GUIDEBOOK
16TH ANNUAL
HARRISBURG AREA
GEOLOGICAL SOCIETY
FIELD TRIP

NOTES ON THE HAMBURG KLIPPE:
BIOSTRATIGRAPHY, ASH LAYERS, OLISTOSTROMES,
AND "EXOTICS"

PREPARED BY: G. ROBERT GANIS
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TABLE OF CONTENTS

TABLE

TABLE OF CONTENTS
(CONTINUED)

FIGURES

MAP FIGURES

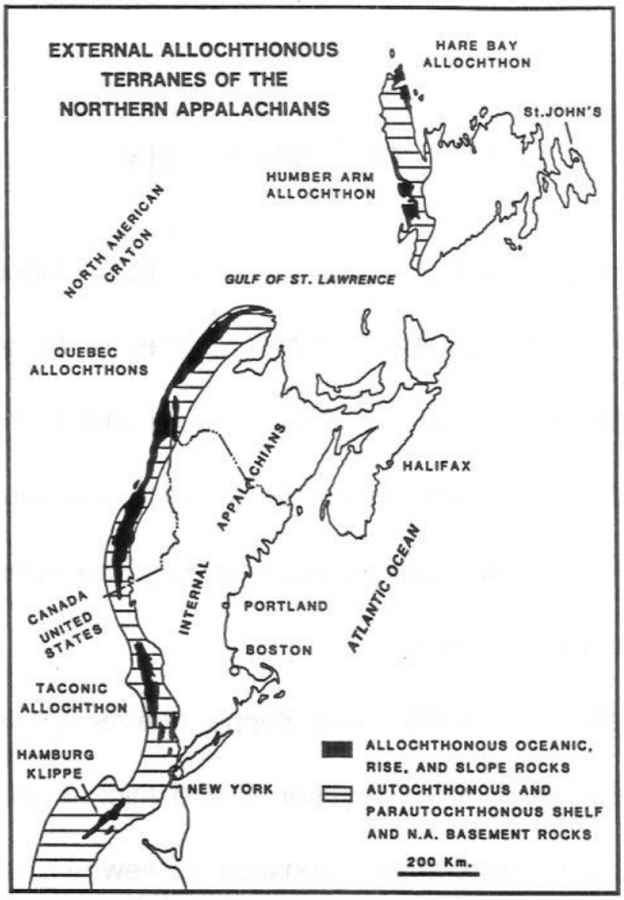
TABLE OF CONTENTS
(CONTINUED)

APPENDICES

I. INTRODUCTION

The 1997 field trip of the Harrisburg Area Geological Society visits the rocks of the Hamburg Klippe. It is the southernmost of a series of Taconic Allochthons along the eastern edge of North America (see Figure 1). Rocks of the "Klippe" have been variously described as a true overthrust and/or an allochthon complex emplaced within the younger Martinsburg basin (see previous work). The term "Hamburg Klippe" is used generically in this regard herein.

The grand setting of the Hamburg Klippe relates to global tectonics of the Ordovician and the location of other continental and micro-continental plates. As an allochthon, the klippe sediments were deposited somewhere else and then moved, deformed and finally obducted onto the Laurentian craton. The where and how of this terrane accretion is a continuing topic of debate. The Hamburg Sequence reportedly contains "exotic" elements [Carswell, et al. (1968); Epstein, et al. (1972); Stephens, et. al. (1982); and Lash and Drake, Jr. (1984)], and the "exotic" label will be discussed. The popular concept for the obduction of the Hamburg terrane onto North America involves the subduction of Laurentia beneath an outboard microcontinent (Lash, et al., 1984 and Lash and Drake, Jr., 1984). According to these authors, during this subduction, deposition within an accretionary wedge occurred against the slope of the



Regional setting of the northern Appalachian external allochthonous terranes. The Taconic-type mélanges were formed during the obduction-emplacement histories of these terranes. After Williams (1978).

FIGURE 1A

Taconic allochthons of the Northern Appalachians, Bosworth (1989).

← (6) HAGS Fieldtrip Stop Number

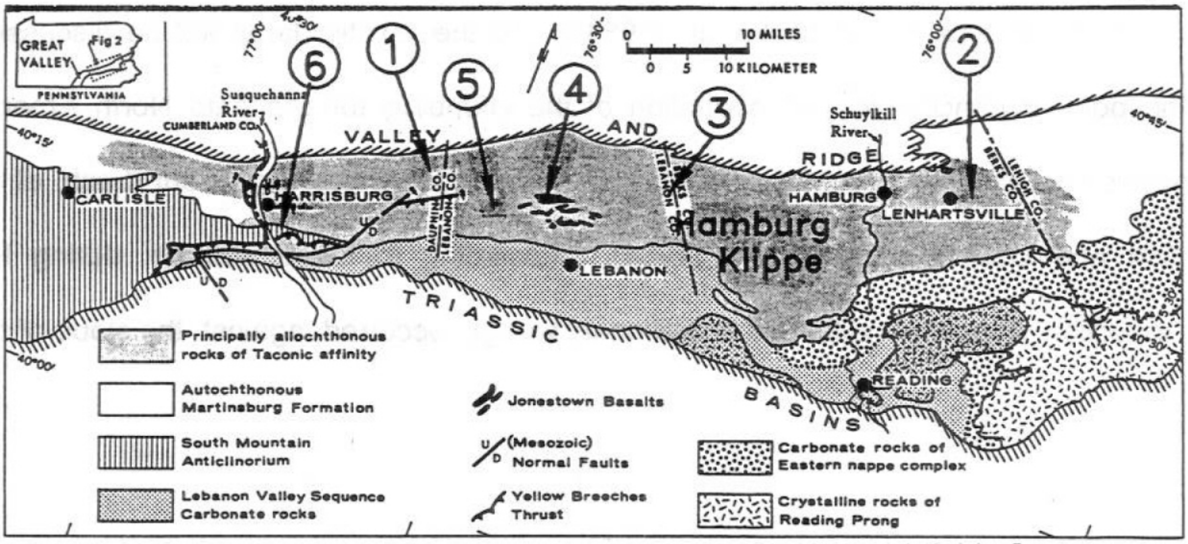


Figure 2. Generalized geologic map of Pennsylvania Great Valley, showing distribution of allochthonous rocks in Martinsburg Formation. Eastern limit after Alterman (1971).

FIGURE 1B

Hamburg Klippe, regional map, Root and MacLachlan (1978).

microcontinent which opposed the Laurentian slope from Early Cambrian through Late Middle Ordovician. This sediment pile was uplifted, detached, and obducted onto the Laurentian margin into or onto the Martinsburg basin during the Taconic Orogeny resulting in large scale nappe formation.

The obduction of the Taconic terrane of eastern New York has been attributed to a similar Laurentian subduction creating an island arc (see Landing, 1986 for a summary discussion). The subduction of Laurentia and related obduction of the Taconian Dunnage zone of Newfoundland is summarized in Cawood, van Gool, and Dunning (1995). The accretion of the Taconic Allochthons onto Laurentia involves the closure of the Iapetus ocean and various models put forward for this event are discussed in van der Pluijm, et al. (1995) and Niocaill, et al. (1997). Basically there are two scenarios, one having Balticia, Siberia, Avalonia, and various microcontinents slowly closing to Laurentia and a competing suggestion that attributes the Taconic Orogeny to the collision of the Andean margin of Gondwana with Laurentia (Dalla Salda, et al., 1992; Dalziel, et al., 1994).

A detailed review of the various proposed configurations for paleogeographic positioning of continental masses during the Ordovician is far beyond the scope of this field trip discussion. However, this brief introduction sets the stage for a more detailed look at the klippe rocks and fossils and what they might add to the debate.

II. FIELD TRIP AGENDA

The primary presentation of new information provided in this field trip is much additional biostratigraphic data both of graptolite and conodont aspect for the Hamburg Sequence. The first relatively close-spaced graptolite-age study for a part of the Hamburg Sequence is presented. The search for graptolites has proven to be especially productive. The results of this collecting has revealed an olithostromal melange of large age differentiation between relatively close-spaced and lithologically varied olistoliths. The geologic setting interpreted from this new detailed biostratigraphic work is described for Stop 1. This stop will set the stage for interpreting the other stops including the visit to the Jonestown Volcanics (Stop 4). At Stop 3 we will see a well exposed, limestone conglomerate-in-turbidite debris flow and another limestone type will be seen at Stop 5.

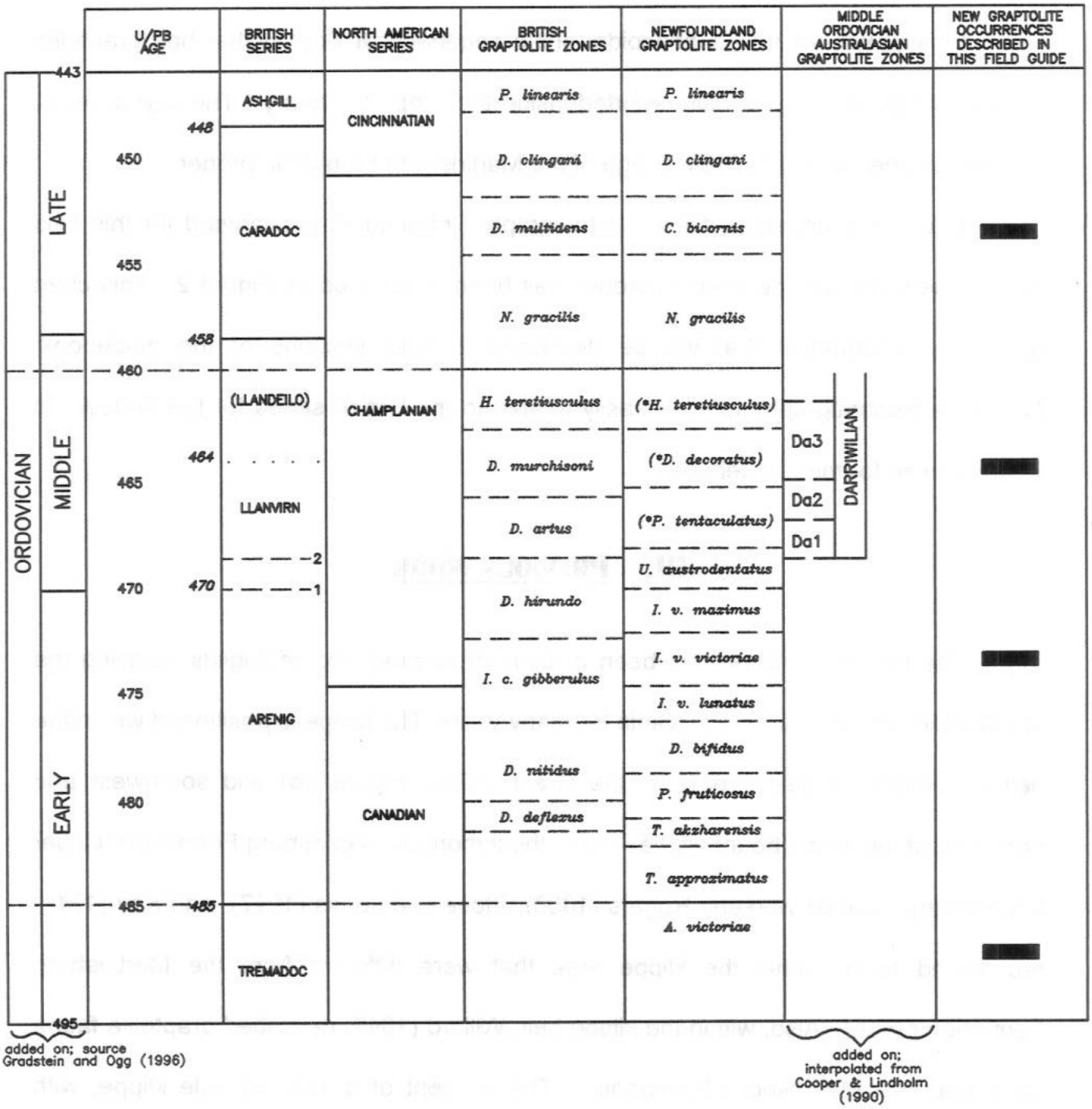
We will also look at newly "rediscovered" volcanic ash beds within deep pelitic red shales at Stop 2. Conodonts in an immediately overlying limy turbidite bed have permitted dating of the ash. These ash beds apparently do not have equivalent age representatives within the platform carbonates of the Laurentian margin.

Finally, we will visit a phacoidal shale sequence at Stop 6 that has graptolite fossils younger than previously reported inside the klippe boundary. The age here, *C. bicornis*, pushes against the lower age of the Martinsburg Formation proper.

In order to understand the biostratigraphic information put forward for this field trip, a time scale with pertinent biozones has been assembled as Figure 2. This chart references information that will be discussed in later sections of the guidebook. Graptolite biostratigraphy is most easily related to the British series for the Ordovician which is used for this Guidebook.

III. PREVIOUS WORK

The Hamburg Klippe has been a focus of interest for geologists studying the Great Valley of eastern Pennsylvania for many years. The klippe is positioned within the belt of Ordovician pelitic rocks of the Great Valley (Figure 1b) and southwest and northeast of the klippe boundary lies the authochthonous Martinsburg Formation (Upper Ordovician). Earlier workers, Rogers (1858), Stose and Jonas (1927), and Kay (1941) recognized rocks within the klippe area that were different from the Martinsburg Formation proper. Also, within the klippe belt, Willard (1943) described graptolite fauna older than the Martinsburg Formation. The concept of a Taconic-style klippe, with comparisons to the classical Taconics of New York and New England, was introduced



From O'Brien, Swindon, Dunning, Williams, and O'Brien (in press A.J.S.)

FIGURE 2 (Partial; complete Figure folded)
TIME SCALE AND GRAPTOLITE BIOZONES

by Stose (1946). He also summarized the dissimilar Klippe rocks compared to the Martinsburg, which included cherts, limestone, volcanic rocks, and red and green shales. Both the Martinsburg Formation and the Hamburg Klippe contain flyschoid rocks (graywacke/shale) that continued to cause some workers, Gray and Willard (1955) and McBride (1962), to include the klippe within the Martinsburg Formation.

Lucian Platt (Carswell, Hollowell, and Platt, 1968) was first to recognize the highly discontinuous nature of the stratigraphy within the klippe sequence and proposed that older allochthonous materials were delivered to and were included within the Martinsburg Basin via gravity slides. This concept differed from a wholly allochthonous klippe structurally positioned above the Martinsburg Formation (Stose, 1946). Since Platt (in Carswell, Hollowell, and Platt, 1968) first proposed allochthonous slices within an authocthonous matrix (the Martinsburg Proper) the issue has been continuously debated. Platt (in Carswell, Hollowell, and Platt, 1968) also reported pre-Martinsburg age graptolites from allochthonous "slices," but did not report Martinsburg age fossils within the Hamburg Klippe area. Platt, et al. (1972) reviewed the Hamburg Klippe problem and concluded that it was composed of smaller and older pieces of rock contained within the Martinsburg Formation. As mapping and study continued within the klippe area (Myers, 1969; Alterman, 1972), the recognition of allochthonous elements within a highly deformed and structural complex setting was advanced. The continued lack of finding Martinsburg age fossils within the klippe area suppressed the interest in Platt's older blocks in the Martinsburg shale model.

The Hamburg Sequence contains abundant carbonate rock described by mappers (listed above) as slices, blocks, or clasts. In one of these blocks Bergstrom and others (1972) found conodonts of Balto-Scandic affinity. This discovery in the Hamburg Sequence suggested a non-Laurentian source for contained inclusions. Epstein and others (1972) discussed the significance of these "exotic" fauna and interpreted the information.

Work on the western terminus of the Hamburg Klippe was completed by Root and MacLachlan (1978). They proposed large discrete allochthons delivered into the Martinsburg Basin by a combination of gravity slides and thrusting. In this scenario, the allochthons would contain only older than Martinsburg fauna, which they reported.

Near the eastern part of the Allochthon, just north of the klippe, Shochary Ridge either conformably overlies the klippe (Wright, Stephens, and Wright, 1979) or was thrust upon the klippe (Stose, 1930; Alterman, 1972; Lyttle and Drake, Jr., 1979; and Lash, Lyttle, and Epstein, 1984). The contents of Shochary Ridge are a fossiliferous variant of the Martinsburg Formation interpreted as a delta by Wright and Stephens (1978). Therefore, if the oldest part of the autochthonous Shochary Ridge (*Diplograptus multidens* Zone) is conformable to the underlying klippe sequence, this age would date the emplacement of the allochthon. This conclusion is not supported by a structural contact interpretation, however.

The subject of the Hamburg Klippe was the theme of two field trips of the Field Conference of Pennsylvania Geologists. In 1982, Stephens, Wright and Platt lead the 47th Field Conference and they proposed the klippe as a single coherent block thrust and/or slide that entered the Martinsburg Basin. They reported no fossil evidence of mixed Martinsburg and pre-Martinsburg age rocks and only graptolites older than the Martinsburg were described from the klippe area. In 1984, Lash, Lyttle, and Epstein, with additional contributions from Repetski and Denkler, lead the 49th Annual Field Conference of Pennsylvania Geologists. They presented a thorough and convincing sedimentological model of the Hamburg Sequence as an accretionary wedge and provided a tectonic model for a subduction complex involving Laurentia subducting under an outboard microcontinent. This plate tectonic model was earlier discussed by Lash, 1980, a, b and Kodama and Lash (1980). Lash, Lyttle, and Epstein (1984) put forth a stratigraphic subdivision of the klippe based on structural slices they proposed. Their stratigraphy was based on meager fossil evidence, however. Repetski (1984) described additional conodont finds of North Atlantic affinity and discussed the implications. Lash and Drake, Jr. (1984) further elaborated upon the accretionary model within a Laurentinan-Microcontinent subduction complex and proposed a stratigraphic subdivision. They also provided a detailed tectonic evolution for the sedimentation and obduction of the Hamburg sequence onto Laurentia. Lyttle and Epstein (1987) mapped the Newark 1° x 2° sheet containing part of the Hamburg Klippe. Drake, Jr. et al. (1989) summarized the Taconic Orogen in the United States, which included a discussion of the Hamburg Klippe, and described its general relationship to the other Taconides of eastern North America.

A subtopic of the Hamburg Klippe is the volcanic rocks they contain near Jonestown, Pennsylvania. The history of their study will be discussed under the section titled "Jonestown Volcanic Complex."

IV. AGE OF THE HAMBURG SEQUENCE BIOSTRATIGRAPHIC EVIDENCE

Efforts to date the constituent contents of the Hamburg Klippe have, thus far, relied upon occurrences of graptolites within the clastic rocks and conodonts within "exotic" and depositional carbonates. The initial evidence supporting a Taconic style klippe was based upon anomalously old graptolite faunas of Middle Ordovician age found in the western part of the allocthon (Willard, 1943; Stose, 1946) which prompted Stose (1946) to propose the Hamburg Klippe, thrust over the younger Upper Ordovician Martinsburg Formation. Willard (1943) described graptolite faunas, from what was believed to be the Martinsburg Formation, of Normanskill and Deepkill ages from

Dauphin County. From the faunal lists reported by Willard, age assignments from various localities can be estimated that include Arenig, Llanvirn, and Llandeilo to early Caradoc ages. Stose (1946) reiterated and added to Willard's Normanskill and Deepkill discoveries within the Hamburg Klippe. Geological mapping in Dauphin County by Carswell, Hollowell, and Platt (1968) resulted in the discovery of additional graptolite occurrences in the western part of the klippe. Several occurrences of Normanskill fauna, described at the time by John Riva (in Carswell et al., 1968) as *Climacograptus scharenbergi* and *C. parvus* were reported as well as a singular occurrence of abundant *Dictyonema sp.* which lead Riva to suspect an Early Ordovician age (Tremadoc) for that locale. A reexamination of *C. scharenbergi* and *C. parvus* by Riva (1974) resulted in an assignment of both forms to *Pseudoclimacograptus scharenbergi* (Lapworth) with a zonal range between *N. gracilis* and *D. multidens Zones* in eastern North America. Platt, et. al. (1972) described three new graptolite occurrences in the western part of the klippe. One is described as probably Berry's (1960) Zone 11 or 12, one as probably late Middle Ordovician and one as Middle Ordovician. Another account of graptolites from the western part of the Hamburg Klippe is found in Root and MacLachlan (1978) who report *Nemagraptus gracilis* Zone and *Didymograptus bifidus* Zone (identification by J. Riva) in two beds separated by only 15 m. This locality is only 150 m south of the Carswell, et al. (1968) Normanskill graptolite reports. Riva (1974) acknowledges a Llanvirn graptolite fauna from the Hamburg Klippe which may be the same collection described by Root and MacLachlan (1978).

Graptolite faunas from the Hamburg Klippe summarized in Stephens, Wright, and Platt (1982), Lash, Lyttle, and Epstein (1984), and Lash and Drake (1984) are consistently described as from *Nemagraptus gracilis* Zone (of Riva - 1972, 1974) and possibly *Glyptograptus teretiusculus* Zone. In all of these summaries literature reports of graptolite ages older than *N. gracilis* are not mentioned except for Stephens, et. al. (1982) which acknowledges the *Dictyonema sp.* (Tremadoc?) report in Carswell, et. al. (1968) and also revised the identification to *D. flabelliforme*. Examination of the specific localities described in these summaries reveals that the eastern klippe examples are only *N. gracilis* Zone and possibly *G. teretiusculus* Zone.

The Hamburg Klippe contains abundant carbonate rocks either interbedded with clastics or as exotic clasts, blocks and slices within a clastic matrix. Most workers in the klippe since Stose (1946) have described emplacement of carbonate exotics and carbonate depositional packages by gravity sliding (into clastics) or debris flows. Bergstrom, Epstein, and Epstein (1972) reported a lower Arenig conodont fauna of North Atlantic provincial affinity, virtually identical to Balto-Scandic types, from carbonate slide blocks in the eastern part of the klippe. After that initial discovery other conodont collections were found in carbonate sequences in the klippe, which are summarized by Repetski (1984), and include ages of Late Cambrian to early Arenig. The significance of North Atlantic Faunal Province conodonts in the Hamburg Klippe and the implications of a cold versus warm water origin is discussed by Repetski (1984).

Three small klippen in New Jersey described as Taconides by Perissoratis, et al. (1979) are interpreted as lithologically similar and probably related to the Hamburg Klippe by Lash and Drake (1984). Graptolite fauna collected from the Jutland Klippe, are described as zones 2 - 4 through zone 12 of Berry (1960, 1968) by Perissoratis, et. al. (1979) and also of the same range by Parris, Miller, and Finney (1995).

Separated from and south of the Hamburg Klippe is an area of shale and other clastic lithologies mapped as the Cocalico Shale (Jones and Stose, 1930). It is similar in content to the Hamburg sequence and was considered part of it by Stose (1946). Jonas and Stose (1930) reported poorly preserved Middle Ordovician age graptolites, "of Normanskill type," from the Cocalico which supports a correlation with the Hamburg sequence. However, unlike the Hamburg sequence, the Cocalico contains little reported carbonate content and only over a limited area at the contact (thrust?) with the underlying Beekmantown Group. Jonas and Stose (1930) included twenty feet of argillaceous and fossiliferous (crinoids, shells, and trilobites) limestone with the Cocalico.

Added to this body of information regarding the biostratigraphic content of the Hamburg Sequence are the new fossil discoveries reported in this field trip guidebook.

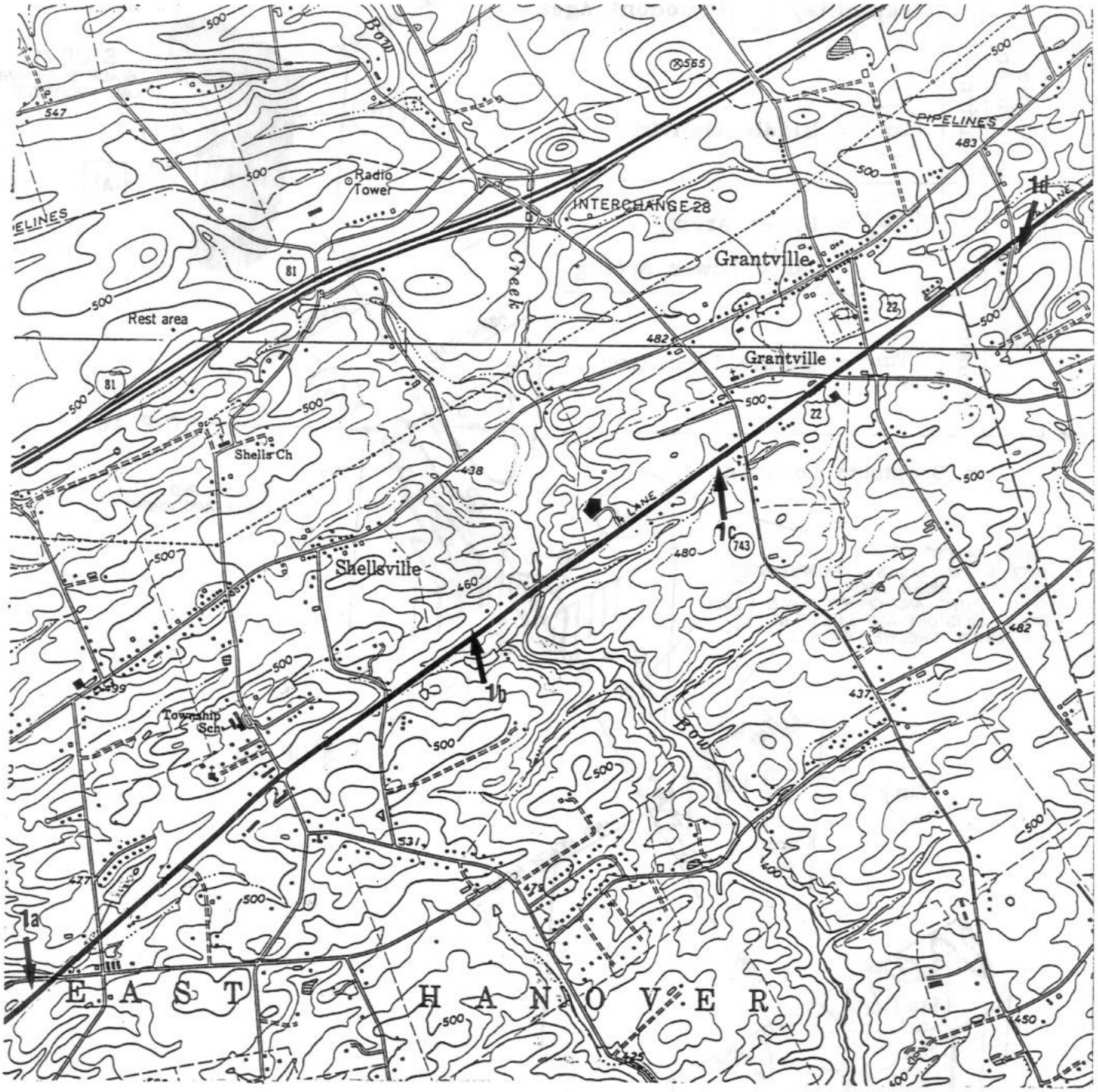
STOP 1

OLISTOSTROMES

Stop 1 is actually a series of stations along a 3.2 mile traverse of intermittent exposures on U.S. Route 22 in eastern Dauphin County and just over the Dauphin-Lebanon County line. The location of the stations can be found on Map Figure 1.

Although we will essentially stay along strike and not cover a lot of distance, we will encounter rocks that range in age from middle Tremadoc to middle Llanvirn or roughly 25 million years. The lithologies will also change quite a bit reflecting a variety of depositional environments.

The rough geology encountered along the traverse is illustrated first on Figure 3. From west to east the first station (1a) is in classic "Bouma cycle" (Bouma, 1962) turbidites of graywacke and shale. These are off slope clastic flows that typically accumulate in thick rapid depositional events. Evidence of high energy sediment transport, channeling, scouring, and the like is preserved as sole marks, load cast, contorted bedding, flute cast and groove marks, etc. Grain size within the turbidite cycle ranges from conglomerate to clay and graded bedding demonstrates the aqueous settling of the turbidite plumes as they deposited into deeper water. It is worth noting that this type of sequence is similar to turbidite deposits of the younger Martinsburg



SCALE: 1" = 2000'
Base map is a reproduction of a U.S.G.S. 7.5 Minute Topographic Quadrangle of Hershey, Pennsylvania, 1969, Photorevised 1990.

STOP 1
LOCATION MAP

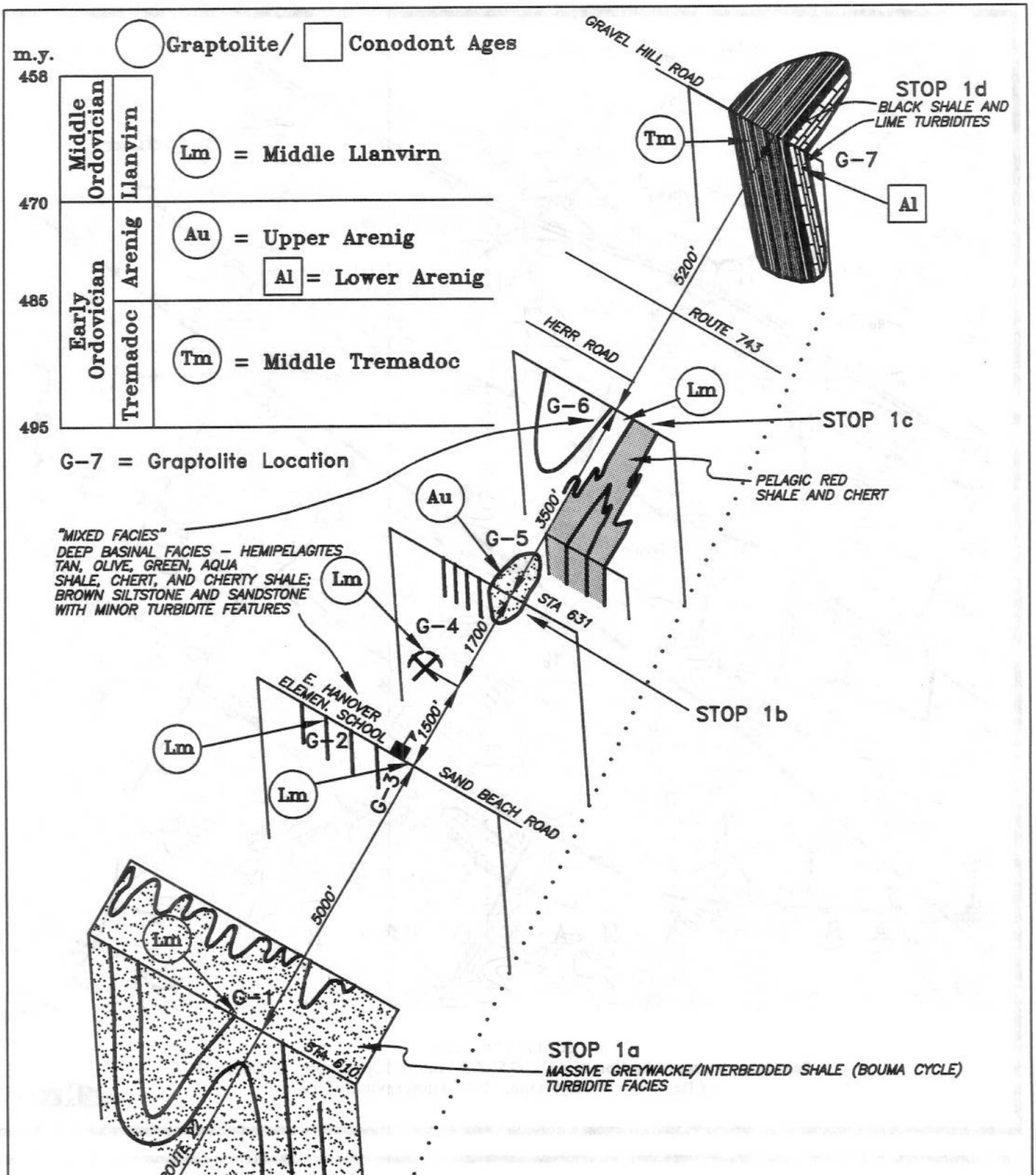


FIGURE 3
FACIES INTERPRETATION AND
BIOSTRATIGRAPHIC AGE OF OUTCROPS;
STOP 1 TRAVERSE

Formation upon which the Hamburg Klippe has overridden and/or entered. Graptolites found in this turbidite exposure are mid Llanvirn in age (Darriwilan 3) and were undoubtedly swept into the sediment plume and transported with it.

Proceeding east, the lithology changes to siliceous (more or less cherty) grey to greenish shale that yielded mid Llanvirn age graptolite, as well. On Figure 3, these exposures are shown as near East Hanover Elementary School. This sediment is interpreted as deeper water, with more quiet and steady (but slower) deposition. Yet, turbidite features still interfinger, with some coarsening to intercalated siltstone and even some preserved sole marks. But the gross aspect of a true "Bouma cycle" turbidite sequence is lost. We are seeing the distal portions of turbidite flows reaching the quieter environment of slower deposited siliceous shales producing a mixed facies much further away and out from the toe of slope. Similarly, Lash and Drake, Jr. (1984) described an intertonguing relationship between shale and graywacke in their Windsor Township Formation in the Hamburg Klippe. With limited and very incomplete exposure exact sedimentological relationships are problematical. The rapid change from turbidites to deeper water shales of the same age could also be the result of a large submarine channel boundary and associated overbank sediments.

With limited time not permitting a stop at every location in Figure 3, we will postpone review of the "mixed facies" until Stop 1c. However, before reaching Stop 1c, we will see another exposure of turbidites similar to Stop 1a. The rocks at Stop 1b are mid to late Arenig in age or roughly 10 million years older than the turbidites of Stop 1a and the shales in between. This Arenig turbidite exposure terminates in short order proceeding east toward more of the mid Llanvirn age graptoliferous mixed facies sediment at Stop 1c. Throughout these changes in facies and age we have essentially stayed along strike.

The Arenig turbidite rocks at Stop 1b are interpreted as a block or slice enclosed by younger mid Llanvirn matrix. The argument for this olistostromal interpretation will be further developed at the end of the Stop 1 narrative as a summary discussion.

Continuing east from Stop 1b is an exposure of "mixed facies" along several hundred feet at Stop 1c. As discussed above, the mixed facies is interpreted as distal turbidites (siltstones and shales) interfingering with deeper water siliceous shales. At Stop 1c there are also red shales and chert that have been interpreted as deep marine by Lash, et al. (1984), "analogous to red and brown clays presently accumulating in the deepest parts of the oceans and are considered to be pelagic or eupelagic deposits (Berger and Von Rad, 1972)." At this stop the turbidite contaminated aqua colored shales grade into red shales and no channeling of turbidites into the shales can be seen. This mixed facies sequence has yielded a faunule of mid Llanvirn age graptolites, the same age as the classic "Bouma cycle" turbidites at Stop 1a and the siliceous shales just east of there. The juxtoposition of these various facies, time and time again across the Hamburg terrain suggest an active tectonic front influencing the sedimentation and continually pushing older materials into younger, thus compressing and overriding the normal spatial relationship of depositional environments. There is much structural deformation in the Hamburg Sequence that further complicates the interpretation of sedimentological relationship by complicated thrusting.

The last station (1d) in the Stop 1 traverse is yet another variation of lithologic content common to Hamburg Sequence, black shales and ribbon bedded limestone. Exposed here is 108 feet of black shale above which is about 12 feet of platey bedded limestone, a covered portion of about 125 feet, and finally brown shale and sandstone with green chert above. Again we have dateable graptolites and in the limestone conodonts have been extracted. The graptolite fauna in the black shale is Tremadoc (most likely mid Tremadoc) age. Chitinour carapaces of phyllocarid arthropods are also found with the graptolites. The age difference (graptolite biozones) between the rocks at Stop 1d (black shales) and 1c is roughly 20 to 25 million years yet we are still essentially along strike. The ribbon bedded limestones yielded conodonts more likely of lowermost Arenig age that is a bit younger than the Tremadoc black shales beneath them. The nature of contact between the black shales and ribbon bedded limestone is not clear due to poor exposure.

The lithologic variation and large age difference between the rocks at 1d compared to the other stations along Stop 1 suggest that the outcrop is an olistolith of older rock in younger similar to the interpretation of Station 1b to its surrounding matrix.

STOP 1

SUMMARY INTERPRETATION

We have seen a variety of rock types and mixed ages spanning mid Tremadoc through mid Llanvirn along the stations of the Stop 1 traverse. Most of the rock is mid Llanvirn and suggests that older outcrops are slices or blocks (olistoliths) within a younger matrix. Could it also be argued that faulting creates these juxtaposed rocks and large age variations? Perhaps it could in a singular instance, but the frequent waxing back and forth of rocks representing large time spans, essentially along strike, would require very large faults in abundance.

Such faults would need displacements of many thousands of feet. This assertion is made by comparison to the Martinsburg Formation flysch basin which spans about 8 million years of sedimentation history and is estimated to be 2,000 m (about 6,000 feet) thick by Stephens, et al. (1982). The sedimentation history of the entire Hamburg Sequence [oldest rocks found (late Cambrian) to youngest rocks (early Caradoc)] spans about 45 million years. Comparisons of the Hamburg sequence and the Martinsburg Formation relates to the turbidites which dominant the Martinsburg and are but a part of the Hamburg. Other parts of the Hamburg are deeper pelitic rocks with much slower sedimentation rates (starved basin). Therefore, the Hamburg Sequence, in total, might not have accumulated at the same sedimentation rate as the Martinsburg except during turbidity inputs. However, the Hamburg Sequence deposition lasted more than five times as long. Assuming that the Hamburg Sequence is only as thick as the Martinsburg still provides for a very rough estimate of 6,000 feet. Lash and Drake, Jr. (1984), however, estimated the thickness of the Hamburg Sequence at 6780 m (roughly 20,000 feet). This means that the combined faulting, including the syndepositional Taconic thrusting and offscraping, would need to position rocks from the earliest parts of the sequence against the middle in a dense pattern consisting of thousands of feet per displacement to produce the age disparities along strike seen through the Stop 1 traverse. This type of fault pattern is not a reasonable suggestion.

The tectonic mixing created in a structural melange resulting from the pucking along thrust boundaries would also require many thousands of feet of fault contact between the youngest and oldest materials, given the thickness that would have originally separated them. The large size of the older inclusions seen along Stop 1b does not fit this melange scenario. Lash (1987) described melanges resulting from mud diapirism in the Hamburg Sequence as "sandstone clasts floating within scaly mudstone." The clasts described are small (meter sized) compared to the kilometer sized inclusions seen along Stop 1; therefore, this type of origin to explain the older inclusions in younger matrix along Stop 1 is not indicated. The large (kilometer) size of the older inclusions may require physical thrusting in concert with debris collapse to move them into subsequent and younger sediment via gravity slides. This is essentially the proposition suggested by Root and MacLachlan (1978) for the emplacement of the western part of the Hamburg Klippe into the Martinsburg Formation. The circumstances and conditions that produce very large olistoliths (megaslices) was discussed by Root and MacLachlan (1978) and Lash, et. al. (1984).

Through Stop 1, we have seen rocks only as young as mid Llanvirn, however, most of the graptolite ages reported from the Hamburg Sequence are much younger upper Llanvirn (formerly Llandeilo) to early Caradoc, Zone 11 (N. gracilis), but mostly reported from the eastern half of the klippe. Based on biostratigraphic sampling of graptolite fauna alone, which is probably very incomplete, a greater variety and age span representation is reported for the clastics of the western half of the klippe. Superficially there does not seem to be a difference in stratigraphic variation between the two halves, however, the significant differences in biostratigraphic content may indicate such a difference does exist. Only more sampling for graptolite fauna in the eastern half will resolve the apparent biostratigraphic differences between the two halves. Conodont ages are restricted to carbonate rocks, some of which are "exotic" to the clastic's that enclose them. Dating the enclosing clastic matrix with such inclusions is tenuous and unprovable unless the carbonate material occurs in an interbedded relationship.

The picture presented is that of an olistostromal melange or wildflysch of blocks-in-shale where the blocks are both carbonate and clastic. The accretionary origin and presence of these kind of deposits are common to the other Taconic terranes. The Etchemin wildflysch in Quebec is considered to have formed as a result of sediment collapse (St. Julien, 1977). Zen (1967) described gravity slide olistostromes in the New York and Vermont Taconics. The obduction of Taconic terranes was interpreted by Rowley and Kidd (1981) as resulting in wildflysh lying at the base of prograding greywackes and suggested that, "olistostromes originated at the front of moving thrust sheets." Lucian Platt (in Carswell, et al., 1968) recognized gravity slide deposits within the Hamburg Sequence and workers since then in the klippe have reported a similar pattern of a broken formation.

The Stop 1 traverse demonstrates (the writer's interpretation) a major domain of Llanvirn age sediment of both turbidite and deeper pelitic variety encapsulating large fragments of older Arenig and Tremadoc debris. Figure 4 is a diagrammatic portrayal of this olistostromal environment, albeit unfolded and unfaulted. The propensity of *N. gracilis* age rocks in the klippe from other areas suggest matrix domains of that age, as well. These debris or wildflysch accumulations, with compressed facies relationships, suggest a moving structural front, plowing and mixing older material into younger with large collapse features driven by actual thrusting and turbidity flows and producing submarine fan deposits. This is the classic Taconic environment referenced earlier.

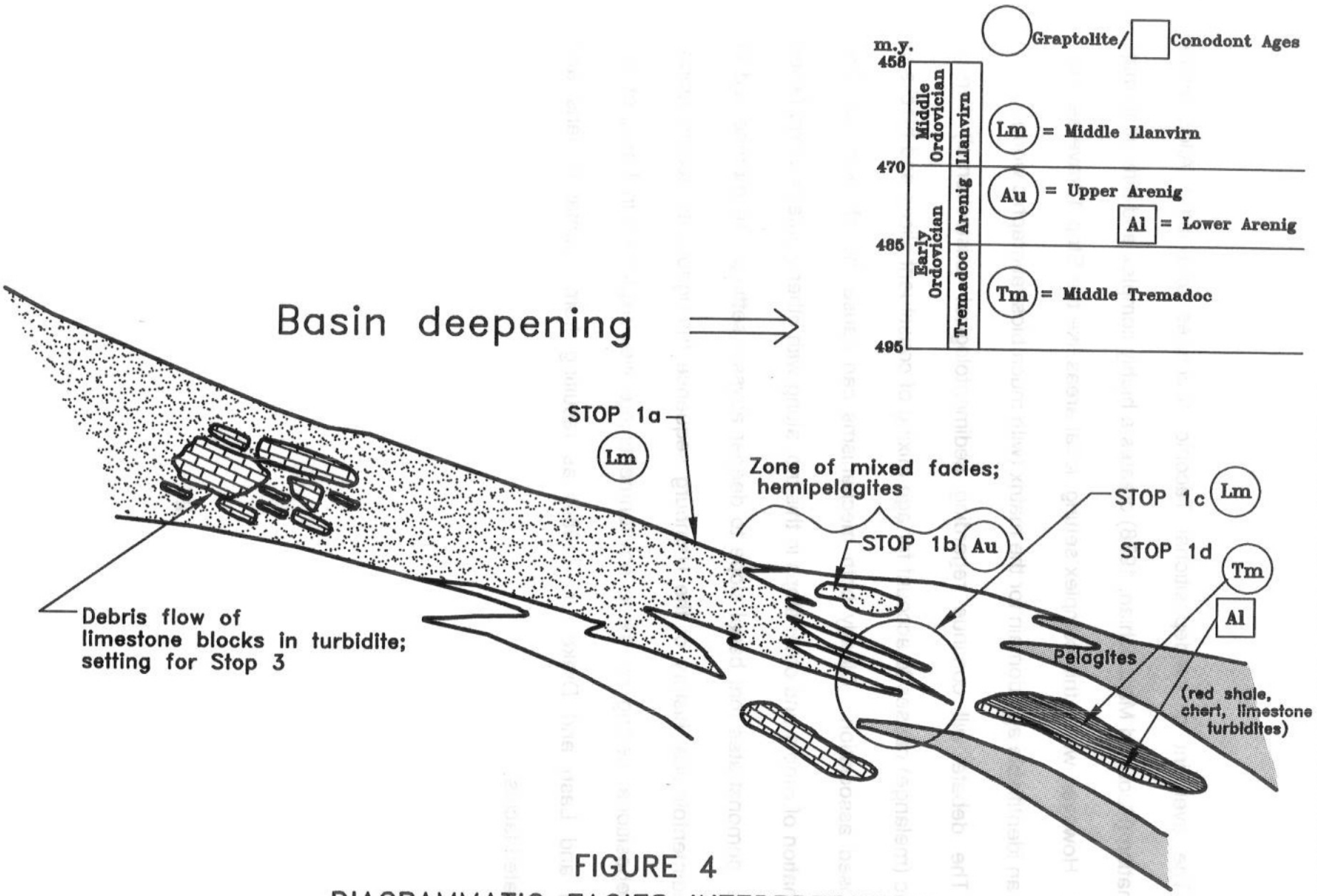


FIGURE 4
DIAGRAMMATIC FACIES INTERPRETATION
OF THE OLISTOSTROME
ALONG THE STOP 1 TRAVERSE

The overprint of syndepositional Taconic structures and latter Alleghanian deformation (Root and MacLachlan, 1978) creates a highly complex and difficult to map terrain. However, within this complex setting, local areas like the Stop 1 traverse, may reveal an identifiable age domain for the matrix (with much biostratigraphic work).

The debate will continue regarding sedimentological (olistostromal) versus tectonic (melange) causes to account for age mixing of constituent slices and blocks in juxtaposed association. Clearly both mechanisms can cause the phenomena. The examination of Stop 1 and other stops in this trip, along with other worker's dated facies reports, demonstrates that basal slope to deeper abyssal settings are represented in the sedimentological history of the Hamburg sequence throughout its accumulation. The depositional setting for these environments are well explained in Lash, et al., (1984) and Lash and Drake, Jr., (1984) as resulting from submarine fans and associated facies.

The repetitive and chaotic pattern of juxtaposed facies and rock bodies of large age differences requires a systematic explanation. An active tectonic front that moved slow enough to allow the sedimentological systems to enjoy periods of stabilization, but which was punctuated with large debris collapses as the sediment rose and slide in advance of structural pressure (and then was subducted) explains the chaotic mixing seen in outcrop. Tectonic offscrapping and internal shear further mixed the debris. Sedimentological packages are left in-tact as large and small inclusions within an enclosing sediment of younger age. The assigning of formations and members in this settling without close biostratigraphic control is not practical.

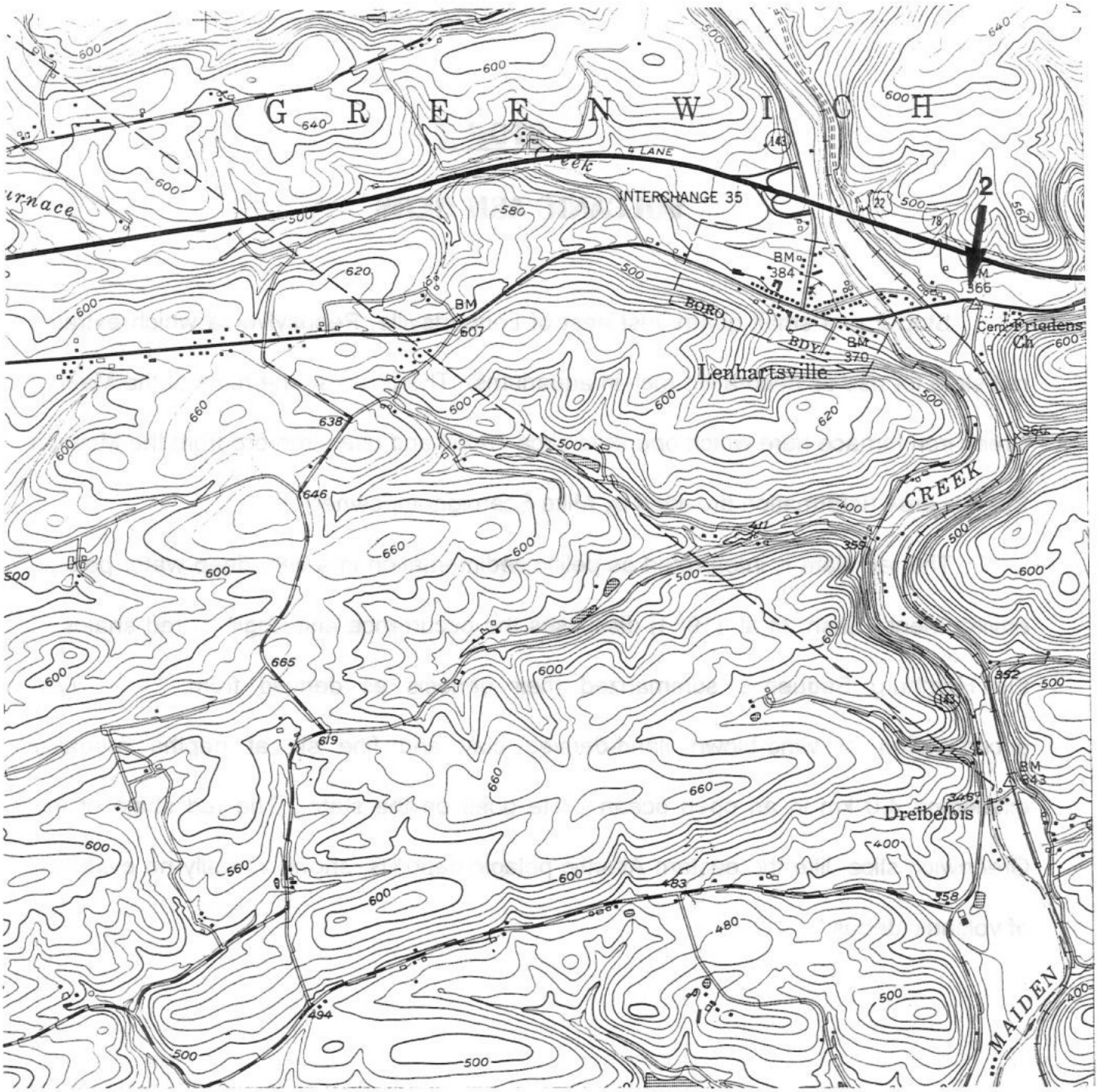
One further point of debate—are all of the "exotic" inclusions syndepositional and reworked native material or could some have been exhumed from pre-existing terranes by erosion? This latter proposition requires an "exotic terrane" impinged against the Hamburg depositional basin and its underpinned basement. Extra basinal clasts of volcanic and plutonic rocks in the Howe Harbor Member (Middle Ordovician Foredeep Fill in Western Newfoundland) are interpreted as,". . . previously subaerially exposed on a fault scarp (and) . . . . represent detritus which was transported to the shelf, subsequently drowned, and then was subject to recurrent slope failure as a result of tectonically induced dewatering and oversteepening of the slope" (Quinn, 1995). If any of the Hamburg "exotics" (carbonate, clastic, or volcanic) are to be interpreted in this fashion, then the disposition (current location) of this "exotic terrane" must be accounted for, unless it was totally consumed into the Hamburg Sequence. This scenario might result from a fragment detached from a larger continental mass. The proposition of truly exotic fragments within the Hamburg Sequence originating from an extra basinal provenance is a matter that bears on the interpretation of the continental elements of the closing Iapetus ocean and cannot be evaluated strictly on a localized regional basis.

STOP 2

VOLCANIC ASH BEDS

Stop 2 is a small quarry just east of Lenhartsville, Pennsylvania which extracts red slate for use as decorative rock in aquariums. There is also the ruins of the Maiden Creek iron furnace here which operated circa 1860s and used iron ore from the Moselm Springs area (information provided by Mike Scarpignoto, owner).

The red slate is interpreted as pelitic sedimentation in a very deep water pelagic environment. Lash, et al. (1984) discusses the occurrence and origin of red shales in the Hamburg Sequence summarized their genesis as derived from, ". . . (an) accumulation of wind-blown, land-derived clay and fine silt at depths probably exceeding 4.0 km in an open ocean." He goes on the state, "The red shale of the Greenwich slice, like the eastern Atlantic pelagic deposits, shows virtually no evidence of volcanic debris."



SCALE: 1" = 2000'
Base map is a reproduction of a U.S.G.S. 7.5 Minute Topographic Quadrangle of Hamburg, Pennsylvania, 1956, Photorevised 1969 and 1977.

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STOP 2
LOCATION MAP

TABLE 1

Section At Stop 2 - Scarpignoto Quarry

UNIT THICKNESS	CUMULATIVE THICKNESS	DESCRIPTION
		aqua shale; footwall of quarry
0' 2"	0' 2"	carbonate nodules (conodonts)
0' 2"	0' 4"	brown ash (confirmed)
0' 2"	0' 6"	carbonate nodules
3' 0" (est)	3' 6"	covered; muck
7' 6"	11' 0"	aqua slate
2' 9"	13' 9"	red slate
0' 6"	14' 3"	brown ash (tentative)
20' 0"	34' 3"	red slate
3' 0"	37' 3"	red slate w/thin interrbedded aqua slate; cherty
2' 7"	39' 10"	brown greywacke with 1/2 ash (tentative) at top
0' 2"	40' 0"	purple "spotted" slate*
0' 5"	40' 5"	red slate
0' 6"	40' 11"	brown greywacke with ash (?)
1' 2"	42' 1"	red slate
16' 0"	58' 1"	interbedded red slate & brown greywacke
2' 0"	60' 1"	aqua slate
0' 9"	60' 10"	yellowish tan shale
2' 0"	62' 10"	fault gouge
0' 8"	63' 6"	brown ash (tentative)
0' 2"	63' 8"	aqua slate
36' 0"	99' 8"	red slate

*I suspect this variety of purple shale is similar to what Stose and Jonas (1927, 1930) and Stose (1946) classified as of, "tuffaceous origin" for outcrop near the JVC and Cocalico Formation (see Stop 4).

However, in this exposure of red slate (shale) there are no fewer than five volcanic ash layers (one confirmed, four suspected), over approximately 100 feet of section (see Table 1). Intermixed with one of the ash layers are spotty carbonate nodules, as an intercalated bed. Conodonts from the carbonate nodules were first described by Raring and Ganis (1973) as lower Middle Ordovician and of North Atlantic faunal aspect. This carbonate, interpreted as turbiditic, was recently reexamined for conodonts and the presence of North Atlantic Province taxa of lower Arenig age was confirmed (John Repetski; personal communication). The ash layers at this quarry were first pointed out to the writer in 1972 by Paul Myers of Lehigh University. A measured section is provided in Table 1 that describes an interbedded sequence of red and aqua slate with greywacke (distal turbidites) as well as the ash beds.

Stose and Jonas (1927) proposed that some of the purple and green shales near the Jonestown Volcanic Complex were of volcanic ash origin (discussed under Stop 4). They did not describe thin brownish colored ash within red shales as seen here. Platt, et al. (1972) mentions "a few bentonite layers" within the Hamburg Sequence, that may be of the same type seen here at Stop 2. Recently, very similar looking thin ash layers have been found within black shale in Lebanon County west of this occurrence.

The age of these ash beds may hold a significant clue to the distance the Hamburg Klippe has traveled. Equivalent age (Lower Arenig) Laurentian platform carbonates are represented regionally by the lower Epler Formation (Great Valley) and the Nittany Formation in the central folded belt of the Appalachians. Neither of these formations have reported volcanic ash beds, although stratigraphically above in the upper Middle Ordovician to Upper Ordovician are well known and very wide spread ash beds in Pennsylvania [see Cullen-Lollis (1986) for summary discussion]. The implication that can be drawn is that the Hamburg depositional basin, which received these ash fall events in the Lower Arenig, was sufficiently removed from the Laurentian platform such that these ash falls are not recorded there in equivalent age rocks. The source of the volcanism thus becomes a very intriguing question.

Volcanic ashes occur in the Indian River Formation of the Taconic Allochthon of eastern New York State, but are post Middle Llanvirn to early Llandeilo (Landing, 1986) and are much younger than the ash layers at Stop 2. In the Taconic foreland of Quebec, Brun and Chagon (1979) described ash in the Black River and Trenton Groups (Middle to Upper Ordovician), again, much younger than the ash beds seen at Stop 2.

STOP 3

LIMESTONE CONGLOMERATE-IN-TURBIDITE DEBRIS FLOW

A well exposed example of a debris flows can be seen at Stop 3. Here, a broken apart limestone conglomerate mass has been scattered within a clastic turbidite flow over a large area. The limestone clasts are of many sizes from small pods to large house-sized blocks and collectively result in a classic olistostrome. Evidence of clastic turbidity current features can be seen in preserved sole marks including good examples of large groove casts.

The limestone conglomerate in this debris flow is polymictic and similar in appearance to that described by Lash, et al. (1984), Lash and Drake, Jr. (1984), and Filock and Lash (1984) as the Onyx Cave Member. These authors attribute this limestone conglomerate to turbidite association and possibly deposited in channels incised into shale and mudstone. A large "block" of black lime mudstone also occurs within this overall association, although its limits (edges) are not exposed. Both the limestone conglomerate and the black lime mudstone are quite impure having insoluble contents of 26.7 and 24.4 percent respectively.

SCALE: 1" = 2000'
Base map is a reproduction of a U.S.G.S. 7.5 Minute Topographic Quadrangle of Bethel, Pennsylvania, 1955, Photorevised 1969.

STOP 3
LOCATION MAP

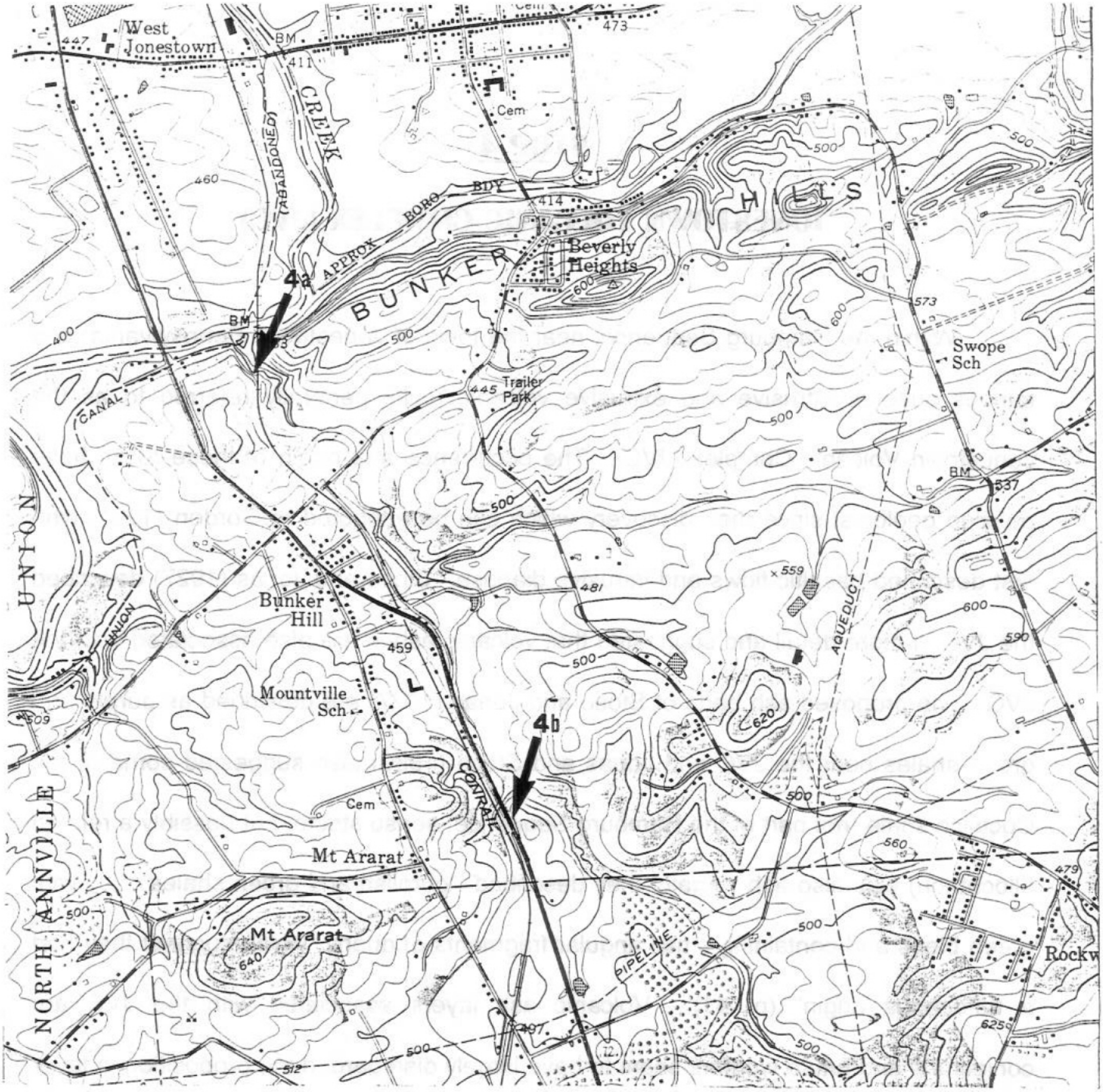
The debris flow nature of this exposure indicates that the original beds have been dislodged and transported via a clastic turbidity event. This is consistent with overall sedimentological premise presented in this field guide of reworked sediment (rock?) transported to subsequent settings via submarine gravity events.

The presence of limestones within the belt of rocks comprising the Hamburg Klippe was recognized by early workers (see Section III, Previous Work). Moseley (1952) specifically described limestones within the "Martinsburg Group" and described different varieties including an intraformational conglomerate seen at Stop 3, which is an area of limestone outcrop he identified. He also recognized that the limestone in this belt contained a high insoluble content. Another one of Moseley's limestone outcrop areas will be visited at Stop 5.

STOP 4

JONESTOWN VOLCANIC COMPLEX (JVC)

Within the Hamburg Sequence, near the town of Jonestown, Pennsylvania, is a curious suite of intrusive and extrusive volcanic rocks generally referred to as the Jonestown Volcanic Complex (JVC). The occurrence and origin of these rocks have puzzled geologist since their discovery which can be attributed to Gordon (1921) who first described basaltic flows and intrusive diabase. Stose and Jonas (1927) described the JVC in more detail and suggested that volcanic ashes are also associated with the JVC. The proposed ash beds of Stose and Jonas (1927) are described as purple and green shales near the JVC and Jonas and Stose (1930) also suggested some of the Cocalico shale (not part of the Hamburg Sequence, sensu stricto, but possibly a related allochthon) was also ash. Again, they described, "purplish and green shales . . . . with green blebs and containing small angular fragments of quartz, which suggest they had a tuffaceous origin" (p. 41). Volcanic ash layers associated with the JVC are conjectural and future workers seem to have largely disregarded the proposition in favor of a deep marine origin for this type of "shale," although Stose (1946) again mentions purple and green shales of probable volcanic origin near the JVC and near Manheim (Cocalico shale).



SCALE: 1" = 2000'
Base map is a reproduction of a U.S.G.S. 7.5 Minute Topographic Quadrangle of Fredericksburg, Pennsylvania, 1955, Photorevised 1978.

STOP 4
LOCATION MAP

Stose and Jonas (1927) described amygdaloidal basalt and altered diabase in the Jonestown area. They noted that this diabase is different from the fresh Triassic age diabases and suggested that it resembled Pre-Cambrian diabase from the Reading and Boyertown Hills (Reading Prong). They also observed a basaltic breccia with baked limestone at the contact between a basaltic flow and underlying limestone. Stose (1946) offered a tentative correlation for the JVC with "lower Cambrian formations."

Moseley (1956) also studied the JVC and reported the significant observation that the basalts have pillow structures. He also reported flow breccias alternating with tuffs, "which are indicated by the bedded character of the rock and by fragmental and shard structures in thin section." The proposition of tuffs within the JVC sequence perhaps needs to be reexamined, however much similar purple and green shale has not been attributed to a tuffaceous origin by subsequent Hamburg Sequence workers.

There are two possible explanations for the JVC, either they are erosional exotics, exhumed from a preexisting volcanic containing terrain, and entered the Hamburg Sequence via submarine gravity slides, or, they were intruded into the accretionary wedge and are in-situ and native to the Hamburg Sequence. This debate should be considered with the same proposition for carbonate rocks within Hamburg

Sequence since the basaltic flows are in contact with limestone. Much of the carbonate content can be, and probably is, depositionally part of the Hamburg Sequence such as the Onyx Cave Member described by Lash, et al. (1984), Filock and Lash (1984) and Lash and Drake, Jr. (1984). Other carbonate containing exposures are exotic clasts within a clastic matrix (i.e., exotic blocks described by Epstein, et al., 1972) and are less clearly ascribable to a native origin. The most confusing scenario would be if there are both native and exotic carbonate materials within the Hamburg Sequence.

Lash (1984) and Lash, et al. (1984) describe the JVC as native to the Hamburg Sequence and have been generated as, "localized off-ridge outpourings of calc-alkaline and tholeiitic magma extruded and intruded into trench and near-trench sediments during bending of the subducting plate." This would suggest that the extrusive and intrusive magmas would be of a compatible and similar geochemical composition which is apparently the case (Robert C. Smith II, Pennsylvania Geologic Survey, personal communication).

Another curious aspect about the JVC is that, in addition to the extrusive and intrusive rocks, the surrounding area has other unique rock bodies not found elsewhere in the Hamburg Sequence. Among these are large isolated ridges of pure monocrystalline sandstone (Lash, et al., 1984; Stose, 1946, called it quartzite). Here, the "megaclast exotic" concept must be at least considered. Viewed in combination with the JVC, the foreign versus native origin gains support. However, Lash, et. al. (1984) explained this anomallously pure sandstone within an otherwise dirty trench setting as resulting from a unique source channel cutting into the sequence from its own plutonic-metamorphic provenance.

The olithostromal interpretation for the rocks seen along Stop 1 may help interpret the JVC. Based on the extreme age mixing seen there, one can envision the JVC as having been originally in-situ only to be collapsed into younger clastics as olistoliths later. Further evidence is needed to qualify the JVC as either native or exotic.

The field trip will visit one of the classic exposures of the JVC just south of the Swatara Creek, within an abandoned railroad cut (Station 4a). Here, basaltic breccias and pillow lavas are well exposed. The brecciated and thermally metasomatized contact with the underlying limestones can be dug out at the north end of the base of the cut. Below the railroad track, on the west side, is a small quarry excavated in limestone along the Swatara Creek. In this limestone, North Atlantic Faunal Province conodonts of upper Tremadoc to lower Arenig age were extracted by John Repetski (Lash, 1984). Since the basalts flowed over this limestone, they cannot be older than this age.

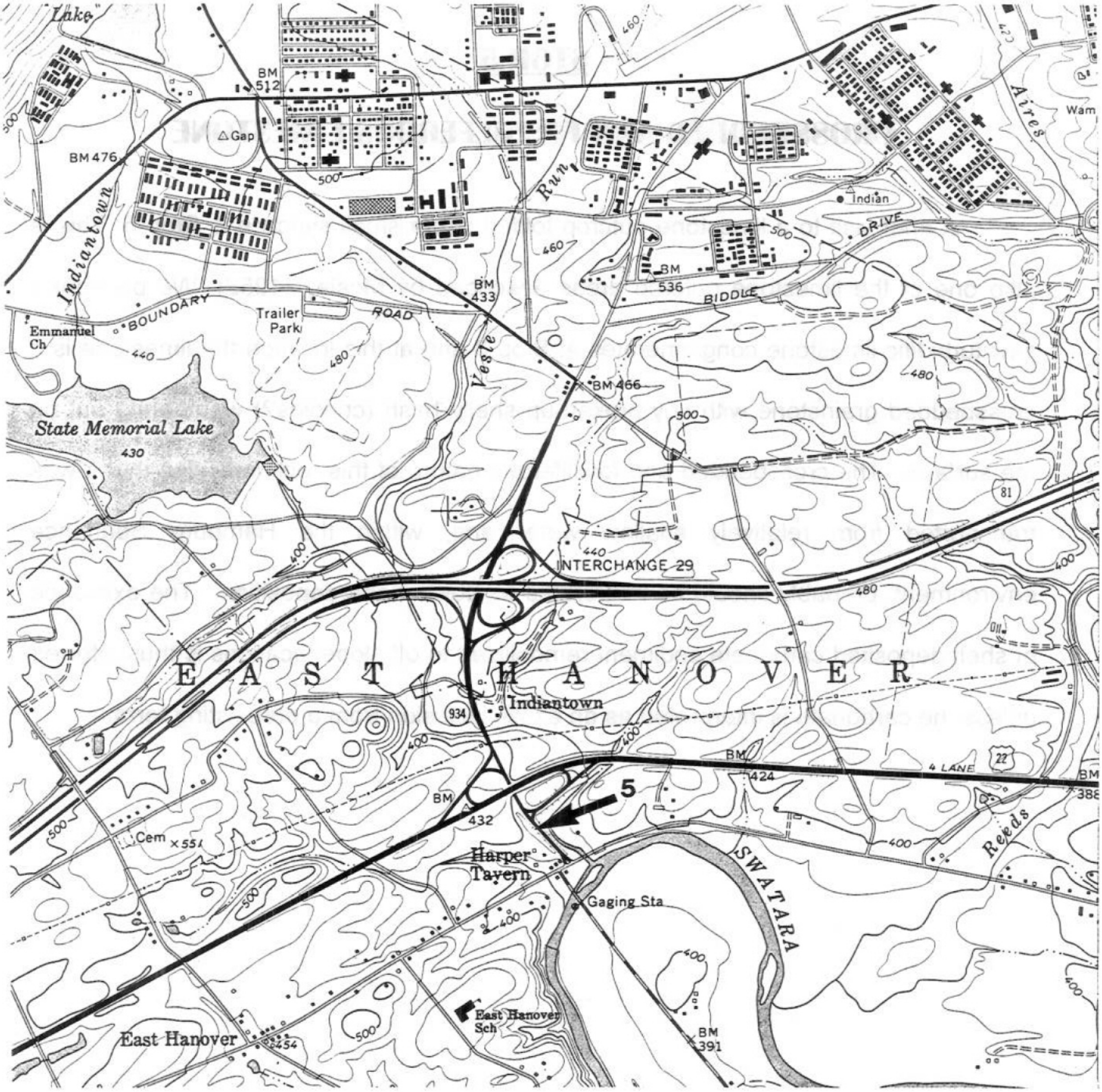
Station 4b is south of Station 4a along Route 72, where diabase intrudes graywacke sandstone. Because graywacke is a significant component of the Hamburg Sequence there is no contradiction in interpreting these intrusions as native from that association.

It is worth noting that the other Taconic Allochthons (see Figure 1) all have associated pillow basalts and/or ophiolitic content in overall settings similar to the Hamburg Klippe.

STOP 5

CROSSBEDDED AND FOSSILFEROUS LIMESTONE

A brief visit to a limestone outcrop folded into a small syncline is Stop 5. This is also one of the limestone outcrop areas described by Mosley (1952). We previously saw turbiditic limestone conglomerates at Stop 3 and at this location the limestone is a crossbedded grainstone with tiny broken-up shelly hash (crinoids?) weathering out on the surface. The crossbedded and fossilferous nature of this rock indicates that it was transported from relatively shallow water and, within the Hamburg Sequence environment, probably should be interpreted as down slope deposition. The existence of shelf deposited carbonate sediment remobilized to off slope locations is thus inferred unless the carbonate is interpreted as an exotic inclusion from a preexisting terrain.



SCALE: 1" = 2000'
Base map is a reproduction of a U.S.G.S. 7.5 Minute Topographic Quadrangle of Indiantown Gap, Pennsylvania, 1969, Photorevised 1977.

STOP 5
LOCATION MAP

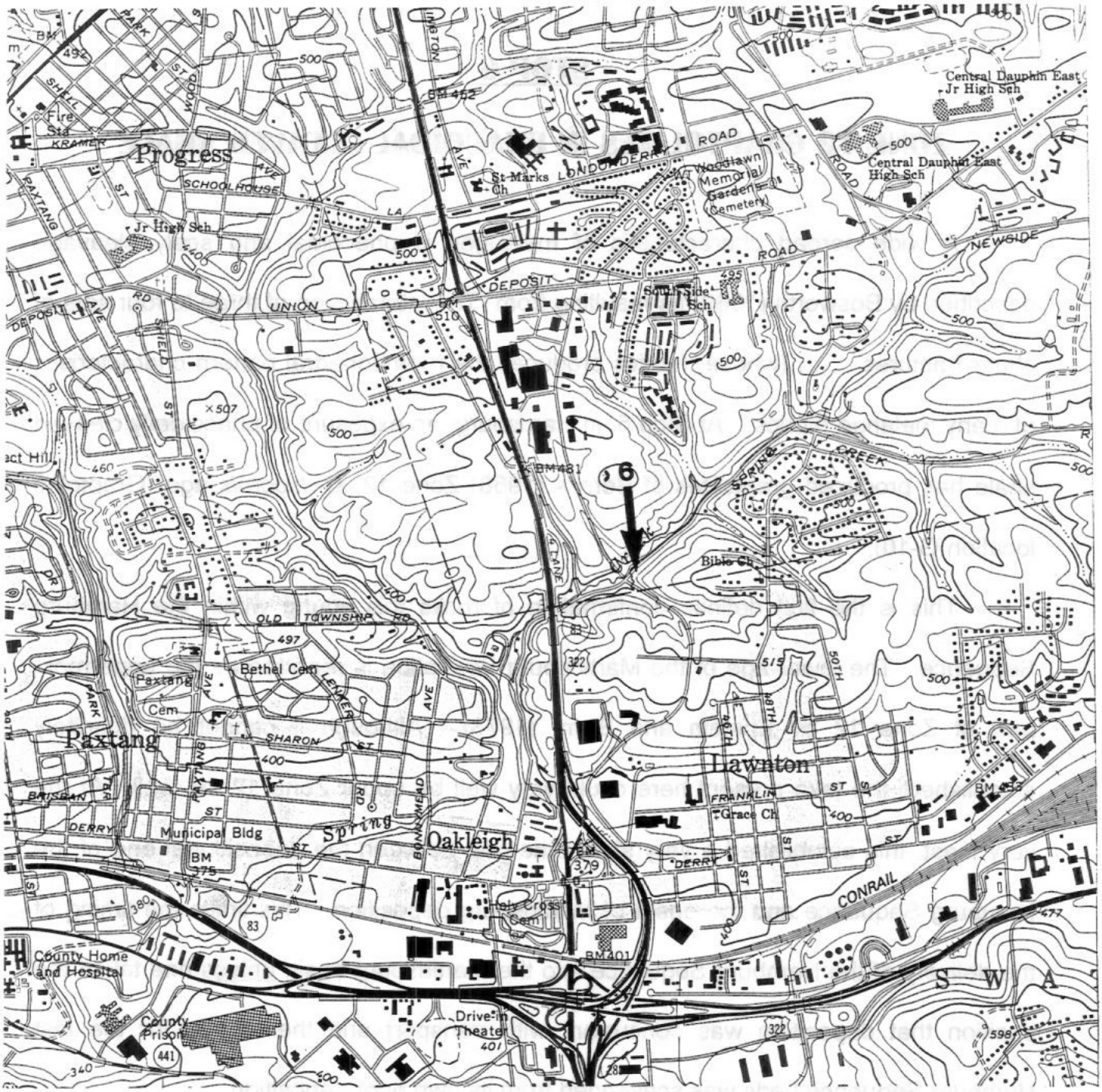
STOP 6

ZONE 12 GRAPTOLITES IN PHACOIDAL CLEAVED SHALE

A wide spread characteristic of melanges is phacoidal and scaly cleavage described by Bosworth (1989) as resulting from "The intersection of three to four sets of shear fractures . . . . (whose) fabrics produces the rhombohedral pattern characteristic of many melange fabrics." At Stop 6, in Harrisburg, an exposure of phacoidally cleaved shale has produced graptolites of Berry's (1968) Zone 12, *C. bicornis* age (Graptolite location G-10).

This is the first definite confirmation of rocks this young within the Hamburg Sequence. The lower age of the Martinsburg Formation is reported as the uppermost part of Zone 12 by Epstein and Berry (1973). Although it cannot be definitely established, the taxa present here could very well be upper Zone 12, as well. At the very least, this established a very short time gap between the depositional end of the Hamburg Sequence and the onset of Martinsburg deposition. This limits the timing of the delivery of the Hamburg Sequence into the Martinsburg basin unless one takes the position that deposition was concurrent with transport and the source for the last Hamburg Sequence beds was scavenged from its own prior deposition.

The scaly cleavage exhibited here and elsewhere was interpreted by Lash, et al. (1984) as shear surfaces in semilithified mud.



SCALE: 1" = 2000'
Base map is a reproduction of a U.S.G.S. 7.5 Minute Topographic Quadrangle of Harrisburg East, Pennsylvania, 1969, Photorevised 1987.

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STOP 6
LOCATION MAP

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APPENDICES

APPENDIX A. GRAPTOLITE FAUNA BY LOCATION

APPENDIX B. FIGURES OF GRAPTOLITE FAUNA

APPENDIX A

GRAPTOLITE FAUNA BY LOCATION

GRAPTOLITE FAUNA BY LOCATION

G-1 *Hustedeograptus sp.*
Age: Da3; mid Llanvirn

G-2 *Pterograptus sp. cf. P. elegans*
Archiclimacograptus sp.
Glossograptus sp. cf. G. holmi
Age: Da3; mid Llanvirn

G-3 *Archiclimacograptus sp.*
Dendrograptus sp.
Crytograptus schaeferi
Pseudophyllograptus sp.
Age: Da3; mid Llanvirn

G-4 *Archclimacograptus sp.*
Age: Probably Da3; mid Llanvirn

G-5 *Isograptus victoriae cf. I.v. victoriae*
Isograptus victoriae cf. I.v. lunatus
Tetragraptus sp. ?
Xiphograptus svalbardensis
Age: mid to late Arenig

G-6 *Archiclimacograptus sp.*
Glossograptus sp. cf. G. holmi
Crytograptus schaeferi
Dictyonema sp.
Age: Da3; mid Arenig

G-7 *Adelograptus sp. cf. A. tenellus*
Age: mid Tremadoc

GRAPTOLITE FAUNA BY LOCATION
(Continued)

G-8 NOT DESCRIBED HEREIN

G-9 NOT DESCRIBED HEREIN

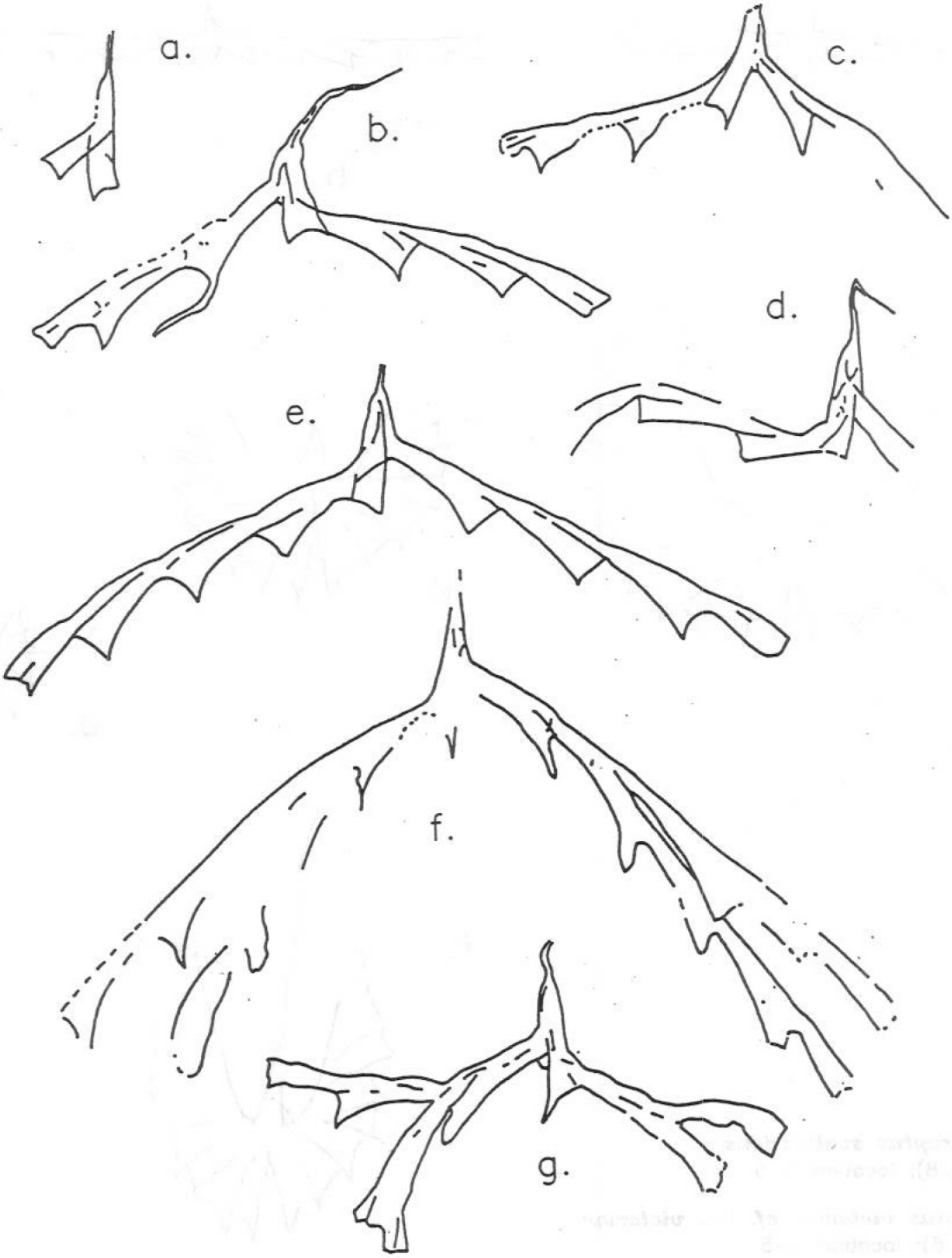
G-10 *Climacograptus bicornis*
Orthograptus amplexicaulis cf. O. a. intermedius
Age: Early Caradoc
(Berry's Zone 12)

LP 24 * *Dicellograptus sp. cf. D. sextans*
Pseudoclimacograptus scharenbergi
Pseudoclimacograptus stenostoma
Age: Early Caradoc
[Berry's Zone 11 (N. gracilis) or Early Zone 12 (C. bicornis)]

* Location from Carswell, et. al. (1968)

APPENDIX B

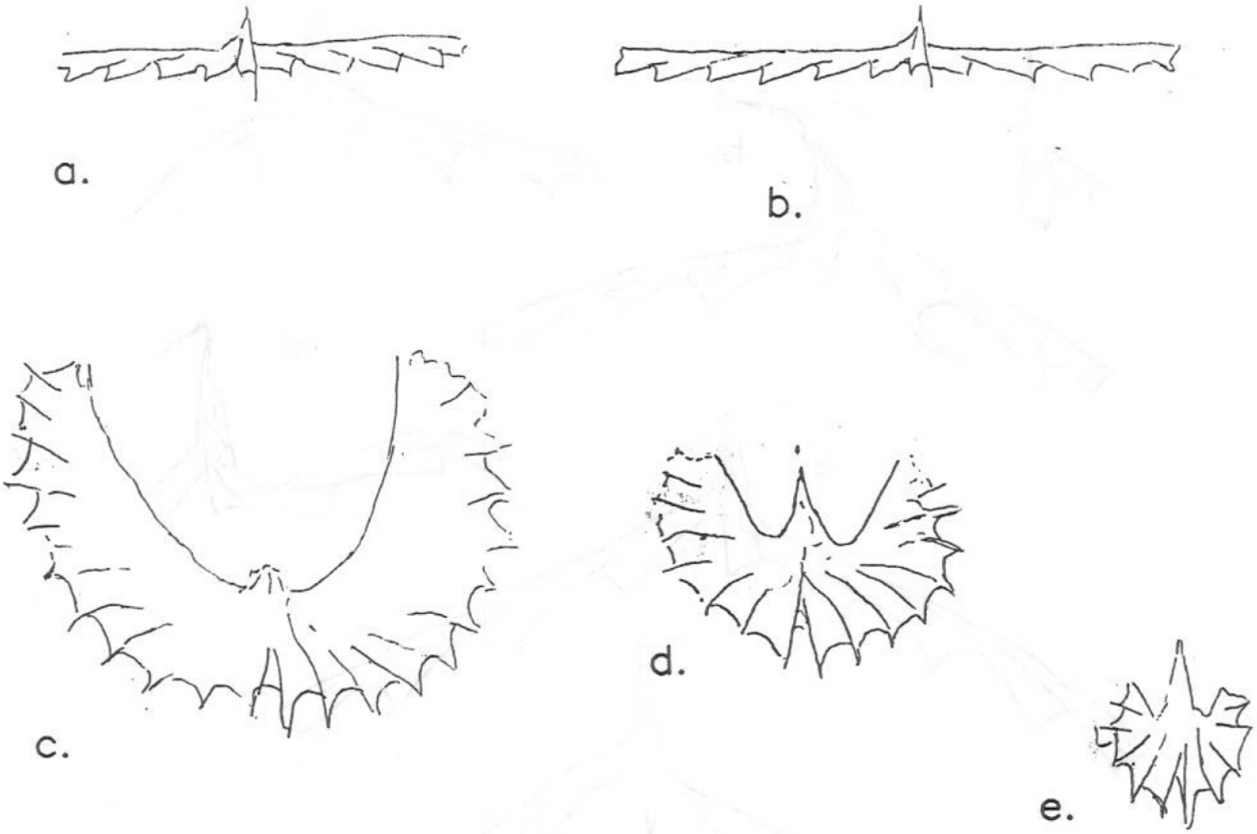
FIGURES OF GRAPTOLITE FAUNA



Adelograptus cf. A. Tenellus
a.–g.; (x15); location G–7

FIGURE 5
Tremadoc Graptolite Fauna

Drawings by S.H. Williams



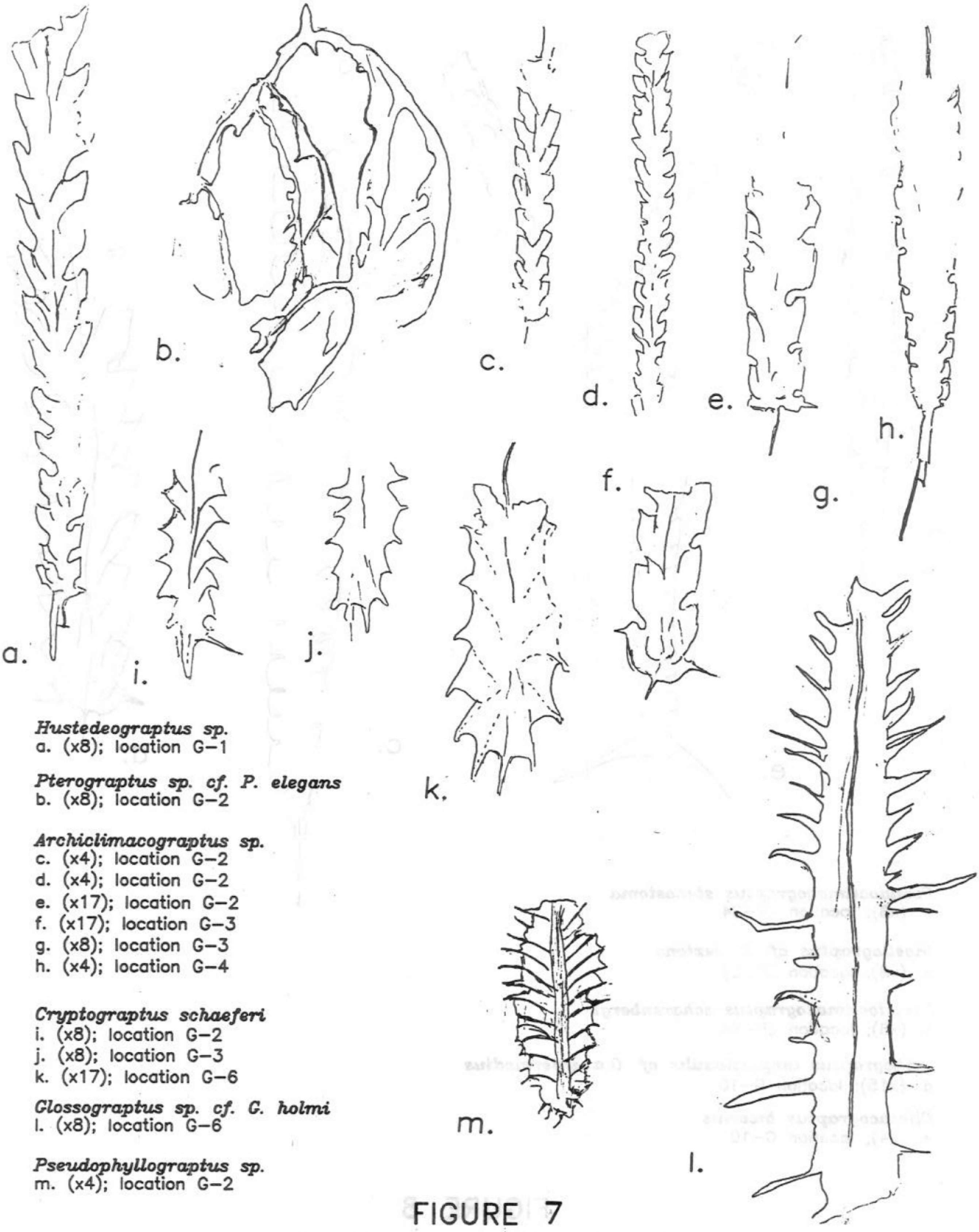
f.

Xiphograptus svalbardensis
a.–b. (x8); location G–5

Isograptus victoriae cf. I.v. victoriae
c.–f. (x8); location G–5

FIGURE 6
Arenig Graptolite Fauna

Drawings by S.H. Williams



***Hustedeograptus* sp.**
a. (x8); location G–1

Pterograptus* sp. cf. *P. elegans
b. (x8); location G–2

***Archiclimacograptus* sp.**
c. (x4); location G–2
d. (x4); location G–2
e. (x17); location G–2
f. (x17); location G–3
g. (x8); location G–3
h. (x4); location G–4

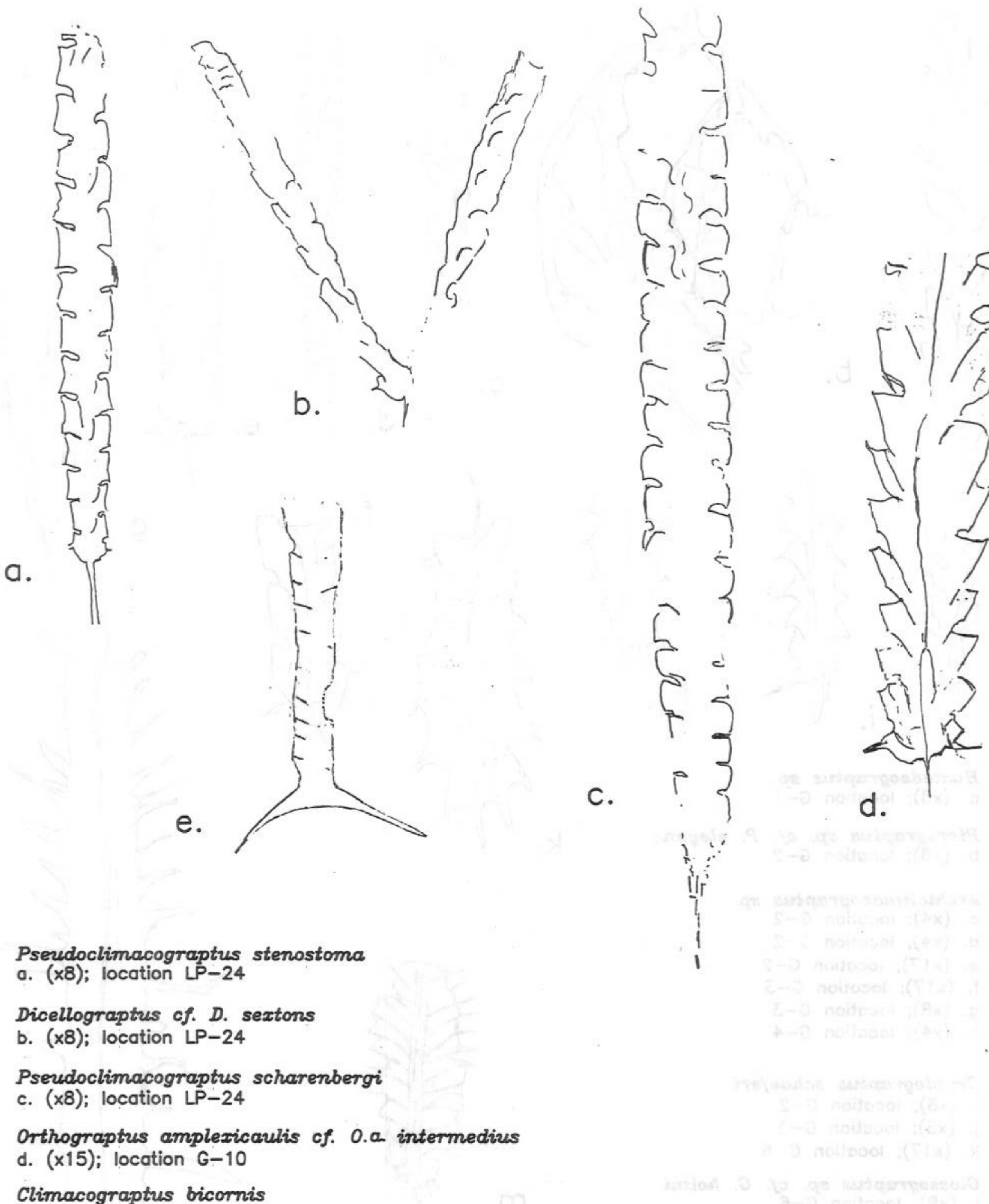
Cryptograptus schaeferi
i. (x8); location G–2
j. (x8); location G–3
k. (x17); location G–6

Glossograptus* sp. cf. *G. holmi
l. (x8); location G–6

***Pseudophyllograptus* sp.**
m. (x4); location G–2

FIGURE 7
Llanvirn Graptolite Fauna

Drawings a,c,d,e,f,g,h,i,j,k by S.H. Williams
Drawings b,l,m by G.R. Ganis



Pseudoclimacograptus stenostoma
a. (x8); location LP–24

Dicellograptus cf. D. sextons
b. (x8); location LP–24

Pseudoclimacograptus scharenbergi
c. (x8); location LP–24

Orthograptus amplexicaulis cf. O.a. intermedius
d. (x15); location G–10

Climacograptus bicornis
e. (x4); location G–10

FIGURE 8
Caradoc Graptolite Fauna

Drawings a,b,c,d by S.H. Williams
Drawing e by G.R. Ganis