Pennsylvania. As indicated on Figure 78, the Taunton Beds have been subdivided by Brett and Baird (1994) into a Lower Interval, the South Lansing Coral Bed, and an Upper Interval. An equivalent to the South Lansing Coral was not detected at the Bowmanstown section, although past study by Ellison (1965) as interpreted by Brett and Baird (1994) indicate its presence in the Harrisburg area. This is significant as it suggests correlation of the Nis Hollow Member with beds within the Sherman Ridge Member of central Pennsylvania. If so, then the proposal of Epstein et al. (1974) who cautiously proposed that the Nis Hollow is a thinner equivalent to the Montebello Member is not correct. A further indication of this is that the Nis Hollow Member's stratigraphic location relative to the basal Tully Mesosequence is only about 75 meters (Figure 12).

Despite the lack of a South Lansing Bed equivalent, other correlations with the Taunton Beds and the Nis Hollow

Member are apparent. Two fossiliferous samples (B-2 and B-178) from mudstone obtained immediately below the Nis Hollow appear equivalent to the lower Taunton Beds. Sample B-178 is derived from a distinct centimeter thick brachiopod-dominated lag and appears similar to the fossil hash within the Taunton Beds. A crinoid calyx (Figure 15) from sampled horizon B-2 indicates the presence of articulated echinoderms also characteristic of the lower Taunton Beds (Brett and Baird 1994). The three meter interval yielding these fossils is mudstone and from a strictly lithologic perspective would not be placed within the Nis Hollow Member. However, from both a sedimentologic and lithologic perspective these beds are more similar to the Lower Taunton Beds of New York. Therefore, this three meter mudstone is readily recognizable relative to the base of the Nis Hollow Member as indicated by Figure 14.

The Nis Hollow Member is a very distinct series of fine sandstone and siltstone beds (Figure 14) at Bowmanstown and was used as a stratigraphic marker by Epstein et al. (1974) for their mapping of the area. For example this bed set (member) with similar litho- and biofacies is readily apparent at North Weissport, PA (locality "4" of Figure 1). The uppermost part of the Nis Hollow Member has large (typically three to five centimeters) matrix-supported brachiopods (Figure 16) dispersed over a half-meter interval (sample B-244-45').

Among the fossils present are *Allanella tullia* (Figure 16) that is also characteristic of the upper Taunton (Brett and Baird, pers. commun. August 1999).

Weissport Member - The fifteen meters of exposed mudstone and shale of the Weissport Member immediately overlying the top of the Nis Hollow Member yields sparse fossils. The presence of ambocoelid brachiopods suggest a possible correlation with either the Simpson Creek Bed or Gage Gully Beds of New York rather than the Spezzano Gully Beds (Figure 78). In either case the sparse fossils, including mollusks such as *Grammysia* and *Spyroceras* (Figure 22), indicate these beds are still correlative with the Windom Shale Member.

The beds of the Weissport Member appear to best correlated with eastern New York (as discussed by Cooper 1933, 1934 and Heckel 1973) rather than western New York (as discussed by Brett and Baird 1994). This is partly based on observations at North Weissport, approximately 3.5 miles north of Bowmanstown. At the North Weissport section (measured by Stevenson and Skinner 1949 and later Sevon in Epstein et al. 1974), this stratigraphic interval is well exposed and yields several distinctive *Leiorhynchus*-dominated lags (Figure 23). As noted here and by Heckel (1969), these beds consist of abundant specimens of *Camarotoechia* (the currently recognized name of '*Leiorhynchus*') *mesacostalis*. Such beds are part of the

Weissport Member of Stevenson and Skinner (1949) and the New Lisbon Member of eastern New York (Cooper and Williams 1935). As shown by Heckel (1973) and discussed by Brett and Baird (1994) these beds do not have western New York equivalents. At Bowmanstown these brachiopod beds change from *Leiorhynchus*-dominated (horizon B-411) to *Mucrospirifer*-dominated (horizon B-455), back to *Leiorhynchus*-dominated (at the 142.5 meter interval indicated on Figure 12). This concurs with Heckel (1973 p. 57) listing only the upper portion of the New Lisbon Beds as equivalent to the basal Tully Member. Cooper (1933) prior to proposing the term New Lisbon, however, placed all of these *Leiorhynchus*-dominated beds as equivalent to the basal Tully Mesosequence based on the rare presence of *Hypothyridina venustula*. As suggested here and concurring with Heckel (1973), the occurrence of *Hypothyridina venustula* appears to be limited to the upper part of the 'New Lisbon" *Leiorhynchus*-dominated beds.

<u>Lower Member of Tully Mesosequence</u> - The base of the Tully Mesosequence is recognized on the rare presence of *Hypothyridina venustula* at the 142.5 meter interval of section measured. As suggested on Figure 78, this bed is tentatively correlated with the DeRutyer Bed (Figure 4) of the Tully Mesosequence (Heckel 1966, 1969, 1973) which is also known to have this brachiopod. The upper five meters of the Lower Tully Member is not as fossiliferous as its

basal contact. The weakly defined, alternating siltstone and silty shale to shaly beds have a rhythmic pattern similar to that observed at Lock Haven for what are recognized as equivalent to the Taughanock beds. However, this correlation is tentative at best due to the lack of other correlative features.

Upper Member of Tully Mesosequence - The remainder of the section appears equivalent to the West Brook Bed of New York as recognized by fossiliferous beds at the 149 meter measured interval (Sample B-490). These slightly calcareous beds are at the same stratigraphic position as the 'Tully Zone fossil bed' (sensu Epstein et al. 1974). This interval was used by Epstein et al. (1974) as a stratigraphic marker of the upper Mahantango Formation. Fossils present are typical of the West Brook and include pelmatozoans, byrozoans, trilobites, brachiopods, and corals. Overlying this interval are less fossiliferous siltstone and shale equivalent to the Moravia Bed (Figure 78) based on their stratigraphic position below the base of the Burket Shale.

Riverside Section

As indicated below, the measured Riverside Section is correlative with the Moscow Formation and overlying Tully Mesosequence of New York state (Figure 78).

Lower South Danville Member - The basal (0 to 24 meter) portion of the measured part of the Riverside section (Figure 44) appears to be correlative with the sparsely fossiliferous portion of the Deep Run Shale of New York (Figure 78). Only a well-preserved specimen of the pelecypod *Grammysia* was found during inspection of this part of the section. This correlation is based on the stratigraphic position of this interval relative to overlying beds with correlative fossil-bearing horizons. Also, these beds share a similar sparsely fossiliferous, fine-textured lithology as the Deep Run Shale of New York (cf. Brett and Baird 1994, Cooper 1933). A fossiliferous lens (sample horizon Ri-1) within this interval contains abundant pelmatazoan columnals (Figure 49), also characteristic of the Deep Run Shale (Brett and Baird 1994 p. 513).

Riverside Member - The base of the Riverside Member consists predominantly of *Zoophycos*-burrowed siltstone from the 24 to 25.5 meter interval of measured section (Figure 44) and is possibly equivalent to the Menteth Limestone. As in parts of New York where there is a sharp contact between the Menteth Limestone and underlying Deep Run Member, a sharp contact is present (cf. Figure 45) between the top of the Lower South Danville Member and the bottom of the Riverside Member. This siltstone at Riverside is less calcareous than the silty limestone to calcareous mudstone characteristic of the Menteth Limestone (cf. Brett and Baird 1994) in New York. One other difference with the New York Menteth Limestone is the sparsity of fossils. However, the stratigraphic location of the siltstone bed at the base of the Riverside Member relative to overlying sampled horizons Ri-4 and Ri-5, strongly suggest it to be a lateral equivalent of the Menteth Limestone.

The 25.5 to approximately 41 meter interval of measured section (Figure 44) at Riverside representing the upper part of the Riverside Member is less silty than the basal meter and a half shown on Figure 45. However, this interval is more silty than overlying exposed beds. Sampled horizon Ri-4 is at the top of this interval (Figure 44) and is correlated with the Kashong Member based on the occurrence of silty bed dominated by *Tropidoleptus carinatus* (Figure 46). Approximately 75 per cent of the fossils within this ecologic epibole (sensu Brett et al. 1990) bed consist of this brachiopod. Specimens vary from juvenile to adult including unusually large individuals up to two centimeters wide. This bed was recognized as characteristic of the Kashong Member by Cooper (1930b p. 227) and has been noted to occur in the uppermost part of the Lower Kashong Member as subdivided by Brett and Baird (1994 p. 518). That this particular *Tropidoleptus*-dominated bed is within the Kashong Member is further suggested by the presence of the phyllocarid *Rhinocaris*, although observed specimens are not well preserved as reported for New York beds by Brett and Baird (1994).

Middle South Danville Member - The lower thirty-seven meters of the Middle South Danville Member at Riverside has sparse fossils. This 41 to 78 meter interval of measured section (Figures 44 and 78) consists of exposed mudstone and shale. Based on these beds being immediately over the distinct *Tropidoleptus*-dominated bed (sample horizon Ri-4), they are correlated to the middle and upper portions of the Kashong Member of New York (Figure 78). However, other characteristics, such as concretions horizons as observed in New York (Brett and Baird 1994) or conglomeratic beds as proposed in this study for the Harrisburg area, were not observed within this portion of the exposed section.

Above the *Tropidoleptus*-dominated bed and overlying non- to sparsely fossiliferous shales is an unexposed interval estimated at sixty-two meters of section. This is the location of Hower Road (Figure 44). This interval (78 to 140 meter of section measured), may contain more definitive information regarding potential correlations with either the Kashong Member, the Unnamed Member of Brett and Baird (1994), or the lower part of the Windom Shale Member (Figure 78).

Another critical sampled fossil horizon is Ri-5 located at the 142 meter interval of measured section (Figure 44) and immediately above the covered Hower Road interval. Sampled horizon Ri-5 yields abraded and disarticulated fossils, with pelecypods, brachiopods and pelmatazoans being predominant. This fauna also includes rare medium-size *Allanella tullia* characteristic of the upper Taunton (Brett and Baird, pers. commun. August 1999). However, unlike the Upper Taunton correlatives at Bowmanstown, representing the upper part of the Nis Hollow Member, those at Riverside are in a shaly mudstone facies. The underlying portion of the section covered by Hower Road (Figure 44) may contain beds which would be lithologically correlative to the Nis Hollow Member. Otherwise an equivalent, from a lithologic perspective, to the Nis Hollow is not recognized at Riverside.

Upper South Danville Member - Based on their stratigraphic position, the slightly calcareous shales referred to here as the Upper South Danville Member and best represented by sampled horizon Ri-5 are correlated to the Spezzano Gully Beds (Brett and Baird 1994). This includes beds up to the 158 meter of measured section (Figure 44). At this interval a distinct lithologic change from mudstone to dark shale is present. Within these dark noncalcareous shales is a fossiliferous lag (sample horizon R-9) yielding *Allanella, Pustulatia* and associated fauna (Figures 48 and 53) readily correlative with the eastern facies of the Gage Gully Beds (Figure 78) located in central New York (Brett and Baird 1994). In contrast to the Bowmanstown locality, the *Allanella-Pustulatia* Assemblage Zone of sample horizon

Ri-9 readily identifies the uppermost Mahantango Formation below the Tully Mesosequence. This biofacies is a chronostratigraphically significant horizon of the pre-Tully Hamilton of central New York according to Brett and Baird (1994, p. 537 in reference to a MS thesis by Grasso 1966, but also see the earlier work of Cooper 1933, 1934 as well as subsequent work of Heckel 1973). Approximately four meters above the dark shales containing sampled horizon Ri-9 is a sharp contact of lighter gray calcareous shale which represents the Tully Mesosequence (Figure 44). However, in contrast to the Bowmanstown section, no New Lisbon Member correlative dominated by *Leiorhynchus* was observed below the Tully Mesosequence at Riverside. The New Lisbon Member is an eastern New York biofacies (sensu Heckel 1973 and Cooper 1934). Therefore, the lower part of the interval between sample horizon Ri-5 and the Tully Mesosequence at Riverside is best correlated with central rather than eastern New York.

Tully Mesosequence - Information concerning correlations at the Riverside locality with New York subdivisions of the Tully Mesosequence as defined by Heckel (1973) is not as definitive when compared to the Bowmanstown and Lock Haven localities. The contact of the Mahantango Formation and Tully Mesosequence at Riverside is recognized where a calcareous shale overlies noncalcareous shale. This boundary is noted at the 163 meter measured interval on

Figure 44. The lowermost interval of the Tully Mesosequence (163 to 168 meters measured including sample Ri-7) at Riverside is shown as equivalent to the Vesper Beds (refer to Figure 4 for listing of Tully Mesosequence beds). This is based on lithology and lack of fossils. The remainder of measured section from 168 to 171 meters (Figure 44) is correlated to the Carpenter Fall Beds based on the presence of pyrite, burrows and styliolines. However, no bed equivalent to the basalmost Carpenter Fall Beds found at Lock Haven with a unique microfauna was detected. Due to poor exposure, comparison with the rest of the Tully Mesosequence is not feasible. However, a classic Tully fauna having rare specimens of the brachiopod *Hypothyridina* is reported to occur in overlying beds by Heckel (1969, 1973) and Willard (1935a, 1939).

Lock Haven Section

The Mahantango Formation at Lock Haven has proven to be the most difficult to correlate with New York or other Pennsylvania sections despite its strategic location between both groups of outcrops. This is due to the genuine sparsity of fossils; monotonous lithology; and lack of distinct disconformities or other stratigraphic markers. No coarser siltstone or very fine sandstone bed(s) that might be correlated with the Nis Hollow Member or Taunton Beds are readily apparent. Stratigraphic indicators, however, are found in the overlying Tully Mesosequence and the uppermost portion of the Mahantango Formation at this locality whereby tentative correlations can be made.

The monotonous facies of the Mahantango Formation at Lock Haven is significant, however. This is due to Lock Haven representing a third type of facies (mainly a "no ichnia" in the classification scheme of Ekdale and Mason 1988) when viewed as the northwest point of a transverse with the Bowmanstown and Riverside localities (Figure 79). This southeast to northwest transverse (Figure 79) shows a depositional pattern similar to the east, central and western facies change observed in New York (Brett and Baird 1994, Cooper 1930a,b, 1933, 1934). One aspect of this change is the occurrence of more fossiliferous lags potentially derived from storm-generated burial (sensu Miller 1991, Miller et al. 1988, Brett et al. 1990) at Bowmanstown than at Riverside and more at the intermediate Riverside locality than at Lock Haven (as schematically shown on Figure 79). This concurs with the deepening bathymetry model of Brett et al. (1990) where such fossiliferous tempestite deposits become more scarce farther away from the storm-wave base (Figure 79). It also indicates the Lock Haven as a depocenter (a concept implied by Heckel 1973) at this point in the Givetian with regards to the deposition of the uppermost Mahantango Formation and Lower Tully Member.

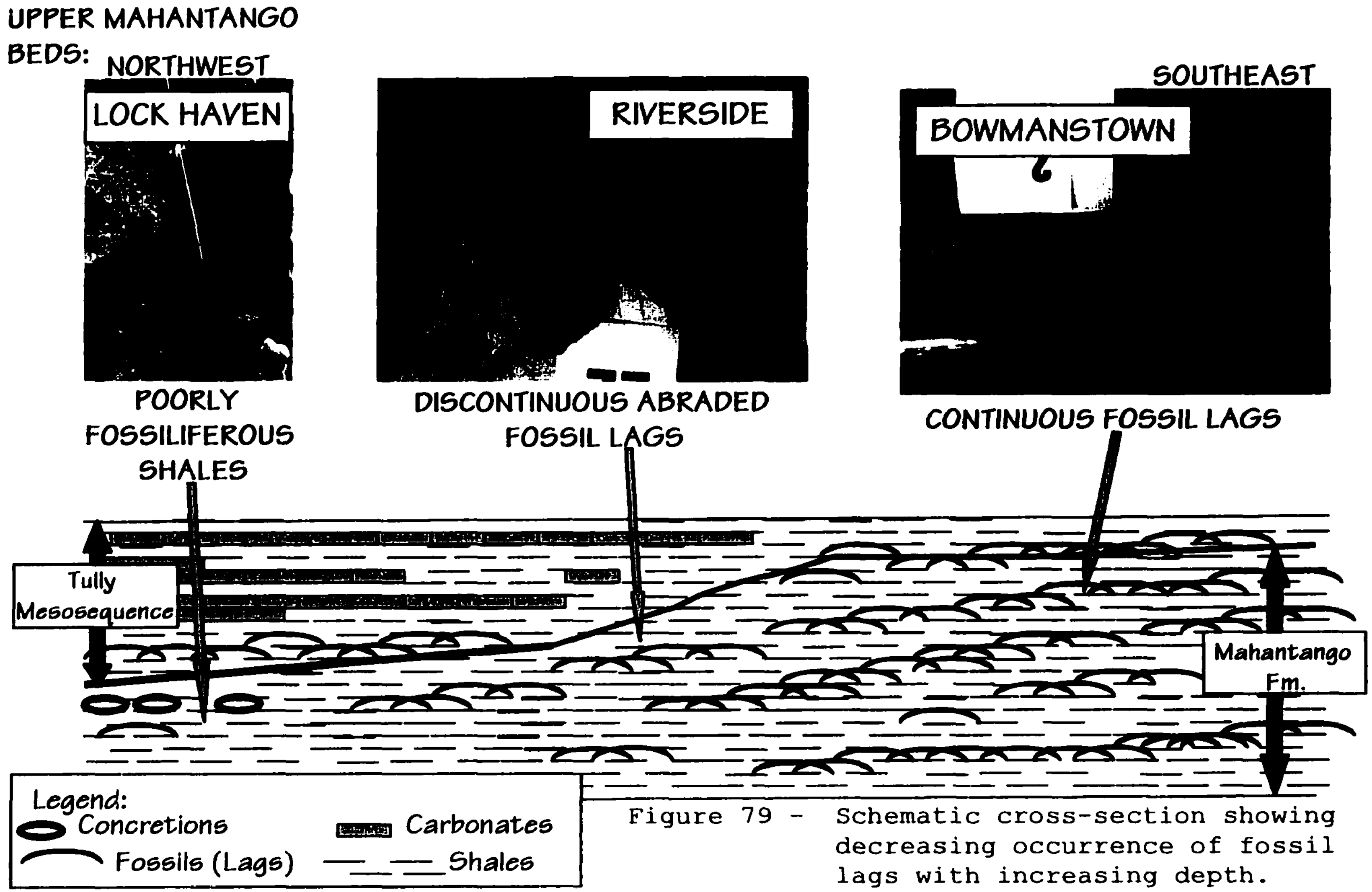


Figure 79 - Schematic cross-section showing decreasing occurrence of fossil lags with increasing depth.

With the above observations in mind, the Mahantango Formation measured at Lock Haven is correlative only with the Windom Shale Member of the Moscow Formation (Figure 78). The basal portion (0 to 12 meters) of the measured part of the Lock Haven section (Figure 56) is correlative with the sparsely fossiliferous upper part of the Spezzano Gully Beds of New York (Brett and Baird 1994). This correlation depicted on Figure 78 is based on the stratigraphic position of these beds in addition to the overall lack of fossils. If this correlation is correct, no fossil horizon equivalent to the Simpson Creek Bed of New York (Figures 77 and 78) is present at the Lock Haven locality. Instead correlatives with the Gage Gully Beds of western New York (Brett and Baird 1994) are present from the 11.5 to 20 meter interval of measured section (Figure 56) below the Tully Mesosequence. Besides stratigraphic position relative to the Tully Mesosequence, this correlation is based on the few fossils from sample horizon LH-6 (11.5 meter interval of measured section on Figure 56) which include nuculoid pelecypods and the straight cephalopod *Spyroceras* (Brett and Baird 1994). No fossils representing the *Allanella-Pustulatia* Zone were observed, therefore making problematic the correlation of the Mahantango Formation between the Lock Haven and other sections.

There are two unique aspects of the Mahantango

Formation within the 11.5 through 17.5 meter interval (Figure 56) which in turn might be useful for further subdivision or alternative correlation. First, at the measured 12.5 meter interval is a concretion layer. Second, at the 17.5 meter interval is a subtle lithic change in which the beds become more calcareous and the contact with the overlying Tully Mesosequence is here recognized. As suggested on Figure 78, these beds might be correlative with the Gage Gully or the post-Gage Gully Beds of New York State within the uppermost Windom Shale Member.

Tully Mesosequence - The exposed Tully Mesosequence at Lock Haven is one of the thickest sections of this unit known in New York or Pennsylvania. Based on this observation one would anticipate the ability to correlate with all of the beds of the Tully Mesosequence described by Heckel (1973) for New York State (see Figure 4). However, the lowermost DeRuyter Bed consisting of a distinct pure limestone to calcareous sandstone can not be determined at present. Instead a semi-distinct contact of non-calcareous versus calcareous shaly beds occurs between the Tully Mesosequence and underlying Mahantango Formation. This "gradational" contact among shaly beds actually appears to be a sharp (hiatal?) contact changing from non-calcareous to calcareous shales. The ambocoelid-bearing beds (sampled horizons of LH-5 on Figure 56) occur approximately a half meter above this contact. Based on its stratigraphic location, this contact represents the "significant, although subtle, regional bevelling" noted by Brett and Baird (1994) to exist between the Tully Mesosequence and underlying rocks.

Based on their stratigraphic position within the Lower Tully Mesosequence, the sparsely fossiliferous calcareous silty shales with occasional horizons of abundant amobocoelid brachiopods are probably equivalent to the Meeker Hill Beds (Figure 78) of Heckel (1966, 1973). These Meeker Hill-equivalents are of a finer texture rather than the fine sandstone and siltstone found in New York.

A poorly exposed, 15 centimeter micritic bed occurs at the 26 meter measured interval (Figure 56). This bed, with no readily observable fossils, probably correlates with the Tully Valley Bed of New York (Figure 78). This is based on stratigraphic position. Overlying the micritic bed are more slightly calcareous shaly beds from 26 to 30.5 meters of measured section (Figure 78). These sparsely to non-fossiliferous beds with weak rhythmic patterns are correlated to the Vesper Beds of New York (Figure 78).

The measured section from 30.5 to approximately 34.5 meters (Figure 56) is equivalent to the Carpenter Fall Beds. This is based on the presence of pyrite, burrows and styliolines. Heckel (1966, 1973) notes a diastem at the lower contact for the Carpenter Fall Beds in New York similar to the erosional contact found between sampled horizons LH-3 and LH-4 (Figure 56). The bed at sampled horizon LH-4 contains a diagnostically unique microfauna whose occurrence elsewhere within the Tully Mesosequence needs to be verified. As with most of the Lock Haven section, macrofossils are rare confirming earlier observations of Heckel (1969, 1973). Only a small, poorly preserved brachial valve possibly of the brachiopod *Hypothyridina* has to date been observed among processed material from this part of the Lower Tully Member.

Overlying the correlatives of the Carpenter Fall Beds at the 35 meter interval of measured section (Figure 56) is a meter thick knobbly limestone bed. This bed, based on lithology and stratigraphic position is correlated to the Smyrna Bed (Figure 78). From approximately the 35.5 to 90 meter interval (Figure 56) is a sequence of cyclic beds having a rhythmic depositional pattern characteristic of the Taughannock Falls Beds (Figure 78) as noted by Heckel (1966, 1973).

At the 90 meter interval indicated by sample horizon LH-2 of Figure 56 is a distinct hiatal contact with a fossiliferous bed which includes pelmatozoans, bryozoans, trilobites, brachiopods, and corals. Based on these features, the 90 to 93 meter interval is correlated to the extensive West Brook Beds (Heckel 1973, Brett and Baird 1994) of the basalmost Upper Tully Member (Figure 78). The remaining Tully Mesosequence overlying this interval is less fossiliferous consisting of siltstone and shale. Based on these features (cf. Heckel 1966, 1973), this interval is correlated to the Moravia Beds (Figure 78).

Summary of Significance of Correlations

Regional scale correlations for the localities studied in Pennsylvania are here proposed as summarized in Figure 78. These proposed equivalencies are based on established and refined correlations of thinner sequences of Givetian aged rocks in New York as best summarized by Brett and Baird (1994). While such correlations for Pennsylvania have previously been proposed or suggested in the works of Willard (1935a,b, 1939) and Ellison (1965), they have not been utilized due to a reluctance by subsequent workers to rely on paleontology for stratigraphic correlations of beds or bed sets. In Pennsylvania unit correlations have typically emphasized lithostratigraphy. Recent work in New York (see Brett and Baird 1993, 1994, 1995, Brett 1995 as well as references cited within) suggest a need for reassessment of the potential of fine-textured beds to give meaningful chronostratigraphic correlations. In the above review of localities such correlations are best shown at the Bowmanstown and Riverside sections. A historic problem has been the poor preservation of the fossils within these rocks due to tectonic deformation as best shown by the

Bowmanstown locality. This again indicates the need to rely on better preserved stratigraphic sections, such as those found in New York, from which to initiate local correlations.

In addition to the reluctance to utilize fossils in fine-textured rocks, past studies in Pennsylvania, when attempting local or large scale correlations would typically rely on correlations of coarser-textured beds or their representative facies (cf. Faill et al 1978, Epstein et al. 1974, Sevon et al. 1989, Slattery 1995). However, as suggested by this study for the Harrisburg area, coarser sequences of sedimentary rocks are more dynamic in their depositional history and less reliable (in most cases) for regional-scale correlations. Again, preliminary findings suggest that the need to assess the fossil-bearing beds within fine-textured sediments which have the potential of a more widespread depositional record.

Implications of This Study for the Proposed Type II Boundary of Slattery (1993, 1995)

An initial goal of this study was to use biostratigraphic information found at several of the sections studied to assess the chronostratigraphic position of a Type II Boundary as proposed by Slattery (1993, 1995). Slattery (1995) considered his proposed Type II Boundary as equivalent to a eustatic event between the Tichenor Limestone and underlying Ludlowville Formation of western New York. Chronostratigraphic correlations based on a variety of paleontologic, lithologic and sequence boundary data as recognized in this study do not concur with this correlation (see Figures 75 and 78). Instead, relative to the contact of the Tichenor and Ludlowville within the Hamilton Group of western New York, the following conditions exist with regard to the studies of Slattery (1993, 1995):

1. The Port Jervis, New York section, along with two nearby sections (Raysmondskill Creek and Sawmill Creek) in northeast Pennsylvania, are recognized as being significantly older and equivalent to the lower part of the Hamilton Group. Specifically, these sections entail the upper Lower and lower Middle Mahantango Formation as recognized by Fletcher and Woodrow (1970). This is in contrast to Slattery (1995) who considered this section as part of the upper Middle Mahantango Formation.
2. In contrast to Port Jervis, the entire Bowmanstown section studied is recognized as being younger than the Tichenor-Ludlowville contact, and as being equivalent to the Windom Shale and Tully Limestone of New York.
3. An age younger than proposed by Slattery (1993,

1995) is also recognized for the two Harrisburg area sections at Girty's Notch and Rockville. As summarized on Figure 78, most of the Sherman Ridge Member is correlated with the Windom Shale of the Moscow Formation of western New York. Further as reviewed in this study, the poorly exposed upper part of the Sherman Ridge appears to be correlative with the Tully Mesosequence. The underlying Montebello Member at these sections is recognized as correlative with the Kashong Shale of the Moscow Formation.

While the Type II Boundary as proposed by Slattery (1993, 1995) is incorrect, his use of the Facies Association concept as initially applied by Prave and Duke (1991) is significant. Slattery's (1993, 1995) study shows that Facies Associations can be recognized in fine-textured dominated beds within the Mahantango Formation. Such beds dominate the Mahantango Formation. Further, with the revised correlations recognized of this study, Facies Associations are found within the *entire* Mahantango Formation. Therefore, future investigations of the fine-textured beds of the Mahantango Formation should attempt to differentiate between the presence of storm-dominated versus tidally-influenced sedimentary rocks as suggested by Facies Associations. As indicated by this study this can, in part, be achieved noting the location of key fossiliferous beds.

CHAPTER SIX

CONCLUSIONS

In conclusion, this study shows the utility of fossil assemblages in Givetian age rocks in Pennsylvania as marker beds for sequence stratigraphic correlations in a fashion similar to that recently established for New York (cf. Brett and Baird 1994). Other new insights have been made despite some of the sections examined here having been the subject of study for over seventy years (cf. Willard 1939). Among the unique insights concerning the localities studied are:

1. The recognition of a channel filled with fine-textured hematitic sandstone in the upper part of the Montebello Member;
2. The indication that the upper portion of the Montebello Member has a fine-textured facies which retains a relatively uniform thickness in contrast to a coarser textured lower facies which varies greatly over geographically short distances;
3. The recognition (discovery) at Bowmanstown of several fossil-bearing horizons in the fine-textured rocks both above and below the Nis Hollow Member in what was previously considered non to poorly fossiliferous strata. Use of the term Bowmanstown Member for those beds below and reuse of the term Weissport Member for those beds above the Nis Hollow

Member are proposed;

4. The correlation of the Nis Hollow Member at Bowmanstown to the Taunton Beds of New York state;

5. The recognition of the *Hypothyridina venustula* brachiopod assemblage at Bowmanstown extending the Lower Tully Mesosequence to a lower stratigraphic position than previously reported;

6. The recognition of several fossil-bearing horizons within the upper part of the Mahantango Formation at the Riverside section which indicate correlation with the Moscow Formation of New York state. The use of the names Lower South Danville, Riverside, Middle South Danville and Upper South Danville Members for this part of Mahantango Formation are proposed;

7. The confirmation of the *Pustulatia postulosa* brachiopod assemblage Zone at Riverside;

8. The discovery of a unique pyritic microfauna within the Lower Tully Member at the Lock Haven locality;

9. The first reported occurrence (in North America?) of the long-ranging, enigmatic microfossil *Jinonicella*;

10. The confirmation of the poorly fossiliferous nature of the upper Mahantango Formation at Lock Haven with only one sparsely fossiliferous horizon (LH-6) being discovered.

Using some of the above findings with other noted observations, revisions to previous chronostratigraphic correlations (cf. Ellison 1965, Willard 1939, Brett and Baird 1994) with those of New York are proposed. This includes:

1. The Montebello and Sherman Ridge Members of the Mahantango Formation are correlative with the Kashong Shale and Windom Shale Members, respectively of the Moscow Formation of New York;

2. The upper part of the Mahantango Formation at Bowmanstown is equivalent to the New Lisbon and Windom Shale Members of the Moscow Formation of New York. However, the uppermost portion previously referred to as the Mahantango Formation is now recognized as correlative to the Tully Mesosequence. In particular, fossil assemblages associated with the distinct Nis Hollow Member of Pennsylvania indicate this unit to be correlative with the Taunton Beds of the Windom Shale of New York;

3. The measured portion of the Port Jervis section is recognized as part of the Lower and Middle Mahantango Formation as defined by Fletcher and Woodrow (1970) and potentially correlative to the contact of the Skaneatales and Ludlowville Formations of New York.

The above listed observations differ from those proposed by Slattery (1993, 1995) who suggested that the Harrisburg localities are penecontemporaneous to the Bowmanstown, PA and Port Jervis, NY sections. Further, none of these localities concur with the suggestion of Slattery (1993, 1995) that these rocks are correlative to the contact of the Tichenor Limestone with the Ludlowville Formation of New York. In the case of the Harrisburg and Bowmanstown localities, the rocks studied are slightly younger than proposed by Slattery (1993, 1995), while the Port Jervis and associated northeast Pennsylvania sections (cf. Figure 1) are older.

This study shows how the presence of fossiliferous beds within fine-textured rocks can be utilized in correlation within the Mahantango Formation of Pennsylvania. Further, as suggested in Chapter Five, the presence of these fossiliferous beds or bed sets are correlative with New York beds, and can be extrapolated with various levels of confidence. However, fine-textured beds of the Mahantango Formation are still difficult to correlate where readily distinguishable marker beds are absent: this is best shown at the Lock Haven locality.

Presented in this paper is the concept of the "Tully Mesosequence". The Tully rocks whether recognized as a Limestone, Formation, Member, or Fossil Zone should be defined within the framework of a Mesosequence with unique lithologic and paleontologic characteristics. These general characteristics help to differentiate this sequence stratigraphic unit from the rest of the underlying Hamilton

Group and the overlying Genesee Group. However, within the Tully Mesosequence there exists three distinct sequence stratigraphic boundaries and possibly two lesser boundaries. Correlation outside of its carbonate-dominated New York depocenter is dependent on being able to recognize first the general characteristics of the Tully Mesosequence relative to these sequence boundaries. Observations of this study and my review of the literature suggests that the Upper Tully Member is more prevalent and extensive than the Lower Tully as both a carbonate and fossil-bearing unit across the Appalachian Basin. However, when present, the Lower Tully is typically a much thicker unit.

Finally, despite intense efforts, only scant conodont remains have been found in these rocks. This is, in part, due to the difficulty in processing a siliciclastic rock sample where an adequate proportion is sufficiently broken down for examination. However, these attempts within Pennsylvania also confirm the observations of other investigations in New York state (cf. Klapper 1981, Kirchgasser et al. 1994, Miller 1991) that indicate the limitations of conodont biostratigraphy within the Givetian of the Appalachian Basin.

APPENDIX A

INVESTIGATIVE METHODOLOGY

(SUMMARY TABLES OF PROCESSING PROCEDURES)

Introduction

The following tables summarize the "processing techniques" used (Tables 3 through 8) and the final "results" of these processing procedures (Table 9 through 14). Tables 3 through 8 show the amount of weighed sample exposed to formic acid; the various number of times a sample was exposed to a liquid for maceration; the number of Sodium Megatungstate (SMT) runs required to separate the fine residue retrieve into its high specific gravity versus low ("light") specific gravity components; a subjective assessment of the overall disaggregate results; and an rough estimate of the number of hours necessary to process an individual sample. Tables 9 through 14 show the initial weight of an individual sample; post-processed weights; and general color changes. Additional information regarding the lithology and paleontology of these samples can respectively be found in Appendices C and D. Details about the processing techniques and a review of the results are found in Chapter 3.

A listing of abbreviation's and symbols used within these tables include:

ID #	Identification Number of a sampled horizon
SMT	Sodium Megatungstate
N/A	"Not Applicable": Sample not processed

TABLE 3
SECTION: BOWMANSTOWN, PA
CHART OF PROCESSING TECHNIQUES

FOOTAGE (METERS)	SAMPLE ID #	FORMIC ACID (grams)/Reaction	NUMBER OF MACERATIONS BLEACH	BOILING WATER	STODDARD'S SOLVENT	NUMBER OF SMT RUNS	OVERALL DISAGGREGATE RESULTS	PROCESS TIME (APPROXIMATE TOTAL HOURS)
0.3	B-1.0'	500 Poor reaction	4	12	2	4	Poor	210
24.4	B-80'	500 Poor reaction	3	18	3	5	Poor	250
26.8	B-98'	500 Poor reaction	3	18	3	4	Poor	250
54.3	B-178'	1000 Poor reaction	4	16	3	8	Fair	150
55.0	B-2	0	3	9	1	1	Very Poor	200
57.3	B-1	0	9	6	1	7	Fair-Good	150
74.6	B-244-45'	0	2	12	2	4	Poor	135
74.6	B-3	0 Poor reaction	2	13	2	11	Fair	80
74.9	B-4	0	2	6	1	5	Fair	220
125.3	B-411'	0	3	12	2	4	Poor	170
139.9	B-455'	0	3	12	2	4	Poor	160
149.4	B-490'	2000 Good reaction	2	12	3	9	Good	220

TABLE 4
SECTION: GIRTY'S NOTCH, PA
CHART OF PROCESSING TECHNIQUES

FOOTAGE (METERS)	SAMPLE ID #	FORMIC ACID (grams)/Reaction	NUMBER OF MACERATIONS			NUMBER OF SMT RUNS	OVERALL DISAGGREGATE RESULTS	PROCESS TIME (APPROXIMATE TOTAL HOURS)
			BLEACH	BOILING WATER	STODDARD'S SOLVENT			
19.51	G-64	2015 excellent	0	0	0	24	Excellent	75
27.01	G-1	0	9	51	9	48	Very Good	420
67.36	G-2	0	3	23	4	39	Very Good	180
99.06	G-3	0	1	12	5	25	Good	110

TABLE 5
SECTION: LOCK HAVEN (LOCKPORT), PA
CHART OF PROCESSING TECHNIQUES

FOOTAGE (METERS)	SAMPLE ID #	FORMIC ACID (grams)/Reaction	NUMBER OF MACERATIONS BLEACH	BOILING WATER	STODDARD'S SOLVENT	NUMBER OF SMT RUNS	OVERALL DISAGGREGATE RESULTS	PROCESS TIME (APPROXIMATE TOTAL HOURS)
30.18	LH-3	2252.3 Fair-Good reaction	0	0	0	17	Good	112
30.79	LH-4	2108.8 Excellent reaction	0	0	0	12	Excellent	112
31.39	LH-1	2000 Excellent reaction	0	1	0	7	Excellent	33
89.92	LH-2	2000 Excellent reaction	0	0	0	35	Excellent	64

TABLE 6
SECTION: PORT JERVIS, NY
CHART OF PROCESSING TECHNIQUES

FOOTAGE (METERS)	SAMPLE ID #	FORMIC ACID (grams)/Reactio	NUMBER OF MACERATIONS BLEACH	BOILING WATER	STODDARD'S SOLVENT	NUMBER OF SMT RUNS	OVERALL DISAGGREGATE RESULTS	PROCESS TIME (APPROXIMATE TOTAL HOURS)
15	PJ-3	0	3	18	3	16	Fair	400
46.75	PJ-1	0	3	18	3	7	Poor	250
63.5	PJ-2	0	6	25	7	35	Fair	250

TABLE 7
SECTION: RIVERSIDE, PA
CHART OF PROCESSING TECHNIQUES

FOOTAGE (METERS)	SAMPLE ID #	FORMIC ACID (grams)/Reaction	NUMBER OF MACERATIONS BLEACH	BOILING WATER	STODDARD'S SOLVENT	NUMBER OF SMT RUNS	OVERALL DISAGGREGATE RESULTS	PROCESS TIME (APPROXIMATE TOTAL HOURS)
17.5	Ri-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
26	Ri-2	0	2	12	2	2	Very poor	220
37.75	Ri-3	2000 Good	2	6	1	5	Fair	150
40.5	Ri-4	500 Poor	2	9	1	5	Poor to fair	125
142.0	Ri-5	2000 Good	2	3	0	4	Fair	125
148.1	Ri-6	2000 Fair	2	13	2	4	Poor	175
160.2	Ri-9	500 Poor	2	12	2	4	Poor to fair	120
166.7	Ri-7	2533 Excellent	0	0	0	11	Excellent	80
169.5	Ri-8	903 Excellent	0	0	0	5	Excellent	40

TABLE 8
SECTION: ROCKVILLE, PA
CHART OF PROCESSING TECHNIQUES

FOOTAGE (METERS)	SAMPLE ID #	FORMIC ACID (grams)/Reaction	NUMBER OF MACERATIONS BLEACH	BOILING WATER	STODDARD'S SOLVENT	NUMBER OF SMT RUNS	OVERALL DISAGGREGAT RESULTS	PROCESS TIME (APPROXIMATE TOTAL HOURS)
47.5	R-4	1170	2	15	3	27	Very Good	200
110.5	R-2	500	0	5	1	16	Fair	36
162.5	R-1	2476.8	3	18	2	11	Very Good	200
196.5	R-3	0	9	54	9	55	Excellent	400
204.0	R-5	2000	1	7	1	8	Very Good	210

TABLE 9
SECTION: BOWMANSTOWN, PA
CHART OF PROCESSING RESULTS

FOOTAGE (METERS)	SAMPLE ID #	INITIAL WEIGHT (GRAMS)	POST-PROCESSED WEIGHT: COARSE >#20 SIEVE (GRAMS)	LIGHT FINES <#20 SIEVE (GRAMS)	HEAVY FINES <#20 SIEVE (GRAMS)	COLOR: FRESH	WEATHERED	POST-PROCESSED
0.3	B-1.0'	1601	1449.9	64	0.6	Dark gray to black	Grayish brown	Lt. olive gray to olive gray
24.4	B-80'	2000	1743.2	100.6	0.6	Dark gray to black	Chocolate brown	Lt. brown & med. gray
26.8	B-98'	2000	1750.4	85.5	0.2	Medium gray	Brownish gray	Olive to med. brown
54.3	B-178'	1829	1551.2	139.8	1.1	Medium gray	Brownish Medium gray	Grayish lt. brown
55.0	B-2	435.50	392.7	13.4	0.1	Dark gray to black	Medium-light brownish gray	Lt. olive gray
57.3	B-1	1264.4	992.9	124.5	0.9	Light gray	Green-brown	Medium yellow brown
74.6	B-244-45'	2000	1915.6	38	2.7	Medium gray	Orange light brown	Lt. green-gray & brown
74.6	B-3	not weighed	997.8	93.7	3.9	Medium gray	Orange light brown	Lt. green-gray & med. brown
74.9	B-4	1251	1038	69.9	1.1	Dark gray to black	Light brownish gray	Light brown to olive gray
125.3	B-411'	2000	1919.7	26.1	29.7	Medium to dark gray	Orange brown	Olive gray
139.9	B-455'	2058	1946.2	26.7	29.4	Medium gray	Light orange brown	Brownish lt. gray
149.4	B-490'	2000	1605.9	109	3.2	Dark gray to black	Light brown to olive gray	Yellowish gray

TABLE 10
SECTION: GIRTY'S NOTCH, PA
CHART OF PROCESSING RESULTS

FOOTAGE (METERS)	SAMPLE ID #	TOTAL WEIGHT (GRAMS)	POST-PROCESSED WEIGHT			COLOR:		
			COARSE >#20 SIEVE (GRAMS)	LIGHT FINES <#20 SIEVE (GRAMS)	EAVY FINE <#20 SIEVE (GRAMS)	FRESH	WEATHERED	POST-PROCESSED
19.51	G-64	2015	683.1	464.4	7.5	Med. to dark med. gray	Light brown to brownish gray	Whitish lt. gray to med. gray
27.01	G-1	8784	5929	1013	3.5	Green-gray	Brown to olive gray	Lt. green gray red-brown
67.36	G-2	3118	1529.4	658.3	8.0	Olive, green to light gray	Brown to green gray	Brown to lt. green gray
99.06	G-3	4500	3300.8	282.4	28.1	Greenish light gray	Brown	Lt. green gray to orange-brown

TABLE 11

SECTION: LOCK HAVEN (LOCKPORT), PA

CHART OF PROCESSING RESULTS

FOOTAGE (METERS)	SAMPLE ID #	INITIAL WEIGHT (GRAMS)	POST-PROCESSED WEIGHT: COARSE >#20 SIEVE (GRAMS)	LIGHT FINES <#20 SIEVE (GRAMS)	HEAVY FINES <#20 SIEVE (GRAMS)	COLOR: FRESH	WEATHERED	POST-PROCESSED
30.18	LH-3	2252.3	1485.4	185.9	0.8	Medium dark gray	Light olive gray	Light medium gray
30.79	LH-4	2108.8	566.5	130	22	Medium gray	Grayish light brown	Medium gray
31.39	LH-1	2000	386.1	36	7	Medium gray	Light brownish medium gray	Light brown
89.92	LH-2	2000	358.6	467	11.2	Medium gray	Light brownish gray	Medium gray

TABLE 12

SECTION: PORT JERVIS, NY

CHART OF PROCESSING RESULTS

FOOTAGE METERS	SAMPLE ID #	INITIAL WEIGHT (GRAMS)	POST-PROCESSED WEIGHT: COARSE >#20 SIEVE (GRAMS)	LIGHT FINES <#20 SIEVE (GRAMS)	HEAVY FINES <#20 SIEVE (GRAMS)	COLOR: FRESH	WEATHERED	POST-PROCESSED
15	PJ-3	3470	3047.9	272.6	16.7	Light gray	Light brown gray	Light green gray
46.75	PJ-1	2822	2383.6	98.7	4.2	Dark gray to black	Red-brown dark gray	Green gray & red-brown
63.5	PJ-2	8455	7056.7	477	4.3	Medium gray	Light brown gray	Light green gray

TABLE 13
SECTION: RIVERSIDE, PA
CHART OF PROCESSING RESULTS

FOOTAGE (METERS)	SAMPLE ID #	INITIAL WEIGHT (GRAMS)	POST-PROCESSED WEIGHT: COARSE >#20 SIEVE (GRAMS)	POST-PROCESSED WEIGHT: LIGHT FINES <#20 SIEVE (GRAMS)	POST-PROCESSED WEIGHT: HEAVY FINES <#20 SIEVE (GRAMS)	COLOR: FRESH	COLOR: WEATHERED	COLOR: POST-PROCESSED
17.5	Ri-1	(N/A)	(N/A)	(N/A)	(N/A)	Medium dark gray	Brownish medium gray	(N/A)
26	Ri-2	2130	1824.5	25.6	1.9	Medium olive gray	Brownish light gray	Olive to lt. brown gray
37.75	Ri-3	2000	1748.7	72.9	1.6	Light to medium gray	Brownish gray	Brown and medium gray
40.5	Ri-4	2000	1811.8	55.4	2.5	Greenish medium gray	Orange-brown medium gray	Grayish olive brown
142.0	Ri-5	2088.8	1905.6	49	2.4	Orange-brown medium gray	Medium-light brownish gray	Light gray olive brown
148.1	Ri-6	2000	1827.5	44.8	1.5	Light gray	Light to medium gray	Lt. green-gray to light brown
160.2	Ri-9	2000	1862.3	32.2	0.4	Medium gray	Brown to gray	Brown to green-gray
166.7	Ri-7	2533	1406.9	133	2.5	Light gray	Light brown to light gray	Medium light gray
169.5	Ri-8	903	211.1	32	2.9	Medium to dark gray	Light brown to light gray	Light gray

TABLE 14
SECTION: ROCKVILLE, PA
CHART OF PROCESSING RESULTS

FOOTAGE (METERS	SAMPLE ID #	INITIAL WEIGHT (GRAMS)	POST-PROCESSED WEIGHT			COLOR:		
			COARSE >#20 SIEV (GRAMS)	LIGHT FINES <#20 SIEVE (GRAMS)	HEAVY FINES <#20 SIEVE (GRAMS)	FRESH	WEATHERED	POST-PROCESSED
47.5	R-4	1170	128.2	508.1	8.1	Medium light gray	Greenish medium gray	Light brown
110.5	R-2	1520	1111.2	175.8	3.0	Medium gray	"Gray"	Gray, red, or white
162.5	R-1	2488	1945.3	324.7	1.0	Medium gray	Lt. brownish gray	Lt. gray w/ brown-green tint
196.5	R-3	7519	5365.6	502.8	582.0	Dark medium gray	Brown	Gray and dark brown
204.0	R-5	2000	1328.1	147.5	2.5	Dark gray	Medium gray	Olive gray

APPENDIX B

GENERAL CHARACTERISTICS OF SECTIONS MEASURED

Introduction

The following tables present the general characteristics observed at each of the sections measured. A listing of abbreviations and symbols used within these tables include:

&	and
abnt.	abundant
f.	fine
cal.	calcareous, calcite
com.	common
cm.	centimeter
lim.	limonite (or iron-stained matrix)
m.	medium; meter
med.	medium
plll.	parallel
pl.	planar
py.	pyrite
qtz.	quartz
tr.	trace
v.	very
w/	with
x-beds	cross-bed(s)

x-lam.	cross-laminae
x-laminae	cross-laminae

Table 15
(1 of 4)
General Characteristics of Section Measured at
Bowmanstown, PA

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
0-1.4	Dark gray to black	Grayish brown	Shale	0.002-0.003	planar
1.4-5.5	Dark gray to black	Grayish brown	Shaly mudstone and shale	0.002-0.01	planar
5.5-7.5	---	---	Covered	---	---
7.5-15.3	Dark gray to black	Grayish brown	Shale	0.002-0.003	planar
15.3-22.75	Dark gray to black	Grayish brown	Shaly mudstone and shale	0.002-0.01	planar
22.75-30.5	M. gray	Chocolate to grayish brown	Shaly mudstone and shale	0.02-0.03	hummocky
30.5-39.5	"Gray"	---	Covered: Silty shale & mudstone	---	---
39.5-54	Medium gray	Brownish Medium gray	Silty mudstone & shale	0.02-0.03	hummocky
54-57	Medium gray	Brownish Medium gray	Mudstone & & shale	0.02-0.03	plll. pl. beds
57-59	Light gray	Green-brown	Siltstone	0.001-0.002	lenticular beds
59-64	Brownish light gray	Tan to grayish brown	Siltstone	0.02-0.03	plll. pl. beds
64-69	Brownish light gray	Tan	Fine grained sandstone	0.2-1.0	plll. pl. beds

Table 15
(2 of 4)
General Characteristics of Section Measured at
Bowmanstown, PA

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
69-70.5	Dark gray	Brownish gray	Mudstone	0.5	planar
70.5-74.6	Medium gray	Orange light brown	Fine grained sandstone	1	plll. pl. beds
74.6-89	Dark gray to black	Light brownish gray	Shaly mudstone	1	plll. pl. beds
89-123.5	---	---	Covered	0.01	plll. pl. beds
123.5-125.5	Medium to dark gray	Orange brown	Shale	0.005-0.01	plll. pl. beds hummocky
125.5-138.5	Light gray	Grayish brown	Mudstone and shale	0.005-0.02	planar
138.5-141.5	M. gray	Light orange brown	Silty mudstone and shale	0.01-0.02	lenticular
141.5-142.5	M. gray	Light orange brown	Silty mudstone and shale	0.01-0.02	lenticular
142.5-149	M. gray	Light orange brown	Silty mudstone and shale	0.01-0.02	lenticular
149-150	Dark gray to black	Light brown to olive gray	Calcareous shaley mudstone	0.02-0.1	plll. pl. beds
150-151	Dark gray to black	Light brown to olive gray	Calcareous silty to shaley mudstone	0.02-0.1	plll. pl. beds
151-162	Gray	Brownish gray	Mudstone and shale	0.005-0.02	plll. pl. beds
162-	Medium to dark gray	Brownish gray	Shale and siltstone	0.02-0.1	plll. pl. beds

Table 15
(3 of 4)
General Characteristics of Section Measured at Bowmanstown, PA

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
0-1.4	fissile x-laminae	clay tr. lim.	trace	Single nuclelid clam.
1.4-5.5		clay	trace	
5.5-7.5	---	---	---	---
7.5-15.3	pillows	clay	trace	
15.3-22.75		clay	trace	
22.75-30.5	pillows x-beds	clay some py.	Ooccassional lags.	Local fossil lags.
30.5-39.5	---	---	---	---
39.5-54	v. large pillows	clay	trace	
54-57		clay com. lim.	common	
57-59		f. quartz; clay com. lim.	trace	Base of Nis Hollow Member.
59-64		f. quartz; clay	scare	
64-69		quartz	scare	

Table 15
(4 of 4)
General Characteristics of Section Measured at Bowmanstown, PA

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
69-70.5		clay	scare to some	
70.5-74.6		quartz	some	
74.6-89		clay some py.	trace	
89-123.5	---	---	---	---
123.5-125.5		clay com. lim.	common	
125.5-138.5		clay	scare to common	Fossil lag at base.
138.5-141.5		clay some py.	Ooccassional lags.	Common fossil lags at top.
141.5-142.5		clay some py.	Ooccassional lags.	Possible vertical burrows at base.
142.5-149		clay some py.	scare	
149-150	discontinous x-laminae	calc. clay com. lim.	common	Slightly mottled (bioturbated) Upper Tully equivalent.
150-151	discontinous x-laminae	calc. clay com. lim.	scare	
151-162		clay	scare	
162-		clay	none observed	

Table 16
(1 of 4)
General Characteristics of Section Measured at Girty's Notch, PA

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
0-2	Light green	Olive-gray	Mudstone	0.01	parallel planar
2-8.5	Green gray	Brown	Shaly to silty mudstone	0.01-0.05	parallel planar
8.5-14	Med. light gray	Brown to greenish-gray	Mudstone and occassional shale	0.01-0.1	"hummocky" lensoid
14-19.5	Med. light gray	Brownish medium gray	Siltstone to fine sandstone	0.03-0.3	"planar"
19.5-26	Medium to dark med. gray	Light brown to brownish gray	Fossiliferous calcareous siltstone	0.03-0.3	cross-beds
26-34	Green-gray	Brown to olive gray	Siltstone to silty mudstone	0.03-0.06	"planar"
34-37	Medium to dark gray (red tint)	Gray brown	Siltstone to fine sandstone	0.15 to 0.45	"planar"
37-38	Dark gray to black	Dark gray	Shaly mudstone	"1.0"	"planar"
37-42	Green to medium gray	Orange brown	Siltstone to fine sandstone	0.001 to 0.36	"planar"
42-"45"	Green to light medium gray	Brown to medium gray	Chertified fine sandstone	0.027 to "3.0" (w/ 7 m. channel)	"planar" w/ "channel"
45-58.5	Green gray	Orange brown	Fine sandstone	1 to 3	"planar"
58.5-60.5	Olive to green medium gray	Orange to dark gray brown	Fine sandstone w/ conglomeratic base	0.06 to 0.12	hummocky
60.5-63.5	Light medium gray	Brown gray	Fine sandstone w/ conglomeratic base	1	"planar" w/ large ripples

Table 16
(2 of 4)
General Characteristics of Section Measured at Girty's Notch, PA

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
63.5-66	White to light gray	Buff to light gray	Fine sandstone conglomerate	0.09 to 1.0	"planar" some ripples
66-68	Olive, green to light gray	Brown to green gray	Silty fine sandstone	0.001 to 0.03	"planar"
68-69.5	Dark gray	Brownish gray	Shaly mudstone	0.001 to 0.6	"planar"
69.5-86.5	Dark gray	Brownish gray	Thin siltstone beds in shaly mudstone	0.001 to 0.6	"planar"
86.5-93	Medium gray	Brownish light gray	Silty fine sandstone	0.3 to 1.0	"planar"
93-97.5	Light green gra to ruby red	Light brown to reddish brown	Fine sandstone w/ hematitic" channel	1 to 5	"massive"
97.5-98.5	Light green gray	Light brown	Fine sandstone	1	"planar"
98.5-100	Green light gray	Brown	Fossiliferous shale to mudstone	0.001 to 0.01	cross-beds
100-105	Green light gray	Brown	Shaly mudstone	0.001 to 0.01	cross-beds
105-112.5	Dark gray	Orange brown	Siltstone (Covered to poor exp.)	0.003 to 0.15	"planar"
112.5-118	Olive to light green gray	Orange brown	Siltstone to fine sandstone	0.003 to 0.3	"planar"
118-	---	---	Covered	---	---

Table 16
(3 of 4)
General Characteristics of Section Measured at Girty's Notch, PA

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
0-2	--	clay	rare	Weakly defined beds.
2-8.5	laminae	clay mica	rare	
8.5-14		clay	rare to common	
14-19.5	bioturbated	quartz, clay	scare	common burrows at base: poorly defined beddings surfaces
19.5-26		quartz, calcareous	common to abundant	large (5 to 10 cm) brachiopod "clasts"
26-34	weak to strongly defined x-laminae	quartz, clay		flute casts; poorly defined beddings surfaces
34-37		hematite; limonite	common	brachiopod "clasts"
37-38	cross-laminae	clay	scarce	gradational change with underlying beds
37-42		quartz	rare	"Chertified" at top.
42-"45"	cross-beds: 0.15 to 0.3m	quartz	rare	"Chertified".
45-58.5	meter size foresets	quartz	rare	Hiatal, shaly basal contact. Poorly defined bedding surfaces.
58.5-60.5	hummocky beds	quartz	none noticed	
60.5-63.5	Large scale ripples m height by 2m width	quartz	scarce to common	Brachiopod and gravel size "clasts".

Table 16
(4 of 4)
General Characteristics of Section Measured at Girty's Notch, PA

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
63.5-66	Some large ripples: 0.075 by 0.4m.	quartz, chertified	rare	Very distinct color (marker bed).
66-68	laminae	clay	rare to occ. common	
68-69.5	laminae	clay or quartz	rare to occ. common	Distinct siltstone bed (0.6m).
69.5-86.5	laminae	clay	rare to occ. common	Siltst. beds 1 to 5 cm
86.5-93	weakly defined cross-beds	quartz	not observed	
93-97.5	hiatal base; weak cross-beds	hematitic quartz	not observed	Distinct ruby-red color; but channel contact poorly exposed.
97.5-98.5		quartz, tr. hematite	not observed	
98.5-100	cross-laminae	clay	abundant to scare	Abundant fossils at base, decreasing upward.
100-105	cross-laminae	clay	rare	adational contact with underlying bed
105-112.5	laminae	clay, quartz	not observed	
112.5-118	laminae, weak hummocks	quartz	rare, small shells	
118-	---	---	---	---

Table 17
(1 of 4)
General Characteristics of Section Measured at
Lock Haven, PA.

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
0-12	Black	Brownish black	Shaly Mudstone	0.001 to 0.06	parallel planar
12-17	Black	Brownish black	Shale	0.001 to 0.01	parallel planar
17-20.5	Dark gray	Brownish dark gray	Calcareous Shale	0.001 to 0.01	parallel planar
20.5-22	Dark gray	Brownish dark gray	Calcareous Shale	0.001 to 0.01	parallel planar
22-30.5	Medium dark gray	Light olive gray	Poorly exposed shale & mudstone	0.001 to 0.015	parallel planar
30.5-32	Medium gray	Grayish light brown	Calcareous mudstone	0.1 to 0.3	parallel planar
32-35	Medium gray	Light brownish medium gray	Calcareous Shale	0.001 to 0.003	parallel planar
35-35.5	Light gray	Tan	Knobbly Calcilutite	0.5	Knobbly
35.5-45.5	Gray & dark gray	Tan to grayish brown	Intercalated calcareous shale & mudstone	0.001 to 0.06	parallel planar
45.5-49	Medium gray	Grayish brown	Calcareous Shaly Mudstone	0.06	parallel planar
49-50	Gray & dark gray	Tan to grayish brown	Intercalated calcareous shale & mudstone	0.001 to 0.15	parallel planar
50-52	Medium gray	Grayish brown	Calcareous Shaly Mudstone	0.08	parallel planar

Table 17
(2 of 4)
General Characteristics of Section Measured at
Lock Haven, PA.

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
52-57.5	Gray & dark gray	Tan to grayish brown	Intercalated calcareous shale & mudstone	0.001 to 0.08	parallel planar
57.5-59.5	Medium gray	Grayish brown	Calcareous Shaly Mudstone	0.075	parallel planar
59.5-79.5	Gray & dark gray	Tan to grayish brown	Intercalated calcareous shale & mudstone	0.001 to 0.15	parallel planar
59.5-83.75	Gray	Brownish gray	Calcilutite	0.1 to 0.5	parallel planar
83.75-89.75	Light gray	Tan	Knobbly Calcilutite	0.1 to 0.5	Knobbly
89.75-92.5	Medium gray	Light brownish gray	Fossiliferous, knobbly Calcilutite	0.25	Knobbly
92.5-95.5	Medium gray	Grayish brown	Calcareous Mudstone	0.005 to 0.2	parallel planar
95.5+	Dark gray to black	Brownish gray	Shale	0.001 to 0.003	parallel planar

Table 17
(3 of 4)
General Characteristics of Section Measured at
Lock Haven, PA.

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
0-12	laminae	clay	Rare	Lensoid fossiliferous lag at 11 m interval, but otherwise unfossiliferous.
12-17	laminae	clay	Rare	Ironstone concretion layer at base.
17-20.5	laminae	clay calcareous	Com. to Abnt. Ambocoelids	Small brachiopods intercalated with unfossiliferous layers.
20.5-22	laminae	clay calcareous	Rare	
22-30.5	laminae	clay	Rare	
30.5-32	laminae; weak cross-laminae	clay, cal. lim., pyrite	Scare macrofossils	Ichnofossils and dacryoconarids occassionally abundant.
32-35	laminae	clay, cal. lim., pyrite	Scare macrofossils	Ichnofossils and dacryoconarids occassionally abundant.
35-35.5	vertical burrows; vugs	clay, cal. lim., pyrite	Rare	
35.5-45.5	laminae	clay, cal. lim.	Rare	Cyclic pattern.
45.5-49	laminae	clay, cal. abnt. lim.	Rare	Weak cyclic pattern. Common ironstone concretions.
49-50	laminae	clay, cal. com. lim.	Rare	Cyclic pattern. Scarce ironstone concretions.
50-52	laminae	clay, cal. com. lim.	Rare	Weak cyclic pattern.

Table 17
(4 of 4)
General Characteristics of Section Measured at Lock Haven, PA.

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
52-57.5	Some poorly defined ripples; laminae	clay, cal. lim.	Rare	Cyclic pattern.
57.5-59.5	laminae	clay, cal.	Rare	Weak cyclic pattern.
59.5-79.5	laminae	clay, cal.	Rare	Cyclic pattern not as pronounced as in underlying beds.
59.5-83.75	laminae	clay, cal.	Rare	
83.75-89.75	weak cross-beds	clay, cal.	Rare	
89.75-92.5	weak cross-beds	clay, cal.	Abundant to Common	
92.5-95.5	laminae	clay, cal.	Scarce	
95.5+	laminae	clay, cal.	Not observed	

Table 18
(1 of 4)
General Characteristics of Section Measured at
Port Jervis, New York

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
0-3	Gray	Brown gray	Shale & Shaly mudstone	0.3	planar
3-9.75	Gray to black	Brown gray	Silty shale & Mudstone	0.003 to 0.08	planar
9.75-13	Gray	Brown gray	Silty shale & Mudstone	3.25	"massive"
13-14.75	Black to Dark gray	Dark gray to brown gray	Shale to Shaly mudstone	0.001 to 0.15	parallel to hummocky
14.75-23	Gray to dark gray	Brown gray	Silty shale & Mudstone	0.006 to 0.3	parallel planar
23-30	---	---	Covered	---	---
30-31.5	Medium gray	Orange brown to Olive gray	Silty shale & Mudstone	0.12 to 0.18	weak hummocks
31.5-32.5	Black to dark gray	Dark gray	Shaly mudstone	0.001 to 0.003	planar
32.5-39	Medium gray	Light gray to Olive brown	Shaly siltstone	0.06 to 0.18	hummocks
39-45	Medium to dark gray	Light brown gray	Silty shale & Mudstone	0.015 to 0.06	planar
45-50.5	Dark gray	Red-brown dark gray	Shaly siltstone	0.15 to 1.0	planar ("massive")
50.5-51	---	---	Covered	---	---

Table 18
(2 of 4)
General Characteristics of Section Measured at Port Jervis, New York

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
51-52.5	Medium dark gray	Brown gray	Shaly siltstone	0.05 to 0.09	planar
52.5-53	Dark gray	Dark brown gray	Shale to Silty mudstone	0.001 to 0.01	planar
53-57.5	Medium gray	Brownish gray	Shaly mudstone to siltstone	"0.1 to 0.5"	weak bedding planes
57.5-58	---	---	Covered	---	---
58-58.5	Medium olive dark gray	Olive gray	Shaly siltstone	0.5	planar
58.5-62.5	Medium gray	Light brown gray	Shaly siltstone to Silty mudstone	"0.05"	planar
62.5-63.25	---	---	Covered	---	---
63.25-64	Dark gray	brown gray	Poorly exposed: Mudstone	"0.05"	planar
64-69	---	---	Covered	---	---
69-72.75	Medium gray	Brown gray	Shaly siltstone to Silty mudstone	0.05	planar
72.75-79.5	---	---	Covered	---	---
79.5-81.25	Dark gray	Brown gray	Poorly exposed: Shaly siltstone	0.05	---
81.25-83.5	Dark gray	Brown gray	Siltstone	0.05 to 0.75	planar

Table 18
(3 of 4)
General Characteristics of Section Measured at
Port Jervis, New York

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
0-3	weak pillows	clay	none observed	
3-9.75	some pillows	clay	none observed	trace very fine sandstone.
9.75-13	abundant pillows	clay, some quartz	none observed	some very fine sandstone
13-14.75	laminae,	clay	trace to some	
14.75-23	pillows	tr. lim. clay some quartz	trace to common	Discontinuous fossil lag at base with chamosite.
23-30	---	---	---	---
30-31.5	weak laminae	clay; quartz	none observed	
31.5-32.5		clay	none observed	Some ball and pillow structures.
32.5-39	cross laminae, roll-ups	clay; quartz	none observed	Hiatal base.
39-45	laminae	clay	none observed	
45-50.5	large (1 m) ball and pillows	clay, quartz lim.	common to scare	Fossil lag at hiatal base: pillows common up section.
50.5-51	---	---	---	---

Table 18
(4 of 4)
General Characteristics of Section Measured at
Port Jervis, New York

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
51-52.5	weak ball and pillows	clay, some qtz.	none observed	"Blocky" weathering pattern.
52.5-53	laminae	clay some qtz.	none observed	
53-57.5	Skilithos	clay some qtz.	Ichnofossils	
57.5-58	---	---	---	---
58-58.5		clay some qtz.	none observed	
58.5-62.5	some weak ball and pillows	clay some qtz.	none observed	istinct black shale at hiatal base
62.5-63.25	---	---	---	---
63.25-64	some roll-ups	clay	extremely rare	
64-69	---	---	---	---
69-72.75	pillows, roll-ups	clay, quartz	none observed	
72.75-79.5	---	---	---	---
79.5-81.25	---	clay, quartz	none observed	
81.25-83.5	bioturbated	clay, quartz	none observed	

Table 19
(1 of 4)
General Characteristics of Section Measured at
Riverside, PA

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
0-1	Gray	Grayish brown	Silty shale	0.02 to 0.03	planar
1-24.75	Medium dark gray	Brownish medium gray	Mudstone	0.02 to 0.03	planar to cross-beds
24.75-26	Medium olive gray	Brownish light gray	Siltstone to v. fine sandstone	0.01 to 0.2	cross-beds
26-40.5	Light to medium gray	Brownish gray	Shaly mudstone to siltstone	0.01 to 0.03	cross-beds
40.5-49.75	Greenish medium gray	Orange-brown medium gray	Siltstone to shale	0.01 to 0.02	hummocky
49.75-59	---	---	Covered	---	---
59-61	Dark to medium gray	Brownish medium gray	Shaly mudstone to shale	0.005 to 0.02	planar
61-64	---	---	Covered	---	---
64-78	Dark to medium gray	Brownish medium gray	Shaly mudstone to shale	0.005 to 0.02	planar
78-140.25	---	---	Covered	---	---
140.25-148	Orange-brown medium gray	Medium-light brownish gray	Fossiliferous mudstone	0.005 to 0.02	Cross-beds
148-158	Light gray	Light to medium gray	Mudstone	0.01 to 0.02	hummocky

Table 19
(2 of 4)
General Characteristics of Section Measured at Riverside, PA

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
158-164	Medium gray	Brown to gray	Shaly mudstone & shale	0.01 to 0.02	hummocky
164-169	Light gray	Light brown to light gray	Calcareous shaly mudstone	0.5	x-beds
169+	Medium to dark gray	Light brown to light gray	Calcareous mudstone	0.02	faint x-beds

Table 19
(3 of 4)
General Characteristics of Section Measured at Riverside, PA

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
0-1		clay, some qtz.	not observed	
1-24.75		clay; tr. calcite	Sparse to rare.	
24.75-26	burrows; x-lam.; faint ripples	quartz; clay	Sparse to rare.	Hiatal base?
26-40.5	x-laminae	clay, some qtz.	Sparse to common	
40.5-49.75	roll-ups & mud clasts	Quartz, clay; lim.	Abundant to scare	Abundant Tropidoleptus.
49.75-59	---	---	---	---
59-61		Clay	Not observed	
61-64	---	---	---	
64-78		Clay	Not observed	
78-140.25	---	---	---	Location of Hower road.
140.25-148		Clay; some lim.	Sparse to common	
148-158		Clay; Com. lim.	Sparse to common	

Table 19
(4 of 4)
General Characteristics of Section Measured at
Riverside, PA

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
158-164		Clay; Lim.	Rare	
164-169	weak cross laminae	Calcite; tr. py.	Not observed	
169+		Calcite; common pyrite	Not observed	

Table 20
General Characterisitics of Section Measured at Rockville, PA
(1 of 10)

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
0.0 - 4.3	Med. to dk gray	Olive gray to mottled brown	Shale to Shaly Siltstone	0.05-0.3	planar parallel
4.3 - 16.8	Medium gray	Olive brown	Siltstone to Fine sandstone	0.06-0.6	planar
16.8 - 28.7	Medium dark gray	Olive gray to mottled brown	Silty fine sandstone	0.25-0.6	massive
28.7 - 45.4	Med. gray to lt. gray	Brown to olive gray	C-f(+) sandstone	0.25-0.5 x-beds	massive
45.4 - 47.5	Medium gray	Lt. brownish gray	C-f(+) sandstone	single bed	mass.
47.5 - 48.5	White to med. lt. gray	Lt. gray to grn. med. gray	Silty fine sandstone w/ gravel	single bed	mass.
48.5 - 49.8	Brownish gray	Tan to buff	M(+)-c sandstone w/ conglomeratic base	0.3-1.0	mass.
49.8 - 51.0	Dark gray	Orange-brown to gray	Silty fine sandstone	0.3-1.0	planar
51.0 - 65.5	Med. gray to lt. gray	Dark gray to Lt. brownish gray	Fine sandstone	0.25-0.5 x-beds	mass., "lensoid"
65.5 - 70.4	Dark to lt. gray	Orange-brown to gray	Silty fine sandstone	0.02-0.2	planar
70.4 - 76.2	Green to light gray	Olive gray	M(+)-c sandstone	1.0-10	mass.
76.2 - 78.3	Olive dk. gray	Orange-brown to buff	M(+) sandstone (poorly exposed)	0.02-0.3	planar

Table 20
General Characterisitics of Section Measured at Rockville, PA
(2 of 10)

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
78.3 - 82.0	Med. gray	Orange-brown	Shale (poorly exposed)	0.003-0.01	planar
82.0 - 82.6	Light greenish-gray	Gray-brown	M-f(+) sandstone	0.6	lensoid
82.6 - 85.3	Medium gray	Orange-brown	Shale to Silty shale w/ SS stringers	0.003-0.03	lensoid
85.3 - 86.9	Green-gray	Orange-brown to olive gray	Fine sandstone w/ silty beds	0.003-0.65	lensoid
86.9 - 88.4	Med. gray to dk. gray	Dark reddish brown	Shaly Siltstone	0.003-0.08	lensoid
88.4 - 92.7	Green-gray	Olive gray	Fine sandstone	0.03-0.3	lensoid
92.7 - 93.4	Dark gray	Reddish brown to Gray, Orange-brown	Silty fine sandstone	0.009-0.09	planar
93.4 - 95.9	Dark gray	Orange-brown to Olive brown	Shaly Siltstone to Silty shale	0.009-0.09	planar
95.9 - 103.9	Green-gray	Lt. brown to Med. gray	Fine sandstone	0.15-0.6	mass.
103.9 - 105.2	Green-gray to dk gray	Dark gray w/ ruby tint	Fine sandstone	0.15	planar
105.2 - 115.2	Med. gray to green-gray	Orange-brown to dark gray	Shaly to sandy Siltstone	0.001-0.07	planar to lensoid
115.2 - 118.4	Greenish med. gray	Black to dark gray	Silty fine sandstone	0.015-0.3	planar

Table 20
General Characterisitics of Section Measured at Rockville, PA
(3 of 10)

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
118.4 - 119.3	Light med. gray	Black to dark gray	Fine sandstone	0.9	planar (mass.)
119.3 - 119.8	Green-gray	Light brown	Fine sandstone	0.01-0.03	planar
119.8 - 122.7	Green-gray	Blackish to brown-gray	Fine sandstone	0.3-1.0	lensoid
122.7 - 125.0	Green-gray	Black to orange-brown	Fine sandstone	0.03-0.15	planar
125.0 - 126.8	Green-gray	Med. gray to black	Fine sandstone	0.9	mass.
126.8 - 127.7	Dark gray	Dark gray	Fine sandstone	0.015-0.15 (x-bed)	planar
127.7 - 128.9	Dark gray	Dark gray	Fine sandstone	0.06-0.09 (x-bed)	planar
128.9 - 132.9	Light med. gray	Brownish light gray	Fine sandstone	0.06-0.15	planar
132.9 - 137.5	Medium gray	Blackish to brown-gray	C-f(+) sandstone w/ cgl. lenses	0.03-0.3 (x-bed)	mass.
137.5 - 140.2	Medium gray	Blackish to brown-gray	C-f(+) sandstone w/ cgl. lenses	0.15-0.6 (x-bed)	lensoid (channel)
140.2 - 141.1	White	Light gray	Conglomeratic coarse sandstone	0.9	mass.
141.1 - 143.4	Olive, green to light gray	Brown to green gray	Silty f. sandstone (poorly exposed)	0.001 to 0.03	"planar"
143.4 - 145.8	Dark gray	Brownish gray	Shaly mudstone (poorly exposed)	0.001 to 0.6	"planar"

Table 20
General Characterisitics of Section Measured at Rockville, PA
(4 of 10)

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
145.8 - 150.6	Dark gray	Orange-brown	Silty f. sandstone	0.001 to 0.03	planar
150.6 - 153.9	Dark gray	Orange-brown	Silty f. sandstone	0.03-0.15	distinct planar beds
153.9 - 156.1	Medium gray	Lt. orange-brown	Fine sandstone	0.15-0.6	lensoid
156.1 - 161.9	Light med. gray	Orange-brown to lt brown (buff)	Fine sandstone	0.06-0.15	lensoid
161.9 - 166.4	Greenish med. gray	Orange-brown to brn-gry to ol. gry.	Silty f. sandstone w/ shaly lenses	0.06-0.15	mass.
166.4 - 169.2	Green-gray	Orange-brown	Fine sandstone	0.15-0.8	lensoid
169.2 - 177.1	Whitish to lt. grn gray	Orange dk. brown	Fine sandstone	0.15-1.0 (x-beds)	mass.
177.1 - 179.5	Green-gray	Orange-brown	Fine sandstone	0.15-0.75	lensoid
179.5 - 182.0	Green-gray	Olive gray brown	Fine sandstone	0.015-0.075	lensoid
182.0 - 183.8	Green-gray	Olive gray brown	Silty f. sandstone	0.003 to 0.03	lensoid
183.8 - 189.9	Green-gray	Brown-gray	Fine sandstone	0.012-0.12	distinct planar beds
189.9 - 191.0	Green-gray	Orange-brown	Silty f. sandstone	1.0	mass
191.0 - 196.0	Whitish to lt. gray	Lt. gray	f-c sandstone	"5.0"	mass.

Table 20
General Characterisitics of Section Measured at Rockville, PA
(5 of 10)

FOOTAGE (METERS)	COLOR FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
196.0 - 196.6	Dark medium gray	Brown to med. gray	Silty oolitic fine sandstone	3-15 mm	poorly defined plll. pl. beds
196.6 - 201.8	Dark gray	Brown gray	Shaly siltstone	?	"mass"
201.8 - 207.3	Med. to dk. gray	Dk brownish black to dk. brown gray	Calcareous siltstone to fine sandstone	0.003-0.06	poorly defined plll. pl. beds
207.3 - 211.2	Med. to dk. gray	Dk brownish black to dk. brown gray	Calcareous silty fine sandstone	0.003-0.06	plll. pl. beds
211.2 - 215.5	Med. gray	Dark gray to dk orange-brown	Fine sandstone	0.015-0.12	distinct plll. pl. beds
215.5 - 220.8	White to lt. gray	Buff to orange lt. brown	Coarse sandstone	0.15-0.5	planar
220.8 - 222.5	Lt. gray	Reddish dk. brown	Silty f. sandstone	0.015-0.3	planar
222.5 - 227.7	White to lt. gray	Buff to lt. brown	c-f sandstone	0.015-0.6	poorly defined plll. pl. beds
227.7 -	---	---	Covered	---	---

Table 20
General Characterisitics of Section Measured at Rockville, PA
(6 of 10)

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
0.0 - 4.3	laminae	mica clay	pelamatozoans	coarsening upward
4.3 - 16.8	x-lam.	mica	not observed	
16.8 - 28.7	weak lam. at base; well mixed (bioturbated) at top.		burrows (*Skilithos* sp.)	Occasional 5 cm thick silt beds
28.7 - 45.4	x-lam., x-beds, hummocky,		not observed	Distinct hummocks and x-beds at base, becoming weaker higher up
45.4 - 47.5	c sand at base, fining upward			Giant ripples at base: 0.3m deep by 4.25m between crests.
47.5 - 48.5		*tr. py., mica*	*Rare brachs*	*Silty w/ rounded qtz. pebbles.*
48.5 - 49.8		qtz.	not observed	
49.8 - 51.0		tr. py., lim.	not observed	
51.0 - 65.5	x-lam., x-beds, hummocky,			Giant ripples at base: 0.4m deep by 4.6m between crests.
65.5 - 70.4	laminae		rare	Coarsening upward with x-lam. and x-beds.
70.4 - 76.2	x-lam., x-beds, well mixed (bioturbated) with weak lam. at top.		not observed	coarsening upward
76.2 - 78.3	weak ripples	ironstone	brachs; *Cruziana*	poorly exposed; oxidized

Table 20
General Characterisitics of Section Measured at Rockville, PA
(7 of 10)

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
78.3 - 82.0			not observed	poorly exposed;
82.0 - 82.6	well-sorted		some	Impressions of fossils on upper bedding surface
82.6 - 85.3	hummocky,	Fe,	not observed	
85.3 - 86.9	hummocky,		Sparse ichnofssils;	
86.9 - 88.4	hummocky,	hem.	not observed	
88.4 - 92.7	x-beds; weak lam.	slightly cal., mag.?	not observed	
92.7 - 93.4	hummocky,	Fe,	not observed	
93.4 - 95.9			not observed	
95.9 - 103.9	weak lam., weak x-beds		not observed	White color stringers.
103.9 - 105.2		tr. hem.	not observed	
105.2 - 115.2	weak x-beds; rip-up clasts;	ironstone conc.		Coarsening upward, w/ ash-like beds at base & SS stringers and occ. plnr. mdstne beds.
115.2 - 118.4	hummocky, lam.		not observed	

Table 20
General Characterisitics of Section Measured at Rockville, PA
(8 of 10)

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
118.4 - 119.3			trace ichnofos.	Ichnofossils along upper bedding surface.
119.3 - 119.8	hummocky,	"lignite"	common ichnofos.	horizontal "feeding" trails.
119.8 - 122.7	weak x-beds hummocky,		not observed	
122.7 - 125.0	hummocky,	r. black "lig."	not observed	
125.0 - 126.8	weak x-beds weak hummocks		not observed	
126.8 - 127.7	distinct x-beds		not observed	
127.7 - 128.9	distinct x-beds		not observed	
128.9 - 132.9	distinct plll. beds		ichnofos.	Trace to com. ichnofossils along base of beddinig surfaces
132.9 - 137.5	x-beds	rounded qtz. pebbles	Brach (clasts)	"Wish-bone" x-beds, typical x-beds = 0.03 M
137.5 - 140.2	large x-beds		not observed	some gravel-size clasts
140.2 - 141.1			*Favosites* (clasts)	Large corals w/ diameters of 0.06 to 0.09m.
141.1 - 143.4	laminae		not observed	
143.4 - 145.8	laminae	hem oolites	Rugose corals & brachs.	*Mediospirifer*

Table 20
General Characterisitics of Section Measured at Rockville, PA
(9 of 10)

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
145.8 - 150.6		hem.	brachs.	Shaly hem. lense
150.6 - 153.9		hem oolites	some	Some ash-like beds.
153.9 - 156.1	x-beds		some	
156.1 - 161.9	hummocky		com. brachs.	White ss. stringers,
161.9 - 166.4	lensoid	hem., cal. shells	abndt. brachs.	com. hem. at base: ash-like.
166.4 - 169.2			not observed	
169.2 - 177.1	x-beds (foresets)		not observed	decreasing texture upward
177.1 - 179.5			not observed	decreasing texture upward
179.5 - 182.0			not observed	decreasing texture upward
182.0 - 183.8	hummocky		not observed	decreasing texture upward
183.8 - 189.9			*Skilithos*	decreasing texture upward
189.9 - 191.0			not observed	
191.0 - 196.0			not observed	No distinct beds.

Table 20

General Characterisitics of Section Measured at Rockville, PA

(10 of 10)

FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS	FOSSILS	REMARKS
196.0 - 196.6	bioturbated w/ weak hummocky beds	abndt. chamosite at	some brachs	Silty oolite at base w/ cal. beds
196.6 - 201.8			tr.	No distinct beds.
201.8 - 207.3		cham. cal. shells	Com to abndt. Spiriferids	Poorly defined bedding.
207.3 - 211.2		cal. shells	Abndt. brach. (clasts)	Fossiliferous: bedding more distinct.
211.2 - 215.5			not observed	Non-fossiliferous: distinct bedding.
215.5 - 220.8			not observed	
220.8 - 222.5	hummocky	Abndt Fe (hem)	not observed	
222.5 - 227.7			not observed	
227.7 -	---	---	---	---

APPENDIX C

DESCRIPTIONS OF SAMPLES COLLECTED

Introduction

The following tables present the general characteristics of each sample collected and processed for this study. The samples are listed in stratigraphic order with the measured interval also presented. A listing of abbreviations and symbols used within these tables include:

&	and
abnt.	abundant
f.	fine
brachs.	brachiopods
cal.	calcareous, calcite
col.	columna(e)
com.	common
cm.	centimeter
crin.	crinoid
diss.	disseminated
Fm.	Formation
fos.	fossils; fossiliferous
hem.	hematite, hematitic
ichnos.	ichnofossils
lim.	limonite (or iron-stained matrix)'
lt.	light

m.	medium; meter
med.	medium
Mem.	Member
pelm.	pelmatazoan
plll.	parallel
pl.	planar
py.	pyrite
qtz.	quartz
tr.	trace
v.	very
w/	with
x-beds	cross-bed(s)
x-laminae	cross-laminae

Table 21
(1 of 2)
Description of Samples:
Bowmanstown, PA

SAMPLE ID #	FOOTAGE (METERS)	COLOR: FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	BED THICKNESS (METRIC)	SHAPE
B-1.0'	0.3	Dark gray to black	Grayish brown	Shale	2-3 mm	x-laminae
B-80'	24.4	Dark gray to black	Chocolate brown	Shaly mudstone	2-3 cm	x-beds
B-98'	26.8	Medium gray	Brownish gray	Shaly mudstone	2-3 cm	x-beds
B-178'	54.3	Medium gray	Brownish medium gray	Mudstone to siltstone	2-3 cm	plll. pl. beds
B-2	55.0	Dark gray to black	Medium-light brownish gray	Shale and mudstone	1-2 mm	lenticular
B-1	57.3	Light gray	Green-brown	Siltstone	2-3 cm	plll. pl. beds
B-244-45'	74.6	Medium gray	Orange light brown	Fine grained sandstone	1 m	plll. pl. beds
B-3	74.6	Medium gray	Orange light brown	V. fine sandstone	1 m	plll. pl. beds
B-4	74.9	Dark gray to black	Light brownish gray	Shaly mudstone	1 cm	plll. pl. beds
B-411'	125.3	Medium to dark gray	Orange brown	Shale	<1 cm	plll. pl. beds
B-455'	139.9	Medium gray	Light orange brown	Silty mudstone and shale	1-2 cm	lenticular
B-490'	149.4	Dark gray to black	Light brown to olive gray	Calcareous shaley mudstone	2-10 cm	plll. pl. beds

Table 21
(2 of 2)
Description of Samples:
Bowmanstown, PA

SAMPLE ID #	FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS AND FOSSILS	REMARKS
B-1.0'	0.3		tr. fos.; tr. lim.	
B-80'	24.4	some f. & mud clasts	v. com. fos.; some py.	poorly defined lag: fossils along bedding surface
B-98'	26.8		com. fos. some lim.	fos. in clusters; "Skilithos".
B-178'	54.3	graded fossil lag w/ oll-ups & mud clast	com. fos.; com. lim.	distinct fos. lag; mottled bioturbated w/ occassional unbroken laminae
B-2	55.0	faint laminae (fissile)	some lim.; tr. fos.	crin. calyx
B-1	57.3	very faint laminae	scare fos.	Base of Nis Hollow Member
B-244-45'	74.6		some fos;	some large fossils (up to 5 cm) Top of Nis Hollow Mem.
B-3	74.6		tr. fos.; some py.	Equivalent to B-245
B-4	74.9	discontinuous laminae	tr. py.	
B-411'	125.3	discontinous & x-laminae	com. fos.; com. lim.	Discontiunous lag; structurally distorted fos.
B-455'	139.9	discontinous rippled laminae	com. fos.; some diss. py.	distinct fos. lag
B-490'	149.4	discontinous x-laminae	com. pelm. col.: com. lim.	slightly mottled (bioturbated) Tully equivalent.

Taable 22
Description of Samples:
Girty's Notch, PA

SAMPLE ID #	FOOTAGE (METERS)	COLOR: FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	BED THICKNESS (METER)	SHAPE
G-64	19.51	Medium to dark med. gray	Light brown to brownish gray	Fossiliferous calcareous siltstone	0.01	"planar"
G-1	27.01	Green-gray	Brown to olive gray	Siltstone to shale & silty mudstone	0.03-0.06	"planar"
G-2	67.36	Olive, green to light gray	Brown to green gray	Silty fine sandstone	0.001 to 0.03	"planar"
G-3	99.06	Green light gray	Brown	Fossiliferous shale	0.001 to 0.01	cross-beds

SAMPLE ID #	FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS AND FOSSILS	REMARKS
G-64	19.51	bioturbated	abundant unbroken brachiopods	Brachiopods 5 to 10 cm in size.
G-1	27.01	weak to strongly defined x-lamina	abndt lim.; com. mica	Some v. f. sand.
G-2	67.36	laminae	clay	
G-3	99.06	cross-laminae	abndt lim.; abndt fos.	

Table 23
Description of Samples:
Lock Haven, PA

SAMPLE ID #	FOOTAGE (METERS)	COLOR: FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	TYPICAL BED THICKNESS (METERS)	SHAPE
LH-3	30.18	Medium dark gray	Light olive gray	Weakly calc. platy shale to mudstone	0.001 to 0.015	parallel planar
LH-4	30.79	Medium gray	Grayish light brown	Calcareous mudstone	0.15	massive; plll. pl. beds
LH-1	31.39	Medium gray	Light brownish medium gray	Calcareous mudstone	0.2	massive; plll. pl. beds
LH-2	89.92	Medium gray	Light brownish gray	Calcareous fos. mudstone	0.2	Knobbly

SAMPLE ID #	FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS AND FOSSILS	REMARKS
LH-3	30.18	laminae	Tr. ichnos.	Uppermost Mahantango Fm. Localized slickenslides.
LH-4	30.79	Some vertical burrows.	Tr. lim.	Lowermost Tully Fm. "Micrite"; some ichnofossils.
LH-1	31.39	laminae; weak x-laminae	Some py. & lim.; tr. fos.	"Micrite"; some ichnofossils.
LH-2	89.92	weak cross-beds	Tr. lim.; abnt. fos.	"Biomicrite"; fossil lag.

Table 24
Description of Samples:
Port Jervis, NY

SAMPLE ID #	FOOTAGE (METERS)	COLOR: FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	BED THICKNESS (METRIC)	SHAPE
PJ-3	15	Light gray	Light brown gray	Siltstone	2-10 cm	plll. pl. beds
PJ-1	46.75	Dark gray to black	Red-brown dark gray	Silty shale	2-3 cm	hummocky; fissile
PJ-2	63.5	Medium gray	Light brown gray	Mudstone	2-10 cm	hummocky

SAMPLE ID #	FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS AND FOSSILS	REMARKS
PJ-3	15	faint laminae	com. lim.; tr. barite; tr. dis. pyrite	fos. in clusters
PJ-1	46.75	bioturbated	com. lim.; some ichnofossils	rare shelly fossils
PJ-2	63.5	x-lam. faint ripples	com. lim.; trace fos.	trace siltstone "Nis Hollow-like"

Table 25
(1 of 2)
Description of Samples:
Riverside, PA

SAMPLE ID #	FOOTAGE (METERS)	COLOR: FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	BED THICKNESS (METERS)	SHAPE
Ri-1	17.5	Medium dark gray	Brownish medium gray	Mudstone	0.02 to 0.03	massive; plll. pl. beds
Ri-2	26	Medium olive gray	Brownish light gray	Siltstone to v. fine sandstone	0.01 to 0.02	cross-beds
Ri-3	37.75	Light to medium gray	Brownish gray	Shaly mudstone to siltstone	0.01 to 0.03	cross-beds
Ri-4	40.5	Greenish medium gray	Orange-brown medium gray	Siltstone to shale	0.01 to 0.02	hummocky
Ri-5	142.0	Orange-brown medium gray	Medium-light brownish gray	Fossiliferous mudstone	0.005 to 0.02	Cross-beds
Ri-6	148.1	Light gray	Light to medium gray	Mudstone	0.01 to 0.02	hummocky
Ri-9	160.2	Medium gray	Brown to gray	Shaly mudstone & shale	0.01 to 0.02	hummocky
Ri-7	166.7	Light gray	Light brown to light gray	Calcareous shaly mudstone	0.5	x-beds
Ri-8	169.5	Medium to dark gray	Light brown to light gray	Calcareous mudstone	0.02	faint x-beds

Table 25
(2 of 2)
Description of Samples:
Riverside, PA

SAMPLE ID #	FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS AND FOSSILS	REMARKS
Ri-1	17.5		sparse fos.	
Ri-2	26	burrows; x-lam.; faint ripples	lim.; sparse fos.	"Nis Hollow-like"
Ri-3	37.75	x-laminae	micaceous; slightly calc.	fos. in clusters; horizontal trails
Ri-4	40.5	roll-ups & mud clasts	some lim.; fos.	distinct fos. (brachs.) lag;
Ri-5	142.0	x-laminae	some lim.; fos.	distinct fos. (brachs.) lag;
Ri-6	148.1		Com. lim.	
Ri-9	160.2		lim.	
Ri-7	166.7	weak cross laminae	tr. py.	no noticeable fossils
Ri-8	169.5		abundant pyrite	no noticeable macrofossils

Table 26
Description of Samples:
Rockville, PA

SAMPLE ID #	FOOTAGE (METERS)	COLOR: FRESH	WEATHERED	COMPOSITION (ROCK TYPE)	BED THICKNESS (METRIC)	SHAPE
R-4	47.5	Medium light gray	Greenish medium gray	Silty f-c sandstone w/ f. gravel		
R-2	110.5	Medium gray	"Gray"	Siltstone to v. fine sandstone		
R-1	162.5	Medium gray	Lt. brownish gray	Silty f. sandtone to shaley siltstone	0.5-3 mm	plll. pl. beds weak ripples
R-3	196.5	Dark medium gray	Brown	Silty oolitic fine sandstone	3-15 mm	poorly defined plll. pl. beds
R-5	204.0	Dark gray	Medium gray	Calcareous siltstone to f. sandstone		

SAMPLE ID #	FOOTAGE (METERS)	OTHER STRUCTURAL FEATURES	MINERALS AND FOSSILS	REMARKS
R-4	47.5		tr. py., lim. & mica	Rounded quartz and fine gravel
R-2	110.5		com. hem. & py.	
R-1	162.5	distinct laminae	tr. py. & lim, abdnt. Qtz.	Horizontal burrows; tr. oolites
R-3	196.5	bioturbated w/ oolitic filled troughs	abndt. chamosite; some brachs	Hummocky troughs?
R-5	204.0			Common brachiopods

APPENDIX D

SPECIFIC FOSSIL IDENTIFICATIONS

(FAUNAL LISTS)

Introduction

The following tables list the fossils identified at each of the targeted sampled horizons of the sections studied. When possible each taxon was counted. In such cases, the total number of specimens identified is indicated (columns with a "#" symbol). A second column with the "%" symbol indicates the percentage of the total number of specimens identified a particular taxon represents. Only a single column is used where, due to preservation or sample size limitations, taxa were not counted. In such situations, the presence of a specific taxon is indicated by an "X". In certain situations where individual specimens could not be counted, but are typically common or abundant, the letters "C" or "A" are used.

A listing of abbreviations and symbols used within these tables include:

#	total number of specimens identified
%	the percentage of the total number of specimens identified
A	abundant

C	common
NC	no conodonts detected.
NF	no noticeable fossils
NLS	no noticeable large shelly macrofossils
NP	not processed
NS	no noticeable shelly macrofossils
R	rare
X	present in sampled horizon

TABLE 27
(1 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-1.0'	B-80'		B-98'		B-178'	B-2	B-1
FOOTAGE (METERS)	0.3	24.4		26.8		54.3	55.0	57.3
	#	#	%	#	%			
MACROFOSSILS	R			A		A	C	NF
Porifera								
"Batostomella" sp.		1	0.40	2	1.79			
Bulb-shaped structure								
?		2	0.81	2	1.79			
Cnidaria								
Pleutodictyum styloporum				1	0.89			
Rugose corals								
Mollusks								
Pelecypod								
Aviculopectinacid		1	0.40					
Carydium bellistriatum		4	1.62	11	9.82			
Carydium varicosum		1	0.40	2	1.79			
Carydium sp.				4	3.57			
Carydium? sp.				7	6.25			
Cypricardella bellastriata				1	0.89			
Cypricardinea sp.								
Edmondia? sp.				3	2.68			
Goniophora rugosa		1	0.40					
"Goniophora" sp.		1	0.40					
Grammysia ovata?								
"Lunulicardium librum"		1	0.40					

TABLE 27
(2 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-1.0'	B-80'		B-98'		B-178'	B-2	B-1
FOOTAGE (METERS)	0.3	24.4		26.8		54.3	55.0	57.3
	#	#	%	#	%			
"Leiopteria" sp.		1	0.40					
Modiella pygmaea		3	1.21					
Modiella? sp.				1	0.89			
Modiomorpha arcuata		1	0.40					
Modiomorpha subalata		1	0.40					
Modiomorpha sp.		2	0.81	1	0.89			
Nuculites oblongatus		6	2.43					
Nuculites? sp.		1	0.40	1	0.89			
Nuculanacea	X	1	0.40					
Nuculoidea corbuliformis		4	1.62					
Nuculoidea lirata		11	4.45					
Nuculoidea opima		2	0.81					
Nuculoidea sp.		3	1.21					
Nuculoidea? sp.				1	0.89			
Orthonota sp.				1	0.89			
Palaeoneila constricta		1	0.40	2	1.79			
Palaeoneila filosa		2	0.81					
Palaeoneila emarginata		8	3.24					
Palaeoneila muta				1	0.89			
Palaeoneila? sp.		1	0.40	1	0.89			
"Panenka" sp.								
Paracyclas lirata		2	0.81					
Paracyclas rugosa		4	1.62					
Paracyclas sp.		2	0.81					

TABLE 27
(3 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-1.0'	B-80'		B-98'		B-178'	B-2	B-1
FOOTAGE (METERS)	0.3	24.4		26.8		54.3	55.0	57.3
	#	#	%	#	%			
Phestia rostellata		1	0.40					
Phthonia nodicostata		1	0.40					
"Pholadomyacea"		4	1.62	1	0.89			
Pterochaenia sp.		2	0.81					
Pterinopecten sp.		1	0.40	1	0.89			
Tellinopsis? subemarginata		1	0.40					
Insertae sedis		2	0.81					
shell frag.		5	2.02	25	22.32			
Rostroconchs								
Conocardium normale		1	0.40					
"*Conocardium*" sp.		2	0.81					
Hippocardium cuneus		1	0.40					
Gastropoda								
Orthonema? sp.		1	0.40					
Palaeozygopleura hamiltoniae		1	0.40					
Palaeozygopleura? sp.		2	0.81	2	1.79			
Cephalopod								
"*Michelinoceras*" sp.				1	0.89			
"*Striacoceras*" sp.		1	0.40					
Tentaculite								
Spyroceras sp.		1	0.40					

TABLE 27
(4 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-1.0'	B-80'		B-98'		B-178'	B-2	B-1
FOOTAGE (METERS)	0.3	24.4		26.8		54.3	55.0	57.3
	#	#	%	#	%			
Dacryoconarid								
Styliolina fissurella				1	0.89			
"Styliolina" sp.		2	0.81					
Brachiopod								
Allanella tullia								
Allanella tullia (dimunitive form)								
Ambocoelia umbonata		1	0.40					
Ambocoelid								
Athyris cora		1	0.40					
Athyris spiriferoides		1	0.40					
Atrypids								
Camarotoechia mesacostalis		14	5.67					
Camarotoechia pauciplicata		1	0.40					
Coelospira? camilla				2	1.79			
Cupularostrum congregata				2	1.79			
Cupularostrum sp.								
Craniops hamiltoniae		1	0.40					
Devonochonetes sp.		1	0.40					
Dignomia aleveata				1	0.89			
Dignomia? sp.				1	0.89			
Emmanuella cf. *praeumbonata*		1	0.40					
Emmanuella cf. *subumbona*		1	0.40					

TABLE 27
(5 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-1.0'	B-80'		B-98'		B-178'	B-2	B-1
FOOTAGE (METERS)	0.3	24.4		26.8		54.3	55.0	57.3
	#	#	%	#	%			
Eumetabolotechia multicostata		8	3.24					
Eumetabolotechia sp.		2	0.81					
"Leiorhynchus" spp.								
Leptocoelia flabellites		2	0.81					
Lingula punctata		1	0.40					
Longispina mucronata		1	0.40					
Meristiella haskinsi (cf. nasuta)		3	1.21					
Meristina sp.		1	0.40					
Mucrospirifer mucronatus		1	0.40					
Mucrospirifer cf. *consorbrinus*								
Mucrospirifer sp.						X		
Mediospirifer audaculus				1	0.89			
Mediospirifer cf. *millerstownensis*				1	0.89			
Nucleospina concinna		11	4.45					
Orbiculoidea? sp,				1	0.89			
Philidastrophia nacrea								
Spinatrypa spinosa		11	4.45					
Spinatrypa? sp.		4	1.62					
Spinocyrtia granulosa								
Striatochonetes setigera								
Strophomenids						X		
"Spirifids"		2	0.81	3	2.68	X	X	
Tropidoleptus carinatus		3	1.21	1	0.89			
Shell Fragment		6	2.43					

TABLE 27
(6 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-1.0'	B-80'		B-98'		B-178'	B-2	B-1
FOOTAGE (METERS)	0.3	24.4		26.8		54.3	55.0	57.3
	#	#	%	#	%			
Insertae sedis		3	1.21	1	0.89			
Bryozoa								
Insertae sedis		1	0.40					
Encrustation on shell		1	0.40					
Echinodermata:								
Asteroid? (portion of body and arm)		1	0.40					
Blastoid calyx?		1	0.40					
Crinoid calyx		1	0.40				X	
"Pelmatozoan" column (1)		3	1.21	7	6.25	X		
"Pelmatozoan" columna (2+)				4	3.57	X		
Plate				1	0.89			
Arthropoda:								
Ostracode								
Ctenolaculina? sp.		1	0.40					
Insertae sedis		4	1.62	4	3.57			
Ponderodictya puntulifera				1	0.89			
Phyllocarida								
Echinocaris? sp		1	0.40					
"*Elymocaris?*" sp.		3	1.21					
Trilobite								
Phacops? sp.		1	0.40					

TABLE 27
(7 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-1.0'	B-80'		B-98'		B-178'	B-2	B-1
FOOTAGE (METERS)	0.3	24.4		26.8		54.3	55.0	57.3
	#	#	%	#	%			
Ichnofossils								
"*Autodetus*" sp.		1	0.40					
Burrow of worm ("*Protoscolex*" sp.		6	2.43					
Burrow of Inart, brach.?		2	0.81					
Cruziana?		3	1.21	1	0.89			
Palaeophycos sp.		2	0.81					
Planolites?		2	0.81	1	0.89			
Feeding trail				4	3.57			
"*Rosselia*"? sp.		1	0.40					
Skilithos sp.								
"*Tomaculum*", "*Granularia*" *or* "*Cryptosiphon*"-like ball structures		23	9.31					
Zoophycos sp.		1	0.40	1	0.89			
Insertae sedis								
Blastoid or Barnacle plate		1	0.40	1	0.89			
Cup-shaped microstructure		1	0.40					
Round organic structures ("Blastomeres")		8	3.24					
TOTAL:		247	100	112	99.11			

TABLE 27
(8 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-1.0'	B-80'		B-98'		B-178'	B-2	B-1
FOOTAGE (METERS)	0.3	24.4		26.8		54.3	55.0	57.3
	#	#	%	#	%			
MICROFOSSILS	NP	"NF"		"NF"		"NF"	X	NF
Conodonts		NC		NC		NC	"NC"	NC
Fragment?							?	
Arthropoda:								
? (Plate)								
Ostracode							X	
?	"X"							
Porifera	X							
Echinodermata:								
"Pelmatozoan" column (1)	X							
Vertebrate								
Fish bone								
Foraminifera								
Agglutinated grains?								
Insertae sedis								
Coprolites	X						X	
Round organic structures ("Blastomeres")							X	

TABLE 27
(9 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-244-45' & B-3	B-4	B-411'	B-455'		B-490'
FOOTAGE (METERS)	74.6	74.9	125.3	139.9		149.4
				#	%	
MACROFOSSILS	C	R	C-A	A		A
Porifera						
"*Batostomella*" sp.						
Bulb-shaped structure ?				1	2.04	
Cnidaria						X
Pleutodictyum styloporum						
Rugose corals						X
Mollusks						X
Pelecypod			X	R	R	
Aviculopectinacid						
Carydium bellistriatum						
Carydium varicosum						
Carydium sp.						
Carydium? sp.						
Cypricardella bellastriata						
Cypricardinea sp.				1	2.04	
Edmondia? sp.						
Goniophora rugosa						
"*Goniophora*" sp.						
Grammysia ovata?						
"*Lunulicardium librum*"						

TABLE 27
(10 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-244-45' & B-3	B-4	B-411'	B-455'		B-490'
FOOTAGE (METERS)	74.6	74.9	125.3	139.9		149.4
				#	%	
"Leiopteria" sp.						
Modiella pygmaea						
Modiella? sp.						
Modiomorpha arcuata						
Modiomorpha subalata						
Modiomorpha sp.						
Nuculites oblongatus						
Nuculites? sp.						
Nuculanacea						
Nuculoidea corbuliformis						
Nuculoidea lirata						
Nuculoidea opima						
Nuculoidea sp.				1	2.04	
Nuculoidea? sp.						
Orthonota sp.						
Palaeoneila constricta						
Palaeoneila filosa						
Palaeoneila emarginata						
Palaeoneila muta						
Palaeoneila? sp.						
"Panenka" sp.						
Paracyclas lirata						
Paracyclas rugosa						
Paracyclas sp.						

TABLE 27
(11 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-244-45' & B-3	B-4	B-411'	B-455'		B-490'
FOOTAGE (METERS)	74.6	74.9	125.3	139.9		149.4
				#	%	
Phestia rostellata						
Phthonia nodicostata				1	2.04	
"Pholadomyacea"						
Pterochaenia sp.						
Pterinopecten sp.				1	2.04	
Tellinopsis? subemarginata						
Insertae sedis				1	2.04	
shell frag.						
Rostroconchs			X			
Conocardium normale						
"*Conocardium*" sp.						
Hippocardium cuneus						
Gastropoda						
Orthonema? sp.						
Palaeozygopleura hamiltoniae						
Palaeozygopleura? sp.						
Cephalopod						
"*Michelinoceras*" sp.						
"*Striacoceras*" sp.						
Tentaculite						
Spyroceras sp.						

TABLE 27
(12 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	**B-244-45' & B-3**	**B-4**	**B-411'**	**B-455'**		**B-490'**
FOOTAGE (METERS)	74.6	74.9	125.3	139.9		149.4
				#	%	
Dacryoconarid						
Styliolina fissurella						
"*Styliolina*" sp.						
Brachiopod	C	X	A	A	A	X
Allanella tullia	X			4	8.16	
Allanella tullia (dimunitive form)				1	2.04	
Ambocoelia umbonata						
Ambocoelid		X				
Athyris cora						
Athyris spiriferoides						
Atrypids			X			
Camarotoechia mesacostalis						
Camarotoechia pauciplicata						
Coelospira? camilla						
Cupularostrum congregata						
Cupularostrum sp.				2	4.08	
Craniops hamiltoniae						
Devonochonetes sp.						
Dignomia aleveata						
Dignomia? sp.						
Emmanuella cf. *praeumbonata*						
Emmanuella cf. *subumbona*						

TABLE 27
(13 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-244-45' & B-3	B-4	B-411'	B-455'		B-490'
FOOTAGE (METERS)	74.6	74.9	125.3	139.9		149.4
				#	%	
Eumetabolotechia multicostata						
Eumetabolotechia sp.						
"*Leiorhynchus*" spp.			X			
Leptocoelia flabellites						
Lingula punctata						
Longispina mucronata						
Meristiella haskinsi (cf. nasuta)						
Meristina sp.						
Mucrospirifer mucronatus				22	44.90	
Mucrospirifer cf. *consorbrinus*				2	4.08	
Mucrospirifer sp.			X	1	2.04	
Mediospirifer audaculus	X					
Mediospirifer cf. *millerstownensis*						
Nucleospina concinna						
Orbiculoidea? sp,						
Philidastrophia nacrea				1	2.04	
Spinatrypa spinosa						
Spinatrypa? sp.						
Spinocyrtia granulosa						
Striatochonetes setigera				2	4.08	
Strophomenids				1	2.04	
"Spirifids"			X	3	6.12	X
Tropidoleptus carinatus						
Shell Fragment				2	4.08	

TABLE 27
(14 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-244-45' & B-3	B-4	B-411'	B-455'		B-490'
FOOTAGE (METERS)	74.6	74.9	125.3	139.9		149.4
				#	%	
Insertae sedis				1	2.04	
Bryozoa						
Insertae sedis						
Encrustation on shell						
Echinodermata:						X
Asteroid? (portion of body and arm)						
Blastoid calyx?						
Crinoid calyx						
"Pelmatozoan" column (1)	X		X			X
"Pelmatozoan" columna (2+)			X			X
Plate						
Arthropoda:						
Ostracode						
Ctenolaculina? sp.						
Insertae sedis						
Ponderodictya puntulifera						
Phyllocarida						
Echinocaris? sp						
"*Elymocaris?*" sp.						
Trilobite						
Phacops? sp.						

TABLE 27
(15 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-244-45' & B-3	B-4	B-411'	B-455'		B-490'
FOOTAGE (METERS)	74.6	74.9	125.3	139.9		149.4
				#	%	
Ichnofossils						
"*Autodetus*" sp.						
Burrow of worm ("*Protoscolex*" sp.						
Burrow of Inart, brach.?						
Cruziana?			X			
Palaeophycos sp.						
Planolites?						
Feeding trail						
"*Rosselia*"? sp.						
Skilithos sp.						
"*Tomaculum*", "*Granularia*" or "*Cryptosiphon*"-like ball structures						
Zoophycos sp.	X			1	2.04	
Insertae sedis						
Blastoid or Barnacle plate						
Cup-shaped microstructure						
Round organic structures ("Blastomeres")						
TOTAL:				49	100	

TABLE 27
(16 of 16)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
BOWMANSTOWN, PA

SAMPLE ID #	B-244-45' & B-3	B-4	B-411'	B-455'		B-490'
FOOTAGE (METERS)	74.6	74.9	125.3	139.9		149.4
				#	%	
MICROFOSSILS	X	NF	NP	X		"NF"
Conodonts	NC	NC	NC	NC		NC
Fragment?						
Arthropoda:						
? (Plate)				X		
Ostracode						
?				X		
Porifera						
Echinodermata:						
"Pelmatozoan" column (1)						
Vertebrate						
Fish bone	?					
Foraminifera						
Agglutinated grains?	X			X		
Insertae sedis						
Coprolites	X					
Round organic structures ("Blastomeres")	?					

TABLE 28
(1 of 5)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
GIRTYS'S NOTCH, PA

SAMPLE ID #	G-64	G-1	G-2	G-3	
FOOTAGE (METERS)	19.51	27.01	67.36	99.06	
				#	%
MACROFOSSILS	A	R	NF	C	
Pelecypod (subtotal)				59	41.3
Actinopteria? sp.				1	0.7
Aviculopecten cf. insignis				1	0.7
"*Aviculopecten*"				2	1.4
Buchiola sp.				1	0.7
"Cardium"				1	0.7
Cypricardella bellastriata				3	2.1
Cypricardella? sp.				1	0.7
Cypricardinia sp.				1	0.7
"Dysodont"				1	0.7
"*Goniophora*"? sp.				1	0.7
"*Grammysiodea*" sp.				1	0.7
Leiopteria laevis				1	0.7
Leiopteria sp. (cf. *laevis*)				1	0.7
Leiopteria sp.				1	0.7
Lunulcardium cortum?				1	0.7
"*Mytilarca*"?				1	0.7
Nucula lirata				1	0.7
Nucula varicosa				1	0.7
Nuculites or *Nucula*				1	0.7
Nuculites or *Tellinopsis*				1	0.7
Orthonota? parvula				3	2.1

TABLE 28
(2 of 5)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
GIRTYS'S NOTCH, PA

SAMPLE ID #	G-64	G-1	G-2	G-3	
FOOTAGE (METERS)	19.51	27.01	67.36	99.06	
				#	%
Palaeoneilo? or Cypricardella?				1	0.7
Paracyclas lirata				6	4.2
Paracyclas rugosa		1			
Paracyclas? sp.				3	2.1
Pterochaenia fragilis				14	9.8
Pterochaenia? sp.				1	0.7
Tellinopsis?				1	0.7
Insertae sedis				7	4.9
Cephalopod					
"*Michelinoceras*" sp.				1	0.7
Gastropod				1	0.7
Dacryoconarid					
"*Styliolina*" sp.				13	9.1
Tentaculite					
Striacoceras? sp.				1	0.7
Brachiopod (subtotal)	A			40	28.0
Chonetes sp.				2	1.4
"*Chonetes*" sp.				2	1.4
Cyrtina crassa	X				

TABLE 28
(3 of 5)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
GIRTYS'S NOTCH, PA

SAMPLE ID #	G-64	G-1	G-2	G-3	
FOOTAGE (METERS)	19.51	27.01	67.36	99.06	
				#	%
Devonochonetes cf. *scitulus*	X			1	0.7
Emmanuella cf. *pennsylvanica*				2	1.4
Eumetabolotechia sp.				3	2.1
"*Leiorhynchus*" sp.				1	0.7
Lingula sp.				1	0.7
Longispina mucronata	X			7	4.9
Longispina? mucronata?				1	0.7
Longispina sp.	X			2	1.4
Longispina? sp.				1	0.7
Mediospirifer sp.	A				
Mucrospirifer mucronatus				4	2.8
Mucrospirifer sp.				2	1.4
Mucrospirifer? sp.				1	0.7
Orbiculoidea sp.				2	1.4
Orbiculoidea? sp.				1	0.7
Protoleptosrophia preplana	X				
Pustulatia pustulosa				2	1.4
Rhipdomella cf. *vanuxemi*				1	0.7
Spinocyrtia sp.	A				
"Spirifid"				1	0.7
Tylothyris pauliformis				1	0.7
Brachiopod?				1	0.7
Inarticulate?				1	0.7

TABLE 28
(4 of 5)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
GIRTYS'S NOTCH, PA

SAMPLE ID #	G-64	G-1	G-2	G-3	
FOOTAGE (METERS)	19.51	27.01	67.36	99.06	
				#	%
Arthropoda:					
Ostracode				24	16.8
Ponderodictya? sp.				8	5.6
Quasillites sp.				1	0.7
Quasillites? sp.				1	0.7
Ctenoloculina cicatricosa				2	1.4
?				12	8.4
Branchiopod					
"*Cyzicus*" sp.				2	1.4
?				1	0.7
Trilobite					
Greenops boothi				1	0.7
Thorax				1	0.7
Vertebrate					
Fish scale				1	0.7
Porifera					
?		2			
TOTALS:	N/C	3		145	102

TABLE 28
(5 of 5)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
GIRTYS'S NOTCH, PA

SAMPLE ID #	G-64	G-1	G-2	G-3	
FOOTAGE (METERS)	19.51	27.01	67.36	99.06	
				#	%
MICROFOSSILS	X	R	R	C	
Gastropod					
Low spiral juvenile		X			
Conodonts	10	NC	"X"	NC	
Icriodus difficilis	X				
I. Janeae	X				
I. sp.	X				
Insertae sedis (Fragments)			4		
Trilobite					
Pygidium	X				
Vertebrate					
Fish teeth	X				
Fish bones			?	X	
Ostracode					
Insertae sedis			?	X	
Dacryoconarid					
"*Styliolina*" sp.				1	
Foraminifera					
Agglutinated grains?			X		
Insertae sedis:					
Coprolites			X		
Round organic structures ("Blastomeres")			A	C	
"Nodicostate" plate of Arthropod or Mollusk			1		
Cup-shaped Microstructures		X			

TABLE 29
(1 of 5)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
LOCK HAVEN, PA

SAMPLE ID #:	LH-5A/B	LH-3		LH-4	LH-1	LH-2	
FOOTAGE (METERS):	18 - 20	30.18		30.79	31.39	89.92	
		#	%			#	%
MACROFOSSILS	X	NLS		NLS	NS	A	
Dacryoconarid							
"*Styliolina*" sp.		2	3.33				
Viriatellina sp.		24	40.00				
Brachiopod						A	
Ambocoelids	C-A						
Atrypids						C	
Lingula "spatulata"		1	1.67				
Mucrospirifer consobrinus						1	3.33
Pseudoatrypa devonica						1	3.33
Rhipdomella cf. penelope						1	3.33
shell fragment		1	1.67			1	3.33
Spinatrypa spinosa						2	6.67
"Spirifids"						2	6.67
Arthropoda:							
?						1	3.33
Trilobite:						X	
Cephalon fragment						2	6.67
Phacops rana						4	13.33
Ostracode							
Arcyzonid?						1	3.33

TABLE 29
(2 of 5)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
LOCK HAVEN, PA

SAMPLE ID #:	LH-5A/B	LH-3		LH-4	LH-1	LH-2	
FOOTAGE (METERS):	18 - 20	30.18		30.79	31.39	89.92	
		#	%			#	%
Cnidaria						C	
Amplexus hamiltonaiae						2	6.67
Cystiphyllum conifollis						1	3.33
Heliophyllum halli						1	3.33
"Rugose coral"						X	
Streptelasma sp.						1	3.33
Mollusks:						R	
Polyplacophora							
"Helmithochiton?" sp.						1	3.33
Echinodermata:						C-A	
"Pelmatozoan" columna (2+)						5	16.67
Bryozoa							
Branching Insertae sedis						1	3.33
Vertebrae?							
"Plate"						1	3.33

TABLE 29
(3 of 5)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
LOCK HAVEN, PA

SAMPLE ID #:	LH-5A/B	LH-3		LH-4	LH-1	LH-2	
FOOTAGE (METERS):	18 - 20	30.18		30.79	31.39	89.92	
		#	%			#	%
Ichnofossils							
Cruziana sp.		1	1.67				
Palaeophycos? sp.		X					
Planolites sp.		15	25.00				
"Planolites" sp.				20+	155	1	3.33
Podichnus-like pits		2	3.33				
"Sphaerodoides"		14	23.33				
TOTAL:		60	100.00	20+	155	30	100
MICROFOSSILS	NP	R		A	A	NP	
Conodonts		"NC"			X		
Polygnathus linguiformis linguiformis gamma				1	3		
Polygnathus linguiformis linguiformis epsilon				1			
Polygnathus parawebbi				3	2		
Polygnathus sp.				2			
"Prioniodina" sp.				1			
M-element				1			
S-element				4	2		
Indeterminant fragments		?		3			

TABLE 29
(4 of 5)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
LOCK HAVEN, PA

SAMPLE ID #:	LH-5A/B	LH-3		LH-4	LH-1	LH-2	
FOOTAGE (METERS):	18 - 20	30.18		30.79	31.39	89.92	
		#	%			#	%
Bryozoa							
Ctenostome internal mold				X			
Dacryoconarid							
Cosulatostyliolina sp.				1			
Styliolina fissurella				C	X		
Styliolina sp.				X	C		
Viriatellina gracilistriata				A	A		
Mollusks				A			
Gastropod							
Multiple spp. internal molds				C			
Pelecypod							
Multiple spp. internal molds				C			
Cephalopod:							
Straight nautiloid internal molds				R			
Ostracode				R			
cf. *Hollina* sp.				1			
Leperditicopid?				3			
Podocipid?				1			
Brachiopod				R			
cf. *Hypothyridina venustula*				1			

TABLE 29
(5 of 5)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
LOCK HAVEN, PA

SAMPLE ID #:	LH-5A/B	LH-3		LH-4	LH-1	LH-2	
FOOTAGE (METERS):	18 - 20	30.18		30.79	31.39	89.92	
		#	%			#	%
Trilobite							
Pygidium				1			
Insertae sedis							
Jinonicellina n. sp.?				R			
Round organic structures ("Blastomeres")		X		A	X		
Coprolites					X		
Ichnofossils							
Pyritized burrows				A	A		

TABLE 30
(1 of 2)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
PORT JERVIS, NEW YORK

SAMPLE ID #	PJ-3		PJ-1		PJ-2	
FOOTAGE (METERS)	15		46.75		63.5	
	#	%	#	%	#	%
MACROFOSSILS						
Plant fragments	13+	33	37+	86	29	64.44
Mollusks:						
Cephalopod:						
Straight nautiloid					1	2.22
Dacryoconarid						
Styliolina sp.					1	2.22
Brachiopod:						
Cupularostrum prolifica					1	2.22
Fimbrispirifer grieri?					1	2.22
Mediospirifer belliplicata					1	2.22
Arthropoda:						
"Blastomeres"	25+	66				
Ostracode?					2	4.44
Echinodermata:						
"Pelmatozoan" columna (2+)					1	2.22
?					1	2.22
Porifera:						
Sponge-like structures			6	12	1	2.22

TABLE 30
(2 of 2)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
PORT JERVIS, NEW YORK

SAMPLE ID #	PJ-3		PJ-1		PJ-2	
FOOTAGE (METERS)	15		46.75		63.5	
	#	%	#	%	#	%
Vertebrae						
Bone fragments					6	13.33
Fish scale			1	2		
TOTAL:	48+	99	44+	100	45	100
MICROFOSSILS	NF		R		"A"	
Conodonts	NC		NC		NC	
Ostracode						
?			X		R	
Vertebrae						
Bone fragments			X		R	
Foraminifera						
Agglutinated grains?					X	
Insertae sedis						
Cup-shaped Microstructures			X		A(200+)	

TABLE 31
(1 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-1	Ri-2	Ri-3	Ri-4		Ri-5	
FOOTAGE (METERS)	17.5	26	37.75	40.5		142.0	
				#	%	#	%
MACROFOSSILS	R	R	C	A		A	
Brachiopod						A	
Allanella tullia						1	0.50
Allanella tullia (dimunitive form)						1	0.50
Ambocoelid						1	0.50
Athyris spiriferoides						8	3.98
Athyris cf.*spiriferoides*						2	1.00
Camarotoechia mesacostalis							
"*Chonetes*" sp.							
Coelospira camilla							
Craniops hamiltoniae				4	4	1	0.50
Cupularostrum congregata							
Cupularostrum horsfordi							
Cupularostrum prolifica							
Cupularostrum sappho				2	2		
Cupularostrum sp.							
Crurispina? nana?							
Cryptonella planirostra							
Cyrtina hamiltonensis							
Devonochonetes scitulus			X			3	1.49
Elita fimbriata						2	1.00
Eoschuchertella pervesa						1	0.50
Eumetabolotechia multicostata						1	0.50
Leiorhynchus quadricostatus.							

TABLE 31
(2 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-1	Ri-2	Ri-3	Ri-4		Ri-5	
FOOTAGE (METERS)	17.5	26	37.75	40.5		142.0	
				#	%	#	%
Leptocoelia sp.							
Lingula punctata						1	0.50
Longispira mucronatus						1	0.50
Megakozlowskiella sculptilis						1	0.50
Megakozlowskiella cf. *raricosta*							
Mediospirifer audaculus						10	4.98
Mucrospirifer mucronatus			X	2	2	3	1.49
Orbiculoidea cf. *tullia*						1	0.50
Protoleptosrophia preplana						1	0.50
Pseudoatrypa? sp.						1	0.50
Pustulatia pustulosa							
Rhipdomella sp.							
Rhipdomella vanuxemi						3	1.49
Rhynchospirina lepida							
Spinatrypa spinosa							
Spinocyrtia granulosa							
Spirifids	X		X	1	1	3	1.49
Striatochonetes setigera						2	1.00
Strophomenids	X						
Tropidoleptus carinatus			C	A		3	1.49
Juvenile (<0.5 cm)				14	14		
Typical (0.5-1.5 cm)				33	33		
Large (1.5+cm)				29	29		
Tylothyris pauliformis				1	1		

TABLE 31
(3 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-1	Ri-2	Ri-3	Ri-4		Ri-5	
FOOTAGE (METERS)	17.5	26	37.75	40.5		142.0	
				#	%	#	%
shell fragment						2	1.00
Arthropoda:							
Ostracode							
Bufina? cf. elata						1	0.50
Ctenoloculina? sp.							
Hollinacea?						1	0.50
Podocopid (Metacopina)							
Ponderodictya? sp.							
Welleria? sp.						1	0.50
Indet. sp.							
Phyllocarida							
Echinocaris? sp						1	0.50
"*Elymocaris*" sp.				1+	1+	1	0.50
Trilobite			X				
Mystrocephala microgemmaeus							
Phacops? sp.						1	0.50
Bryozoa							
Paleschara radiata							
Ptilocella sp.							
Fragment of colony							
Encrustation on shell						2	1.00

TABLE 31
(4 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-1	Ri-2	Ri-3	Ri-4		Ri-5	
FOOTAGE (METERS)	17.5	26	37.75	40.5		142.0	
				#	%	#	%
Porifera							
Insertae sedis						1	0.50
?				1	1		
Echinodermata:	A						
"Pelmatozoan" single columnae	X		X	1	1	51	25.37
"Pelmatozoan" columna (2+)	X		X	4	4	21	10.45
Mollusks:							
Gastropoda:			C				
"*Cyclonema*" sp.							
cf. *Glyptotomaria (Dictyomaira) capilloria*				1	1	1	0.50
"*Palaeozygopleura*" sp.						1	0.50
Indet. sp.						1	0.50
Pelecypod							
Buchiola sp.							
Carydium bellistriatum				2	2	5	2.49
Carydium varicosum						2	1.00
Cypricardella bellastriata						2	1.00
Cypricardella gregaria							
Cypricardinea indenta						9	4.48
Glyptocardia speciosa							
Gramatodon hamiltoniae						3	1.49
Grammysiodea arcuata						1	0.50

TABLE 31
(5 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-1	Ri-2	Ri-3	Ri-4		Ri-5	
FOOTAGE (METERS)	17.5	26	37.75	40.5		142.0	
				#	%	#	%
Grammysiodea sp.						1	0.50
Leiopteria laevis						1	0.50
Leiopteria cf. *rafinesqui*						12	5.97
Leiopteria sp.						1	0.50
Lyrriopecten priamus						1	0.50
Modiella? pygmaea?							
Modiomorpha subalata						1	0.50
Modiomorpha? sp.			X			1	0.50
Nuculites oblongatus						1	0.50
Palaeoneila constricta							
Palaeoneila emarginata						1	0.50
Phthonia nodicostata						1	0.50
Prothyris lanceolata				1	1	1	
*Pseudaviculopecten*sp..						1	0.50
"*Pterinopecten*" *tenuis*							
Pterinopecten proteus							
Pterochaenia? sp.							
shell fragment						1	0.50
Rostroconch							
Hippocardia cumeus						1	0.50
Indet. sp.							
Polyplacophora							
"Chiton plate"							

TABLE 31
(6 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-1	Ri-2	Ri-3	Ri-4		Ri-5	
FOOTAGE (METERS)	17.5	26	37.75	40.5		142.0	
				#	%	#	%
Cephalopod:							
"Bactrites" sp.							
Straight nautiloid	X						
Ammonoid?							
Tentaculite				1	1		
Tentaculites cf. *bellulus*						1	0.50
Dacryoconarid							
Styliolina sp.						2	1.00
Viriatellina gracilistriata						1	0.50
Cnidaria							
"Favosites" argus						2	1.00
Ichnofossils							
"Beaconites" sp.							
Cruziana sp.				1	1		
"Granularia" sp.			X				
Planolites sp.			X	1	1		
Skilithos? sp.						1	0.50
Zoophycos sp.						7	3.48
Infilled Burrow				1	1	3	1.49
Insertae sedis							
TOTAL:				101	100	201	99.50

TABLE 31
(7 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-1	Ri-2	Ri-3	Ri-4		Ri-5	
FOOTAGE (METERS)	17.5	26	37.75	40.5		142.0	
				#	%	#	%
MICROFOSSILS	"NP"	R	"C"	"NF"		"NF"	
Conodonts		?					
Icriodus brevis							
"Conodont Pearl"		1					
Ostracode							
Ponderodictya puntulifera							
Indeterminate molds			X				
Bryozoa							
Fragment of colony							
Dacryoconarid							
Styliolina sp.							
Vertebrae							
Bone fragments							
Fish scales?			X				
Porifera							
Triaxon spicule			1				
Foraminifera							
Agglutinated grains?			C				
Insertae sedis							
Coprolites			X				

TABLE 31
(8 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-6	Ri-9		Ri-7	Ri-8
FOOTAGE (METERS)	148.1	160.2		166.7	169.5
		#	%		
MACROFOSSILS	R	A		NF	R
Brachiopod		A			
Allanella tullia		16	6.40		
Allanella tullia (dimunitive form)					
Ambocoelid					
Athyris spiriferoides					
Athyris cf.spiriferoides					
Camarotoechia mesacostalis		3	1.20		
"Chonetes" sp.		1	0.40		
Coelospira camilla		1	0.40		
Craniops hamiltoniae					
Cupularostrum congregata		1	0.40		
Cupularostrum horsfordi		1	0.40		
Cupularostrum prolifica		1	0.40		
Cupularostrum sappho					
Cupularostrum sp.		8	3.20		
Crurispina? nana?		1	0.40		
Cryptonella planirostra		2	0.80		
Cyrtina hamiltonensis		1	0.40		
Devonochonetes scitulus					
Elita fimbriata					
Eoschuchertella pervesa					
Eumetabolotechia multicostata		1	0.40		

TABLE 31
(9 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-6	Ri-9		Ri-7	Ri-8
FOOTAGE (METERS)	148.1	160.2		166.7	169.5
		#	%		
Leiorhynchus quadricostatus.		2	0.80		
Leptocoelia sp.		2	0.80		
Lingula punctata					
Longispira mucronatus					
Megakozlowskiella sculptilis					
Megakozlowskiella cf. *raricosta*		1	0.40		
Mediospirifer audaculus					
Mucrospirifer mucronatus		1	0.40		
Orbiculoidea cf. *tullia*					
Protoleptosrophia preplana					
Pseudoatrypa? sp.					
Pustulatia pustulosa		29	11.60		
Rhipdomella sp.					
Rhipdomella vanuxemi					
Rhynchospirina lepida		1	0.40		
Spinatrypa spinosa		1	0.40		
Spinocyrtia granulosa		6	2.40		
Spirifids		29	11.60		
Striatochonetes setigera					
Strophomenids					
Tropidoleptus carinatus		34	13.60		
Juvenile (<0.5 cm)					
Typical (0.5-1.5 cm)					
Large (1.5+cm)					

TABLE 31
(10 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-6	Ri-9		Ri-7	Ri-8
FOOTAGE (METERS)	148.1	160.2		166.7	169.5
		#	%		
Tylothyris pauliformis					
shell fragment		33	13.20		
Arthropoda:					
Ostracode					
Bufina? cf. elata					
Ctenoloculina? sp.		1	0.40		
Hollinacea?					
Podocopid (Metacopina)		1	0.40		
Ponderodictya? sp.		1	0.40		
Welleria? sp.					
Indet. sp.		4	1.60		
Phyllocarida					
Echinocaris? sp					
"*Elymocaris*" sp.					
Trilobite					
Mystrocephala microgemmaeus		1	0.40		
Phacops? sp.					
Bryozoa					
Paleschara radiata		2	0.80		
Ptilocella sp.		1	0.40		
Fragment of colony		1	0.40		
Encrustation on shell					

TABLE 31
(11 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-6	Ri-9		Ri-7	Ri-8
FOOTAGE (METERS)	148.1	160.2		166.7	169.5
		#	%		
Porifera					
Insertae sedis					
?					
Echinodermata:					
"Pelmatozoan" single columnae	X				
"Pelmatozoan" columna (2+)					
Mollusks:					
Gastropoda:					
"*Cyclonema*" sp.		1	0.40		
cf. *Glyptotomaria (Dictyomaira) capilloria*					
"*Palaeozygopleura*" sp.					
Indet. sp.					
Pelecypod		C			
Buchiola sp.		1	0.40		
Carydium bellistriatum					
Carydium varicosum					
Cypricardella bellastriata					
Cypricardella gregaria		1	0.40		
Cypricardinea indenta					
Glyptocardia speciosa		1	0.40		
Gramatodon hamiltoniae					

TABLE 31
(12 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-6	Ri-9		Ri-7	Ri-8
FOOTAGE (METERS)	148.1	160.2		166.7	169.5
		#	%		
Grammysiodea arcuata					
Grammysiodea sp.		1	0.40		
Leiopteria laevis					
Leiopteria cf. *rafinesqui*					
Leiopteria sp.		1	0.40		
Lyrriopecten priamus					
Modiella? pygmaea?		1	0.40		
Modiomorpha subalata					
Modiomorpha? sp.					
Nuculites oblongatus					
Palaeoneila constricta		1	0.40		
Palaeoneila emarginata					
Phthonia nodicostata					
Prothyris lanceolata					
*Pseudaviculopecten*sp..		1	0.40		
"Pterinopecten" tenuis		1	0.40		
Pterinopecten proteus		5	2.00		
Pterochaenia? sp.		1	0.40		
shell fragment		20	8.00		
Rostroconch					
Hippocardia cumeus					
Indet. sp.					
Polyplacophora					
"Chiton plate"		2	0.80		

TABLE 31
(13 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-6	Ri-9		Ri-7	Ri-8
FOOTAGE (METERS)	148.1	160.2		166.7	169.5
		#	%		
Cephalopod:					
"Bactrites" sp.		1	0.40		
Straight nautiloid					
Ammonoid?		1	0.40		
Tentaculite					
Tentaculites cf. *bellulus*					
Dacryoconarid					
Styliolina sp.					
Viriatellina gracilistriata					
Cnidaria					X
"Favosites" argus					
Ichnofossils					
"Beaconites" sp.		1	0.40		
Cruziana sp.		1	0.40		
"Granularia" sp.		2	0.80		
Planolites sp.		2	0.80		
Skilithos? sp.		1	0.40		
Zoophycos sp.					
Infilled Burrow					
Insertae sedis		15	6.00		
TOTAL:		250	100		

TABLE 31
(14 of 14)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
RIVERSIDE, PA

SAMPLE ID #	Ri-6	Ri-9		Ri-7	Ri-8
FOOTAGE (METERS)	148.1	160.2		166.7	169.5
		#	%		
MICROFOSSILS	R	"NF"		R	R
Conodonts					1
Icriodus brevis					1
"Conodont Pearl"					
Ostracode					
Ponderodictya puntulifera				X	
Indeterminate molds					
Bryozoa					
Fragment of colony	1				
Dacryoconarid					
Styliolina sp.	1				
Vertebrae					
Bone fragments					
Fish scales?					
Porifera					
Triaxon spicule					
Foraminifera					
Agglutinated grains?					
Insertae sedis					
Coprolites					

TABLE 32
(1 of 3)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
ROCKVILLE, PA

SAMPLE ID #	R-4	R-2	R-1		R-3		R-5
FOOTAGE (METERS)	47.5	110.5	162.5		196.5		204.0
			#	%	#	%	
MACROFOSSILS	C	NF	R		C		C
Bryozoan							
Bryozoan: sp. indet.			13	54.17			
Sulcoretepora sp.			1	4.17			
Cnidaria							X
Polyp-like structure			5	20.83			
Rugose *corals*							X
Arthropoda:							X
Ostracode							
Ostracode: sp. indet.			2	8.33			
Trilobite:							
Dalamanitid							X
Echinodermata:							X
"Pelmatozoan" column (2+)			1	4.17			X

TABLE 32
(2 of 3)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
ROCKVILLE, PA

SAMPLE ID #	R-4	R-2	R-1		R-3		R-5
FOOTAGE (METERS)	47.5	110.5	162.5		196.5		204.0
			#	%	#	%	
Brachiopod							C
Atrypids							C
Devonochonetes scitulus					1	16.67	
Megastrophia sp.					1	16.67	
Mediospirifer belliplicata					1	16.67	
Mediospirifer sp.					1	16.67	
Spinocyrtia sp.					1	16.67	
Spiriferids	C						X
Shell Fragment			2	8.33	1	16.67	X
Ichnofossils							
Skilithos sp.			X				
Planolites sp.			X				
TOTAL:			24	100	6	100	

TABLE 32
(3 of 3)
SPECIFIC FOSSIL IDENTIFICATION OF SAMPLES:
ROCKVILLE, PA

SAMPLE ID #	R-4	R-2	R-1		R-3		R-5
FOOTAGE (METERS)	47.5	110.5	162.5		196.5		204.0
			#	%	#	%	
MICROFOSSILS	X	X	"NF"		X		X
Vertebrate							
Fish bones		X					
Conodonts	10	X	NC?		NC		NC
Icriodid? fragment		1	?				
Icriodus brevis	2						
Icriodus expansus	4						
Icriodus spp.	4						
Ostracode							
Ostracode: sp. indet.							X
Pelecypod							
Small (juvenile) clam							X
Foraminifera							
Agglutinated grains?					X		
Insertae *sedis*							
Coprolites		1					
Round organic structures ("Blastomeres")		10					
Oolites					A		
Cup-shaped Microstructures					X		

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