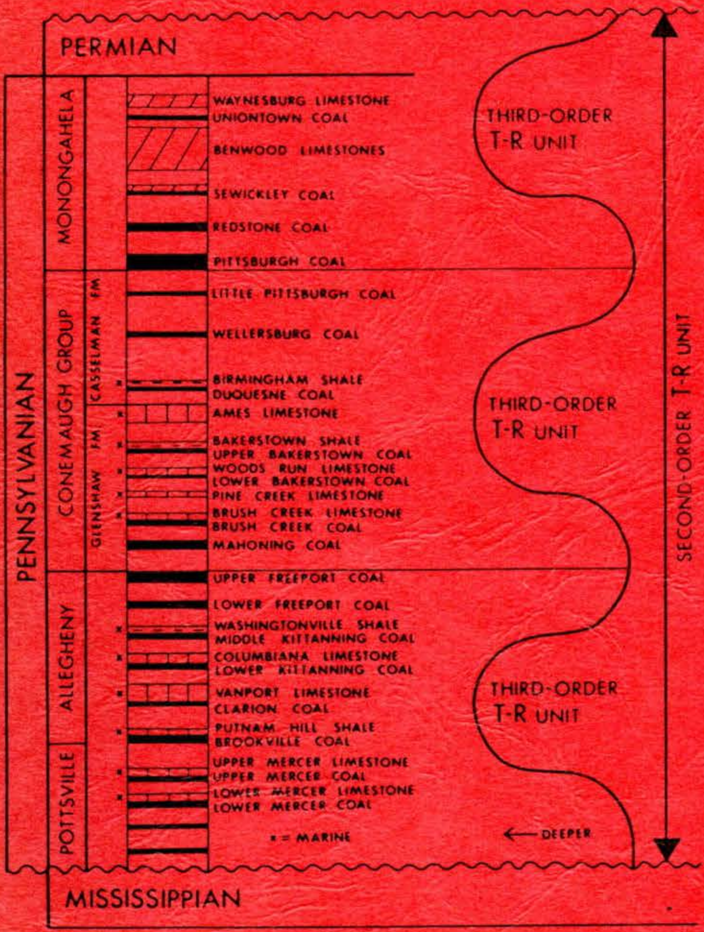
STRATIGRAPHIC ANALYSIS OF CARBONIFEROUS ROCKS IN SOUTHWESTERN PENNSYLVANIA USING A HIERARCHY OF TRANSGRESSIVE-REGRESSIVE UNITS



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Eastern Section Meeting of

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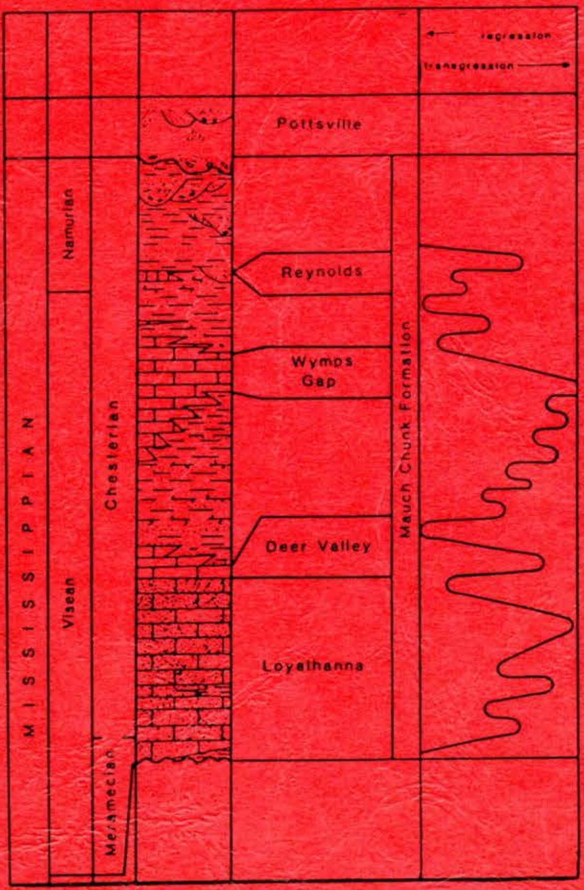

by

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and

David K. Brezinski

STRATIGRAPHIC ANALYSIS OF CARBONIFEROUS ROCKS IN SOUTHWESTERN PENNSYLVANIA USING A HIERARCHY OF TRANSGRESSIVE-REGRESSIVE UNITS -- A GUIDEBOOK

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FIELD TRIP III

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PREFACE

Mississippian and Pennsylvanian (Carboniferous) stratigraphic sequences have historically been the subject of extensive investigations because of their profound cyclic or rhythmic (i.e., cyclothemic) stratigraphy and their abundance of economic mineral resources (e.g., coal, hydrocarbons, clay, and limestone). Naturally, such investigations have been carried out at a variety of different scales of observation. This field trip will illustrate the effectiveness of describing, correlating, and interpreting Carboniferous stratigraphic sequences relative to a hierarchy of chronostratigraphic transgressive-regressive units (i.e.,"T-R units"). A total of six different scales of T-R units will be discussed as we correlate among outcrops of Upper Mississippian (Chesterian) and Upper Pennsylvanian (Desmoinesian, Missourian) strata in southwestern Pennsylvania.

We do not contend that our methods and ideas are "the final words" on Carboniferous stratigraphic analysis. Our methods and ideas are a current product of more than a century of testing other models and methods of analysis, and we encourage other workers to test and develop the methods and ideas presented herein. When combined with biostratigraphic, radiometric, and magnetostratigraphic data, a hierarchal scheme of allocyclic T-R units may provide a practical chronostratigraphic framework for the Carboniferous.

Much of the information provided herein is extracted from our Ph.D. dissertations (Brezinski, 1984; Busch, 1984) and Masters thesis (Wells, in progress) conducted at the University of Pittsburgh under senior advisor Harold B. Rollins, and additional advisors Thomas H. Anderson, Jack Donahue, Norman K. Flint, John Carter, and Jeffrey Schwartz.

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INTRODUCTION TO FIELD TRIP

Historical Background

The recognition and correlation of sedimentary sequences using a hierarchy of transgressive-regressive units (abbreviated "T-R units") is an old, but underemphasized, concept. For example, Suess (1888) suggested that a hierarchy of world-wide stratigraphic units be erected on the basis of at least three scales of "eustatic" (i.e., global) sea level cycles. Suess (1888, p. 537-540) wrote:

> "While the subsidences of the crust are local events, the subsidence of the sea extends over the whole submerged surface of the planet. As a first step towards an exact study of phenomena of this kind we must commence by separating from the various other changes which affect the level of the strand, those which take place at an approximately equal height, whether in a positive or negative direction, over the whole globe; this group we will distinguish as eustatic movements..... Such movements have occurred at various periods and in different degrees.... The middle Cretaceous transgression presents itself on the Amazon, the Athabasca, the Elbe, the Nile, the Tarym, and the Narbada, in Borneo and Saghalien, and on the Sacramento; it marks a general physical change which affected the whole surface of the planet. In this lies the explanation of the remarkable fact that it has been found possible to employ the same terminology to distinguish the sedimentary formations in all parts of the world. This would have been impossible if the limits of the formations had not been drawn by natural processes simultaneously in operation over the widest areas."

Nevertheless, Suess' eustatic hypothesis was not even considered by the authors of some of the most widely used texts on stratigraphy such as Grabau (1913) and Krumbein and Sloss (1963). More recently, Vella (1965, p. 5-8) provided one of the best arguments for using allocyclic T-R units as a means of systematizing much of stratigraphic classification:

> "Sedimentary cycles thus appear to be basic stratigraphic units, as Suess realized long ago, and to be closely related to standard rock-stratigraphic units (groups, formations), biostratigraphic units (zones), and time-stratigraphic units (stages, series, systems). Each sedimentary cycle corresponds to

one relative rise and fall of sea level, cuts across lateral facies changes, and, like a stage, consists of many interdigitating lithofacies and zones..... Far more important than the question of the possible cause of sedimentary cycles is the unavoidable conclusion, from objective stratigraphic and paleontological evidence, that sedimentary cycles (and associated unconformities) are synchronous, not diachronous, features -- a conclusion that has been voiced or implied by Suess, Stille, Klupfel, Wanless and Shepard, Hallam, Wells, Newell, Fairbridge, and Hollingworth.....

Only limited progress can be made by a purely empirical approach to stratigraphy. For further progress it is necessary to formulate and test working hypotheses. Four general working hypotheses have already been proposed in stratigraphy. The oldest is the long-rejected hypothesis of catastrophism. The second is the hypothesis of uniformitarianism, which Lyell considered to refute the catastrophic hypothesis, and which implies that all changes during the past were gradual. The third hypothesis is Suess' eustasism, which is really a more sophisticated version of catastrophism. The fourth is Stille's periodic catastrophism, which is merely an alternative for the features that Suess sought to explain by eustasism.

Stille's hypothesis is rejected mainly because of the strong evidence in many parts of the world that diastrophism is continous, not periodic. The hypothesis of uniformitarianism was probably not correctly interpreted by Lyell, because, as pointed out by Hollingworth (1962), present-day climate changes and sea level changes are not gradual in terms of geological time. The acceptance of Lyell's view by most present-day geologists, in spite of the advances in Quaternary geology since Lyell's time, seems to be really an admission of defeat, and no effort is made to test it. Suess' hypothesis seems to have little against it, and offers an extremely simple and satisfactory method of systematizing stratigraphy throughout the world. It has never been fairly tested, and we cannot know how it will work until it has been applied to known geological data.

Geologists long ago rid themselves of the naive belief that all stratigraphic boundaries are synchronous from place to place. Many have yet to rid themselves of the equally naive belief that all stratigraphic boundaries are diachronous from place to place or are purely local in extent. Each stratigraphic boundary, especially each unconformity, must be viewed with an open mind. Stratigraphic codes will need to provide formal nomenclature for sedimentary cycles, and for any other stratigraphic units required for testing any particular hypothesis. If they do not provide this nomenclature, progress in stratigraphy is likely to be seriously hindered."

Vella's landmark contribution to stratigraphy has gone virtually unnoticed and has been ignored by commissions on stratigraphic nomenclature.

The advent of seismic stratigraphy (i.e., especially seismic profiling) has recently done much to re-emphasize the importance of using transgressive-regressive units for stratigraphic description and correlation. For example, Vail et al. (1977) outlined a hierarchy of first-, second-, and third-order "depositional sequences" (i.e., T-R units) that can be correlated world-wide and are undoubtedly the net result of eustatic (global) sea level fluctuations. The Phanerozoic Eon is composed of two first-order depositional sequences having periodicities of 225 and 300 million years (Vail et al., 1977). Major unconformities within these first-order depositional sequences form the boundaries of second-order depositional sequences, having periodicities of tens-of-millions of years (Vail et al., 1977). Phanerozoic third-order depositional sequences have periodicities of 1 - 10 million years (Vail et al., 1977). Vail et al.'s work has been widely cited.

Recent isotope studies, mainly dealing with with oxygen isotopes in DSDP cores (e.g., Kerr, 1981a; Kerr, 1981b), have done much to reveal the presence of paleotemperature (i.e., climate) cycles corresponding to "minor" T-R units, as predicted by the Milankovitch Theory (Berger, 1980). Similarly, Anderson and Goodwin (1980) and Goodwin and Anderson (1980) have hypothesized that most stratigraphic sequences can be subdivided into allocyclic T-R units about 1 - 5 meters thick (i.e., punctuated aggradational cycles, or PACs) that can be correlated at least basinwide and represent intervals of tens-of-thousands of years. Anderson and Goodwin (1982) have since noted that PACs can be grouped into larger T-R units, or "cyclothemic PAC sequences", about 10 - 20 meters thick (Fig. 1). These cyclothemic PAC sequences, therefore, have periodicities of hundreds of thousands of years. Many workers have recognized T-R units of

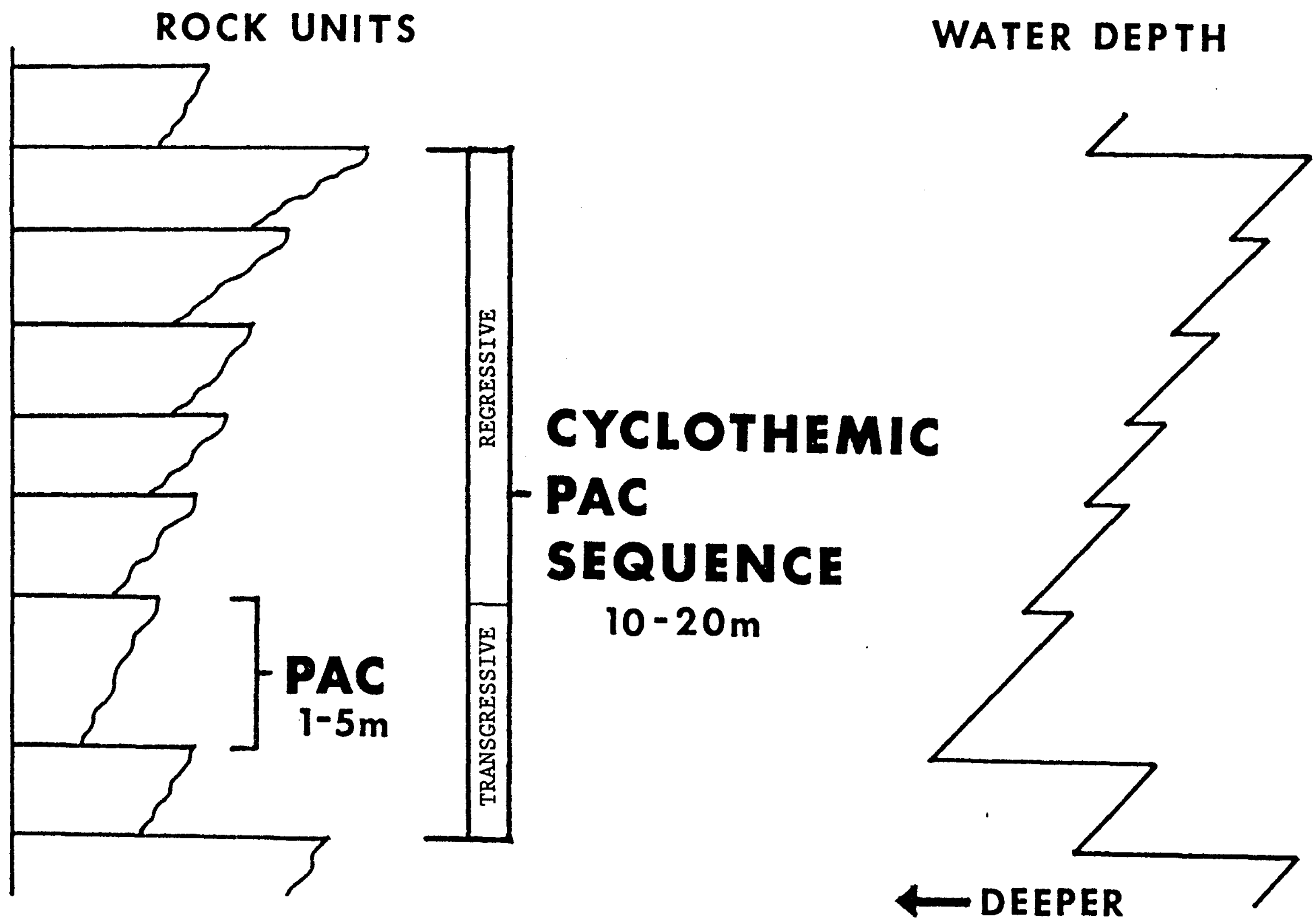


Figure 1: Concept of punctuated aggradational cycles (PACs) and cyclothemic PAC sequences, modified after Anderson and Goodwin (1982).

the same scale as PACs and cyclothemic PAC sequences, but very few workers have attempted to correlate such small-scale units. The PAC Hypothesis is simply the hypothesis that such minor T-R units exist and can be correlated at least basinwide. Unfortunately, the PAC hypothesis has been misinterpreted, underemphasized, and met with unfounded hostility from many "gradualists" who contend just the opposite (i.e., that most minor T-R units are local, autocyclic units that cannot be correlated) without ever testing to see if the opposite is true. As a result, the PAC Hypothesis remains largely untested.

Carboniferous T-R Units

Carboniferous sedimentary sequences have been subdivided into "sedimentary cycles" (e.g., Dawson, 1854; Newberry, 1874; Udden, 1912) or "cyclothems" (Wanless and Weller, 1932) for over a century. Chang (1975) and Ramsbottom (1979) have even defined hierarchal classifications of Carboniferous T-R units of Europe. Most recently, however, Busch (1984) and Busch and Rollins (1984) combined information on various scales of Carboniferous T-R units (e.g., Wanless and Wwller, 1932; Moore, 1936; Heckel, 1977; Heckel et al., 1979; Chang, 1975; Vail et al., 1977; and Ramsbottom, 1979) with the PAC Hypothesis (Anderson and Goodwin, 1980) to derive a hierarchy of time-stratigraphic T-R units relative to which Carboniferous sequences can be systematized (Table 1). According to this hierarchy, Vail et al.'s (1977) first-, second-, and third-order "depositional sequences" are referred to as first- second-, and third-order "T-R units". They are also referred to collectively as "major" scales of T-R units. All Mississippian rocks are part of one second-order T-R unit, and all Pennsylvanian rocks are part of another second-order T-R unit

TABLE 1: HIERARCHAL CLASSIFICATION OF CARBONIFEROUS TRANSGRESSIVE-REGRESSIVE UNITS

	Names of Carboniferous Transgressive-Regressive Units					
MAGNITUDE OF TRANSGRESSIVE-REGRESSIVE UNIT	Vail et al., 1977	Chang, 1975 and Ramsbottom, 1979	Moore, 1936	Anderson and Goodwin, 1980 and 1982 (as applied here)	Heckel 1977 and Heckel et al. (1979)	Wanless and Weller, 1932
1st Order: 225 to 300 million years	1st Order Depositional Sequences					
2nd Order: 65 million years	Penn.-Permian 2nd Order Depositional Sequence	Penn.-Permian Synthem				
3rd Order: 8 to 10 million years	3rd Order Depositional Sequence					
4th Order: 0.8 to 1,5 million years		Mesothems				
5th Order: 400 to 500 thousand years		Cyclothems	Megacyclothems	Cyclothemic PAC Sequences	Cyclothems	Cyclothems
6th Order: 100 to 225 thousand years			Cyclothems (ls.-shale couplets)	Punctuated Aggradational Cycles (PACs)	Minor T-R Sequences	

(Modified after Busch and Rollins, 1984)

(Vail et al., 1977). Therefore, Mississippian and Pennsylvanian sequences are separated by a major, global unconformity, and the largest T-R units within either Mississippian or Pennsylvanian sequences are the smaller third-order T-R units. Upper Pennsylvanian third-order T-R units of the Northern Appalachian Basin have periodicities of about 8 - 10 million years (Busch and Rollins, 1984).

In contrast to the three scales of major T-R units, there are also three scales of "minor" T-R units making up the Busch-Rollins (1984) hierarchy (Table 1). Fourth-order T-R units tend to have periodicities of about 0.8 - 1.5 million years in the Upper Pennsylvanian of the Northern Appalachian Basin and have been referred to as "mesothems" by Ramsbottom (1979). Fifth-order T-R units have periodicities of about 400,000 to 500,000 years and include Wanless-Weller (1932) cyclothems, Heckel's (1977) Kansas cyclothems, and Moore's (1936) megacyclothems. Sixth-order T-R units have periodicities not greater than about 100,000 to 225,000 years and can also be referred to as PACs (following Anderson and Goodwin, 1980) or "minor T-R sequences" (following Heckel et al., 1979).

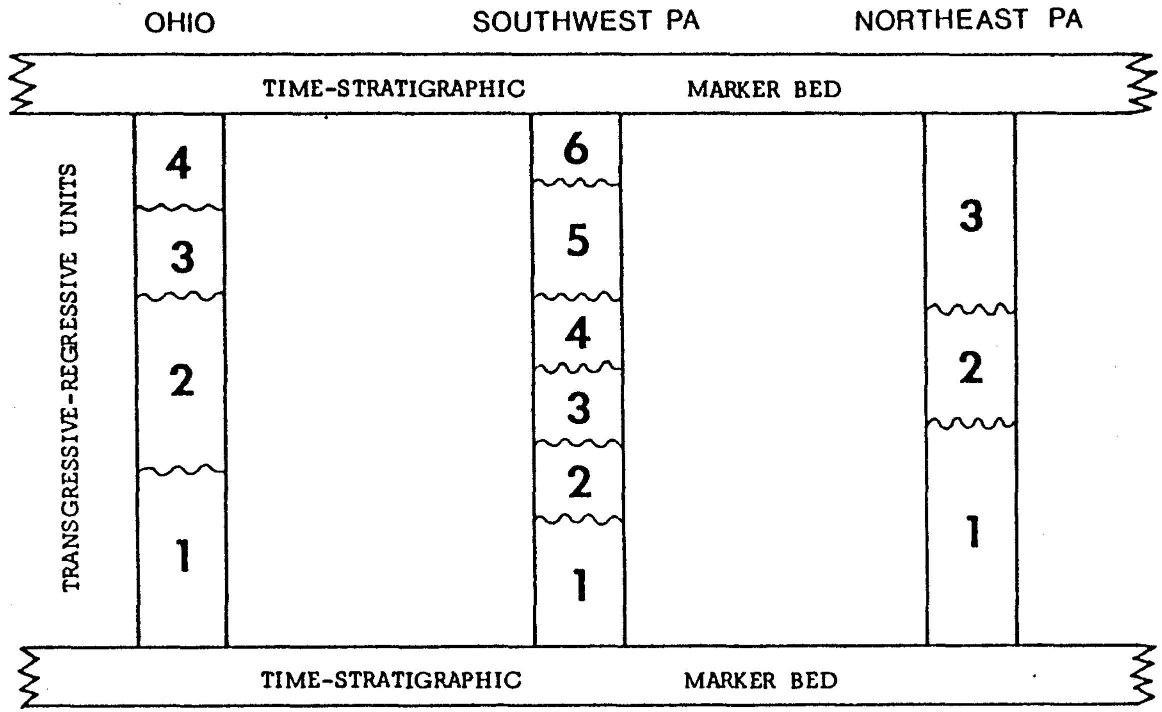
Allocyclicity vs. Autocyclicity

Stratigraphic sequences composed of T-R units can be the net result of an autocyclic mechanism, an allocyclic mechanism, or a combination of both. An autocyclic mechanism is a mechanism that operates only within a particular environment of deposition and is, therefore, largely generated by aspects of that local environment itself. An allocyclic mechanism is a mechanism that is not generated by aspects of any particular environment of deposition. Rather, it is an "overriding" mechanism which affects many environments of deposition simultaneously, even to a basinwide or global extent.

Busch and Rollins (1984) modeled hypothetical sequences of autocyclic T-R units and allocyclic T-R units relative to a time-stratigraphic interval between two hypothetical marker beds. They noted that if all the T-R units between the two marker beds are autocyclic, then there should be a variable number of those T-R units at different locations within the basin of deposition. For example (Fig. 2), if all fifth-order T-R units between two marker beds in the Appalachian Basin were formed by an autocyclic process such as delta switching, then one might find four of the fifth-order T-R units developed in Ohio, six in southwestern Pennsylvania, and three in northeastern Pennsylvania. On the other hand, if all the T-R units between two marker beds are allocyclic, then there should be a constant number of those synchronously-formed T-R units at different locations within the basin of deposition. For example (Fig. 3), if all fifth-order T-R units between two marker beds in the Appalachian Basin were formed by an allocyclic process such as eustatic sea level fluctuation, then one might find four of the fifth-order T-R units developed in Ohio, four in southwestern Pennsylvania, and four in northeastern Pennsylvania.

We have found that Carboniferous sequences of fifth-order T-R units in the Appalachian Basin are best explained by a model of allocyclic dominance with some concomitant autocyclic influence. The number of fifth-order T-R units between two marker beds is generally constant, but an "extra" unit is occasionally encountered (Busch and Rollins, 1984). An extra unit is generally considered to be the net result of an autocyclic process. Autocyclic channel-fill or fining-upward point-bar sequences are found at the top of some Mississippian (Brezinski, 1984) and Pennsylvanian (Busch, 1984) fifth-order T-R units. These intervals represent fluvial

DELTA SWITCHING MODEL FOR TRANSGRESSIVE-REGRESSIVE UNITS



AUTOCYCLIC

Figure 2: Hypothetical illustration of a stratigraphic interval between two time-stratigraphic marker beds, where T-R units of a certain scale have all been formed by an autocyclic process such as delta switching. If all of the T-R units are autocyclic, then there should be a variable number of such randomly-formed T-R units at different locations within the same basin. For example, if all fifth-order T-R units between two marker beds in the Appalachian Basin were formed by an autocyclic process such as delta switching, then one might find four of the fifth-order units developed in Ohio, six developed in southwestern Pennsylvania, and three developed in northeastern Pennsylvania. (Adapted from Busch, 1984)

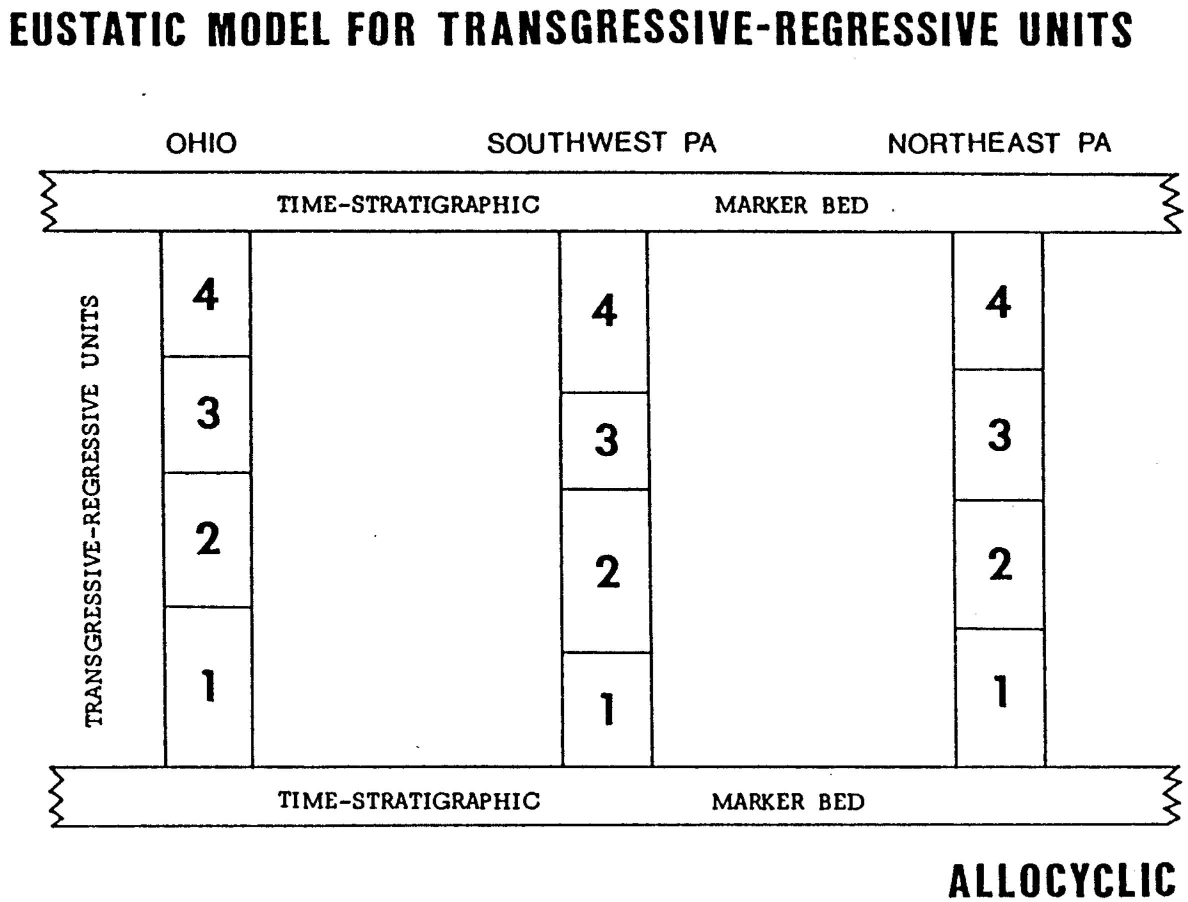


Figure 3: Hypothetical illustration of a stratigraphic interval between two time-stratigraphic marker beds, where T-R units of a certain scale have all been formed by an allocyclic process such as eustatic sea level fluctuation. If all of the T-R units are allocyclic, then there should be a constant number of such synchronously-formed T-R units at different locations within the same basin. For example, if all fifth-order T-R units between two marker beds in the Appalachian Basin were formed by an allocyclic process such as eustatic sea level fluctuation, then one might find four of the fifth-order units developed in Ohio, southwestern Pennsylvania, and northeastern Pennsylvania. (Adapted from Busch, 1984)

entrenchment that accompanied the regressive (progradational) phase of deposition of a T-R unit (Busch and Rollins, 1984).

Discussion of Field Trip

On the first day of this field trip we will examine the hierarchy of T-R units present in the Upper Pennsylvanian Conemaugh Group of southwestern Pennsylvania. The Conemaugh Group is essentially one third-order T-R unit (Busch and Rollins, 1984) that developed over an interval of about 10 million years (Shulik, 1979). The transgressive basal half of this Conemaugh third-order T-R unit extends from the base of the Upper Freeport coal (a third-order regressive maximum) to the Ames Limestone (a third-order transgressive maximum). This interval contains the entire Glenshaw Formation and is the interval we will examine most closely throughout day one (Fig. 4). The Glenshaw Formation is composed of fourth-, fifth-, and sixth-order T-R units.

As discussed by Busch (1984) and Busch and Rollins (1984), the most obvious T-R units within the Glenshaw Formation are the fifth-order T-R units, about 15 - 90 feet (5 - 30 meters) thick. The genetic surfaces between these units are either marine transgressive surfaces or "climate change surfaces" (Fig. 5). Transgressive surfaces are easy to discern, because they are simply defined as contacts between marine facies and the immediately subjacent nonmarine facies that was transgressed. Climate change surfaces are defined as contacts between nonmarine facies presumed to have formed under subaerial (often arid) conditions (e.g., paleosols or calcretes) and immediately superjacent nonmarine facies presumed to have formed under more humid (or subaqueous) conditions (e.g., coal or lacustrine limestones). As such, climate change surfaces tend to be more

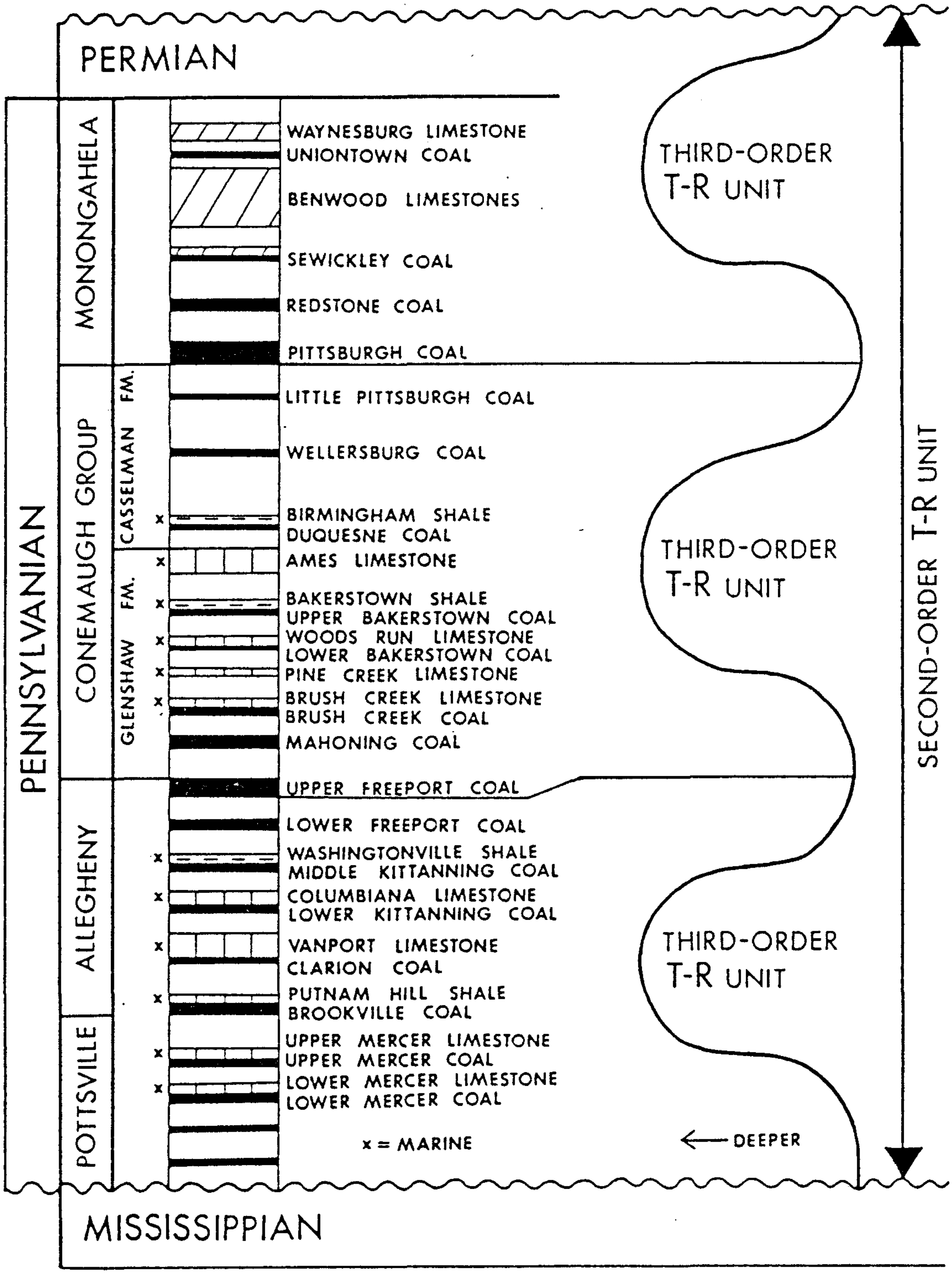


Figure 4: Schematic stratigraphy of the Pennsylvanian System of the Northern Appalachian Basin. Second-order and third-order T-R units are delineated relative to the position of prominent limestones and coals. (Adapted from Busch and Rollins, 1984)

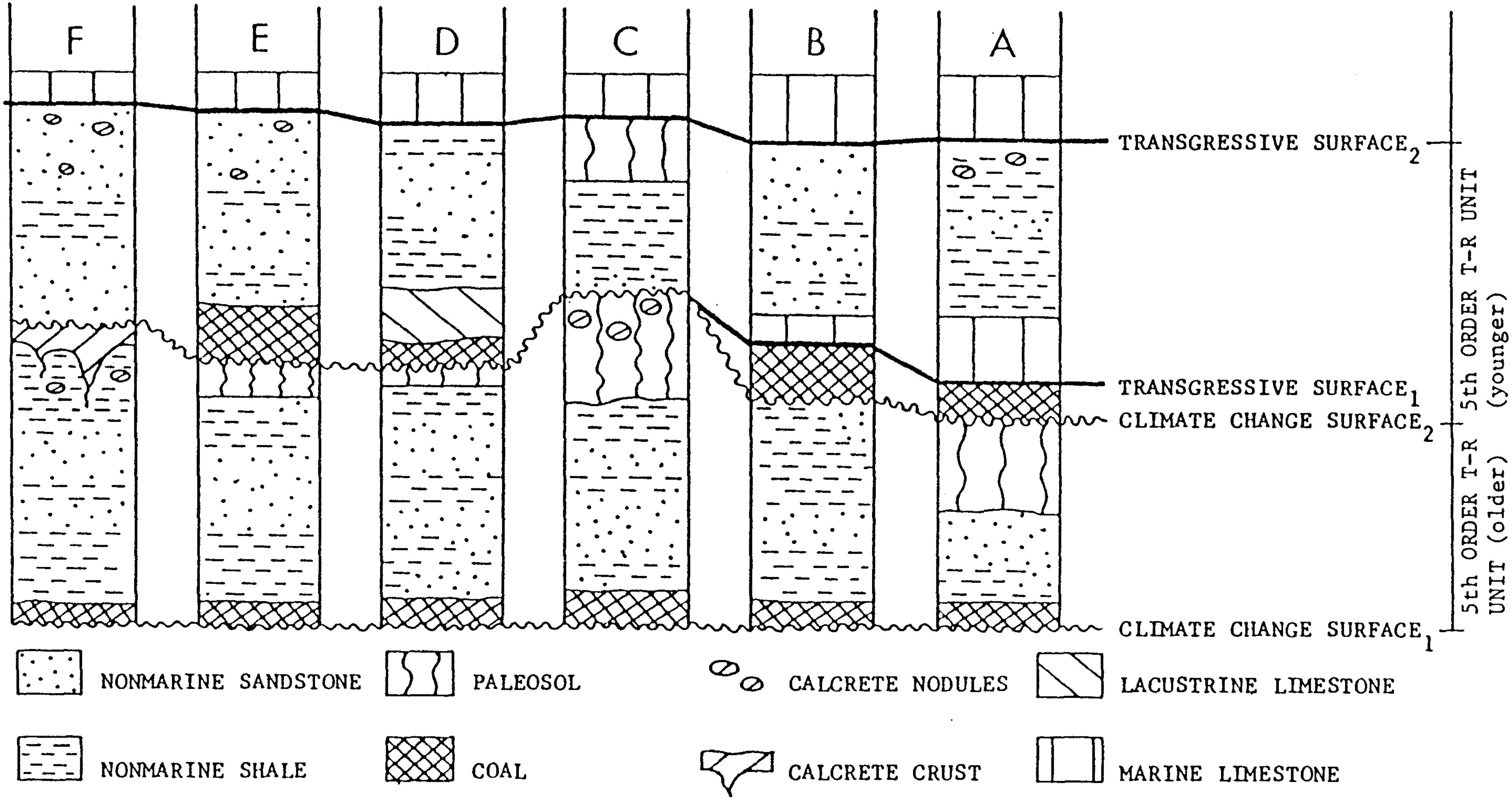


Figure 5: Schematic illustration of six hypothetical localities (A-F) to exemplify the two types of episodically developed surfaces commonly encountered in Pennsylvanian stratigraphic sequences of the Northern Appalachian Basin. Transgressive surfaces (▬▬) are easily defined as the contacts between marine facies (e.g., marine limestones) and immediately subjacent, transgressed, nonmarine facies (e.g., coals or paleosols). Climate change surfaces (∿∿) are defined as the contacts between subaerial nonmarine facies (e.g., calcretes or paleosols) and immediately superjacent, subaqueous to semi-subaqueous, nonmarine facies (e.g., lacustrine limestones or coals). (Adapted from Busch, 1984)

cryptic than transgressive surfaces. Nevertheless, Somerville (1979a, 1979b) and Wright (1981) have already divided some Lower Carboniferous rocks of Wales on the basis of the same type of widespread, prominent partings (i.e., climate change surfaces) at the top of paleokarstic surfaces (including calcretes) and paleosols. They attributed the formation of the partings to emergence (i.e., regression) at the end of a transgressive-regressive episode of deposition.

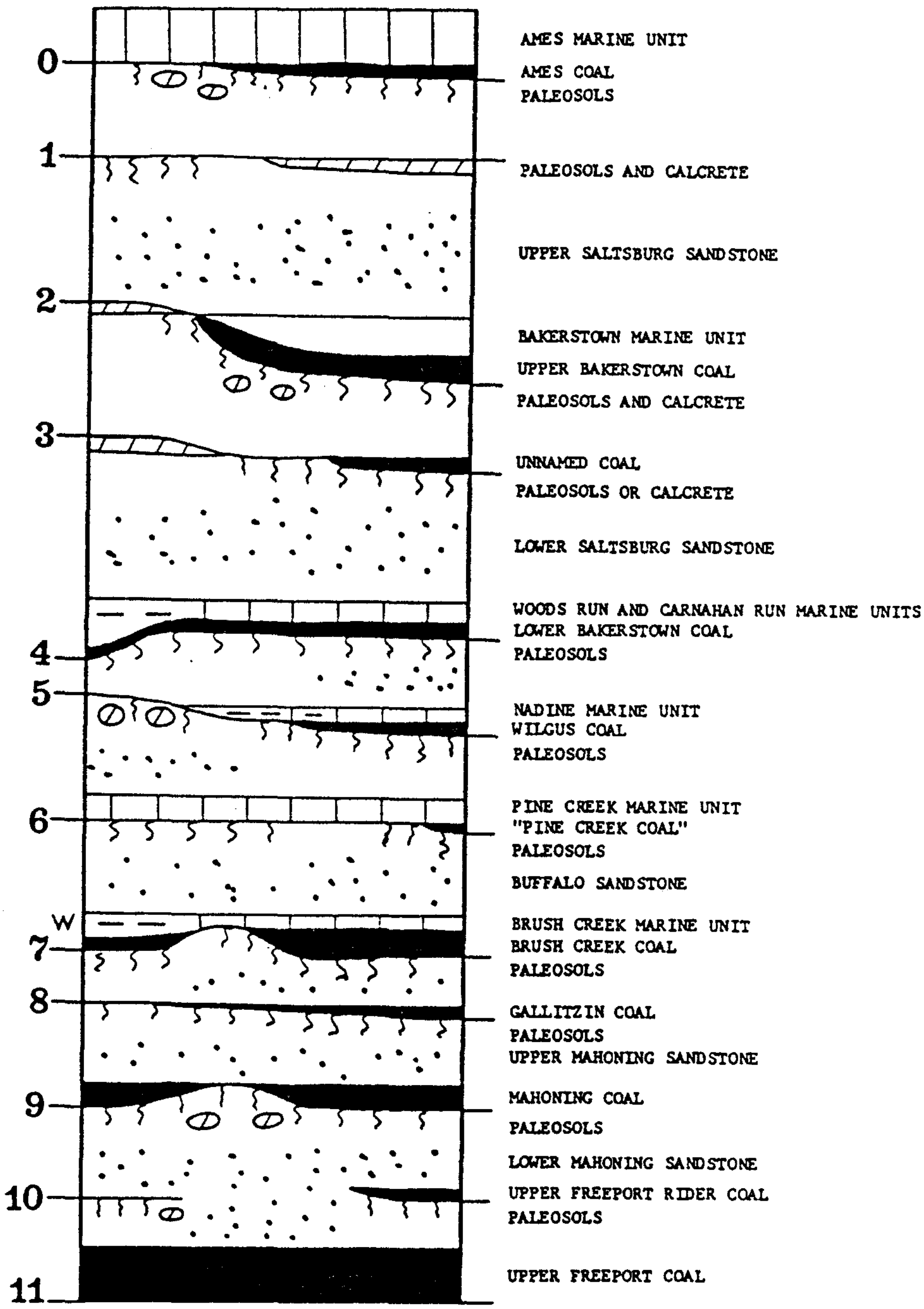
Two fifth-order T-R units are exemplified on figure 5. The older unit is located between climate change surface 1 and climate change surface 2. The younger unit is located between climate change surface 2 and transgressive surface 2. Note that this younger fifth-order T-R unit also contains transgressive surface 1 between its basal transgressive coal (nonmarine) and the marine limestone marking maximum transgression. Transgressive surface 1 is not a fifth-order genetic surface, but climate change surface 1, climate change surface 2, and transgressive surface 2 are fifth-order genetic surfaces. Therefore, the character of any genetic surface, when traced laterally, can vary between being a climate change surface or a transgressive surface. The transgressive surfaces are probably formed as a series of nearly isochronous, sixth-order (i.e., PAC-scale) transgressive surfaces arranged in stepwise fashion until maximum transgression is achieved (Anderson et al., 1984). Climate change surfaces, however, tend to represent the actual start of transgression at the same time at each locality. For example, climate change surface 2 on figure 5 marks the start of a fifth-order transgressive phase. It probably developed as a result of a sixth-order transgressive phase (i.e., climate change) that resulted in the formation of coals and gleyed paleosols at many localities (e.g., Holbrook, 1973). A second sixth-order transgression probably resulted in the formation of transgressive surface 1 at locality A, while the formation of coal, lacustrine limestone, and gleyed paleosols continued at all other localities. Finally, a third sixth-order transgression caused transgressive surface 1 to develop at (i.e., transgress) locality B. This third sixth-order transgression thus resulted in the formation of marine limestone at localities A and B, while gleyed soils, coals, or lacustrine limestones continued to form at the other localities depicted. It would also have marked the time of maximum transgression developed during deposition of the younger (upper) fifth-order T-R unit; however, other sixth-order genetic surfaces could be present in the upper (i.e., regressive) part of that fifth-order T-R unit.

Twelve fifth-order genetic surfaces, separating eleven fifth-order T-R units, can be delineated from the base of the Upper Freeport coal (i.e., fifth-order genetic surface 11) to the base of the Ames coal and/or Ames marine unit (i.e., fifth-order genetic surface 0). We will examine all twelve of these fifth-order genetic surfaces, which Busch and Rollins (1984) simply referred to as "transgressive surfaces" 11 - 0.

Fourth-order T-R units, or mesothems (Ramsbottom, 1979), can be delineated within the Glenshaw Formation based upon variations in the development of marine facies among the fifth-order T-R units (Fig. 7). For example, the most widespread marine facies developed during the Ames marine event, and no marine facies developed during the Upper Freeport Rider, Mason-Gallitzin, Unnamed, or Harlem transgressive phases. The fourth-order genetic surface between fourth-order T-R units 3 and 2 is evident because the Woods Run marine event was more extensive than the Cambridge-Nadine event. It is possible to define five complete

Figure 6: Generalized stratigraphy of the stratigraphic interval from the Upper Freeport coal to the Ames Limestone (Glenshaw Formation, Conemaugh Group) for Allegheny County, Pennsylvania. Numbers along the left margin denote fifth-order genetic surfaces (i.e., climate change surfaces and transgressive surfaces) separating fifth-order T-R units. Total thickness of this interval is about 350 feet.

w = Worthenia tabulata (gastropod) epibole.



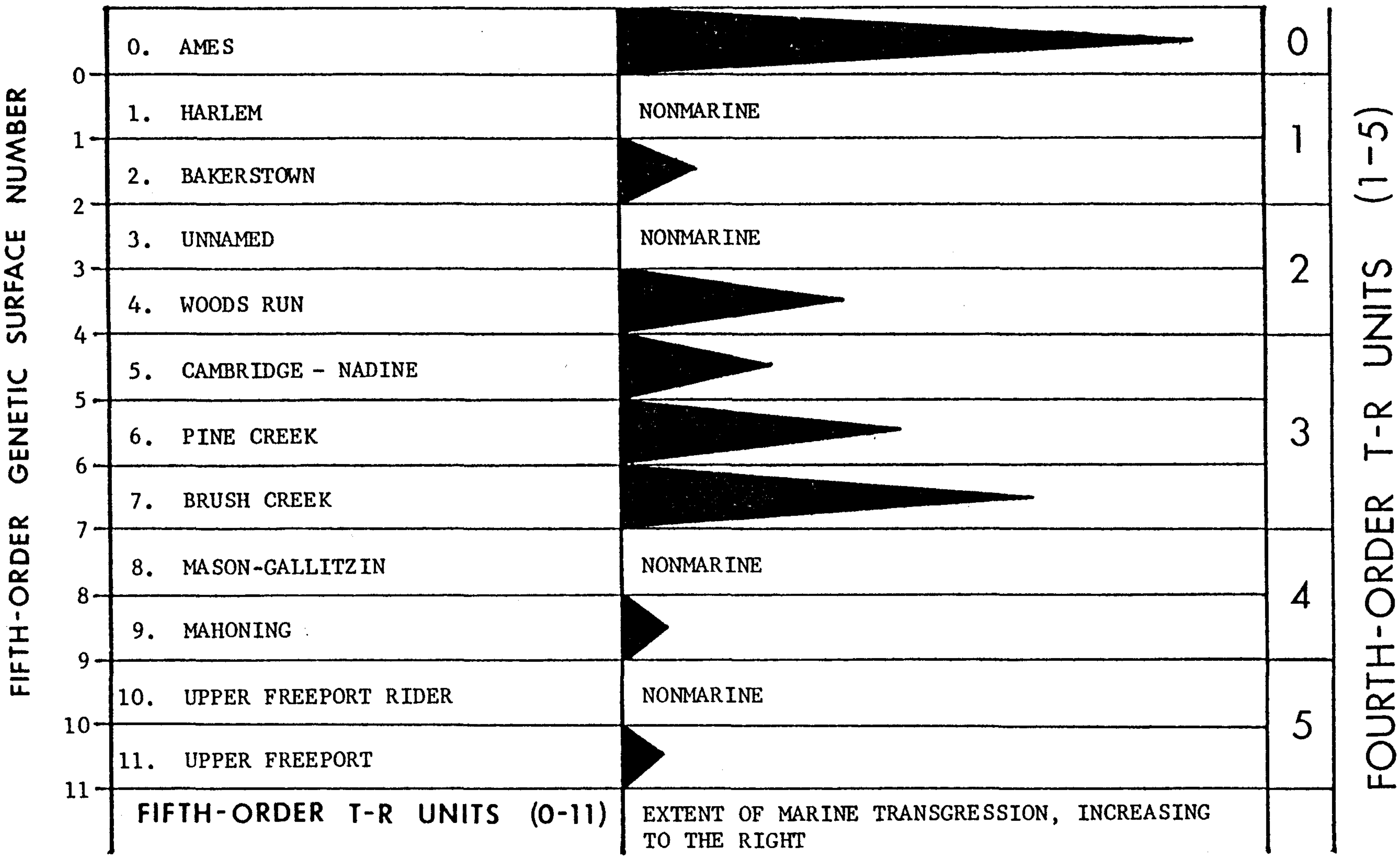


Figure 7: Fourth-order T-R units of the Glenshaw Formation - Upper Freeport Coal study interval delineated on the basis of relative extent of maximum marine transgression within the fifth-order T-R units. See text for discussion. (Adapted from Busch, 1984)

fourth-order T-R units from the base of the Upper Freeport coal (i.e., fifth-order genetic surface 11) to the base of the Ames coal (i.e., fifth-order genetic surface 0). (Busch, 1984)

We will discuss the development of sixth-order T-R units (i.e., PACs) throughout the field trip, particularly at stop 6 on the first day, where we will view two sixth-order T-R units within the Brush Creek marine unit. The exposure and availability of macrofossils within two limestones and their surrounding marine shales within the Brush Creek marine unit at stop 6 is excellent and clearly reveals the presence of two sixth-order T-R units. Two sixth-order T-R units may also be present within the Brush Creek marine unit at stop 2 (of the first day). Prior study of faunal diversity changes upwards through the Brush Creek interval there by Shaak (1972) suggests the presence of only a single transgressive-regressive trend; however, Shaak's samples were widely-spaced spaced samples of gross lithofacies changes and were, therefore, probably not adequate to reveal the presence of a sixth-order T-R unit within the basal 1 - 2 feet of the marine facies. Wells (1984, this guidebook) has noted the presence of sixth-order T-R units at some localities of the Woods Run marine unit, and she is in the process of evaluating the lateral persistence of such units.

On the second day of the field trip, we will examine an Upper Mississippian (Chesterian) third-order T-R unit that extends from the top of the Mississippian Pocono Formation to the disconformable base of the Pennsylvanian Pottsville Formation (also a second-order genetic surface), as illustrated in figure 8. The transgressive maximum of this third-order T-R unit is represented by the most open marine facies of the Wymps Gap Limestone. Furthermore, this third-order T-R unit constitutes the Mauch

Chunk Formation of Pennsylvania (Fig. 9).

Three fourth-order T-R units can be delineated within the Mauch Chunk third-order T-R unit in Pennsylvania (Fig. 8). They are the Loyalhanna, Wymps Gap, and Reynolds fourth-order T-R units, which we will examine throughout the second day of the field trip. We will also discuss the development and lateral persistence of fifth-order T-R units within the fourth-order T-R units.

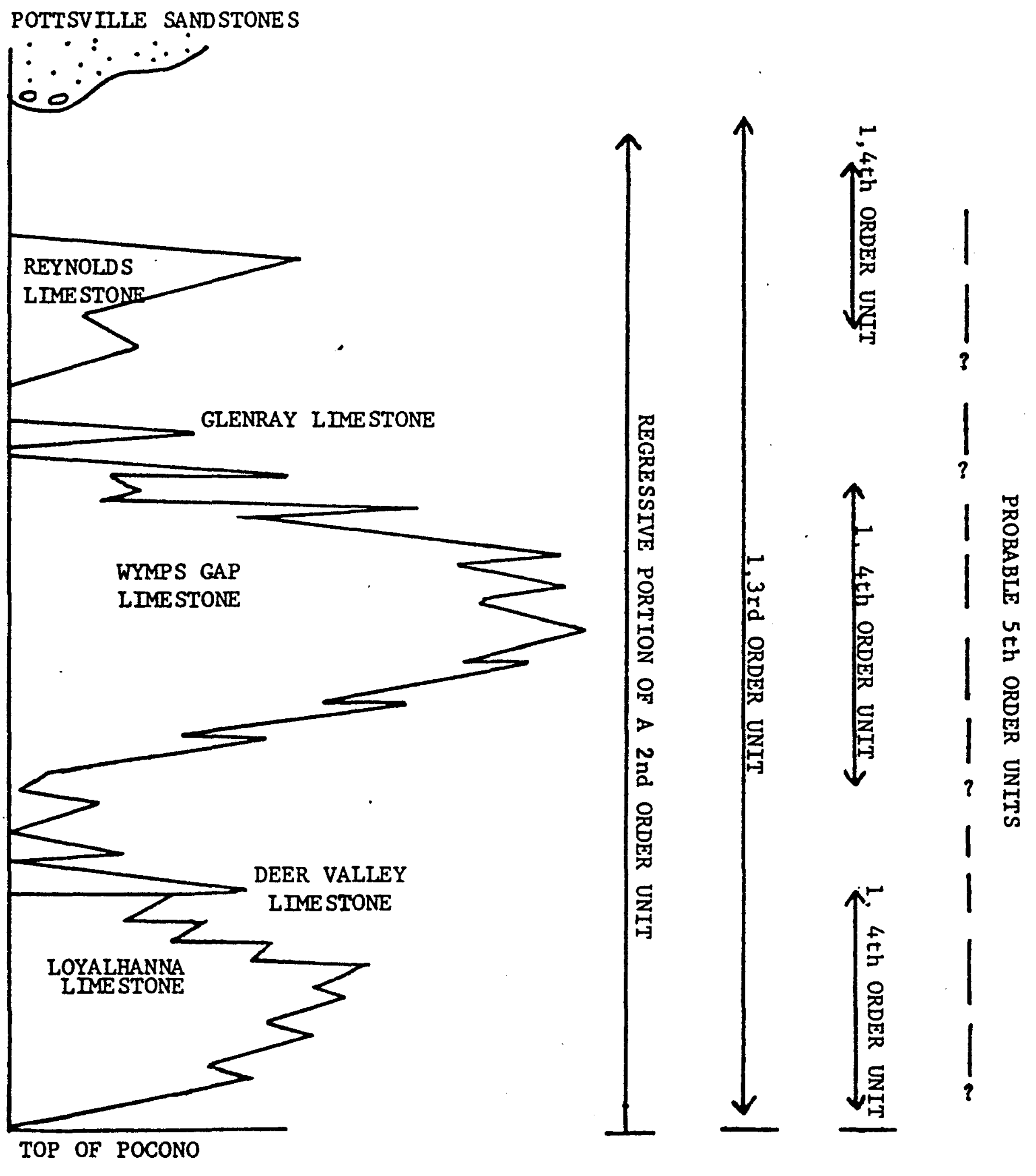


Figure 8: Upper Mississippian T-R units in southwestern Pennsylvania, to be examined on day 2 of the field trip.

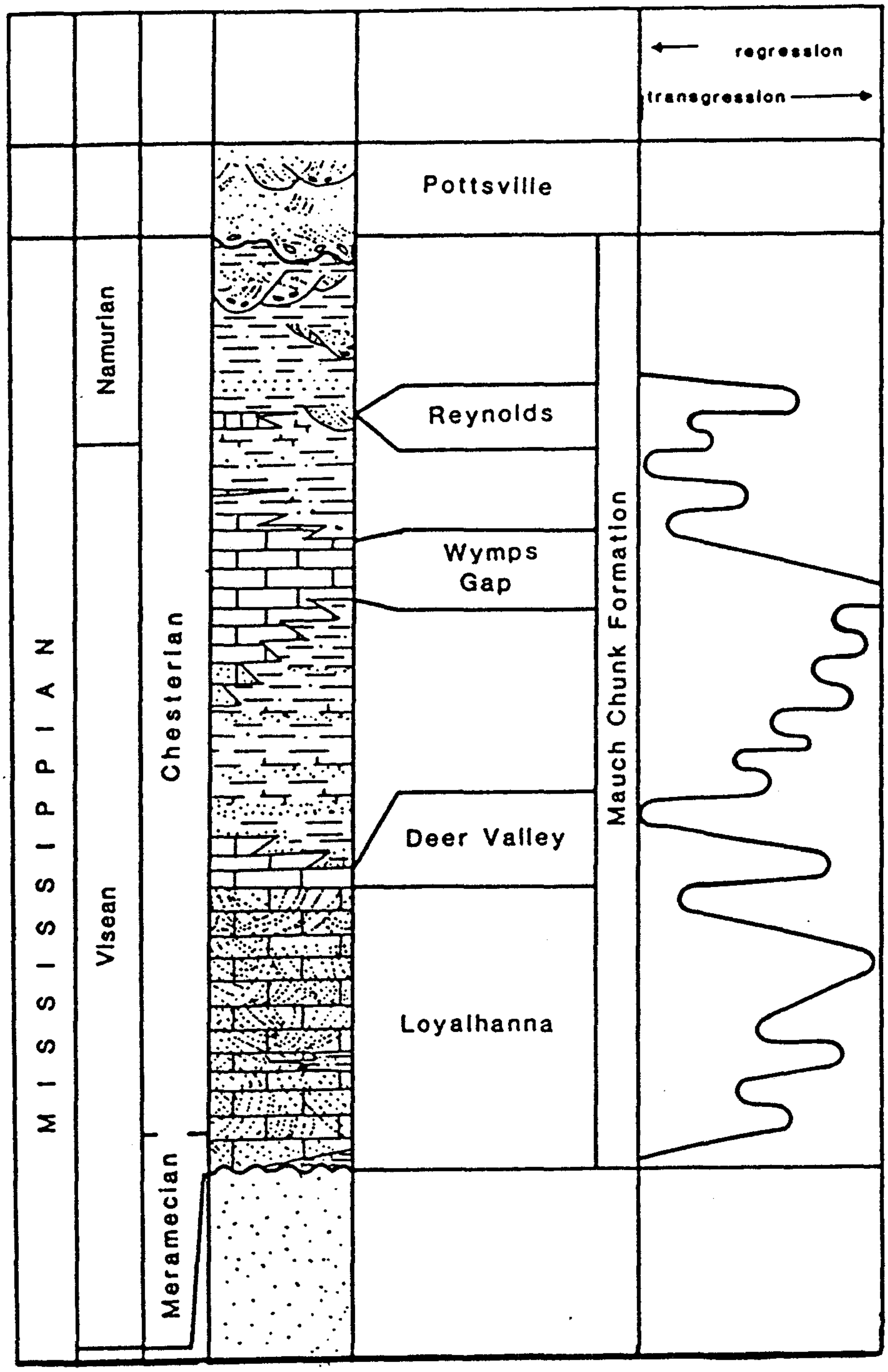
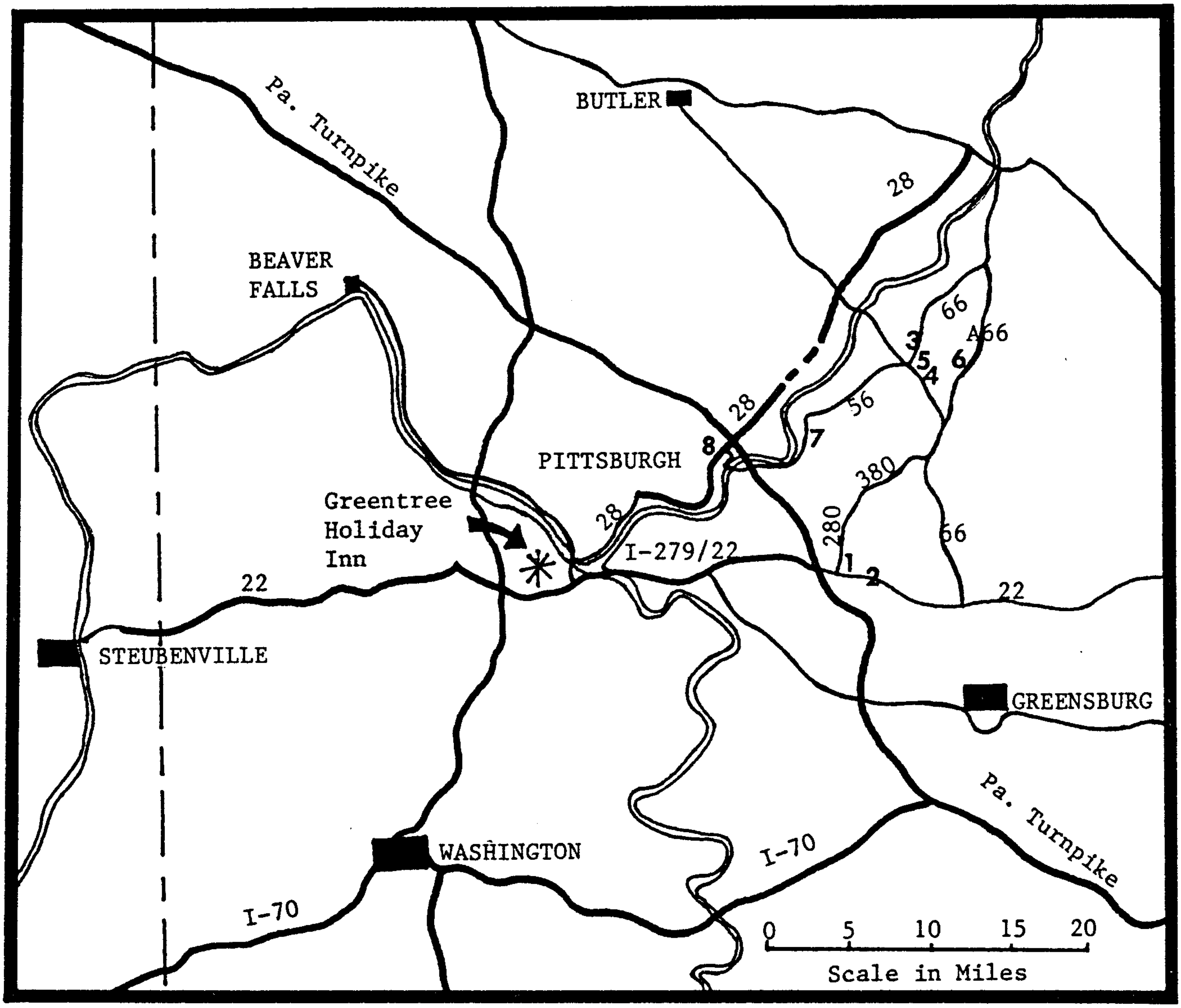


Figure 9: Subdivisions of the Upper Mississippian (Chesterian) Mauch Chunk Formation in southwestern Pennsylvania as discussed by Brezinski (1984).

FIELD TRIP ROAD LOG, SATURDAY OCTOBER 13, 1984.

UPPER PENNSYLVANIAN STRATIGRAPHY



= State Route Numbers. = Field Trip Stops.

Figure 10: Field trip route map for day one, Saturday October 13, 1984.

Total Miles	Interval Miles	
0.0	0.0	Leave Greentree Holiday Inn parking lot via long driveway.
0.1	0.1	Turn Left onto Mansfield Ave.
0.5	0.4	Turn Right onto Greentree Road.
0.6	0.1	Turn Left onto Parkway East (Interstate Route 279) towards Pittsburgh.
2.3	1.7	Enter Fort Pitt Tunnel; stay in right-hand lane.
3.15	0.85	Exit Right, onto Route 376 East.
14.2	11.05	Note Pittsburgh coal on both sides of Route 376 near the crest of the hill. The base of the Pittsburgh coal is the top boundary (i.e., third-order genetic surface) of the Conemaugh third-order T-R unit (Fig. 4) and, as such, is a third-order regressive maximum. The Pittsburgh coal itself forms the base of another, superjacent (i.e., younger) third-order T-R unit.
17.2	3.0	Exit Left, onto Route 22 East towards Murraysville. Note the outcrops of Casselman Formation lithofacies along the highway, which constitute the regressive upper portion of the Conemaugh third-order T-R unit.
17.3	0.1	Pass under Pennsylvania Turnpike; note the additional exposures of Casselman Formation (Upper Conemaugh Group) lithofacies.
18.3	1.0	STOP 1: Park on right-hand side of Route 22 at the Driving Range. The Ames Limestone marker bed is exposed directly across the highway; it overlies fifth-order genetic surface 0 (Fig. 6) and forms the transgressive maximum of the Conemaugh third-order T-R unit (Fig. 4). The Ames marine unit also forms the base of fourth-order T-R unit 0 on figure 7. The Bakerstown marine unit (overlying genetic surface 2 - figure 6) and the Woods Run marine unit (overlying genetic surface 4 - figure 6) are exposed to the east, as described in figure 11.
		Continue East on Route 22.
18.6	0.3	Note red platy shales of the Bakerstown marine unit on right-hand side of highway, behind the Bi-Lo gas station.
19.15	0.55	Note the thin, cryptic Woods Run marine unit (limestone)

STATE: PA COUNTY: ALLEGHENY QUAD.-LOC NO: MURRAYSVILLE - 1

LATITUDE: 40N° 26 ′ 10 ″ LONGITUDE: 79W° 44 ′ 38 ″

TWP.: SECTION:

NATURE OF EXPOSURE: From intersection of Routes 22 and 286, west along Route 22 to Ames exposure on north side of highway at above coordinates.

DESCRIPTION BY: Busch & Wells

5th ORDER GENETIC SURFACE	UNIT DESCRIPTION OF EXPOSURE	FT.	IN.
	1. buff, platy to flaggy, unfossiliferous shale	6+	
	2. AMES: pale olive clay shale with common chonetids and <u>Crurithyris</u>	1	6
	3. AMES: gray, very argillaceous, marine limestone; phosphatic in basal 6" at granules; common marine fossils, especially <u>Crurithyris</u>	1	6
	4. AMES: highly fossiliferous, pale olive shale	1	
	5. Coal smut; 0 - 2" thick (Ames Coal)		2
0			
	6. gray, crumbly claystone	4	
	7. concealed interval: thickness measured with level, then corrected for a dip of 15 feet / mile based upon Sarg (1971) structure contour map.	35	
	8. BAKERSTOWN: red and tan, platy shale with bivalves, mostly <u>Dunbarella</u> and nuculoids.	7	6
2			
	9. white clay, plastic, with smut coal streaks		1
	10. pale olive, flaggy clay shale	10	6
	11. Coal smut (Unnamed Coal)		½
3			
	12. white, plastic clay		1
	13. gray, crumbly claystone	5	
	14. medium to dark gray, silty, platy to flaggy shale with plant fragments, <u>Planolites</u>, and cross-laminated lenses of siltstone and very fn.-gr. sandstone.	14	
	15. medium to dark gray, platy shale with plant fragments and <u>Planolites</u>	18	6
	16. platy, dark gray shale, with plant fragments and ironstone nodules to 1" in diameter	3	
	17. WOODS RUN: nodular, bioturbated, very argillaceous, ferruginous calcilutite to calcarenite with abundant marine fossils (RB-82-282)		4
	18. WOODS RUN: ferruginous, dark gray to black, shelly marine shale (RB-82-281)		2
4			
	19. platy, dark gray, unfossiliferous shale	5	

Figure 11: Description of stratigraphy exposed at stop 1 (adapted from Busch, 1984).

		within dark gray shales exposed on the left-hand side of Route 22, beneath overpass.
20.0	0.85	Turn Right into Murphy Mart Shopping Center and park. STOP 2: Figure 12 is a description of strata exposed along Route 22 across from the shopping center parking lot and on the hillside at the western edge of the parking lot. The complete stratigraphic section contains the Glenshaw Formation interval from genetic surface 7 (beneath the Brush Creek marine unit) to genetic surface 2 (beneath the Bakerstown marine unit). Leave stop 2, and proceed back to Route 22 via exit driveway at east end of shopping center parking lot.
20.4	0.4	Turn Left at traffic light, onto Route 22 West.
20.9	0.5	Exit Right off of Route 22 to a stop sign, then proceed Right (East) on Route 286.
27.2	6.3	Pass Route 366 overpass.
32.2	5.0	Turn Right onto Route 66 North at stop sign -- Turn Right at stop sign to continue on Route 66 North.
34.05	1.85	Bear Left onto Route 356.
37.45	3.4	Turn Left at stop sign.
39.1	1.65	Turn Right onto Route 56.
40.35	1.25	Proceed straight through traffic lights (and thereby leave Route 56) towards Leechburg.
40.9	0.55	STOP 3: Park on left side of road beneath billboards. We will examine the lower portion of the Glenshaw Formation which is exposed along the highway on the hill where we are parked. The stratigraphic section (Fig. 13) starts at the bridge at the base of the hill, adjacent to the river (where the Upper Freeport coal overlying fifth-order genetic surface 11 is exposed). The very top of this stratigraphic section (Fig. 13) is located in a small abandoned quarry (genetic surfaces 4 and 5) that we do not have permission to examine. We will, however, examine the same interval nearby at stop 4. Make a U-Turn and proceed south, back towards Route 56.
41.3	0.4	Turn Left at traffic light, onto New Route 56; proceed East towards Vandergrift.
42.0	0.7	Make U-Turn at first intersection; proceed West on Route 56.

STATE: PA COUNTY: ALLEGHENY QUAD-LOC NO: MURRAYSVILLE - 2

LATITUDE: 40N ° 25 ' 39 " LONGITUDE: 79W° 42 ' 20 "

TWP.: SECTION:

NATURE OF EXPOSURE: Northwest side of Route 22 and northwest edge of adjacent shopping center parking lot, to 0.4 mile west of intersection at above coordinates. Also known as "William Penn Supply Co. locality".

DESCRIPTION BY: Busch.

5th ORDER GENETIC SURFACE	UNIT DESCRIPTION OF EXPOSURE	FT.	IN.
	1. BAKERSTOWN: red and tan, platy shale, with Dunbarella and nuculoids	8	
	2. Coal smut (Upper Bakerstown Coal)		½
2			
	3. white clay with coaly streaks		3
	4. pale green, silty, flaggy to platy shale	10	6
	5. Coal smut (Unnamed Coal)		½
3			
	6. white, plastic clay		½
	7. gray crumbly claystone	5	
	8. flaggy, pale green-gray shale, with scattered zones bearing plant fragments	36	6
	9. dark gray platy shale, with plant fragments	4	
	10. WOODS RUN: dark gray, platy shale with marine fossils common (RB-82-286)	1	3
	11. WOODS RUN: massive, calcareous shale to very argillaceous limestone, with abundant marine fossils. (RB-82-285)		6
4			
	12. dark gray, platy to flaggy shale; weathers buff, plant fragments uncommon in upper part.	13	6
	13. NADINE: intraclastic ironstone or highly weathered, ferruginous, intraclastic limestone; bears molds of crinoid columnals in thin section (RB-82-307; RB-83-89).		6
5			
	14. buff, platy to flaggy shale with thin interbeds of very fn.- to fn.-gr. sandstone	9	6
	15. gray platy shale, unfossiliferous	4	6
	16. PINE CREEK: gray, platy to fissile shale, weathers buff and bears marine fossils plus calcilutite nodules (RB-82-284)		6
	17. PINE CREEK: massive, gray to brown, crinoidal calcilutite to fine calcarenite (RB-82-283)	1	
	18. PINE CREEK: gray to green-gray, silty soft shale, with marine fossils including crinoids and brachiopods.		1
6			
	19. interbedded thin- to medium-bedded siltstone or very fn.-gr. sandstone and platy gray shales; calcrete lenses in upper 4 feet, to 4 inches thick.	11	
	20. flaggy, micaceous siltstone, with fn.-gr. sandstone lenses 1 - 6 inches thick and cross-laminated.	12	
	21. dark gray, platy shale, with plant fragments and lenses of very fn.- to fn.-gr. sandstone that have disconformable basal contacts.	15	6
	22. dark gray platy shale, with plant fragments; occasional thin lenses of fn.-gr. sandstone	11	
	23. BRUSH CREEK: dark gray, platy shale, with ironstone nodules and marine fossils	6	
	24. Coal, 0 - 14 inches thick (Lower Brush Creek Coal)	1	2
7			
	25. dark gray shale with plant fragments	3+	

Figure 12: Description of stratigraphy exposed at stop 2 (adapted from Busch, 1984).

STATE: PA COUNTY: WESTMORELAND QUAD.-LOC NO.: VANDERGRIFT - 1

LATITUDE: 40N ° 37 ' 17 " LONGITUDE: 79W ° 36 ' 48 "

TWP.: ______ SECTION: ______

NATURE OF EXPOSURE: "Gosser Hill Section": along highway from south end of bridge across Kiskiminetas River at West Leechburg, up hill (south) to abandoned quarry at the above coordinates.

DESCRIPTION BY: BUSCH & WELLS

5th ORDER GENETIC SURFACE	UNIT DESCRIPTION OF EXPOSURE	FT.	IN.
	1. brown, unfossiliferous, flaggy siltstone	8+	
	2. platy, green-gray, unfossiliferous shale	17	
	3. CARNAHAN RUN: dark gray to dark olive, platy shale with marine fossils (RB-82-312 at base, RB-82-313 at 3' above base, RB-82-314 at 6' above base, RB-82-315 at 9.5' above base, RB-82-316 at top)	11	6
4			
	4. medium gray, platy shale with common plant fragments	13	
	5. NADINE: Burke (1957) noted the presence of a thin marine zone at this horizon, at this locality, but it is now concealed.		6?
5			
	6. medium gray, platy shale with plant fragments; largely concealed	4	
	7. concealed	6	
	8. medium- to cs.-gr., cross-bedded, buff to white sandstone; base is disconformable	16	
	9. buff, platy shale with plants and plant fragments	2	
	10. PINE CREEK: brown, flaggy, soft shale with molds of brachiopods, crinoids, etc., there are also weathered ironstone nodules	4	
	11. PINE CREEK: gray, very argillaceous, crinoidal calcilutite with brachiopods and thick calcareous shale interbeds. RB-82-310 at base; RB-82-311 at 8" above base.	2	6
	12. PINE CREEK: gray-green, soft clay shale, with molds of marine fossils; RB-82-309 at base.	2	9
	13. dark gray to black, platy to flaggy shale with coal streaks and plant fragments	4	10
	14. Coal (Upper Brush Creek - Pine Creek)		8
6			
	15. brown/gray claystone		6
	16. fissile, dark gray shale	12	
	17. green-gray, platy shale with scattered, large ironstone nodules	4	
	18. BRUSH CREEK: dark gray, platy to flaggy shale with uncommon marine fossils including <u>Worthenia tabulata</u>		4
	19. BRUSH CREEK: Nodular, arenaceous, crinoidal calcilutite; argillaceous and bearing ironstone nodules and marine fossils (RB-82-308)		8
7			
	20. interlaminated, cross-laminated, very fn.-gr. sandstone and dark gray siltstone	4	
	21. thin-bedded, current cross-laminated, argillaceous, very fn.- to fn.-gr. sandstone, grades upwards into dark gray platy, silty shale.	20	6
	22. Coal (Mason - Gallitzin Coal)		2
8			
	23. brown/gray claystone	5	
	24. brown, platy shale	7	
	25. fn.- to cs.-gr. sandstone, medium- to thick bedded and interbedded with thin beds of gray to brown, platy shale	8	
	26. Olive, flaggy to platy shale, becoming gray-brown upwards	12	6
	27. dark gray claystone with coal streaks	1	
9			
	28. brown to gray claystone with caliche nodules	17	
	29. brown, flaggy, silty shale	11	
	30. medium to cs.-gr. sandstone in beds 1" - 6" thick and interbedded with brown, flaggy shale of similar bed thicknesses; shale content increases upwards; sandstone beds of relatively constant thickness and with very low-angle cross-laminations (cravasse-splay sequence?)	15	
	31. cross-laminated to cross-bedded, medium- to cs.-gr. sandstone in beds 2" to 6" thick, with thin brown shale partings; base disconformable.	7	
	32. silty, flaggy, gray shale	3	6
	33. medium to dark gray, platy to flaggy shale, with common plants, plant fragments, and ironstone nodules	15	6
	34. Coal, bright and dull bands, upper and lower bench discernible. (Upper Freeport Coal)	4	
11			
	35. gray clay		

Figure 13: Description of stratigraphy exposed at stop 3 (adapted from Busch, 1984).

42.15	0.15	STOP 4: Park by the roadcut on the right-hand side of Route 56, near a few small trees. The Carnahan Run Shale facies of the Woods Run marine unit (overlying fifth-order genetic surface 4 - figure 6) is exposed here (Fig. 14). Continue west on Route 56 towards opposite end of same roadcut.
42.5	0.35	STOP 5: Park by the roadcut on the right-hand side of Route 56. It is possible to examine fifth-order genetic surfaces 3 and 2 at this end of the roadcut (Fig. 14). Note that the lithofacies surrounding genetic surface 3 at this stop are much different than those encountered surrounding genetic surface 3 at stop 2. Continue West on Route 56.
42.7	0.2	At traffic lights, make another U-Turn and again proceed East on new Route 56 to Vandergrift.
46.05	3.35	Stop sign in Vandergrift: bear left after stop sign, onto Alternate Route 66 North (also still Route 56 East).
46.4	0.35	Turn Left at intersection to continue on Alternate Route 66 North: proceed north across bridge.
46.55	0.15	Turn Left at traffic light on north side of bridge, onto Lincoln Ave.
46.6	0.05	Turn Right onto Kepple Ave.
47.1	0.5	STOP 6: Park at the top of the hill on the left-hand side of the road. An excellent exposure (Fig. 15) of the Glenshaw Formation interval from fifth-order genetic surface 11 (beneath the Upper Freeport coal) to fifth-order genetic surface 7 (beneath the Brush Creek marine unit) is present along the Kepple Ave. hill that we just ascended. The Brush Creek marine unit is composed of two sixth-order T-R units here. The first of the sixth-order T-R units is composed of units 10 through 6 on figure 15. The base of a second sixth-order T-R unit is composed of units 5 through 1 on figure 15. Make a U-Turn and proceed east, back down the Kepple Ave. hill
47.55	0.45	Turn Left onto Lincoln Ave.
47.6	0.05	Turn Right onto Alternate Route 66 South; proceed South across the bridge.

STATE: PA COUNTY: WESTMORELAND QUAD.-LOC NO.: VANDERGRIFT - 3

LATITUDE: 40N ° 36 ′ 47 ″ LONGITUDE: 79W ° 37 ′ 09 ″

TWP.: ________ SECTION: ________

NATURE OF EXPOSURE: Steep roadcut on northeast side of Route 56, Weinel Crossroads, starting at above coordinates and running northwest.

DESCRIPTION BY: Busch & Wells

5th ORDER GENETIC SURFACE	UNIT DESCRIPTION OF EXPOSURE	FT.	IN.
	1. buff, platy shale (interbedded with brown siltstone in upper 23')	34+	
	2. BAKERSTOWN: olive, platy shale, mottled red and containing productid brachiopods and bivalves (Dunbarella and nuculoids); RB-82-330.	5	6
2			
	3. medium gray, platy shale, interbedded with some flaggy siltstone and very fn.-gr. sandstone; base is disconformable with about 2' of relief.	10	
	4. gray and red, crumbly claystone	6	6
	5. brown to buff, platy to flaggy clay shale	8	6
3			
	6. pale olive, platy to flaggy, very calcareous, silty shale, with calcrete lenses to several inches thick	7	
	7. green, silty, flaggy shale	11	
	8. dark gray, platy to flaggy, silty shale, with plant fragments	11	6
	9. CARNAHAN RUN: gray-green to dark gray, flaggy shale with common marine fossils (KW-83-41); common Amphiscapha		6
	10. CARNAHAN RUN: dark gray, platy shale with marine fossils (crinoids and Amphiscapha.	1	
	11. CARNAHAN RUN: dark gray to gray-green, platy shale with calcilutite nodules (i.e., KW-83-40) and lenses of marine fossils including Amphiscapha.	1	
4			
	12. dark gray, arenaceous, platy to flaggy shale, micaceous and bearing plant fragments plus plants (e.g., Neuropteris)	6	

Note: At the western side of the roadcut, the Carnahan Run Shale is comprised of about 10 feet of dark olive shale, platy, and with Dunbarella and Amphiscapha, in place of units 9-11 above.

Figure 14: Description of stratigraphy exposed at stops 4 and 5 (adapted from Busch, 1984).

STATE: PA COUNTY: ARMSTRONG QUAD.-LOC NO.: VANDERGRIFT - 2

LATITUDE: 40N° 36′ 30″ LONGITUDE: 79W° 33′ 38″

TWP.: SECTION:

NATURE OF EXPOSURE: Along road on northwest side of North Vandergrift that leads to Kepple Hill and parallels Route 66, section starts at above coordinates.

DESCRIPTION BY: BUSCH

5th ORDER GENETIC SURFACE	UNIT DESCRIPTION OF EXPOSURE	FT.	IN.
	1. platy to flaggy, unfossiliferous, gray-green shale	20+	
	2. BRUSH CREEK: medium gray, platy to flaggy shale with Dunbarella	2	
	3. BRUSH CREEK: dark gray, fissile to platy shale with Dunbarella and other bivalves	1	
	4. BRUSH CREEK: dark gray, fissile to platy shale, with ironstone nodules and common marine fossils		8
	5. BRUSH CREEK: medium gray, arenaceous and argillaceous, nodular calcilutite with common marine fossils		3
	6. BRUSH CREEK: dark gray, fissile shale with bellerophontacean gastropods and microfossils only	1	4
	7. BRUSH CREEK: dark gray, fissile to platy shale, with ironstone nodules and common marine fossils including Worthenia tabulata		3
	8. BRUSH CREEK: medium gray, arenaceous and argillaceous, nodular calcilutite with common marine fossils		6
	9. medium to dark gray, platy shale with common plant fragments and plants	7	3
	10. Coal, smut (Lower Brush Creek Coal)		1
7			
	11. cross-laminated, very fn.-gr. sandstone and siltstone, medium gray	8	6
8?			
	12. dark gray (basally) to tan (top), crumbly claystone with caliche nodules	8	9
	13. very pale olive, flaggy, crumbly shale	14	9
9			
	14. light gray, plastic clay		2
	15. medium to dark gray, crumbly claystone with caliche nodules to 4" diameter	1	6
	16. nonmarine limestone, caliche-calcrete type.	1	2
	17. brown to tan, crumbly claystone	4	10
	18. oxblood-red, crumbly claystone; 8" to 28"	2	4
	19. pale, gray-green, platy to flaggy, arenaceous shale with lenses of very fn.-gr. sandstone basally; 9' to 10.5' thick	9	
10			
	20. gray, crumbly claystone with a light gray clay at top and also with a very discontinuous smut coal layer on top of the unit.	2	6
	21. basal micaceous, fn.-gr. sandstone and siltstone bearing large plants, grades upward into pale gray-green, platy to flaggy shale; there are nodules or lenses of calcrete, highly fractured, argillaceous, in upper 6'.	26	6
	22. medium to dark gray, platy to flaggy shale with plants occasionally	19	2
	23. dark gray to black, platy shale with plant fragments	3	
	24. black, platy to fissile shale, unfossiliferous		
	25. Coal, bright, poorly exposed (Upper Freeport Coal)	2	11
11			
	26. gray, crumbly claystone		

Figure 15: Description of stratigraphy exposed at stop 6 (adapted from Busch, 1984).

47.8	0.2	Turn Right at intersection on south side of bridge, and proceed onto Route 56 West.
51.35	3.55	Turn Left at traffic light, and stay on Route 56 West.
52.05	0.7	Bear left at the "Y" in the road, and stay on Route 56 West.
61.0	8.95	Turn Right at traffic light to stay on Route 56 West and Hill Road.
61.6	0.6	Turn Left onto Entrance Drive and immediately pull off on left-hand side of road into a small parking lot. STOP 7: We will examine outcrops of the Glenshaw Formation on the north side of the parking lot (northeast of the Hill Road - Entrance Drive intersection). Fifth-order genetic surfaces 6, 5, and 4, are well exposed here; overlain by the Pine Creek, Nadine, and Woods Run marine zones, respectively (Fig. 16). Return to intersection of Hill Road and Entrance Drive.
61.75	0.15	Note additional exposures of the Pine Creek Limestone, overlying fifth-order genetic surface 6, on left side of highway.
65.5	3.75	Cross over the Pennsylvania Turnpike.
66.5	1.0	Cross over railroad tracks in Oakmont, and continue straight towards Hulton Bridge.
66.7	0.2	Enter onto Hulton Bridge (over the Allegheny River).
67.05	0.35	Turn Right at north end of Hulton Bridge, and proceed east on Freeport Road.
67.8	0.75	Turn Left at traffic light in Harmarville, onto Route 910 North. Proceed straight, beneath Route 28 overpass.
68.35	0.55	Turn Right onto on-ramp (circular) for Route 28 South.
69.5	1.15	STOP 8: Park on the right-hand side of Route 28 South, at the west end of highway bridge. This is the well known "Hulton Bridge locality" in which strata from the Pine Creek Limestone (overlying fifth-order genetic surface 6) to the Ames Limestone (overlying fifth-order genetic surface 0) are exposed (Fig. 17). Fifth-order genetic surfaces 3 and 4 have been eroded out (during Pennsylvanian time), and the interval where they would be expected to occur consists of autocyclic fluvial point-bar deposits. Genetic surfaces 6 and 5 are similarly eroded in certain portions of the outcrop, and we will examine their points of truncation.

STATE: PA COUNTY: WESTMORELAND QUAD.-LOC NO.: NEW KENSINGTON WEST - 3

LATITUDE: 40N° 32' 39" LONGITUDE: 79W° 45' 36"
to: 40N 32 59 — 79 45 39

TWP.: ____ SECTION: ____

NATURE OF EXPOSURE: Cliffs at corner of Hill Road and Entrance Drive then north to small borrow pit on opposite side of hill.

DESCRIPTION BY: Busch & Wells.

5th ORDER GENETIC SURFACE	UNIT DESCRIPTION OF EXPOSURE	FT.	IN.
	1. platy, olive shale, unfossiliferous	14+	
	2. WOODS RUN-CARNAHAN RUN: platy, olive shale, as above, with rare ostracodes (RB-82-299B)	1	6
	3. WOODS RUN: ferruginous, dark brown to dark gray, massive, ferruginous limestone or very calcareous shale; abundant marine fossils including brachiopods, rugosans, bryozoa, cephalopods, etc. (RB-82-299A)		8
4	----------		
	4. brown, argillaceous, fn.- to very fn.-gr. sandstone; bears abundant, large plant parts and roots to 8 inches in diameter.	1	
	5. brown, platy to flaggy, unfossiliferous shale, silty near top	5	6
	6. NADINE: gray marine shale with lenses of light to medium gray calcilutite that contain crinoids, brachiopods, and bivalves, plus phosphate granules; limestone lenses are up to 6 inches thick and weather to white or pale yellow color. (RB-82-298)		8
	7. Coal smut (Wilgus Coal)		½
5	----------		
	8. white, plastic clay (RB-82-300)		½
	9. flaggy, sandy, micaceous, gray and brown siltstone and silty shale	13	6
	10. fn.- to med.-gr., calcareous sandstone (RB-82-301)	1	
	11. buff to brown, flaggy shale and siltstone	20	6
	12. flaggy, gray, silty shale with a calcareous nodule horizon at top	5	
	13. platy to flaggy, silty, gray-green shale, unfossiliferous, contains scattered ironstone nodules to 4 inches in length.	4	
	14. PINE CREEK: gray-green, soft clay shale, with plant fragments plus many marine fossils including bivalves, brachiopods, gastropods, and crinoids. (RB-82-296)	4	
	15. PINE CREEK: argillaceous, crinoidal calcarenite; generally separated into two benches about 1 foot thick and an intervening bioturbated calcareous shale or very argillaceous limestone. This unit has developed into burrowed mounds at various locations along the outcrop, the same as those developed in the Brush Creek Limestone occasionally. One of these conic mounds extends downward about 6 feet into underlying units. (RB-82-297 is mound lithology)	2	6
	16. PINE CREEK: gray-green, silty shale with brachiopods and bivalves	1	6
	17. PINE CREEK: dark gray, silty shale with marine fossils (RB-82-295)	5	
6	----------		
	18. dark gray to green-gray, platy to flaggy shale, unfossiliferous	8	
	19. BRUSH CREEK?: shale, as above, with productid brachiopods	1	
	20. shale, same as unit 18	4+	
7	----------????		
	For additional discussion, see Donahue and Rollins, 1974a, stop 3.		

Figure 16: Description of stratigraphy exposed at stop 7 (adapted from Busch, 1984).

STATE: PA COUNTY: ALLEGHENY QUAD.-LOC NO.: NEW KENSINGTON WEST - 2

LATITUDE: 40N ° 31 ' 37 " LONGITUDE: 79W ° 51 ' 06 "

TWP.: ________ SECTION: ________

NATURE OF EXPOSURE: High cliffs along west side of Route 28 and Allegheny River with stratigrphically lowest point located at the above coordinates.

DESCRIPTION BY: Busch and Wells. Locality also known as Holton Bridge Locality.

5th ORDER GENETIC SURFACE	UNIT DESCRIPTION OF EXPOSURE	FT.	IN.
	1. red, platy, unfossiliferous shale	8	
	2. AMES: gray-green, calcareous shale, with abundant marine fossils including Crurithyris	1	2
	3. AMES: gray, argillaceous, fine calcarenite to calcilutite with common marine fossils (RB-82-280 at top; RB-82-278 from near base)	2	6
	4. AMES: Crurithyris-rich, very argillaceous calcarenite (RB-82-279)		4
	5. Coal, smut (Ames Coal)		
0			
	6. gray, crumbly claystone	4	
	7. red fissile shale to crumbly claystone	14	
	8. red, platy shale with calcareous nodules	6	6
	9. green shale with limestone nodules	6	6
1?			
	10. pale green, cross-laminated siltstone	8	
	11. red, platy shale	10	
	12. BAKERSTOWN: dark gray, platy shale, with ironstone nodules like RB-82-276, plus scaphopods and marine bivalves.	5	
	13. dark gray to black, silty, soft shale, carbonaceous	2	6
	14. Coal (Upper Bakerstown Coal)	1	3
2			
	15. gray clay	3	4
	16. massive unit (point-bar sequence) of cross-bedded and thin- to medium-bedded, fn.- to med.-gr. sandstone and shale; bedding inclined to the northwest; base disconformable.	27	
	17. massive, cross-bedded, med.- to cs.-gr., brown sandstone; base is disconformable.	19	
	18. interbedded, medium beds of fn.-gr. sandstone and brown, platy, silty shale; all beds are foresets dipping westerly; this unit thickens to about 32 feet on the western end of the outcrop and replaces the underlying interval that contains the Nadine marine unit.	4	
	19. platy, silty, gray-green shale, unfossiliferous	8	6
	20. NADINE: 2" to 6" marine calcilutite with phosphate granules and cryptic marine fossils; fossils include brachiopods, rugosans, spirifers, and chonetids. (RB-82-274)		6
	21. NADINE: green-gray to dark gray, platy shale with plant fragments and Dunbarella; unit thickens westerly to about 7 feet, where it bears many thin, marine, calcarenite lenses; unit is truncated by unit 18 in much of the outcrop.	4	
	22. gray to black, friable siltstone to soft shale, with coal lenses to 2" thick; abundant plant fossils.	6	
	23. Coal, discontinuous, 0 - 18" (Wilgus Coal)	1	6
5			
	24. gray clay; 4 to 5.5 feet thick	4	
	25. red and gray, fissile shale on western half of exposure; on eastern half there is only 4 feet of red shale overlain by 24.5 feet of silty, olive, platy shale and flaggy siltstone.	28	6
	26. green, platy to flaggy, silty shale, with ironstone nodules in basal 3'	4	9
	27. PINE CREEK: very argillaceous, nodular, marine limestone		8
	28. PINE CREEK: massive, argillaceous, calcilutite to calcarenite, crinoidal (RB-82-289 from base).	1	
6			
	29. dark gray, crumbly claystone	1	
	30. red and gray, crumbly claystone	2	
	31. nodular, ferruginous micrite to calcilutite with sparry fractures and glaebules, nonmarine (calcrete); RB-82-288 from top, RB-82-287 from base.	1	6
	32. gray fissile shale and claystone, with caliche nodules to 6" in diameter.	2	
	33. green-gray flaggy shale with lenses of cross-laminated, fn.-gr. sandstone	3	
	34. cross-bedded, med.- to cs.-gr. sandstone; tabular foreset beds dip 15-20 degrees along N 20 W and about N 30 E; trough cross-beds common also.	7+	

Figure 17: Description of stratigraphy exposed at stop 8 (adapted from Busch, 1984).

Frequent rock slides occur along this cliff, and small rocks almost constantly fall from above. Therefore, wear your hard hat and exercise extreme caution while we view the exposure.

Continue in a westerly direction towards Pittsburgh on Route 28 South: stay in right-hand lane.

74.3	4.8	Pass by the entrance to Highland Park Bridge.
75.8	1.5	Note "Sharps Hill locality" on right: Upper Glenshaw Formation and basal Casselman Formation lithofacies, including the Ames Limestone, are well exposed here.
79.95	4.15	Continue straight through traffic light on East Ohio Street.
80.45	0.5	Allegheny Center.
80.8	0.35	Turn Right onto Ridge Ave., through North Side.
81.7	0.9	Turn Left onto West End Bridge.
82.15	0.45	Continue through West End Circle (keep right).
82.25	0.1	Enter Route 51.
83.2	0.95	Enter Parkway West (Interstate Route 279) towards Greentree.
84.8	1.6	Exit Right from Parkway West onto Greentree Exit.
84.9	0.1	Turn Left at stop sign onto Mansfield Ave.
85.0	0.1	Continue straight through traffic light on Mansfield Ave.
85.2	0.2	Turn Right into Greentree Holiday Inn driveway to parking lot.

End of Field Trip Log for First Day.

FIELD TRIP DAY TWO: CHESTERTIAN TRANSGRESSIVE-REGRESSIVE UNITS

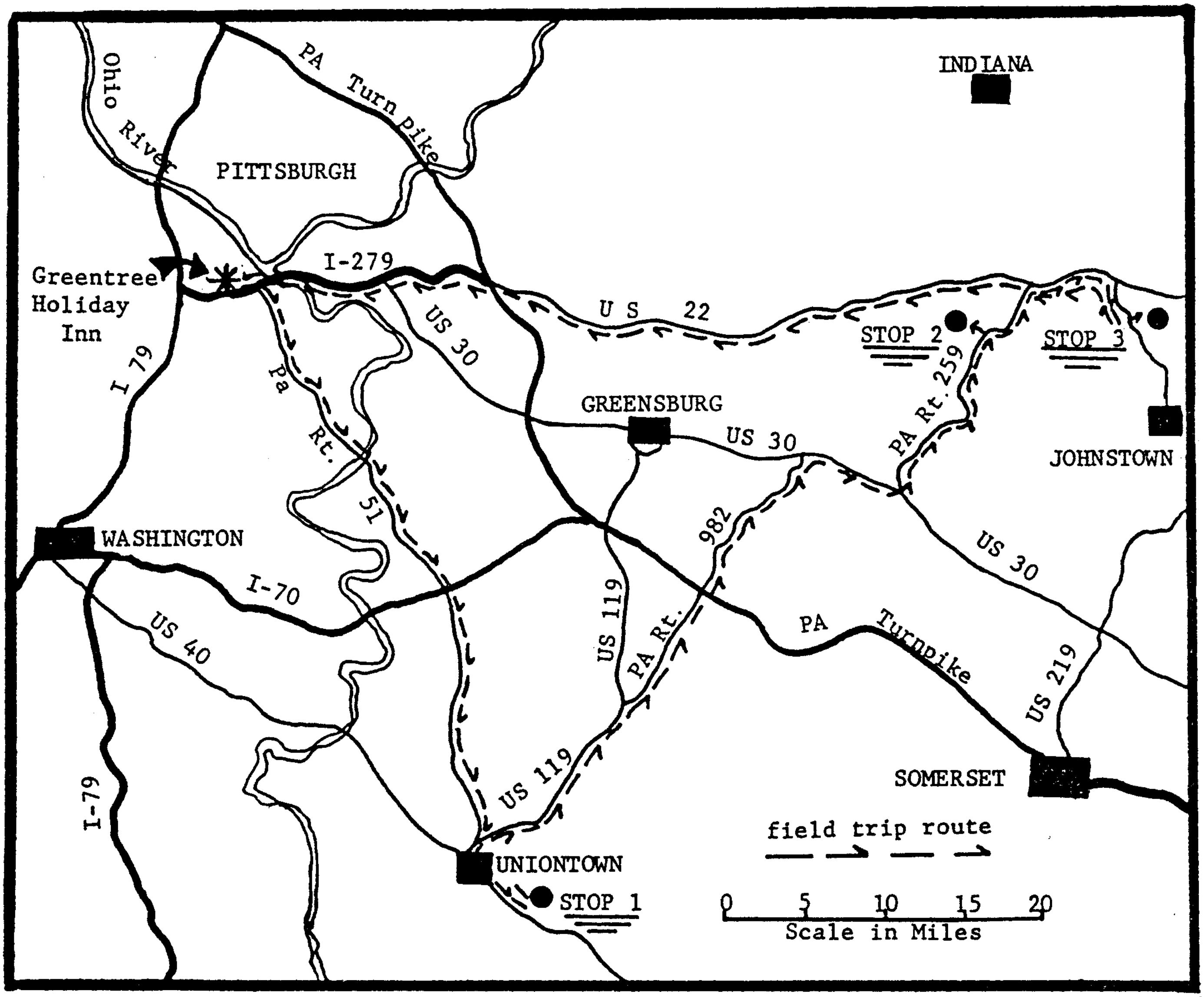


Figure 18. Field trip route for second day stops.

Total Miles	Interval Miles	
		Road log starts at Greentree Holiday Inn parking lot. Departure 7:30 A.M.
0.1	0.1	Leave parking lot and turn left on Mansfield Avenue. Go through the first light.
0.5	0.4	Stop light. At second light turn right on Greentree Road, cross over I-279 turn left onto I-279 east.
0.6	0.1	Stop light. Enter Penn-Lincoln Parkway (I-279).
1.1	0.5	Exit I-279 onto PA Route 51 outh.
1.7	0.6	Channel sandstone on left is the site of the 1983 rock fall which killed 3 people. Joint plane running roughly parallel to the excavated face were the reason several large blocks toppled onto passing motorists and construction personnel.
2.6	0.9	Stop light. Intersection with US Route 19. To the left are the Liberty Tunnels.
5.0	2.4	Intersection with PA Route 88.
8.4	3.4	Intersection with Lebanon-Church Road.
9.3	0.9	To the left is a huge slag dump. This is the flux residue from steel-making which has been discarded.
9.4	0.1	Along the right side of the road is an extensive high-wall from an old strip mine. This is in all likelihood old workings of the Pittsburgh Coal Seam. Across from the Wendy's are slumps indicating an old entryway.
1.1	5.7	To the left are sandstones and shales of the upper Conemaugh Group (Casselman Formation)
15.3	0.2	Route 51 bridge over the Monongahela River at the town of Elizabeth.
26.2	10.9	Pass over Interstate 70.
27.7	1.5	Enter Fayette County.
30.7	3.0	Stop light. Enter town of Perryopilus.
31.8	1.1	To the right are sets of old abandoned coke ovens. When the Pittsburgh Coal Seam was mined in this area it was found that it was easier to cake coal near the mine than to transport the coal to coke ovens along the Monongahelia River.

Total Miles	Interval Miles	
33.2	1.4	Overpass and exit for PA Route 201.
37.4	4.2	On the left is an exposure of the upper portion of the Glenshaw Formation of the Conemaugh Group. This exposure is capped by the Ames marine interval, the uppermost strata of the Glenshaw Formation. A nearly continuous section can be measured from the Woods Run Marine Interval down the road up to the top of the Ames. The complete section is given below the left. This Woods Run section was the subject of a paleoecological study by Donahue, Rollins and Shaak (1972). The Ames at this exposure cannot truely be considered a limestone, but rather an argillaceous nodular limestone. The fauna present in this exposure conform to the biofacies model proposed by Brezinski (1983), with the transgressive _Neochonetes_ shale immediately overlying the coal and the regressive _Crurythris_ shale present at the top of the section (Figure 15B).

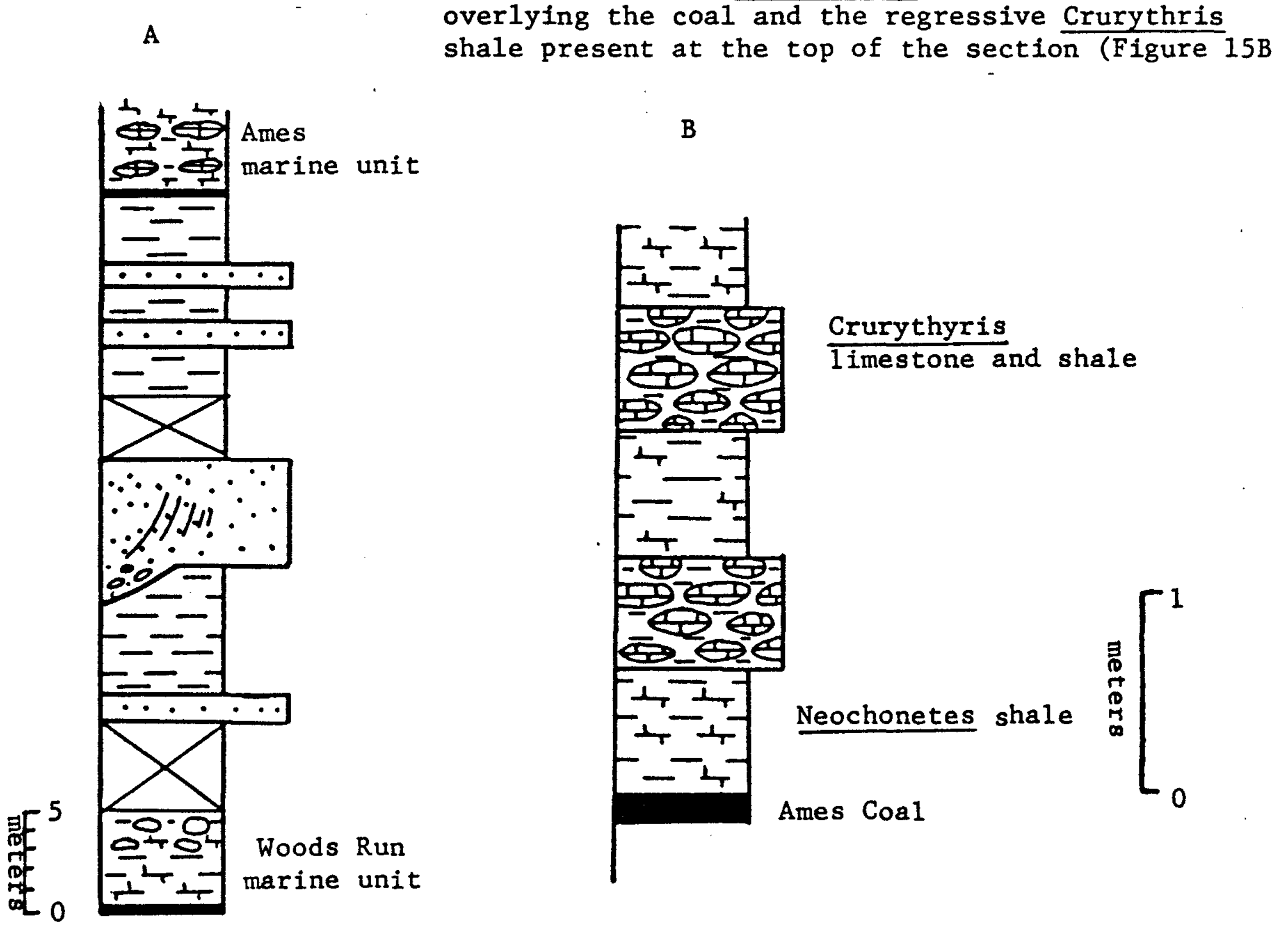


Figure 19. Measured section of Picolomini Mine section of the Glenshaw Formation. Section A represents total section exposed and Section B a detailed illustration of the Ames marine unit capping the section.

Total Miles	Interval Miles	
43.1	5.7	Cross over four lanes of new US 119.
44.2	1.1	Stop light. End PA Route 51.
44.3	0.1	Stop light. Intersection West Màin Street.
44.4	0.1	Stop light. Intersection West South Street.
44.45	0.05	Stop light. Turn left on US Route 40 East (National Road).
46.5	2.05	Enter Hopwood Pennsylvania.
47.8	1.3	To the left is an exposure of sandstone of the Pottsville Group. From its stratigraphic position its probably the Connoquenessing Sandstone.
48.2	0.4	To the left are sandstones of the Pocono Formation. Conduct a U-Turn onto US 40 West.
49.0	0.2	STOP-1, park along truck stopping area. (BEWARE OF RUNAWAY TRUCKS!!)

STOP 1. Runaway truck exposure along US Route 40 on the west flank of Chestnut Ridge.

At this exposure we will be examining two of the three major transgressive-regressive marine units of the Appalachian, Chesterian. Near the base of the exposure is the uppermost beds of the Loyalhanna Limestone. Unvortunately, it is poorly exposed as is most of the Mauch Chunk Clastics which intervene between it and the Wymps Gap Limestone. However, the Wymps Gap and Reynolds marine units are well exposed.

Two scales of major T-R units are exemplified at this exposure. The Chesterian represents a period of global regression of a second order (Kaskaskia Sequence) cycle. Therefore the entire Chesterian represent a portion of a second order Cycle (Vail _et al_. 1977). Superimposed upon the back side of the second order cycle is a third order cycle which is marked by a transgressive (Loyalhanna) phase a maximum transgressive phase (Wymps Gap) and a regressive (Reynolds) phase. The interpretation that the Wymps Gap represents a transgressive apex is based on detailed facies reconstruction conducted by Brezinski (1984). From this reconstruction a water depth for the Wymps Gap of this area was estimated to be approximately 40 m. Conversely the Loyalhanna (as we will see at STOP 2) throughout its extent can be interpreted as a shoal-water deposit, and the Reynolds often contains indications of current agitation. Furthermore, the Wymps Gap Limestone has been correlated, on the basis of faunal evidence (conodont, crinoids), to the Hardinsburg and/or Glen Dean marine units of Kentucky and Illinois. Ettensohn (1980) has shown that the Hardinsburg of northeastern Kentucky is the culmination of a regional transgression. Swann (1964) has likewise interpreted the Glen Dean of the Illinois Basin as an apex of a significant deepening event. Consequently, it appears that during this interval of time (i.e. during Wymps Gap, Hardinsburg and/or Glen Dean deposition) a major transgressive event climaxed.

Also evident at this exposure are three fourth order transgressive-regressive units. These are manifested in the Loyalhanna, Wymps Gap and Reynolds marine intervals. These are the three most laterally continuous and easily recognized marine units in the Chesterian of the northcentral Appalachian Basin. Moreover, each of these fourth order transgressive-regressive units are made up of a number of smaller, fifth order, transgressive-regressive units. Owing to the cover of much of this exposure these fifth order units are not particularly well exhibited at this stop. At the next two stops we will see this scale of cycle much more readily.

Evidence for the fifth order units are minor marine units such as the Glenray Limestone which is separated from the underlying Wymps Gap and overlying Reynolds by sections of red, nonmarine siltstones and shales. Other evidence is the thin (2 m) Deer Valley Limestone which overlies the Loyalhanna in areas to the south, and shale-limestone couplets which are prominent as a regressive facies of the Wymps Gap. A final evidence that each of the fourth order units are made up of smaller fifth order units is a pervasive mudcrack horizon which separates two distinct benches of the Reynolds Limestone to the south, where it is better developed.

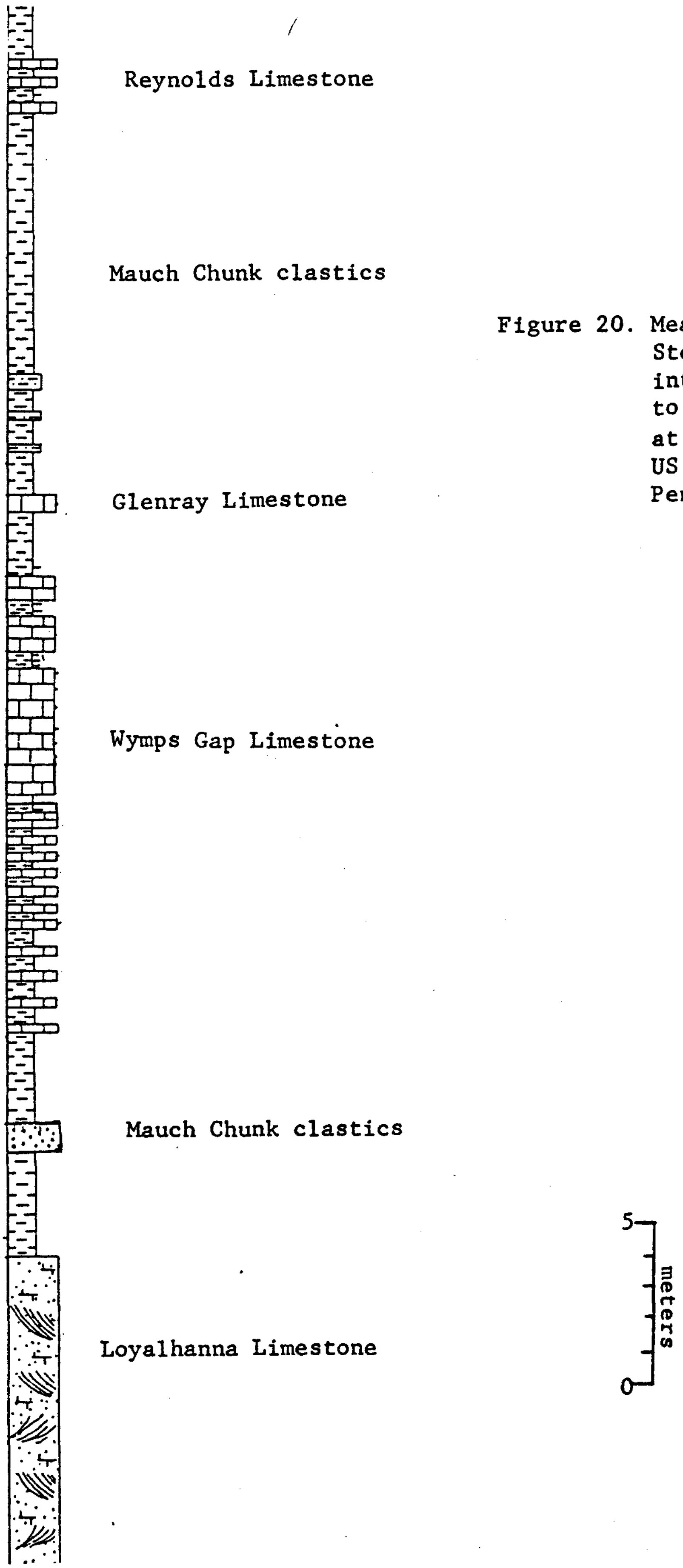


Figure 20. Measured section at Day Two, Stop 1. Section includes interval from top of Loyalhanna to top of Reynolds Limestones, at runaway truck turn-off along US Route 40 east of Hopwood, Pennsylvania.

Total Miles	Interval Miles	
49.0	0.0	Resume from STOP 1.
52.2	3.2	Continue on US 40 west back to Uniontown. At second traffic light bear left onto Main Street.
52.3	0.1	Turn right. Following signs to return to PA Route 51.
52.4	0.1	Stop sign. Turn left onto Bailey Avenue. Straight through 2 stop lights.
52.7	0.3	Stop light. Turn right on Pittsburgh Street (PA Route 51). Continue straight through next stop light.
53.6	0.9	Stop light. Turn right onto four-lane US 119. Continue north on US 119.
63.9	10.3	Stop light. Enter Connellsville. Junction PA Route 201, West Crawford Avenue.
64.4	0.4	Bridge across the Youghiogheny River. Continue north on US 119.
67.5	3.1	Stop light. Junction PA Route 982, turn right on PA Route 982 north.
75.2	7.7	Stop sign. Laurelville, Junction of PA Route 31.
75.4	0.2	Enter Westmoreland County.
76.5	1.1	Cross over Pennsylvania Turnpike (Interstate 76 and 70).
78.8	2.3	Stop sign. Kecksburg, follow signs for PA Route 982.
79.5	0.7	Stop sign. Left turn.
80.6	1.1	Enter village of Manmouth.
81.2	0.6	Stop sign. Right turn.
81.5	0.3	Enter village of Weltytown.
82.9	1.4	Stop sign. Junction PA Route 130. Right turn onto 982/130.
83.0	0.1	Turn left onto PA Route 982 from 982/130.
84.2	1.2	At Y in road bear right on 982 north toward Whitney.

Total Miles	Interval Miles	
87.7	3.5	Enter town of Baggely.
88.3	0.6	Stop sign.
88.4	0.1	Stop light. Six Pack Shop.
88.9	0.5	Junction US Route 30. Turn west on US 30 to Latrobe. LUNCH STOP. Road Log will resume at Junction of PA Route 982.
90.5	1.6	Junction PA Route 217. Town of Kingston. Across Loyalhanna Creek along the westbound lanes of US 30 is an exposure the Loyalhanna-Mauch Chunk-Wymps Gap sequence. Owing to the danger of speeding traffic at that exposure we will not use it as a stop. However below is a columnar section of sequence illustrating the transgressive-regressive units. The gorge through which we are passing is Loyalhanna gorge through Chestnut Ridge Anticline; the type area of the Loyalhanna Limestone.

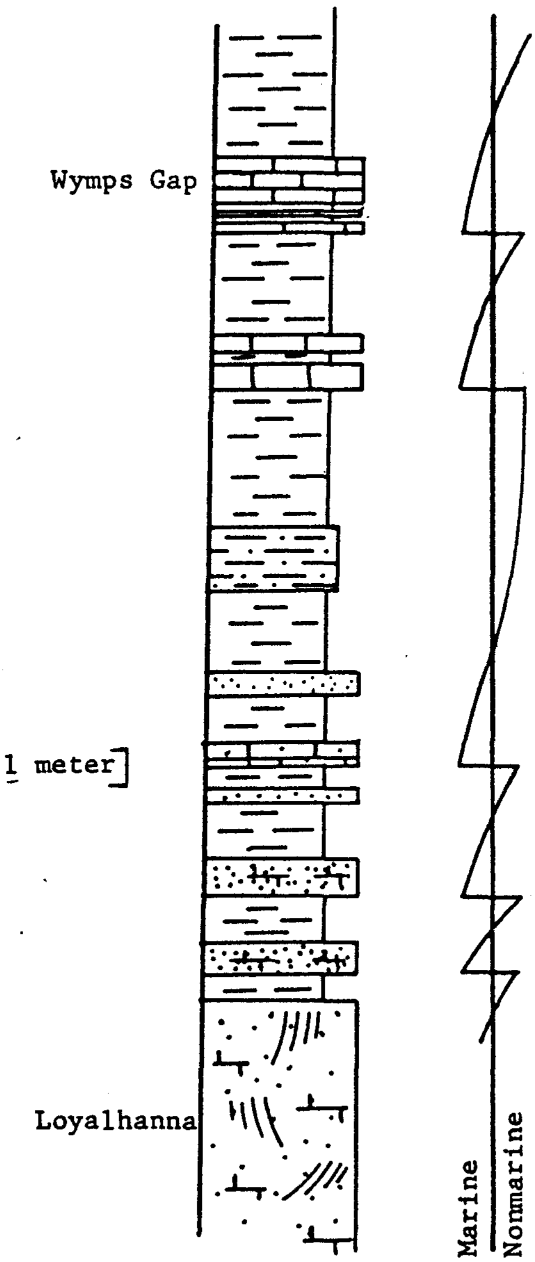


Figure 21. Measured section of Mauch Chunk Formation at US Route 30 Loyalhanna Creek near Kingston, Pennsylvania.

Total Miles	Interval Miles	
94.5	4.0	Entrance to Idlewild Park.
95.0	0.5	Junction PA Route 259. Turn left (north) on Route 259.
102.8	7.8	Stop sign. Left turn on 259.
109.1	6.3	Stop sign. Town of Bolivar.
109.6	0.5	Stop sign. Right turn.
109.7	0.1	Stop sign. Left turn, then turn right immediately before railroad tressle on bricked side street. Climb steep incline to railroad right of way, and turn left along track to the west toward Chestnut Ridge.
110.8	1.1	Stop at turn-out along the tracks. Proceed west along tracks on foot for approximately 300 m. STOP 2 (BEWARE OF SILENT FAST MOVING TRAINS.)

At this stop we will once again see the transgressive apex of a third order unit (ie Wymps Gap) as well as two of the three fourth order units (Loyalhanna and Wymps Gap). The last stop (Stop 1) was the northernmost exposure of Reynolds known in the basin. Moreover, the Wymps Gap is known no further north and extends only slightly further to the northeast than the present exposure. The Loyalhanna on the other hand extends to the northeast almost another 200 km (120 mi). How then can the Wymps Gap be interpreted as the transgressive culmination of a third order unit when the Loyalhanna is more geographically widespread? The Loyalhanna transgressed over a low-relief erosional plain resulting from pre-Loyalhanna erosion. Therefore, a small increase in sea level would result in the inundation of a large area of low-relief. Prior to the Wymps Gap transgression a thick wedge of Mauch Chunk clastics was deposited which necessitated greater water depth before the wedge would have been submerged. Consequently, the reason for the greater aerial restriction of the Wymps Gap is the wedge of clastic which were deposited previous to the Wymps Gap transgression.

At this exposure the crossbedding which is so diagnostic of the Loyalhanna can be seen. Adams (1970) found that Loyalhanna paleocurrents are directed largely to the northeast. He attributed this to strong flood tide currents causing an almost unimodal transport direction.

You also should note the significant change in thickness and character in the Wymps Gap from Stop 1 to this stop. At Stop 1 the Wymps Gap was approximately 10 m (31 ft.) thick and consisted of a dark-gray, fetid wackestone. At this stop it is less than two meters thick and is gray-green, argillaceous and contains abundant indications of current activity.

This stop is meant to illustrate some minor transgressive-regressive units in the interval of Mauch Chunk clastics which separate the Loyalhanna and Wymps Gap. These fifth order units are repeated as many as five times between the final Loyalhanna shallowing and the maximum transgression of the Wymps Gap. What is unusual is the change in lithologic character in each succeeding unit upsection. This is discussed in detail in contributed paper (# 5) of this guidebook. Consequently, the Wymps Gap transgression appears to have been episodic in nature. Therefore, the Wymps Gap represents; the culmination of a third order transgressive unit; a single fourth order t-r unit; and transgressed by a step-like progression of fifth order units.

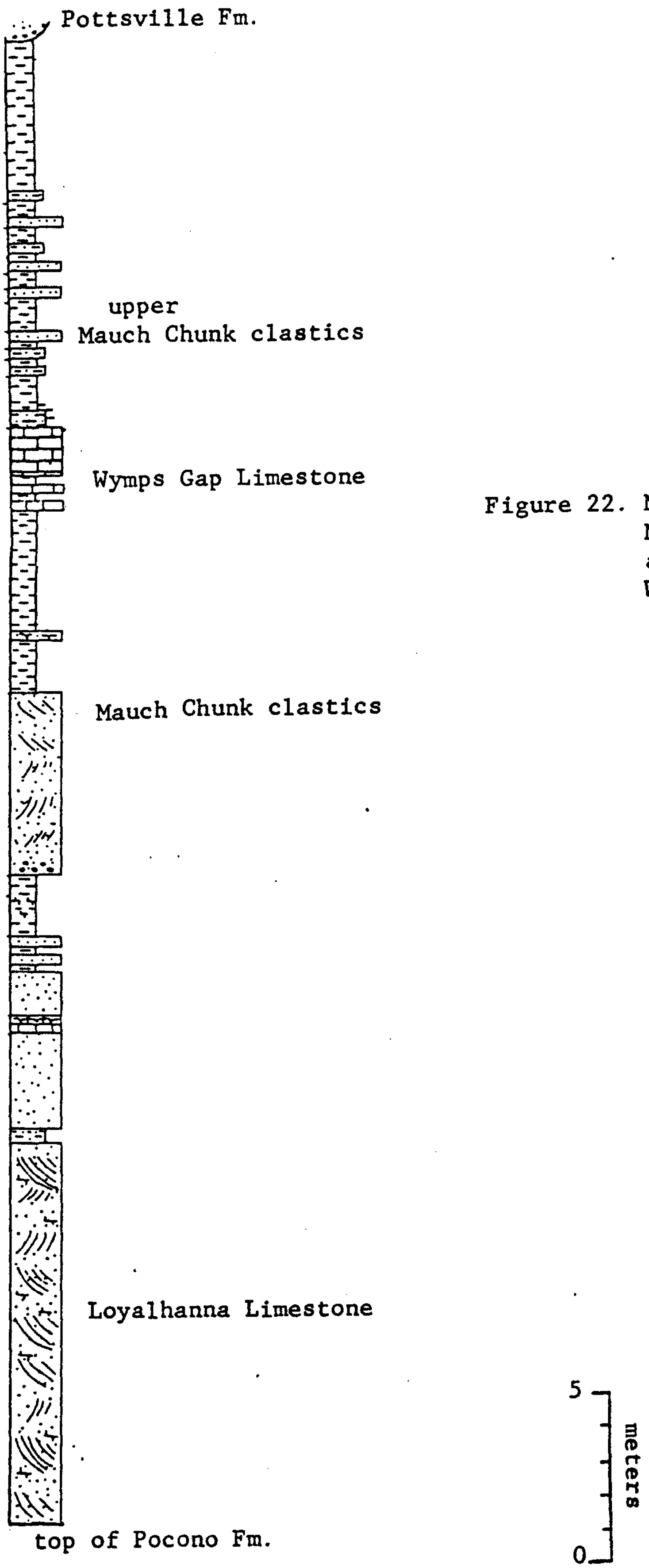


Figure 22. Measured section of Loyalhanna-Mauch Chunk-Wymps Gap sequence at railroad cut west of Bolivar, Westmoreland County, Pennsylvania.

Total Miles	Interval Miles	
111.9	1.1	Retrace route back to PA Route 259.
112.2	0.3	Cross Conemaugh River bridge into town of Robinson, Indiana County.
116.6	4.4	Stop sign. Junction US Route 22. Turn right onto US 22 east.
119.3	2.7	To the right is an exposure of the Upper Bakerstown Coal.
121.6	2.3	Junction PA Route 403. Exit to the right.
121.7	0.1	Stop sign. Right turn onto PA 403 east.
124.4	2.7	Enter village of Cramer.
124.9	0.5	Exposure of Pottsville Group sandstones on the left.
125.2	0.3	Charles F. Lewis Nature Area, Gallitzin State Forest. STOP 3. (CAUTION: there is invariably high-speed traffic along this road, especially coal trucks!!!)

Conemaugh River Gorge through Laurel Hill Anticline.

At this stop we will again examine the interval of clastics which separates the Loyalhanna and Wymps Gap Limestones. At this exposure, like the last, this interval of clastics is made up of a number of fifth order transgressive-regressive units. Typically, the marine portions of the transgressive-regressive units are comprised of white, well-sorted, quartz sandstones with erosional bases, presumably originating by littoral processes. These sandstones grade upsection into red shales and siltstones which are often mudcracked and root-mottled. Fossils are absent in sandstones lower in the section, but become increasingly common as the Wymps Gap is approached.

Another important aspect of this stop is to illustrate that each of the fourth order transgressive-regressive units (i.e. Loyalhanna, Wymps

Gap, and Reynolds) is made up of a number of subsidiary fifth order transgressive-regressive units. These fifth order units are manifested in the Loyalhanna of the plateau province by thin (< 1 m) red siltstone beds (Brezinski, 1984). These siltstone beds indicate deposition during regression of a fifth order unit. These deposits were subsequently truncated by the highly erosive transgressive portion of the next unit.

In the Broad Top coal field, the Loyalhanna equivalent, the Trough Creek Limestone, is characterized by interbedded limestones and red shales. In this nearshore area the two major carbonate benches exhibit a sharp (erosional) bases and grade upward into mudcracked red siltstones and shales. These parallic deposits were deposited during minor (fifth order) sea level oscillations which inundated low-lying shoreline areas. Shallowing and shoreline progradation produced the gradation of lithologies into the subaerially deposited red shales. Consequently, the Loyalhanna was deposited by minor (fifth order) transgressive-regressive sea-level changes rather than by a single steady fourth order transgression and regression. Other fourth order units were, in all likelihood, deposited in the same manner, however, decerning the fifth order units in offshore deposits is more difficult.

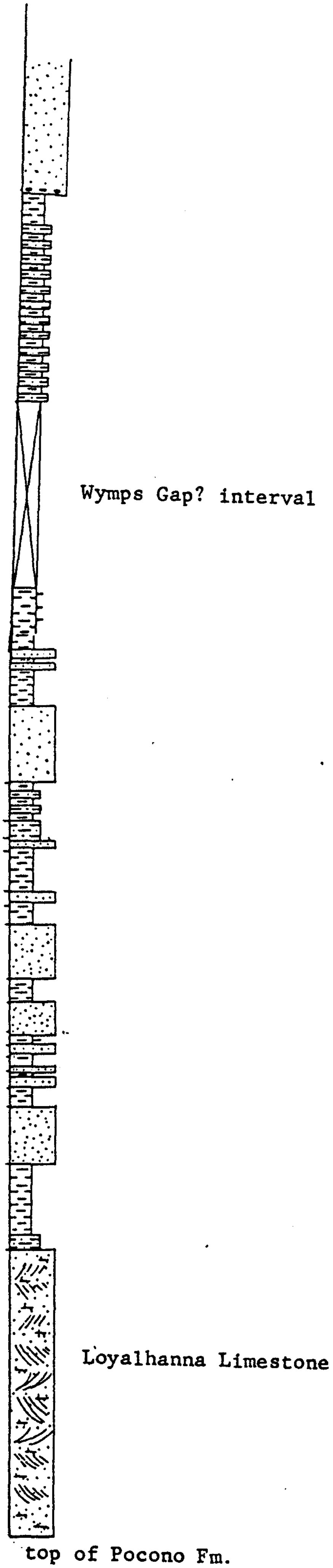


Figure 23. Measured section of Loyalhanna-Mauch Chunk sequence along PA Route 403 at Conemaugh River Gorge through Laurel Hill.

Total Miles	Interval Miles	
128.8	3.6	Retrace Route back to US 22. Enter US 22 west.
137.3	8.5	Crest of Chestnut Ridge Anticline.
137.5	0.2	To the right is a view of the Homer City power plant.
139.8	2.3	Exposure of the Morgantown Sandstone.
140.0	0.2	Junction US 119 north.
157.8	11.8	Junction US 119 south.
158.7	6.9	Junction PA Route 66. On the northeast portion of this cloverleaf is an excellent exposure of the Ames Limestone.
162.3	3.6	On the right is an exposure of the Pittsburgh Coal Seam.
167.5	5.2	Junction PA Route 286.
167.8	0.3	Exposure of the Ames Limestone.
168.8	1.0	Junction with the Pennsylvania Turnpike (I-76) and I-279 west.
171.9	3.1	Exposure of Pittsburgh Coal on both sides of highway.
182.9	11.0	Exit I-376 east.
183.9	0.9	Fort Pitt Bridge over the Monongahelia River
183.9	0.1	Fort Pitt Tunnels.
185.6	1.7	Greentree exit from I-279.
185.7	0.1	Stop sign. Turn left.
185.8	0.1	Stop light.
186.0	0.2	Stop light. Entrance Greentree Holiday Inn. Finish Field Trip Log.

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ADDITIONAL CONTRIBUTIONS

SEA LEVEL AND STRUCTURAL CONTROLS ON PALEOGEOGRAPHY AND SEDIMENTATION DURING DEPOSITION OF THE UPPER PENNSYLVANIAN GLENSHAW FORMATION OF THE NORTHERN APPALACHIAN BASIN

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Introduction

The Upper Pennsylvanian (Desmoinesian - Missourian) Glenshaw Formation (Conemaugh Group) of the Northern Appalachian Basin is composed of fourth-, fifth-, and sixth-order T-R units (Busch & Rollins, 1984). The sixth-order T-R units represent intervals of about 100,000 to 225,000 years and can also be referred to as punctuated aggradational cycles (PACs) following Anderson and Goodwin (1980) or as minor T-R sequences following Heckel et al. (1979). The fifth-order T-R units represent intervals of about 400,000 to 500,000 years, contain sixth-order T-R units, and are the same scale as Wanless-Weller (1932) cyclothems, Moore (1936) megacyclothems, and Heckel (1977) or Heckel et al. (1979) Kansas cyclothems. The fourth-order T-R units represent intervals of about 0.8 to 1.5 million years, are composed of two or three fifth-order T-R units, and are the same scale as Ramsbottom's (1979) mesothems.

Boundaries between any two T-R units have been termed "genetic surfaces", which are also either climate change surfaces or transgressive surfaces (Busch, 1984; see Introduction herein). A maximum of twelve fifth-order genetic surfaces occur from the base of the Upper Freeport coal (fifth-order genetic surface 11) to the base of the Ames coal (fifth-order genetic surface 0); an interval essentially conforming to the Glenshaw Formation (Busch and Rollins, 1984). The twelve fifth-order genetic surfaces define the presence of eleven fifth-order T-R units, and the Ames marine interval is the base of a twelfth fifth-order T-R unit (Fig. 1).

Paleogeography During Marine Events

Busch (1984) identified fifth-order genetic surfaces and T-R units at more than 300 localities of the Glenshaw Formation - Upper Freeport coal interval in the Northern Appalachian Basin. Precise correlation of the various fifth-order T-R units and genetic surfaces was then accomplished by aligning the measured sections relative to prominent marker beds and biozones. The most prominent marker beds are the widespread Ames Limestone (overlying genetic surface 0) and the widespread Upper Freeport coal (overlying genetic surface 11). Other markers, however, include the red Bakerstown Shale (overlying genetic surface 2) and the Worthenia tabulata (gastropod) epibole of the Brush Creek marine unit (overlying genetic surface 7). These accurate correlations revealed the presence of eight marine units that were developed as a result of fifth-order transgressions (i.e., events). They are listed below:

Name of Marine Unit	Named Marine Facies Within the Unit
a) Ames	Ames limestone and shale
b) Bakerstown	Bakerstown shale, Noble limestone and shale
c) Woods Run	Woods Run limestone and shale, Portersville limestone and shale, Carnahan Run shale, Friendsville shale
d) Cambridge	Cambridge limestone and shale, Nadine limestone and shale
e) Pine Creek	Pine Creek limestone and shale, Meyersdale shale and limestone?, Upper Brush Creek limestone and shale
f) Brush Creek	Brush Creek limestone and shale (PA.), Hughes River Flint, Lower Brush Creek limestone and

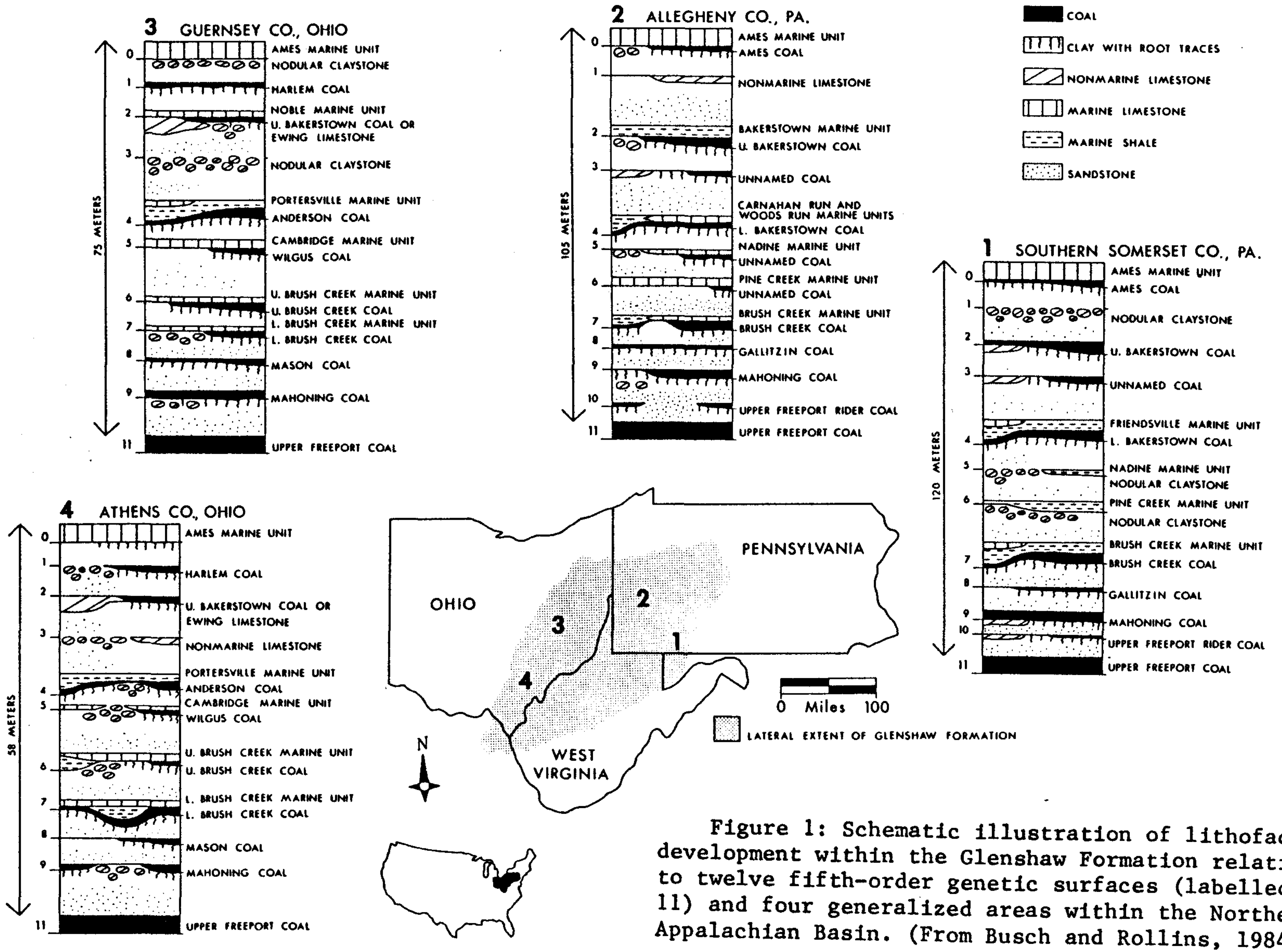

Figure 1: Schematic illustration of lithofacies development within the Glenshaw Formation relative to twelve fifth-order genetic surfaces (labelled 0 - 11) and four generalized areas within the Northern Appalachian Basin. (From Busch and Rollins, 1984)

	shale (Ohio)
g) Mahoning	Mahoning shale, Uffington shale
h) Upper Freeport	Upper Freeport shale

The position of maximum transgression (i.e., most open marine conditions) was located within each of the above fifth-order T-R units, at each locality, based upon faunal data. That position is usually, but not always (e.g., Dodin, 1974), represented by the lithofacies having the maximum faunal diversity (e.g., Donahue and Rollins, 1974a; Brezinski, 1983). The maximum transgression data were then compiled on maps (Figs. 2 - 10) to illustrate the paleogeography developed at the time of maximum transgression within each marine event. Coordinates given on figures 2 - 10 are present-day latitude and longitude.

The Upper Freeport marine event is currently known by marine shale facies overlying the Upper Freeport coal at a single locality in Perry County, Ohio (i.e., Flint, 1951, locality F-239). The transgression probably proceeded from the west or southwest to that position (Fig. 2). Similarly, the Mahoning Shale is known to be a marine facies at only three or four localities. Three of these localities occur within 55 miles of one another along a northeast-trending line in northern West Virginia and southwestern Pennsylvania (Fig. 3). One of these localities is the type locality for the Uffington Shale (= Mahoning Shale) at Uffington, West Virginia, which was originally thought to overly the Upper Freeport coal. A black marine shale and associated thin marine limestone occurs below the Brush Creek marine unit in east-central Ohio and may represent a fourth locality for the Mahoning marine unit. If this questionable fourth locality is actually another occurrence of the Mahoning marine unit, then the Mahoning marine transgression probably proceeded southeast

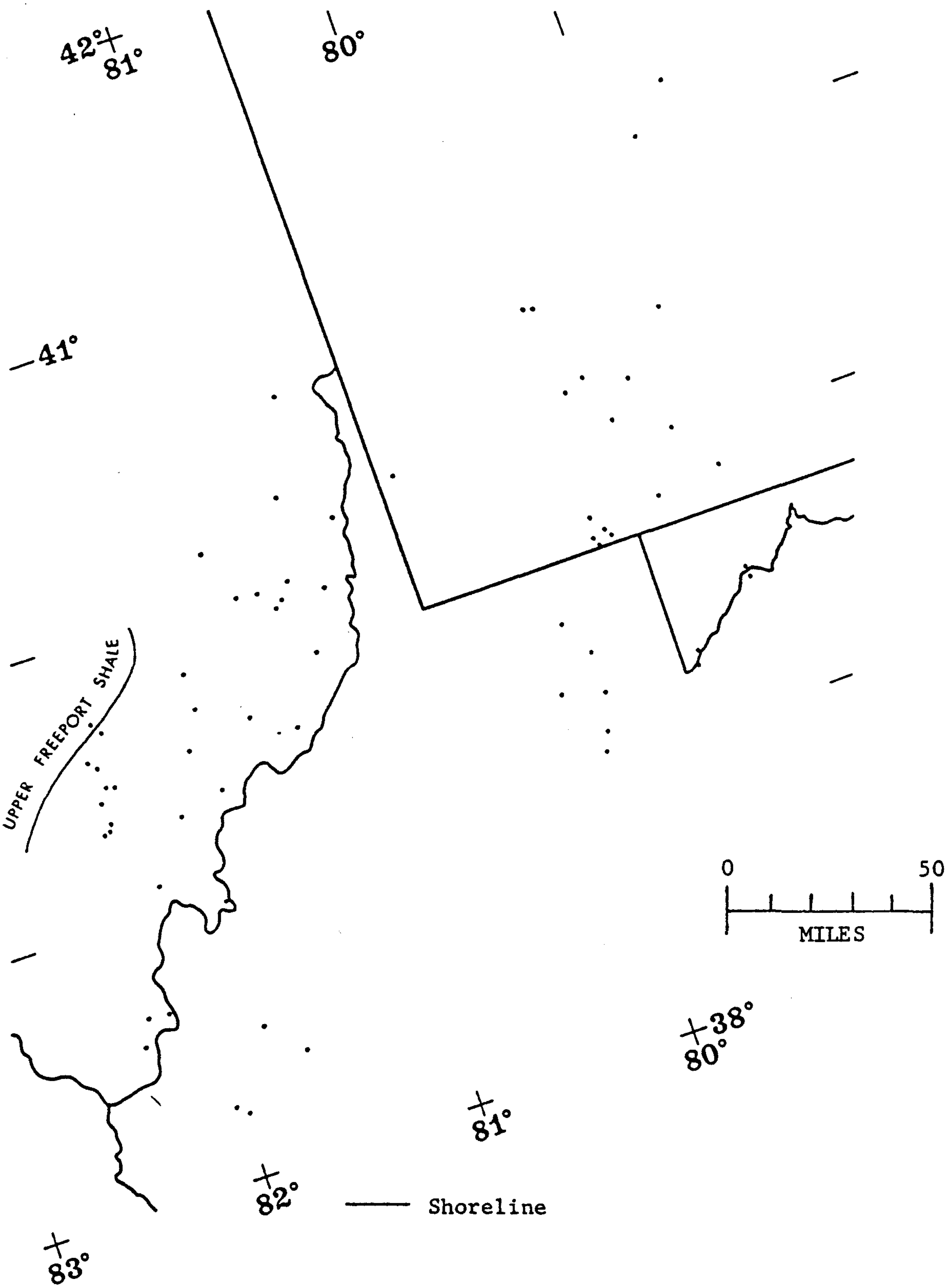

Figure 2: Paleogeography and marine facies developed at time of maximum transgression during deposition of the Upper Freeport fifth-order T-R unit. Black dots are data points. (Busch, 1984)

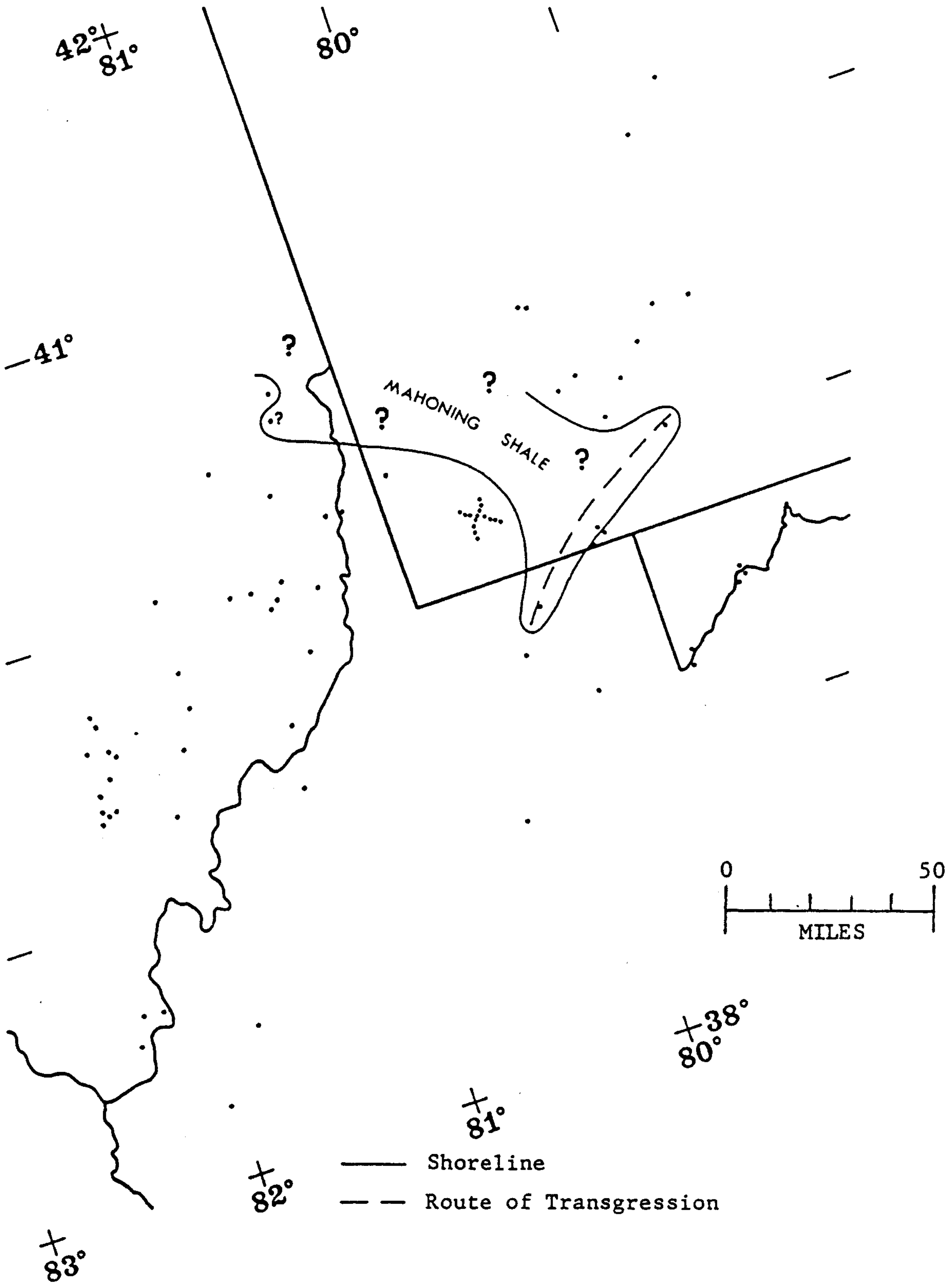

Figure 3: Paleogeography and marine facies (Mahoning or Uffington Shale) developed at time of maximum transgression during deposition of the Mahoning fifth-order T-R unit. Black dots are data points. (Busch, 1984)

into Pennsylvania from the northern tip of the northern West Virginia panhandle (Fig. 3). More data are needed to evaluate that possibility.

The Brush Creek marine event was the first well developed Missourian marine event (Fig. 4). Marine facies (limestones and shales) were extensively developed throughout the study area, and four deltas (A - D) were developed along a northeast-trending shoreline, located in the southeastern portion of the map area. Islands developed in Ohio and Pennsylvania, and most of these occurred along a linear tract from Athens to Jefferson Counties in Ohio. Spicular (siliceous) carbonate muds were deposited at the southern end of that island tract (Lower Brush Creek Chert). The most open marine facies seems to have developed in southwestern Pennsylvania and approximately along the Ohio - West Virginia border, where the most diverse fossil associations were observed. Two sixth-order T-R units are commonly discernible within the Brush Creek marine unit of those same areas (Fig. 5) and probably denote the dominant routes along which transgression proceeded. Those areas were largely characterized by deposition of carbonate sands and argillaceous muds. A notable exception is the thick spiculite facies (i.e., Hughes River Flint) that developed along the crest of the Burning Springs Anticline in West Virginia.

The Pine Creek marine event was nearly as well developed as the Brush Creek marine event; however, the northeast-trending shoreline was not located as far to the southeast (Fig. 6). Two prominent delta lobes developed along that shoreline, however, and are labelled B and C on figure 6. A marine red shale facies (Meyersdale) developed in an embayment between those delta lobes. Oolitic carbonate muds were deposited north of delta C, probably in the lee of the shoreline. This is the only observed

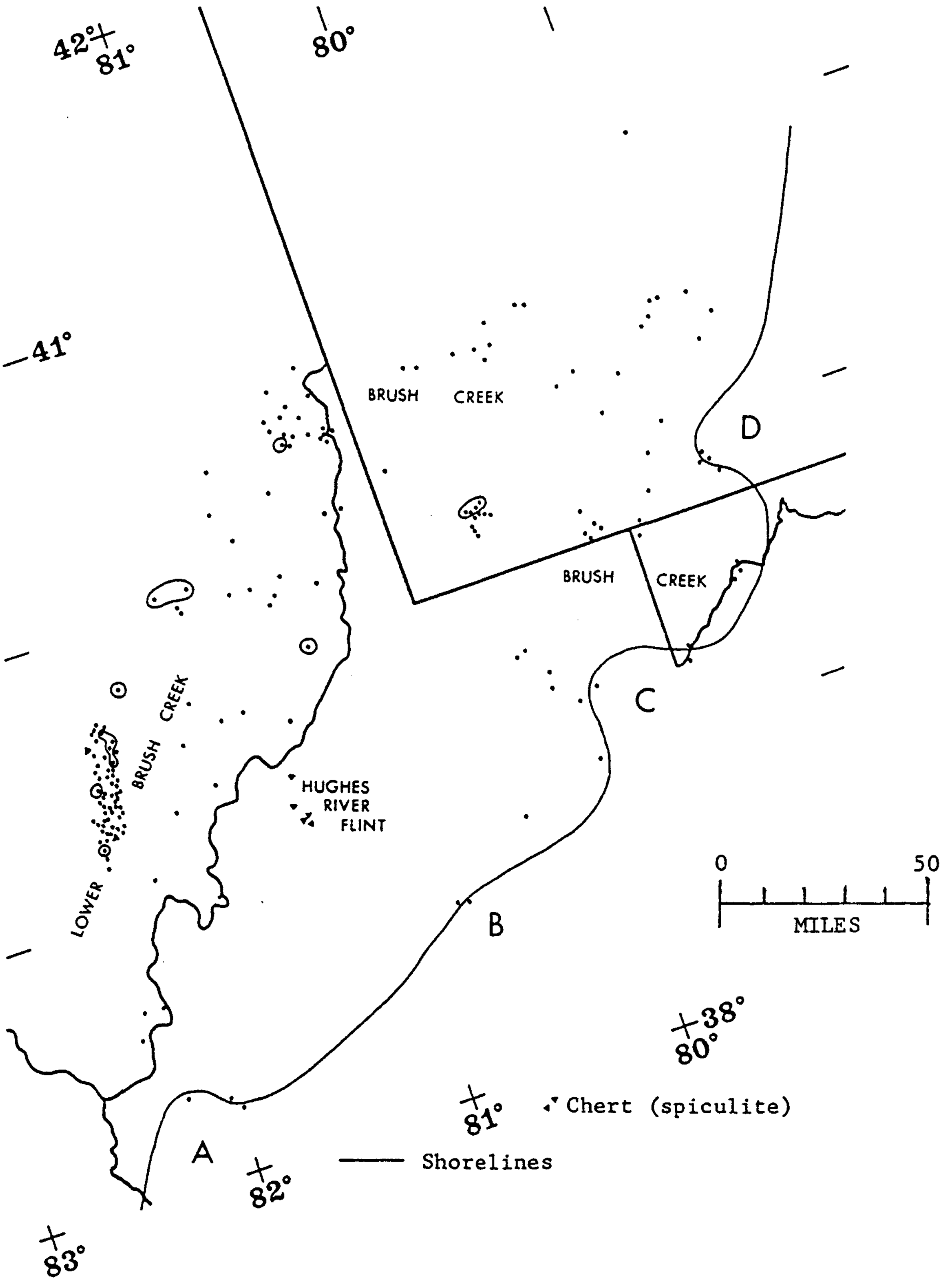

Figure 4: Paleogeography and marine facies (Brush Creek limestone and shale, Lower Brush Creek limestone and shale, Hughes River Flint) developed at time of maximum transgression during deposition of the Brush Creek fifth-order T-R unit. Black dots are data points. Letters A-D label possible delta lobes. (Busch, 1984)

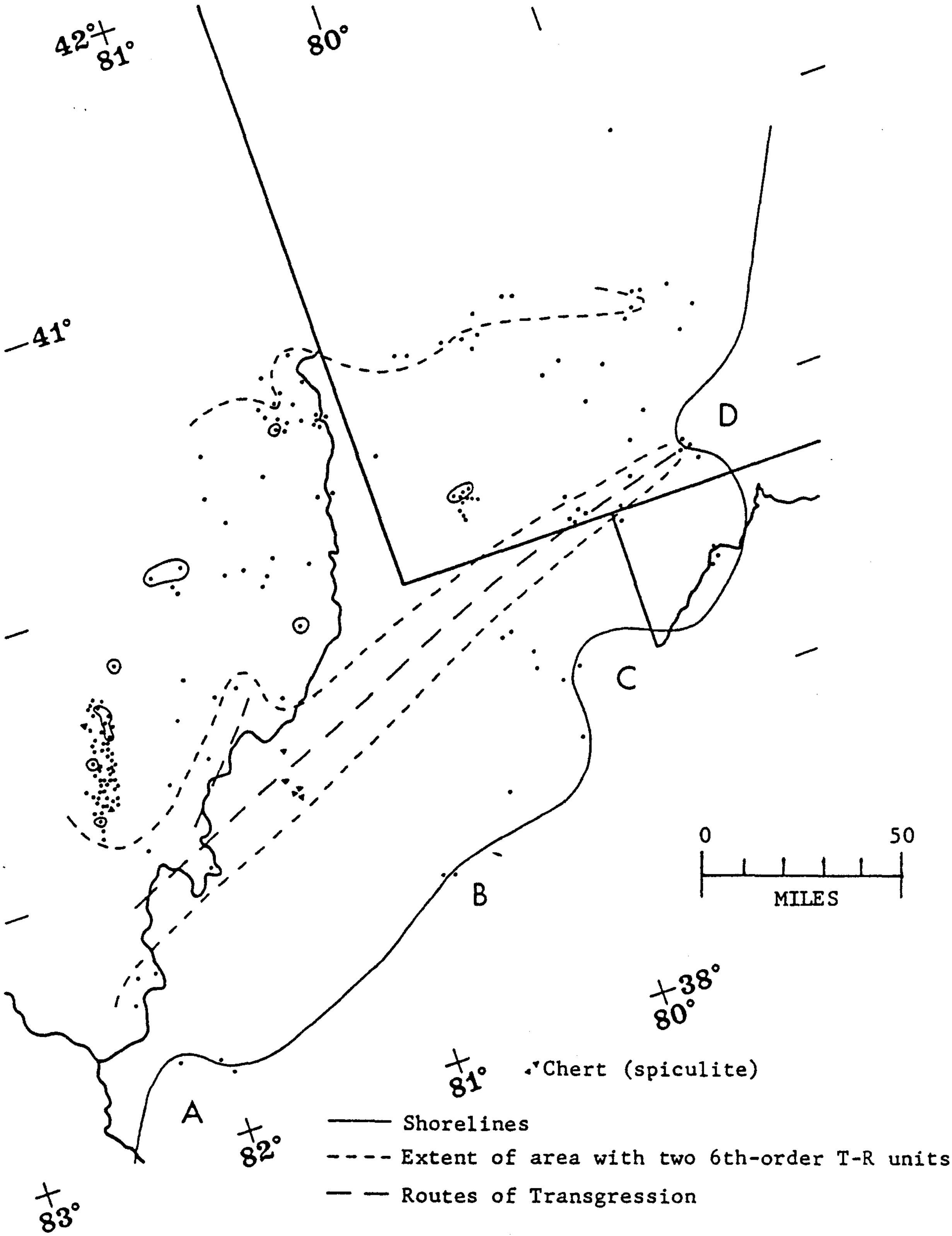

Figure 5: Extent of marine transgression at time of maximum transgression during development of the Brush Creek fifth-order T-R unit (after figure II.10) modified to show the lateral extent of Brush Creek marine facies within which two sixth-order T-R units can generally be delineated. (Busch, 1984)

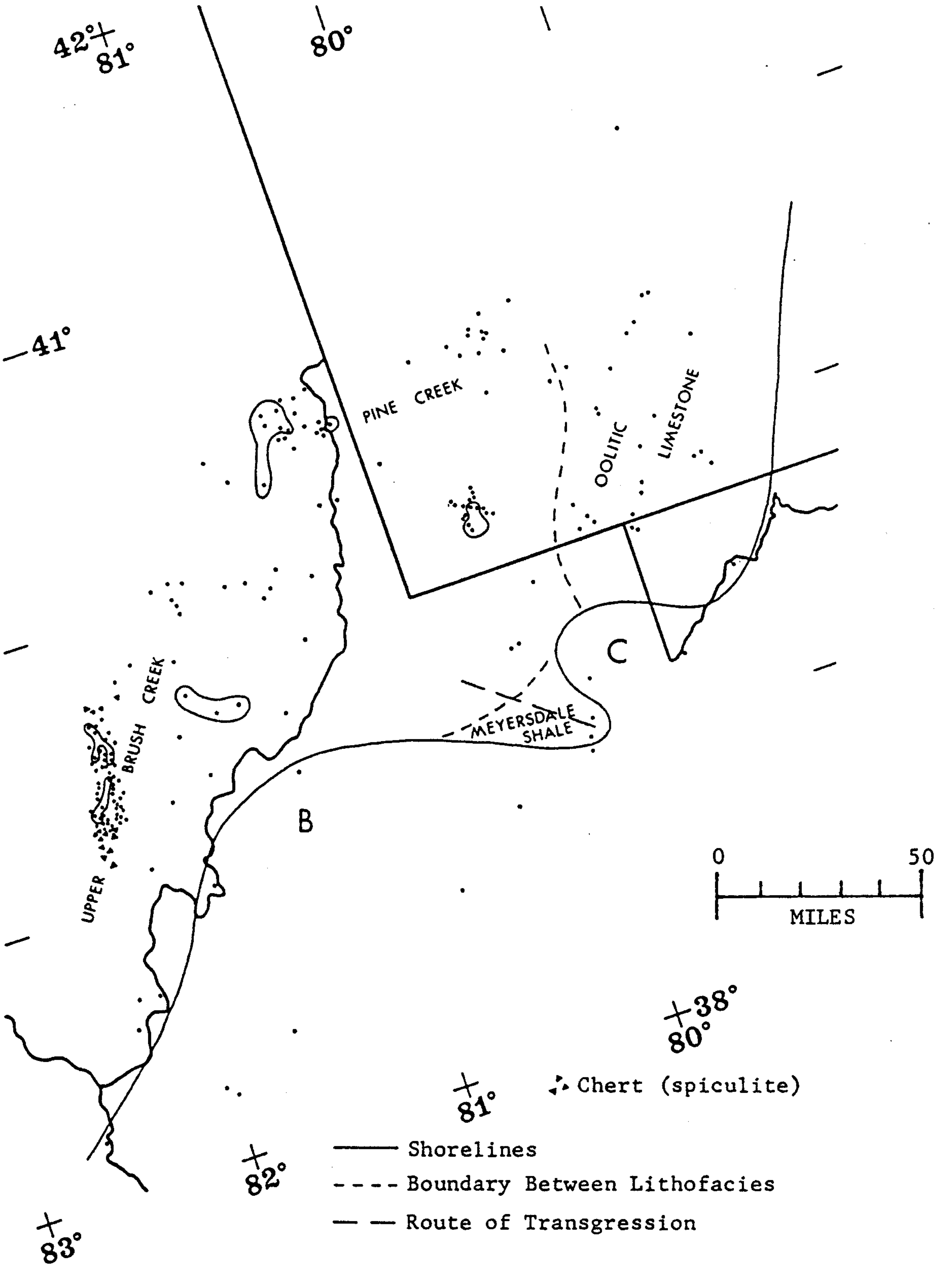

Figure 6: Paleogeography and marine facies (Pine Creek limestone and shale, Meyersdale red shale and oolitic limestone, Upper Brush Creek limestone and shale) developed at time of maximum transgression during deposition of the Pine Creek fifth-order T-R unit. Black dots are data points. Letters B and C label possible delta lobes. (Busch, 1984)

occurrence of an oolite facies in the Glenshaw Formation. The remaining areas were sites of deposition of carbonate sands, muds, and argillaceous muds in a more open, very shallow, marine setting where adiverse fauna thrived. This led to the formation of typical Pine Creek and Upper Brush Creek argillaceous limestone and shale facies. At least six islands were present within that more open environment. The most prominent of the islands developed in Athens County, Ohio, where spiculites formed on the north and south ends of a two-island land area (Fig. 6). This reflects a depositional setting similar to that in which spiculites developed during the Brush Creek marine event.

The southeastern shoreline extended even further to the northwest during maximum transgression of the Cambridge marine event than it had during the Pine Creek transgressive maximum (Fig. 7). At least four deltas developed along that shoreline (A - D) with interdistributary bays between them. The embayment, or seaway, between delta lobes C and D was particularly well developed. Argillaceous muds (Nadine shale) were deposited in the shallow, brackish(?), southeastern end of that embayment, and a bivalve-dominated fauna (including nuculoids and Dunbarella) thrived there. The remaining marine environments were also shallow, but were more open than the large seaway-embayment. They were sites of deposition of carbonate muds, silts, and sands, leading to the development of the Cambridge and Nadine Limestones. A few marine, quartzose sand patches of very low relief and limited extent also developed from the mouth(?) of delta A to about 10 - 12 miles north of that position. These are probably reworked distributary sands derived from delta A. Many Cambridge Limestone samples from the same area contained a substantial quartz sand fraction. Islands existed north of delta A, about 20 - 40 miles north of delta B,

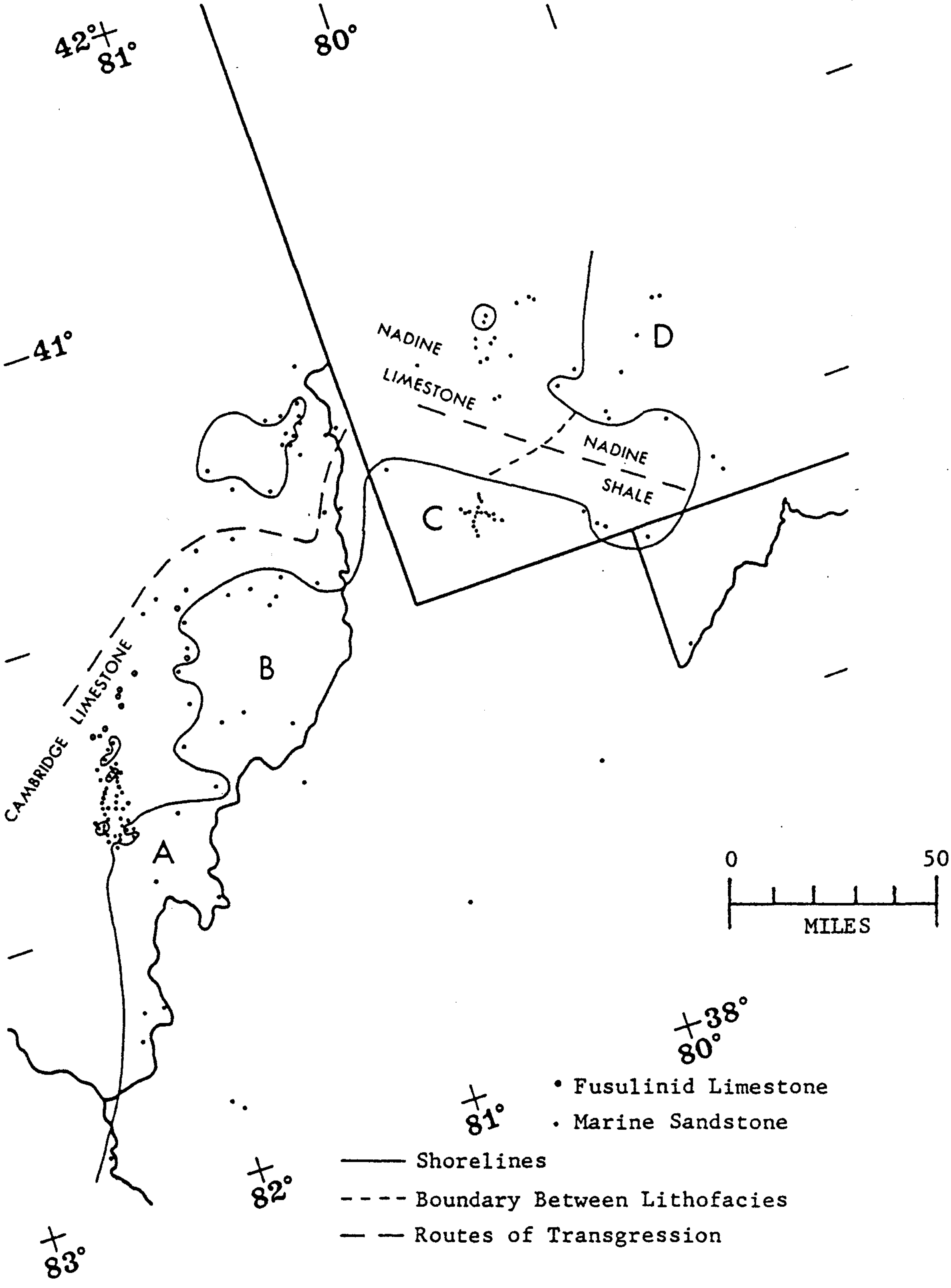

Figure 7: Paleogeography and marine facies (Cambridge limestone and occasional sandstone, Nadine limestone and shale) developed at time of maximum transgression during deposition of the Cambridge fifth-order T-R unit. Black dots are data points. Letters A-D label possible delta lobes. (Busch, 1984)

and about 25 miles west of delta D. Fusulinids (Triticites) were common at the north end of the islands associated with delta A and also along the northwest margin of delta B. This linear fusulinid distribution probably parallels depositional slope, as fusulinids appear to have been depth sensitive (Ross, 1983). Ross (1983) estimated that Fusulinaceans (i.e., Triticites) occupied benthic niches less than 15 - 20 meters deep.

Only delta lobe A seems to have persisted along the southeastern shoreline at maximum transgression of the Woods Run marine event (Fig. 8). A few islands remained 10 - 20 miles north of that delta, and a large island existed just west of the northern West Virginia panhandle. Argillaceous muds and patchy carbonate muds (Portersville facies) were deposited in areas north of delta A and adjacent to all the islands. That environment of deposition also graded eastward into areas where carbonate muds and sands of the Woods Run facies developed. More diverse faunas seem to have thrived there, so the environment was probably somewhat deeper and/or more open than the Portersville depositional environment. Consequently, the main route of transgression seems to have been from the north-northwest through southwestern Pennsylvania. Two marginal environments of deposition developed on the northeastern edge of the study area at this time. Dark, argillaceous muds (Friendsville) were deposited in very shallow, brackish(?) areas adjacent to the shoreline that were inhabited by bivalves (e.g., Dunbarella), inarticulate brachiopods (e.g., Lingula and Orbiculoidea), and bellerophontacean gastropods. Northward and seaward of that environment, less organic muds were deposited (Carnahan Run), where Amphiscapha gastropods or Dunbarella bivalves abounded.

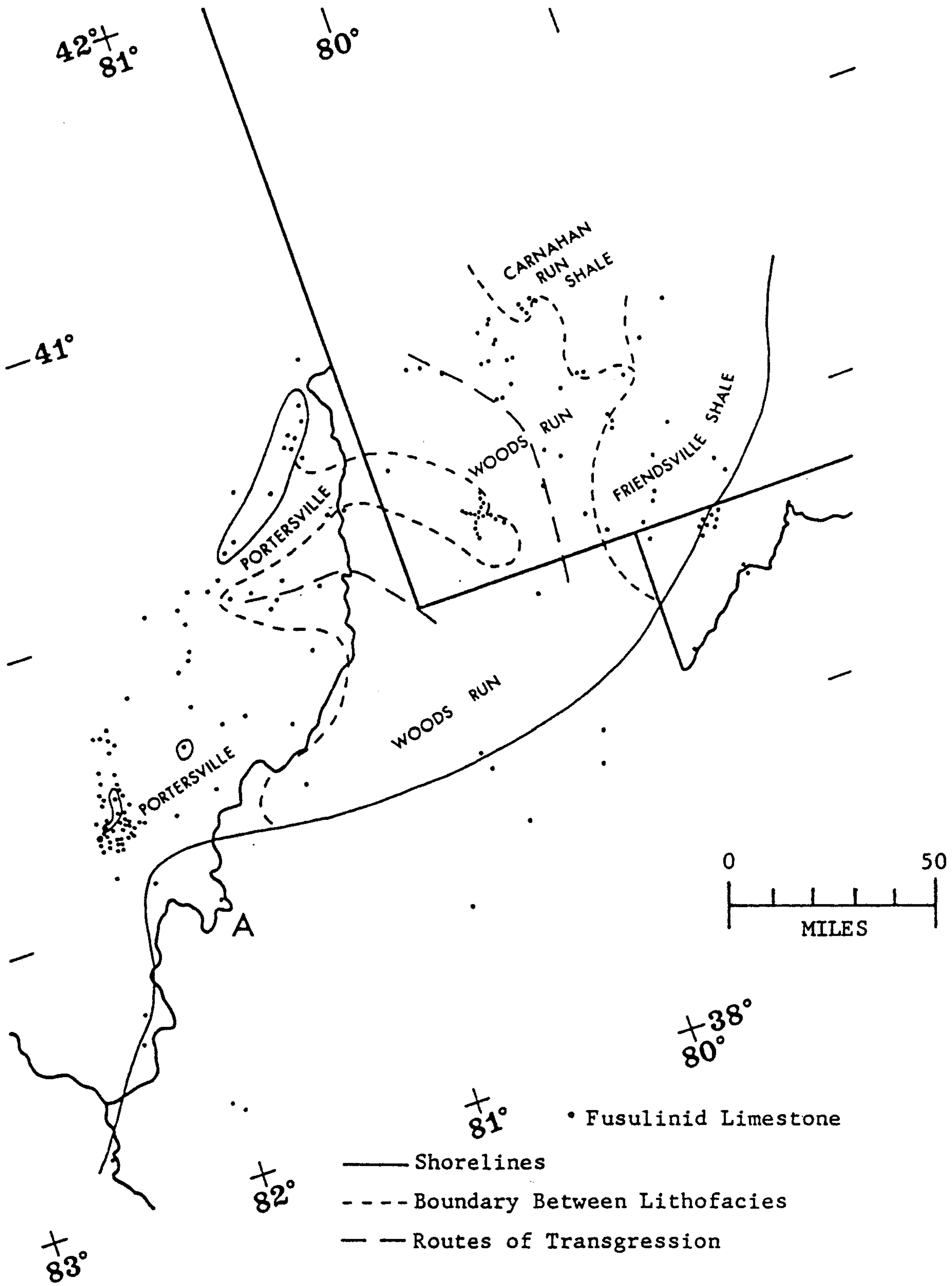

Figure 8: Paleogeography and marine facies (Woods Run limestone and shale, Portersville limestone and shale, Carnahan Run Shale, Friendsville Shale) developed at time of maximum transgression during deposition of the Woods Run fifth-order T-R unit. Black dots are data points. Letter A labels a possible delta lobe. (Busch, 1984)

The southeastern shoreline was very lobate at the time of maximum transgression of the Bakerstown marine event. Delta lobes A and D were very well developed, but lobe C was less prominent (Fig. 9). A large island or peninsula occupied an area in eastern Ohio and the northern West Virginia panhandle. The Bakerstown marine event mainly resulted in the deposition of marine argillaceous muds of the Bakerstown shale facies in narrow seaways in Pennsylvania (west of delta D) and West Virginia (between deltas C and D, and northwest of delta C). Nuculoid bivalves and Dunbarella thrived in such environments, suggesting brackish(?) conditions. Crinoidal carbonate muds of the Noble facies were deposited in a narrow seaway between delta A and the eastern Ohio island-peninsula landmass. More open conditions prevailed in that seaway (i.e., there was a more diverse fauna) than in the more eastern seaways of the Bakerstown environment. Therefore, the Noble seaway marks the major route of transgression from the west. Fenestral carbonate muds were deposited in supratidal ponds adjacent to the Noble seaway (Rock Riffle Limestone paleoenvironment). A fauna consisting mainly of spirorbid annelids and ostracodes thrived in those ponds.

The Ames marine event was the most extensive Upper Pennsylvanian marine incursion, and it apparently developed as a result of at least two sixth-order transgressions (e.g., Al-Qayim, 1983). No islands were developed at the time of maximum transgression of the Ames marine event, and the eastern shoreline was established farther to the southeast than during any other incursion of the Conemaugh Group (Fig. 10). Only two delta lobes are actually discernible (A and B); although the distribution of marine shale facies suggests the presence of two or three more northerly deltas (C - E). The entire eastern shoreline was bordered by marginal

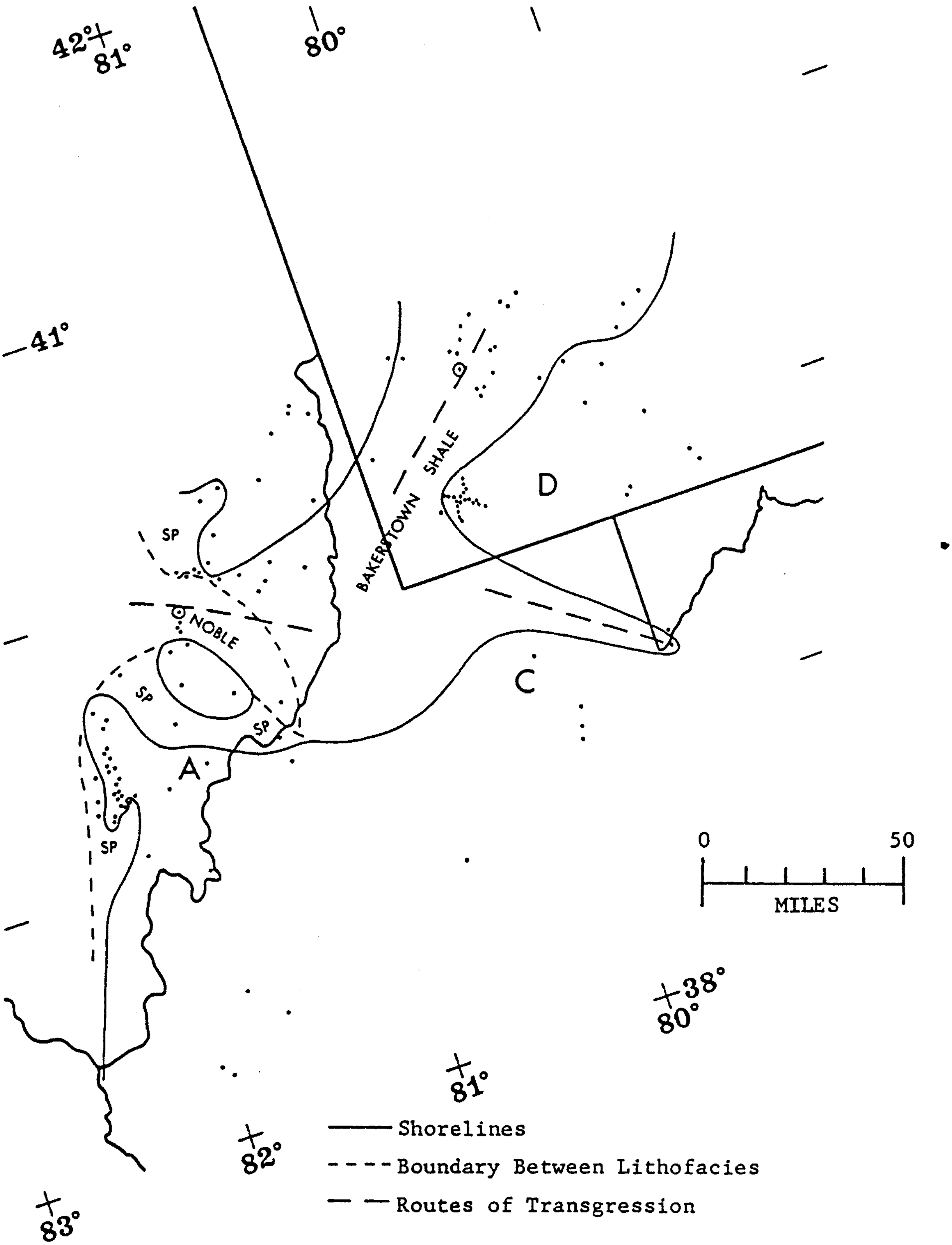

Figure 9: Paleogeography and marine facies (Bakerstown Shale, Noble shale and limestone, Rock Riffle supratidal pond limestones - SP) developed at time of maximum transgression during deposition of the Bakerstown fifth-order T-R unit. Black dots are data points. Letters A, C, and D label possible delta lobes. (Busch, 1984)

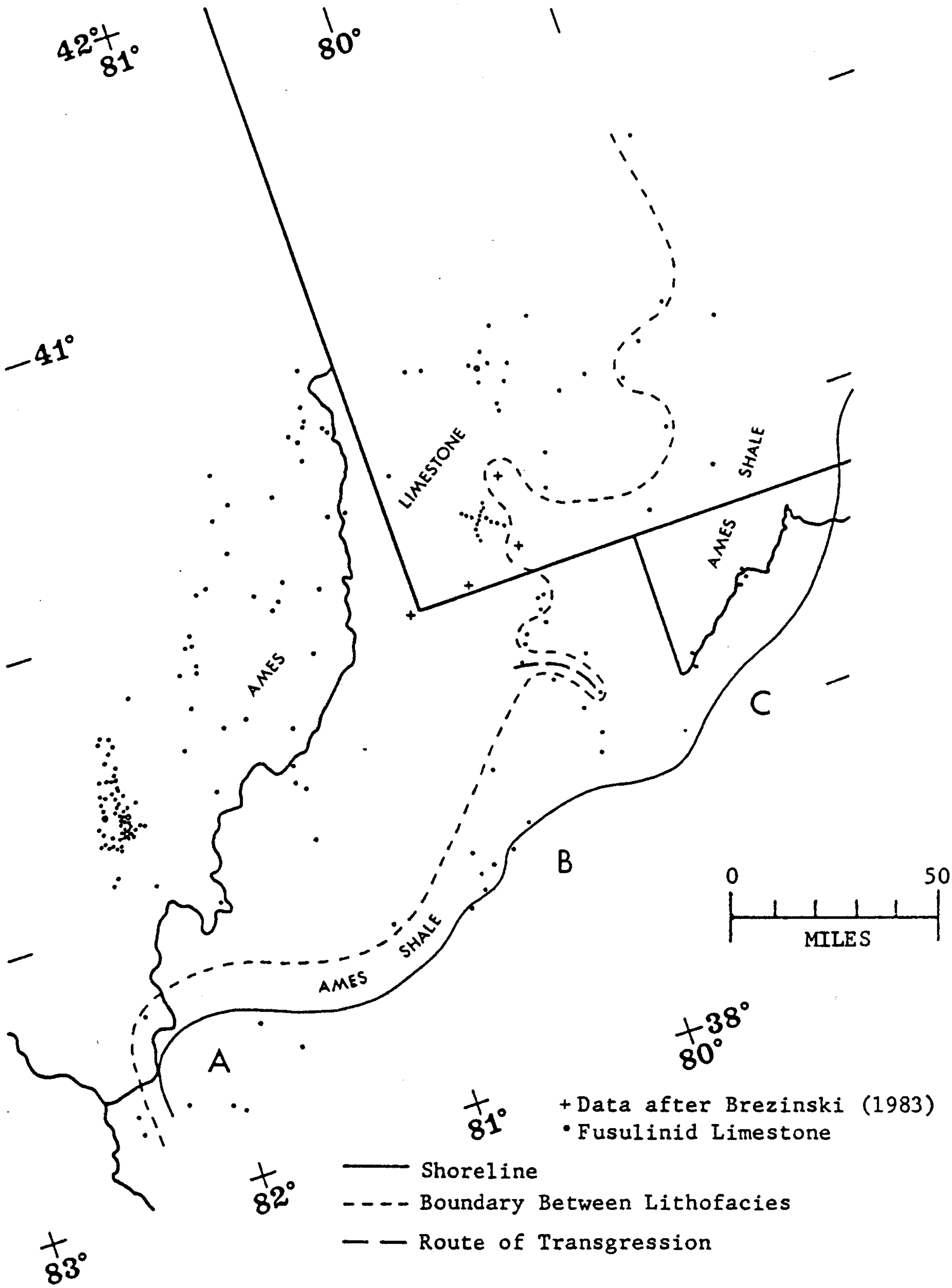

Figure 10: Paleogeography and marine facies (Ames limestone and shale) developed at time of maximum transgression during deposition of the Ames fifth-order T-R unit. Black dots are data points. Letters A-C label possible delta lobes. (Busch, 1984)

marine environments, where dark argillaceous muds of the Ames shale facies were deposited. Marine carbonate muds and sands developed in all of the remaining marine areas from Ohio (Ames Limestone) to northeastern Pennsylvania (Mill Creek Limestone - Chow, 1951). A minor route of transgression may have been present north of delta B, where an arcuate lobe of the Ames Limestone facies extends into the Ames shale facies. This is the only route of transgression discernible on figure 10. The primary route of the Ames transgression (i.e., primary axis) probably developed through central and northeastern Ohio (Fig. 11).

Water depths established in the study area during Glenshaw Formation fifth-order transgressive maxima were probably quite shallow. For example, there are no phosphatic, black, "core" shales in the Glenshaw Formation like those which may have formed in 40 - 200 meters of water in Midcontinent areas during these Missourian marine events (Heckel, 1977). The marine facies can generally be regarded as paralic. There is a noticeable lack of deep water taxa and an abundance of shallow marine to brackish taxa. Some of the most open marine facies contain fusulinids (Triticites) which probably inhabited water depths less than 15 - 20 meters, based on estimates by Ross (1983).

The characteristics of each marine event, and the development of each fifth-order T-R unit, conform well to the "bank model" of Carboniferous sedimentation (Laporte and Imbrie, 1964). Each marine event inherited the topography that existed just prior to that event. Transgression proceeded along topographic lows, while islands and larger landmasses formed on the small and large topographic highs, respectively. Sedimentary aggradation was an important depositional process during the fifth-order transgressive maxima and the subsequent regressions. The aggradation was

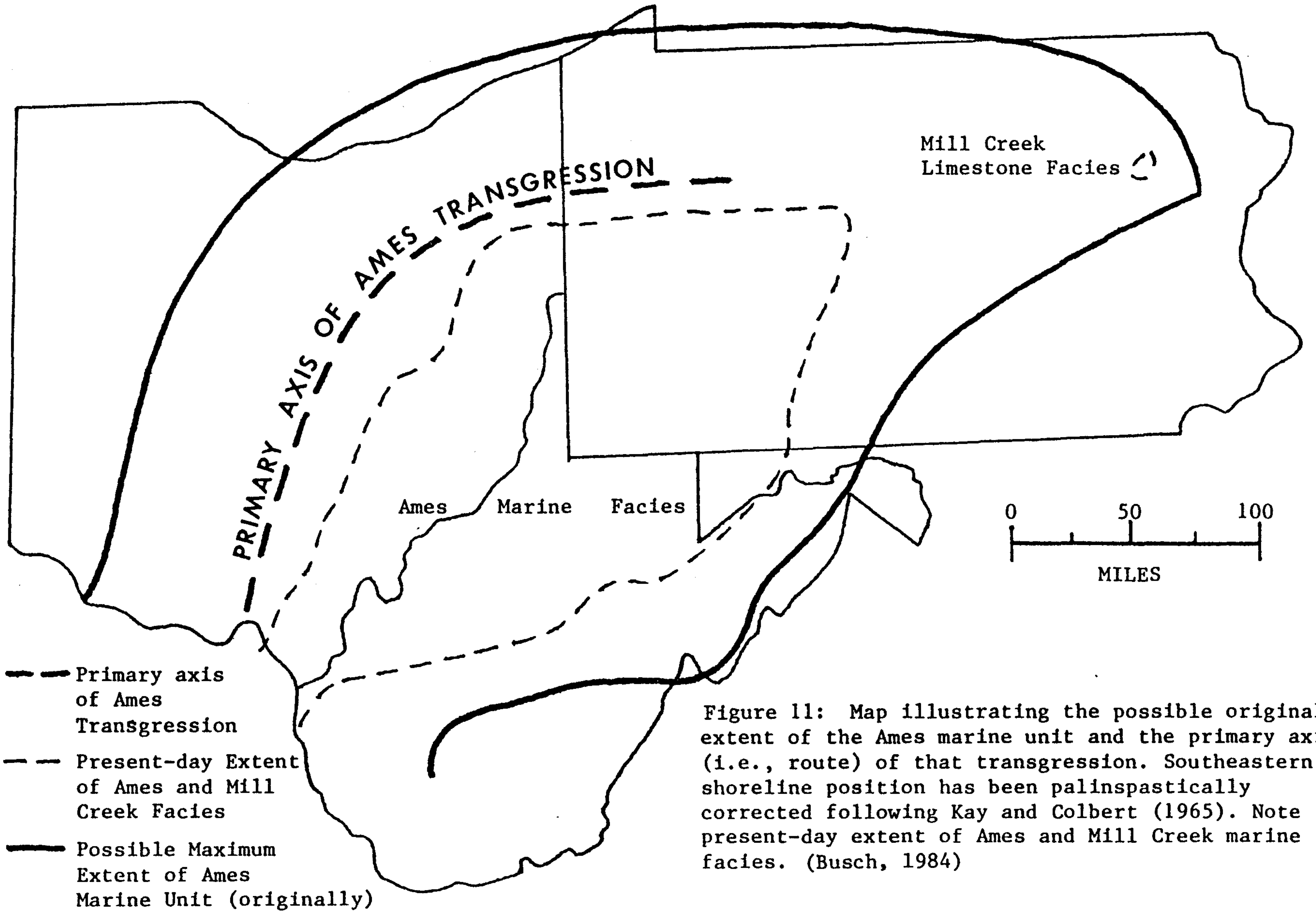

Figure 11: Map illustrating the possible original extent of the Ames marine unit and the primary axis (i.e., route) of that transgression. Southeastern shoreline position has been palinspastically corrected following Kay and Colbert (1965). Note present-day extent of Ames and Mill Creek marine facies. (Busch, 1984)

accompanied by progradation of island shorelines and the deltaic southeastern shoreline.

Structural Controls on Paleogeography and Sedimentation

Previous workers have noted the relationship between Pennsylvanian facies development and paleotopography (e.g., Williams et al., 1968; Holbrook, 1973; Donaldson, 1974). Some of those workers have even related the paleotopographic and facies variations to specific processes such as differential compaction (Mueller and Wanless, 1957) or differential sedimentation and subsidence (Williams and Ferm, 1964). A particularly detailed study by Madar (1981) showed that lithofacies of the lower Glenshaw Formation were developed syntectonically in southwestern Pennsylvania. Sandstones and coals were found to be thickest in presently existing synclines (e.g., Latrobe Syncline) and appreciably thinner on existing anticlines (e.g., Jacksonville and Chestnut Ridge Anticlines). Madar's data also suggest that similar thickness changes occur within the Brush Creek marine unit.

Many of the fifth-order transgressions that occurred during deposition of the Glenshaw Formation proceeded geographically along linear or arcuate routes within the study area illustrated in figures 2 through 10. The axis of deepest marine waters within each of these routes could be thought of as a secondary axis, because the main route of marine transgression (and primary axis) for each marine event was probably through central and northeastern Ohio, much the same as illustrated for the Ames marine event in figure 11. All of the routes of transgression labelled on figures 2 - 10 were assembled on figure 12 to compare their locations and orientations. These routes are basically oriented along two directions. One set has a northeast-trending orientation parallel to present strike, while another set trends northwest and therefore normal to present strike. Some major zones of strike-parallel normal faulting associated with the Rome Trough and its "Eastern Fork" have also been plotted on figure 12 after Donaldson and Shumaker (1979) and Wagner (1976). Some of the routes of transgression conform to these fault zones. Other routes, however, have orientations parallel to that of major cross-strike lineaments such as the Pittsburgh-Mt. Washington (Lavin et al., 1982), Parsons (Wheeler, 1980), and 40 Degrees North Latitude (Root and Hoskins, 1977) lineaments. Such lineaments, or cross-strike structural discontinuities (CSDs) are diffuse, transverse zones of intense faulting and jointing (Wheeler, 1980).

Figure 13 illustrates all of the fault zones of figure 12 which seem to have affected the development of routes of transgression. Three of these fault zones have been extended based upon the transgression-route data. Five major cross-strike lineaments (CSDs) have also been defined on figure 13, based upon the location of cross-strike routes of transgression. Two of those lineaments have not previously been named (X and Z), but the other three tend to conform with the Pittsburgh-Mt. Washington, Parsons, and 40 Degrees North Latitude lineaments as mentioned earlier. Therefore, figure 13 presents the structural features which primarily affected paleogeographic and facies developemnt of the Glenshaw Formation. Topographic lows apparently developed parallel to these major structural features, and transgressions proceeded along them. Topographic highs such as islands developed almost exclusively between these topographic lows. Furthermore, delta lobes along the southeastern shoreline on figures 2 - 10 seem to have persisted in location, and the locations of deltas C and

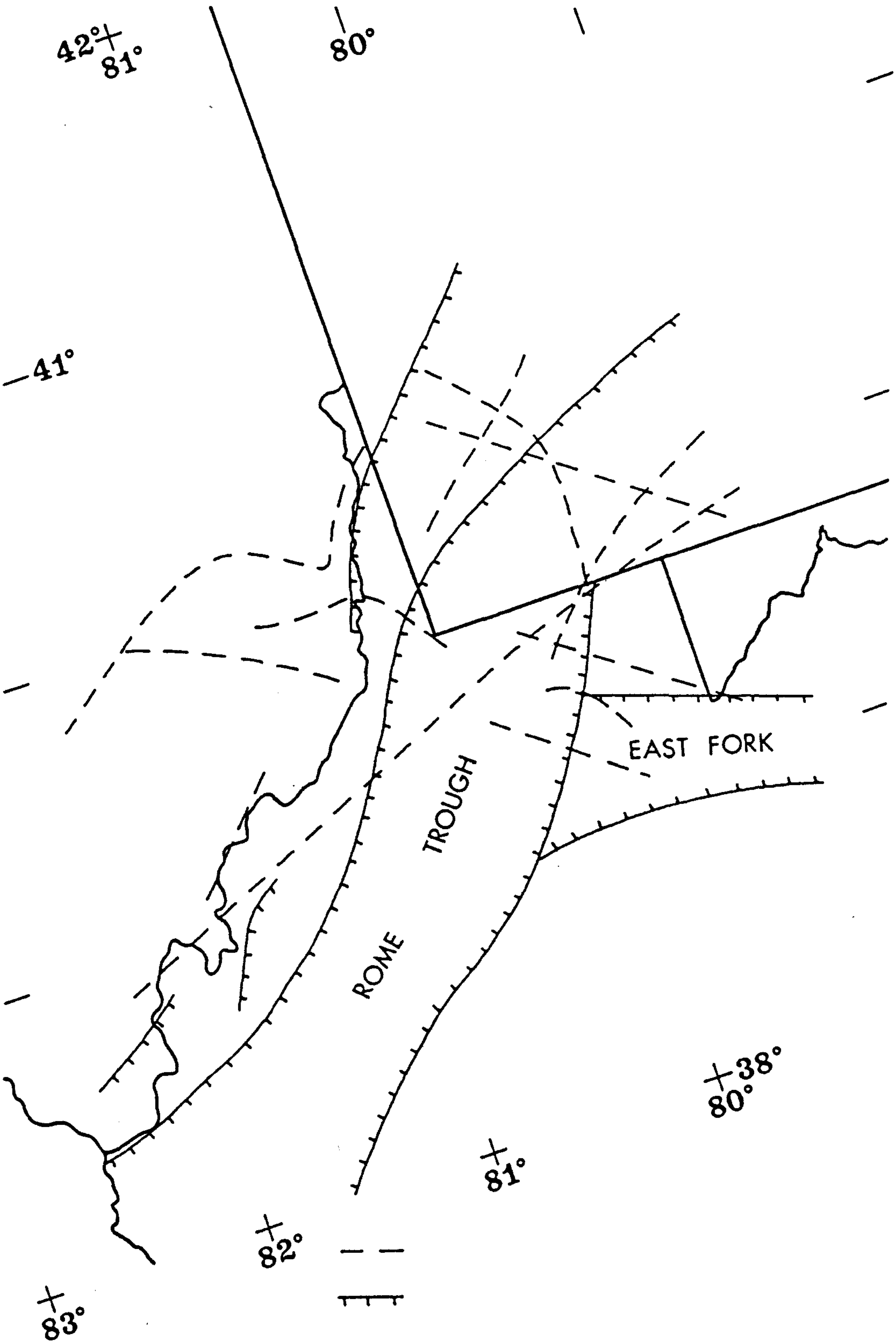

Figure 12: Map showing the location of all routes of transgression taken from figures II.8 to II.16, and the location of major faults associated with the Rome Trough, that may have affected Pennsylvanian paleogeography and depositional processes (Donaldson and Shumaker, 1972; Wagner, 1972). (Busch, 1984)

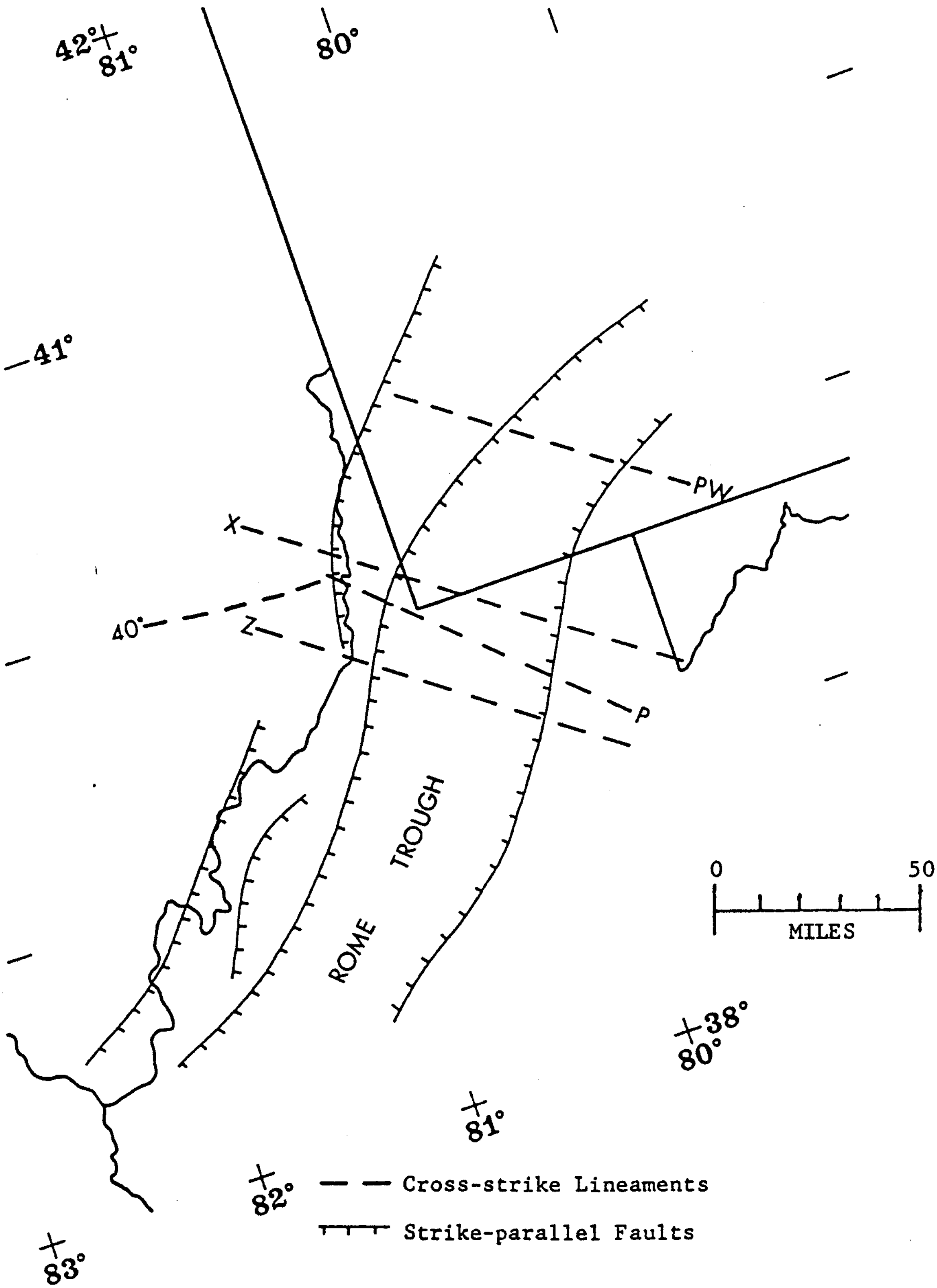

Figure 13: Map showing the location of strike-parallel faults, associated with the Rome Trough, and presumed cross-strike lineaments that affected Upper Pennsylvanian paleogeography and depositional processes. Lineaments are the Pittsburgh-Mt.Washington (PW), Parsons (P), 40 Degree North Latitude (40°), and unnamed (X and Z). See text. (Busch, 1984)

D seem to be related to the cross-strike lineaments. Thus, Upper Pennsylvanian drainage patterns may have developed in relation to topographic lows along the lineaments.

Conclusions

Paleogeographic changes and facies development associated with deposition of the Glenshaw Formation were primarily affected by climatic changes and concomitant sea level fluctuations that led to the formation of minor T-R units (Busch and Rollins, 1984). Topographic variations relative to strike-parallel fault zones and major cross-strike lineaments (or CSDs - Wheeler, 1980) also controlled major aspects of paleogeography such as routes of transgression, position of deltas, and position of islands.

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Pennsylvanian Trilobites as Environmental Indicators: an example from the Glenshaw Formation (Missourian-Virgilian) of the Appalachian Basin

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INTRODUCTION

Trilobites are often intuitively thought of as indicators of offshore, normal-marine environments. For species from the Pennsylvanian this may not always be the case. Numerous occurrences of trilobites from the Pennsylvanian Formations of the Appalachian Basin suggests that trilobites of this age may have preferred more nearshore environmental settings than previously believed. This hypothesis will be tested in the Glenshaw Formation (Missourian-Virgilian) of the Conemaugh Group of Pennsylvania and Ohio.

The Glenshaw Formation provides an excellent opportunity for the testing of this hypothesis because: 1) numerous paleoecological studies of Glenshaw marine intervals (Donahue, Rollins and Shaak, 1972; Donahue and Rollins, 1974; Rollins and Donahue, 1975; Rollins, Carothers and Donahue, 1979; Brezinski, 1983) provide a paleoecological framework to which trilobite distributions can be compared, 2) Glenshaw marine episodes were of short duration (Donahue and Rollins, 1975) and so represent thins intervals which can be easily studied, 3) since the location of the paleoshoreline is moderately well known, environmental and ecological inferences regarding distance from the shoreline can be made.

BIOFACIES MODEL

Brezinski (1983) has proposed a generalized model to explain the distribution of biofacies and lithofacies in upper Pennsylvanian marine units of the north-central Appalachian Basin. The model subdivides indigenous marine biota into four biofacies which are distributed with respect to the onshore-offshore stress gradient. The model proposes that the diversity and abundance of stenotopic species (e.g. bryozoans, brachiopods and fusulinids) decrease toward the paleoshoreline, whereas, those of eurytopic species (gastropods and bivalves) increase. The most offshore biofacies recognized was numerically dominated by spiriferid brachiopods, bryozoans, fusulinids and crinoids, and typically occurred in limestone and nodular limestone lithologies. These lithologies typically formed in areas farthest removed from the sources of clastic input. Shoreward, the fusulinids and bryozoans are generally absent and only a few of the hardier species of brachiopod (Composita. Crurythyris) can be found. This greatly reduced brachiopod biofacies grades concommittantly with lithology in a shoreward direction, into a molluscan biofacies present in more parallic shales and calcareous shales. In several marine units transgressive facies are marked by a basal layer of chonetid brachiopods. These chonetids appear to have been opportunists, who colonized and normalized the substrate during transgression. Regressive facies are indicated by profuse accumulations of the brachiopod Crurythyris, which is often associated with molluscs in a gray-green shale which commonly overly limestone outcrops. Transgressive and regressive periods probably represented times of elevated physiological stress as indicated by the low diversity of the associated biofacies (Rollins, et al., 1979).

With this generalized biofacies model in mind, the distribution of trilobites may now be considered.

TRILOBITE DISTRIBUTION

Three species of trilobites are found in the Glenshaw strata: *Ameura missouriensis*, *Ditomopyge scitula*, and *Ditomopyge sp*. Both *A. missouriensis* and *Ditomopyge scitula* are found throughout the Glenshaw interval. *D. sp*. is restricted to the Ames marine unit.

Trilobites have been recovered from 38 exposures of marine units from the Glenshaw Formation of western Pennsylvania and eastern Ohio. Collections from the 38 localities are restricted to, in acending, the Brush Creek, Pine Creek, Woods Run, and Ames marine intervals. The trilobites were commonly recovered from similar lithofacies and biofacies from each of the marine intervals.

Mostly commonly, trilobite specimens are present within dark gray to black calcareous shales of the Brush Creek, Woods Run and Ames horizons. Sixteen of the 38 occurrences (42%) were from the black shale lithology. This lithology invariably contains a molluscan biofacies with minor numbers of chonetid and productid brachiopods. As discussed above in the biofacies model, the black shale lithofacies and molluscan-dominated biofacies are both interpreted to be nearshore facies which formed in areas of high clastic input and elevated nutrient concentrations (Brezinski, 1983).

The second most common occurrence of trilobites is within the *Crurythyris* biofacies. This biofacies is best developed in the regressive deposits of the Ames interval, but is also present in the Brush Creek and Pine Creek intervals. Eleven of the 38 occurrences (29%) have been noted from this biofacies.

TABLE I

Species	Association				
	molluscan	chonetid	*Crurythyris*	brachiopod-bryozoan	
Ameura missouriensis	6	--	--	2	
Ditomopyge scitula	10	5	6	3	
Ditomopyge sp	--	1	5	--	
total/percent	16/42	6/16	11/29	5/13	38/100

Trilobites were also recovered from the chonetid biofacies. This biofacies is most prevalent in Pine Creek and Ames intervals, but was also noted in the Brush Creek interval. Only 6 occurrences (6%) were noted from this biofacies. Lithologically, this biofacies is present in thin gray-green calcareous shales to argillaceous limestone, which commonly underlie many of the limestone outcrops. The lithology and biofacies were formed during the initial stages of transgression of several of the marine episodes, and probably represent a high stress environment at the leading edge of the transgressing sea.

The remaining 5 occurrences (13%) were within the limestone lithologies which contain diverse brachiopod and bryozoan faunas (*Neospirifer*, *Punctospirifer*, *Hustedia*, *Rhombopora*, *Stenopora*). This is interpreted as offshore, normal-marine limestone deposited under open-circulation conditions.

CONCLUSIONS

Trilobites from the Glenshaw Formation of Pennsylvania and Ohio tend to occur in nearshore or high stress environments, and are commonly associated with eurytopic faunas.

Fifty-eight percent of the trilobite occurrences are in brachiopod-dominated biofacies (i.e., Crurythyris biofacies (29%), Chonetid biofacies (16%), offshore biofacies (13%) and their distribution appears to follow Bretsky's (1969) contention that Carboniferous trilobites are indicators of offshore environments. However, all but the 5 occurrences in the offshore biofacies, or 87%, are within biofacies which can be interpreted as occupying nearshore or high stress settings. Additionally, the general increase in numbers and number of occurrences of trilobites onshore follows the distribution expected for a eurytopic species and trophic generalist (Valentine, 1972). In nearshore unstable settings eurytopes abound since there is an abundance of nutrients but a paucity of competitors. However, in offshore areas resources are more partitioned than in a nearshore environment and competition is greater for available resources. In this setting the trophic generalist is at disadvantage to more specialized trophic types. Consequently, the generalist does not compete well for available resources and therefore would be present, but less abundant in offshore areas.

The data presented herein suggests that Pennsylvanian trilobites may be used as nearshore or high stressed environmental indicators.

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THE WOODS RUN MARINE UNIT OF SOUTHWESTERN PENNSYLVANIA

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INTRODUCTION AND STRATIGRAPHY

The Woods Run Limestone is a very fossiliferous, ferruginous, argillaceous, marine limestone of the Upper Pennsylvanian Glenshaw Formation (Conemaugh Group) in southwestern Pennsylvania. It is named for distinct outcrops on Brighton Road, west of Woods Run in Allegheny County, Pennsylvania (Raymond, 1909), and lies stratigraphically between the subjacent Nadine marine limestone and the superjacent Bakerstown marine shale (Wells, 1983). The thickness of the limestone is quite variable ranging from about one inch in Steubenville, Ohio to two feet (.6 m) in much of southwestern Pennsylvania. The Woods Run Limestone is also correlative with and interfingers with the marine Portersville Shale (Condit, 1912), the marine Carnahan Run Shale (Burke, 1957; see Wells, 1983) and the marine Friendsville Shale (Swartz, Price, and Bassler, 1919). The Portersville Shale (Ohio and Pennsylvania) is a gray to black, soft shale that sometimes contains calcilutite nodules, the Carnahan Run Shale (Pennsylvania) is a dark gray calcareous clay shale, and the Friendsville Shale (Maryland and Pennsylvania) is a black, platy to fissile clay shale. The Woods Run Limestone and its three correlative marine facies constitute the "Woods Run marine unit" (marker bed).

SUBFACIES OF THE WOODS RUN LIMESTONE

Based upon petrographic investigation now in progress, two separate sub-lithofacies can be recognized within the Woods Run Limestone facies: a packstone subfacies and a wackestone subfacies (Fig. 1).

<u>Packstone subfacies</u>: Throughout the northeastern portion of its distribution in Pennsylvania, the Woods Run Limestone is a medium to dark gray, ferruginous, argillaceous packstone with abundant fossils. Megafossils include cephalopods, gastropods, crinoids, ostracodes, brachiopods, rugose corals and occasional trilobites. The microfauna consists of brachiopod spines, bryozoa, mollusc shell fragments, plant fragments and arthropod fragments. Many of the thin sections contain small angular quartz grains as well as abundant pyrite. Granular phosphate and a minute amount of glauconite are also found in a few thin sections. Small scale festoon-crossbedding is observed at one locality and is the most evident sedimentary structure displayed, although microscopic sedimentary structures are seen petrographically in thin section. These structures are exhibited as burrows within micritic intraclasts and as bioturbated skeletal debris which is irregularly distributed throughout the micrite. The lack of bedding within the Woods Run Limestone lithofacies is one of its most distinguishing lithologic characteristics and is evident in both subfacies.

<u>Wackestone subfacies</u>: An argillaceous, dark gray wackestone predominates southwest of and interfingers with, the packstone subfacies. It contains the same fossils as the packstone lithofacies, but there appears to be a slight decrease in fossil abundance. Quartz, pyrite and a small amount of granular phosphate can be observed in thin section, but glauconite is absent from this subfacies.

<u>Woods Run Limestone coated-grains</u>: Two distinct types of coated-grains occur within both subfacies of the Woods Run Limestone: 1) skeletal fragments en-

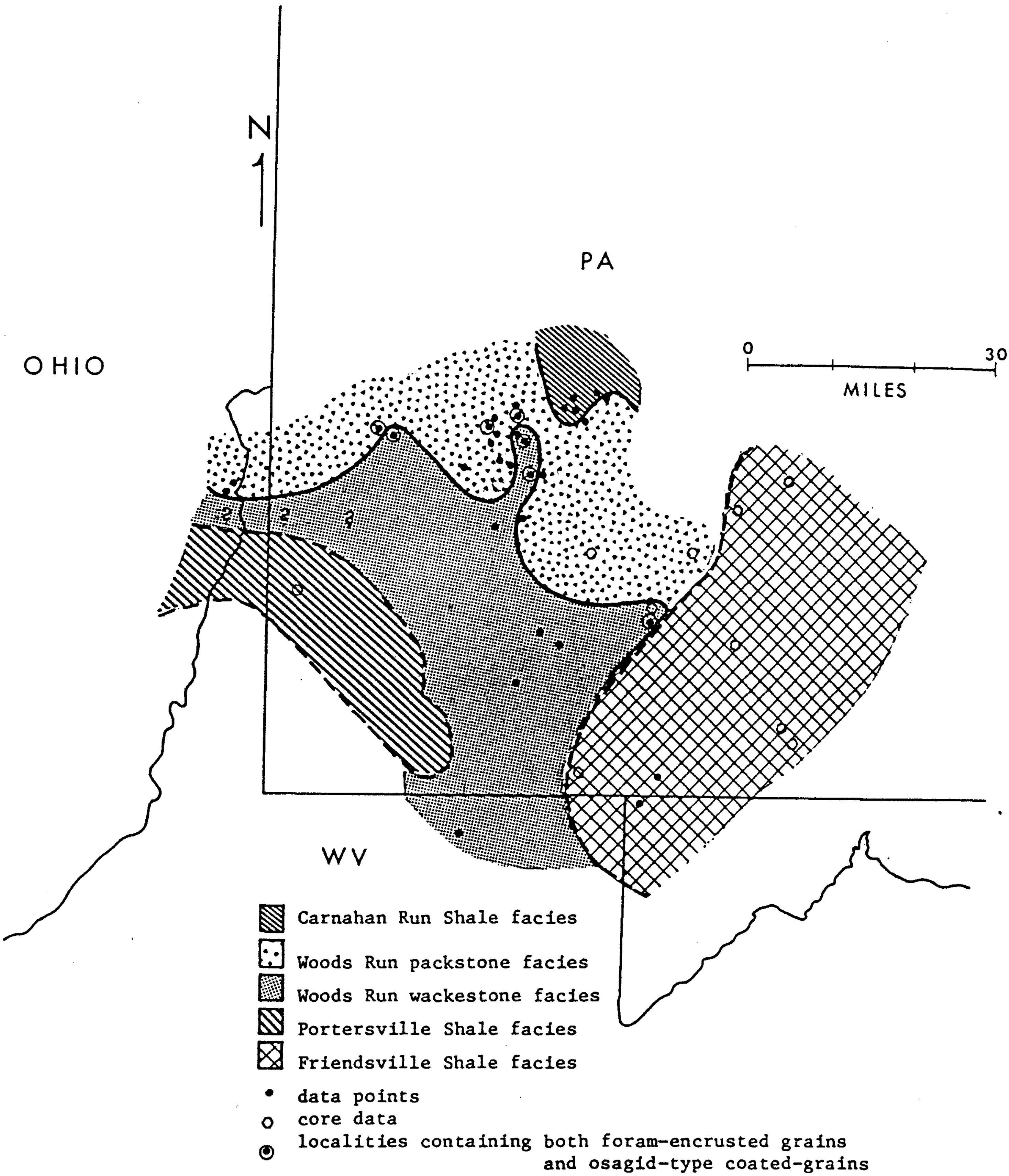


Figure 1. Lithofacies development of the Woods Run fifth-order T-R unit during maximum transgression. Boundaries for the extent of the Friendsville Shale and Portersville Shale were adapted from Busch (1984). Core descriptions were furnished courtesy of the Pennsylvania Geological Survey.

crusted by calcareous smaller foraminifers and 2) algal concretions of Osagia incrustata Twenhofel, 1919, emend. Henbest, 1963. Foram-encrusted coated-grains were observed within the Ames Limestone of the Appalachian Basin by Al-Qayim (1983), and both types of coated grains occur within the Leavenworth Limestone of the Midcontinent (Toomey, 1972; 1974). Identification to the genus level of the foraminifers and associated algae is presently under investigation.
The presence of these aggregate grains within the Woods Run Limestone lithofacies is a significant factor which allows conclusions to be drawn regarding the water depth of this unit. Henbest (1963) and Toomey (1974) both suggest that osagid-type coated-grains form in shallow marine waters, in the zone of wave and current action where photosynthesis can occur. The presence of osagid-type coated-grains within the Woods Run Limestone is an indication of a fairly shallow depositional environment.

The abundance and diversity of fossils suggests that the Woods Run Limestone is an open marine facies, and although smaller foraminifers are found within the limestone, it lacks the presence of fusulinids which are typical of open, normal marine offshore facies. Perhaps then, water depths for the Woods Run Limestone were below the minimum depth (under 13 meters; see Stevens, 1969) for the development of the fusulinid fossil community.

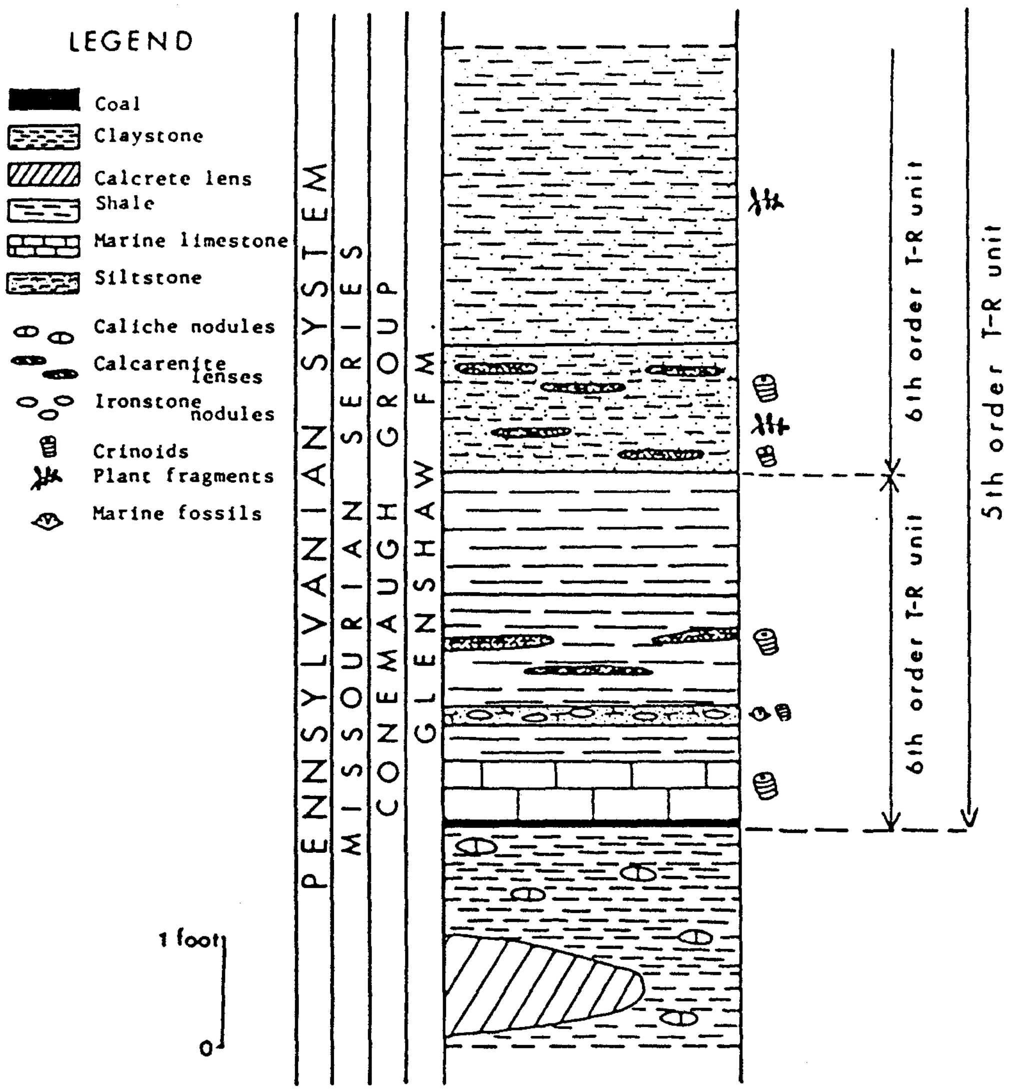
The presence of these two types of coated-grains along with the absence of fusulinids and the crossbedding within this lithofacies suggests that the Woods Run lithofacies is a very shallow water marine deposit. It is a deeper facies than the Portersville Shale, Carnahan Run Shale or Friendsville Shale since it contains the most abundant and diverse fauna but even at its deepest, the Woods Run Limestone lithofacies was only a few meters deep.

THE WOODS RUN MARINE EVENT

Various scales of Carboniferous transgressive-regressive units have been defined by many different workers, and Busch (1984) and Busch and Rollins (1984) have shown that such T-R units can be classified relative to a hierarchy of six scales of allocyclic T-R units. The Woods Run marine unit is the marine portion of one fifth-order T-R unit that can be correlated at least basinwide (Wells, 1983; Busch, Wells, and Rollins, 1984), and represents an interval of about 400,000 to 450,000 years (Busch and Rollins, 1984).

Preliminary lithofacies and biofacies data of an investigation now in progress, suggests that two smaller-scale T-R units can sometimes be recognized within the Woods Run marine unit of the Woods Run fifth-order T-R unit. As exemplified in Figure 2, these smaller-scale T-R units are often symmmetric in favor of a thicker regressive (progradational) portion. They can be referred to as punctuated aggradational cycles (PACs) following Anderson and Goodwin (1980) or sixth-order T-R units following Busch and Rollins (1984). One aspect of a study now in progress is to examine the lateral persistence of these minor T-R units within the Woods Run marine unit. They may be autocyclic T-R units developed locally or allocyclic T-R units developed basinwide.

SEWICKLY BRIDGE LOCALITY
SEWICKLY, PA.



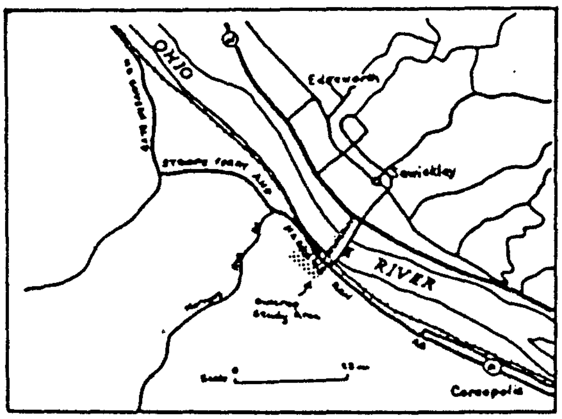


Figure 2. An illustration of sixth-order T-R units within the Woods Run fifth-order T-R unit at Sewickly Bridge Locality (Ambridge Quad.), Sewickly, Pennsylvania (40°31′54″N latitude, 80°11′22″W longitude).

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Upper Mississippian Transgressive-Regressive Episodes

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INTRODUCTION

It has been recognized for some time that the Late Mississippian was a time of fluctuating sea level. As Sloss (1963, p. 102) points out:

> Chesterian strata....... are typified by a succession with numerous cyclical repetitions of sandstone, shale and limestone.

Sloss went on to say that Chesterian cyclicity was merely a prelude for what was to follow during the Pennsylvanian. Studies of Late Mississippian cyclicity have dealt with the Illinois Basin (Swann, 1964) and northwestern Europe (Ramsbottom, 1979). Studies of Appalachian Basin Chesterian cyclicity have previously only examined large scale cycles (third-order or greater) and have ignored episodes of short duration (Ettensohn, 1980).

Like Vail et al. (1977), Ramsbottom (1979) and Swann (1964) recognized that several scales of cyclicity are often decernable. The following paper discusses scales of cycles evident in Chesterian rocks of the Appalachian Basin and their duration and possible correlation.

CHESTERIAN SECTION

Chesterian rocks of the Appalachian Basin were deposited in two dramatically different environmental settings. In West Virginia and Virginia a thick section of carbonate rocks (Greenbrier Group) was deposited. However, in northeastern Pennsylvania deposition of nonmarine red clastic rocks (Mauch Chunk) took place. In northern West Virginia and southwestern Pennsylvania, carbonates of the Greenbrier Group interfinger with clastics of the Mauch Chunk Formation to form vertical repetitions of marine and nonmarine rocks. In acending order, the carbonate units consist of the Loyalhanna, Deer Valley, Wymps Gap, Glenray, and Reynolds Limestones (Figure 1). Each of these carbonate units varies in thickness and areal extent as a result of the strength and duration of their respective inundations. Three marine episodes (Loyalhanna, Wymps Gap, and Reynolds) were the longest and most aerially extensive. The Wymps Gap Limestone appears to have been the deepest of the inundations based on facies reconstruction by Brezinski (1984). The festoon crossbedding of the Loyalhanna and current features (graded bedding, and crossbedding) of the Reynolds suggest that these two units were deposited in considerably shallower waters.

SCALES OF TRANSGRESSIVE-REGRESSIVE UNITS

Within the Chesterian strata as many as four different scales of transgression and regression are evident. The largest scale discernable is the regressive nature of the entire Chesterian section (Sloss, 1963). This would be equivalent to the regressive phase of the Kaskaskia Sequence of Sloss (1963) and the second-order Devonian-Mississippian cycle of Vail et al. (1977). Moreover, the entire Chesterian is represented by a single more of less complete transgressive-regressive unit. This unit is equal to a third-order cycle of Vail et al. (1977) and consists of a transgressive (Loyalhanna) phase, a maximum transgression (Wymps Gap) phase, and a regressional (Reynolds) phase. These three episodes correlate nicely with episodes discussed by Ettensohn (1980) and Swann(1964) for the Chesterian sections of eastern Kentucky and Illinois

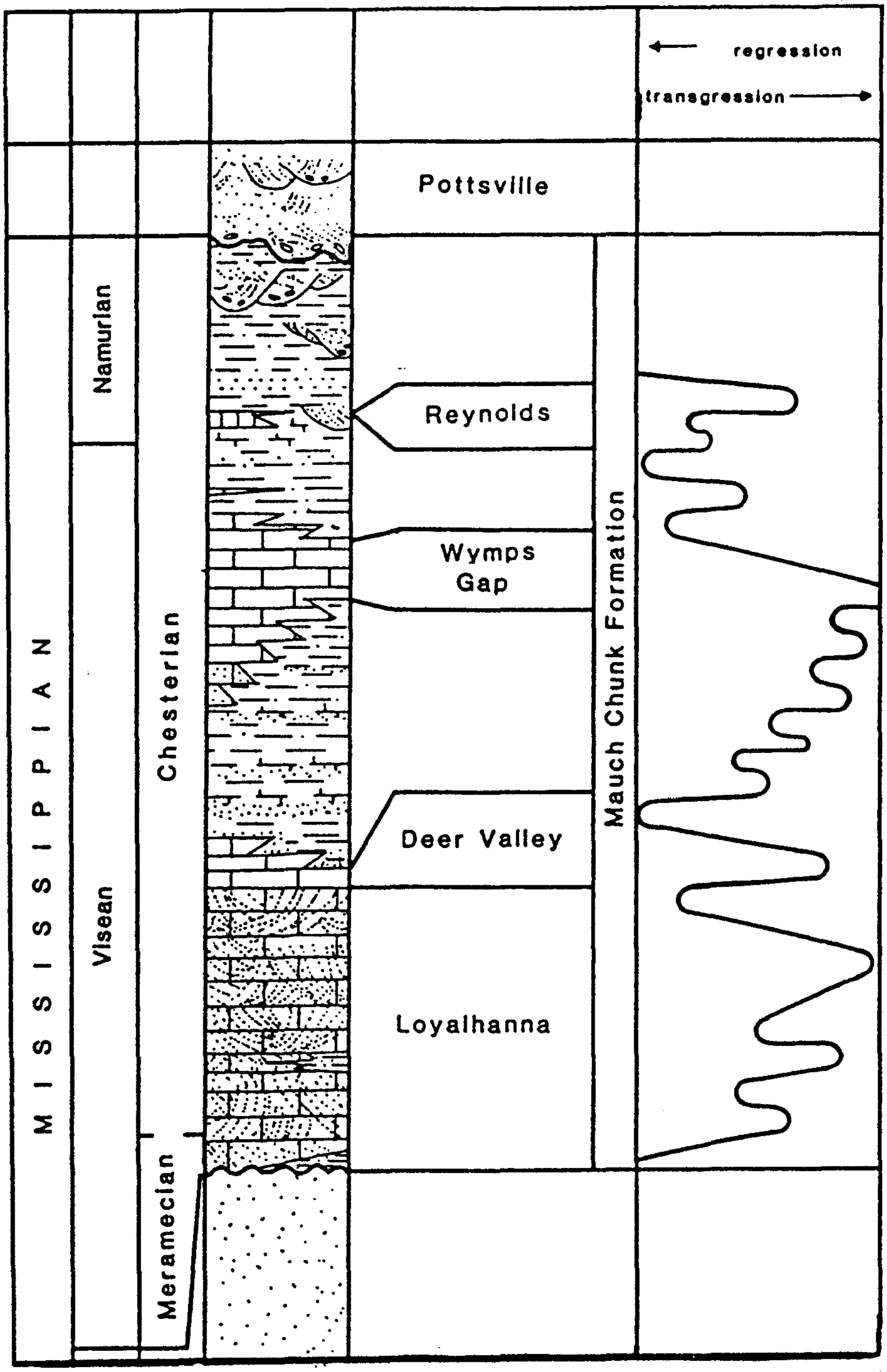

Figure 1. Stratigraphic column of Chesterian strata of the north-central Appalachian Basin and correlative sea level curve.

respectively. The duration of this third-order transgressive-regressive unit would be from 8-11 m.y. (Shulik, 1979). This is approximately equal to what Swann (1964) has estimated for the duration of the Chesterian of the Illinois Basin. Each of the major marine units in this sequence (i.e. Loyalhanna, Wymps Gap, Reynolds) are in themselves single fourth-order transgressive-regressive units. Since three of these fourth-order units make up the Chesterian, they each should have a duration of from 3.o to 3.6 m.y. This is comparable to Ramsbottom's estimation of 3.6 m.y. for the duration of a mesothem (= fourth-order T-R unit) during the Dinantian of northwestern Europe. Superimposed the fourtn-order units is a smaller scale of transgressive-regressive units (fifth-order). Inasmuch as no single, complete, well-exposed section of this sequence is known, determining the precise number of fifth-order T-R units is impossible. As many as 16 of these units may be present. A conservative estimate is 12 -14 (see Figures 1,2). Swann (1964) in his study of Chesterian cyclicity stated that as many as 15 major transgressions and regressions could be recognized in upper Mississippian strata of Illinois. If Swann's major transgressions are equated with the fifth-order transgressive-regressive units of the present study, then a close correlation between the two areas may be made. If 15 fifth-order transgressive-regressive units are present in North American Chesterian strata, the approximate duration of each would be from 500,000 to 750,000 years. This is in the vicinity of what Busch and Rollins (1984) have estimated for fifth-order transgressive-regressive units and Ramsbottom (1979) for cyclothems (= fifth-order T-R units) of northwestern Europe.

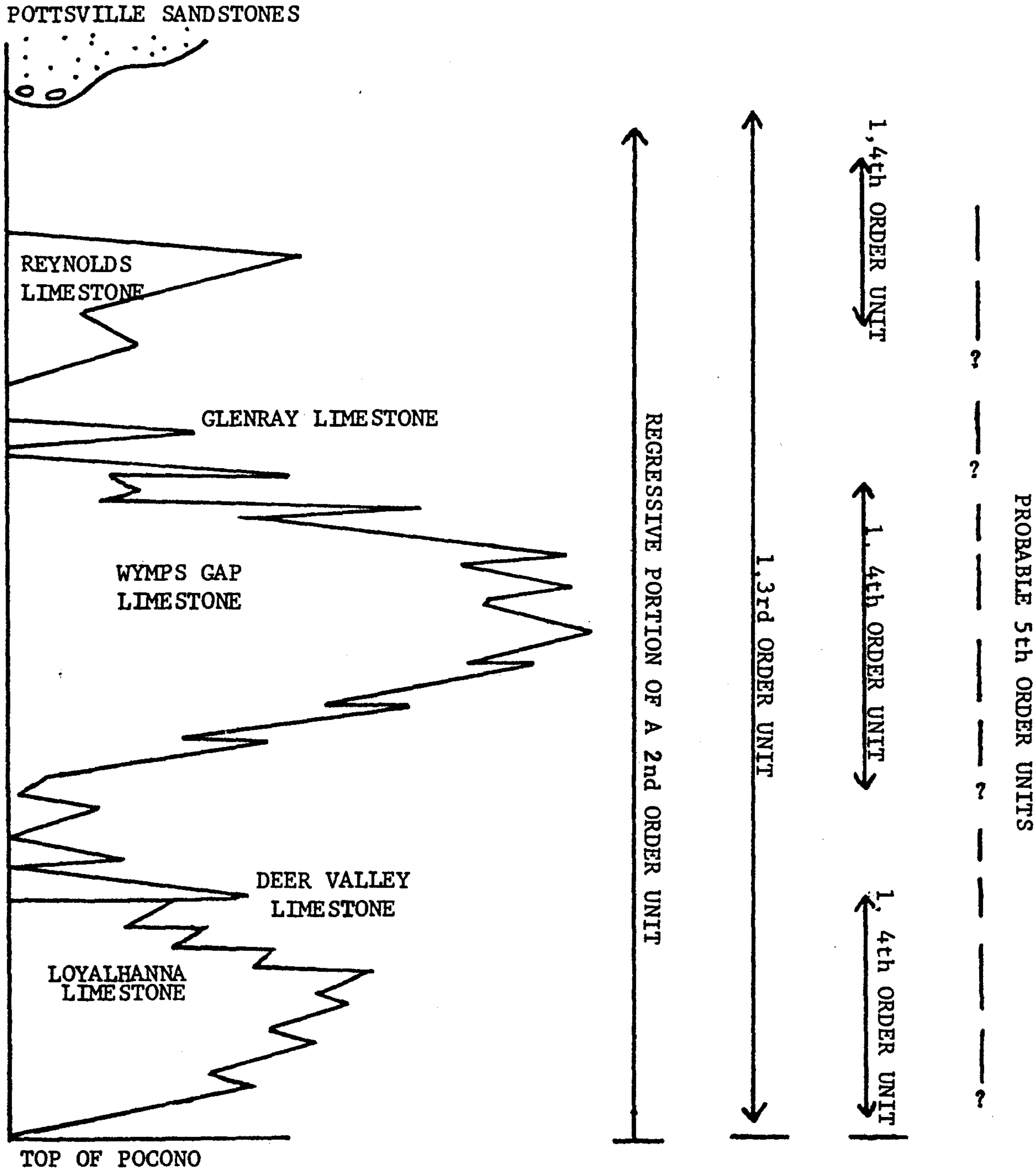

Figure 2. Major marine units of Chesterian rocks of the northcentral Appalachian Basin and corresponding scales of transgression and regression.

Although the possibility exists that still smaller (sixth-order) transgressive-regressive units are present in the Chesterian strata of the Appalachian Basin, no evidence to distinguish this scale of cyclicity was seen.

CORRELATION

Inasmuch as the Chesterian transgressions and regressions appear to have been caused by factors outside the basin of deposition, they afford a means by which correlation may be conducted. A mentioned above, second and third-order transgressive-regressive units are easily correlatable with the Illinois Basin. Correlation of fourth-order units are a little more tenuous. Since the Wymps Gap is the apex of a third-order T-R unit it should be correlated with the maximum transgressive unit of the Illinois Basin. This would be the Hardinsburg of Glen Dean Members (Swann, 1964; Ettensohn, 1980). On the basis of conodonts (Horowitz and Rexroad, 1972), this appears to be a correct correlation. With this correlation established, the Loyalhanna may be correlative to either the Ste. Genevive or Aux Vases Limestones of the Illinois section.

Correlation of fifth-order T-R units would, at this time, be inappropriate inasmuch as a complete reconstruction of the Appalachian section in not complete.

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Faunal Diversity and Community Composition as Indicators of Episodic Transgression in the Mauch Chunk Formation (Chesterian) of Southwestern Pennsylvania

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INTRODUCTION

The Mauch Chunk Formation of southwestern Pennsylvania consists of intertonguing marine carbonates (Loyalhanna and Wymps Gap Limestone) and nonmarine red clastics. The clastic interval which separates the Loyalhanna and Wymps Gap Limestone tongues contains as many as five thin marine intervals which record minor sea level oscillations. The marine units are typified by sharp bases and upper cantacts which grade into nonmarine siltstone and shale that are often mudcracked and root-mottled. In any particular section of the clastic interval, there is a noticible change upsection, in the lithology and fauna of these marine units. This change is indicated by an increase in the offshore character of the marine units from bottom to top through the clastic interval. Marine units near the base of the clastic interval consist of well-sorted calcareous slightly fossiliferous sandstones of presumed littoral origin. Progressing upsection, however, the marine units are composed of fossiliferous marine shale and locally limestone. Along with this lithologic change there is a concommittant change in the composition of constituent fauna. In the littoral sandstones only rare fragmented brachiopods valves can be found, but higher in the section the marine shales contain a molluscan fauna and the limestones a moderately diverse brachiopod fauna. This progressive change upsection of the lithology and fauna led Brezinski (1984) to suggest that each succeeding marine episode demonstrated a greater marine influence and ultimately culminated in the episode or episodes represented by the Wymps Gap Limestone.

The purpose of this paper is to document the vertical changes in lithology and fauna within a single section of the clastic interval near Bolivar, Pennsylvania.

LITHOLOGIC VARIATION

At the Bolivar exposure five marine units (and their resultant shallowing facies) are present in the clastic interval between the Loyalhanna and Wymps Gap Limestones. The basal unit (unit 1) consists of a white well-sorted, crossbedded calcareous sandstone to arenaceous grainstone with only a few fragmented brachiopod valves. This sandstone grades upward into a dove-gray sandy fenestral limestone, 1m thick. The limestone represents the shallowing portion of the episode. The next higher marine unit (unit 2) consists of a crossbedded sandstone similar to the basal sandstone except that it contains rounded clasts 3 to 5 cm in diameter, of the subjacent fenestral limestone. This sandstone grades upward into a red-brown sandy siltstone (the shallowing portion of the episode). Located near the top of the red-brown sandy siltstone is a bench of calcareous red shale containing abundant marine bivalves (unit 3 ?). This bed marks the marine episode. The bivalve bed is overlain by more than 6m of crossbedded, locally conglomeratic sandstone and topped by a 1.5 m of gray shale and a mudcracked domal stromatolite bed. The domal stromatolite bed is directly overlain by gray marine shale containing abundant bivalves (unit 4). The marine shale grades upward into dark gray to variegated nonmarine shales. These shales are then overlain by argillaceous lime wackestone of the Wymps Gap Limestone (unit 5).

COMMUNITY VARIATIONS

The lower two marine interval (units 1 & 2) of the clastic interval at the Bolivar exposure are essentially unfossiliferous. However, in the next 3 overlying units there is an increase in faunal diversity and changes in community composition. This suggests that each ensuing transgressive episode was progressively deeper than the proceeding one. Unit 3 contains a restricted marine fauna of mytilids and nuculid bivalves. The depauperate fauna in conjunction with the red-brown encapsulating siltstone lithology may be interpreted as developing in an oxygenated yet stressed environment at or near the shoreline. Analogies may be drawn or modern mytilids which inhabit the intertidal setting in restricted bays (Stanley, 1972). Unit 4 contains a considerably more diverse fauna dominated by bivalves and to a lesser extent productid brachiopods (Figure 1). The nuculid bivalve Phestia is a dominant component of the fauna. Also present are the bivalves Wilkingia, Schizodus, Aviculopecten, the gastropod Bellerophon and trilobite Paladin. Modern nuculid-dominated communities are found inhabiting muddy offshore environments. The Wymps Gap Limestone makes up unit 5 and it is represented by a diverse association of brachiopods and bryozoans. Such a diverse community dominated by relatively stenotopic organisms suggests open marine circulation. Many of the bryozoan genera present, such as Fenestella and Rhombopora are indicators of normal marine waters and open circulation (McKinney and Gault, 1981).

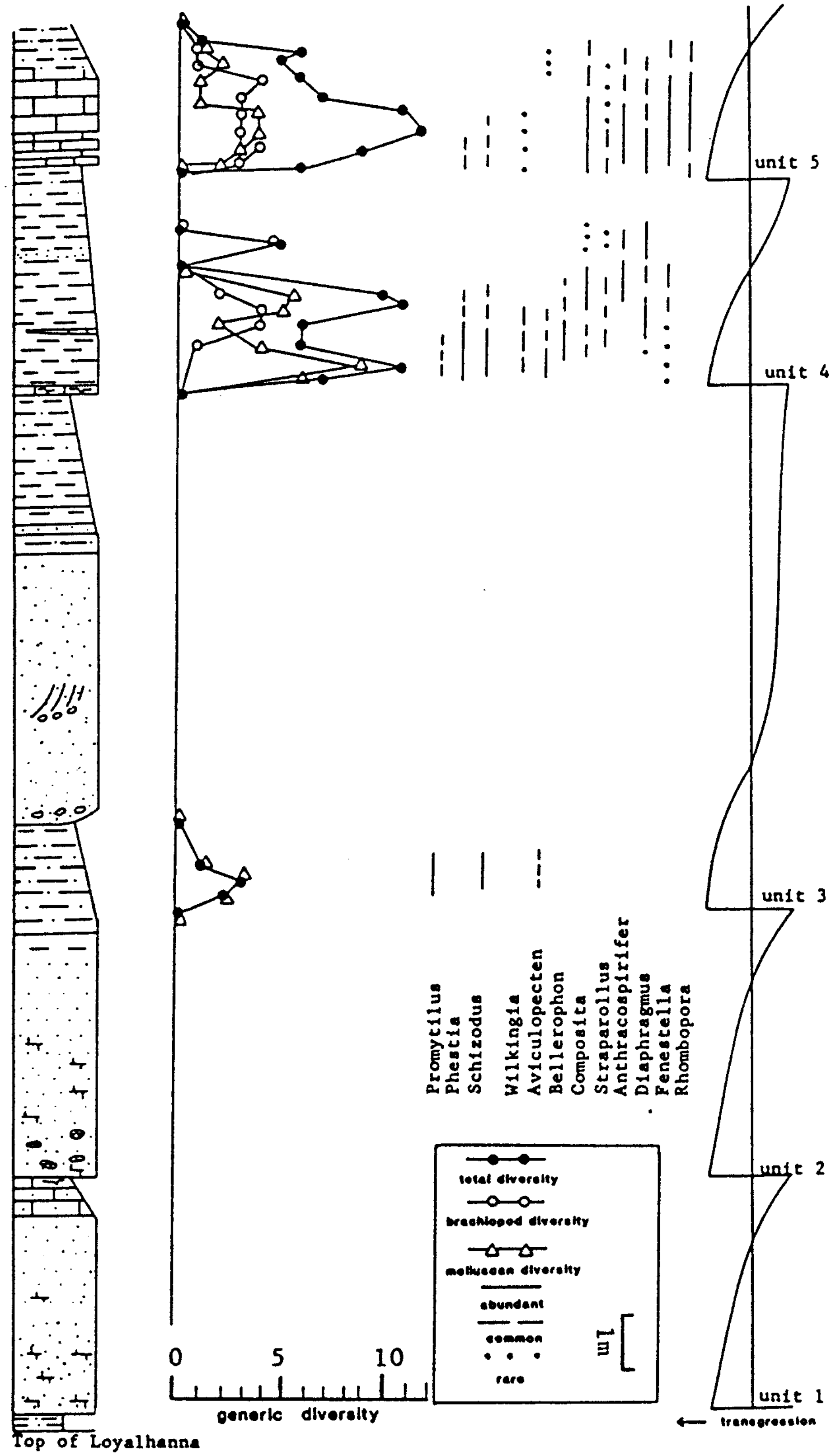

Figure 1. Composite diagram illustrating vertical variations in lithology, faunal diversity, and community composition in the Bolivar, Pennsylvania exposure of the Mauch Chunk Formation.

CONCLUSIONS

The iterating lithologic change in conjunction with an increase in faunal diversity and change in community composition upsection in the Mauch Chunk clastic interval towards the Wymps Gap horizon suggests that the Wymps Gap transgression was episodic and progressive. With each succeeding transgressive episode the shoreline was pushed farther to the north and east resulting in a vertical facies distribution in which both lithology and fauna become more and more offshore in nature upsection. This episodic transgression culminated in the maximum transgression episode, the Wymps Gap Limestone. Those units lower in the section are represented by littoral and shallow sublittoral sandstones as the marine portion episode. Higher in the section, however, the marine portions of subsequent episodes is represented by an intertidal to shallow subtidal, muddy subtidal, and open circulation subtidal environments respectively. Likewise, there is an upsection increase in faunal diversity and a replacement of bivalve-dominated by brachiopod-dominated communities.

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