PAC ANALYSIS OF THE *DICOELOSIA* EPIBOLE IN THE LOWER DEVONIAN KALKBERG FORMATION OF EASTERN NEW YORK STATE

Andy, Best wishes and thanks, Jim

by

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Dr. Edwin J. Anderson, Advisor — Date

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Dr. Peter W. Goodwin, Advisor — Date

DEDICATION

This work is dedicated to the loving memory of my father, William George Connor. A very special man in whom understanding, insight and unparalleled wit combined to present life as a joyful learning experience.

ACKNOWLEDGEMENTS

A special thanks is extended to Drs. Edwin J. Anderson and Peter W. Goodwin, the two principle advisors to this thesis. All facets of this project were greatly enhanced by their open exchange of ideas, constructive criticisms, and untiring support.

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Throughout the course of this work I have relied heavily on the kindness of many people:

The combination of typing and encouragement was shared by my mother, Mrs. Jane G. Connor, and Ms. Patricia Stellfox, both of whom I will never be able to thank enough.

The Stellfox family, Warren, Nancy, Patti and Warren, gave me a home away from home and allowed me to feel like one of the family.

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ABSTRACT

Application of the PAC Hypothesis (Goodwin and Anderson, 1981) to shallow shelf facies containing the *Dicoelosia* Zone (Rickard, 1962) in the Lower Devonian Kalkberg Formation, reveals the presence of three PACs that are correlated throughout the Hudson Valley. Microfacies and paleoenvironmental analysis demonstrates that, in vertical succession, each of these PACs was deposited in a successively deeper environment of deposition. This eposodic deepening is interpreted to have occurred as a result of a sequence of two minor punctuation events and two major punctuation events. A comparison of the stratigraphic position of the *Dicoelosia* epibole with PACs shows the epibole to occur in two successive PACs at different localities, and therefore not to be an accurate time-stratigraphic unit. The first and lower PAC contains *Dicoelosia* only at the basin axis near Catskill. The PAC immediately above the first PAC contains *Dicoelosia* only at the areas flanking the basin axis to the north and south and not at the basin axis. Therefore, since the occurrence of *Dicoelosia* is laterally discontinuous in both PACs, the *Dicoelosia* epibole does not exist as a chronostratigraphic horizon of *Dicoelosia* abundance.

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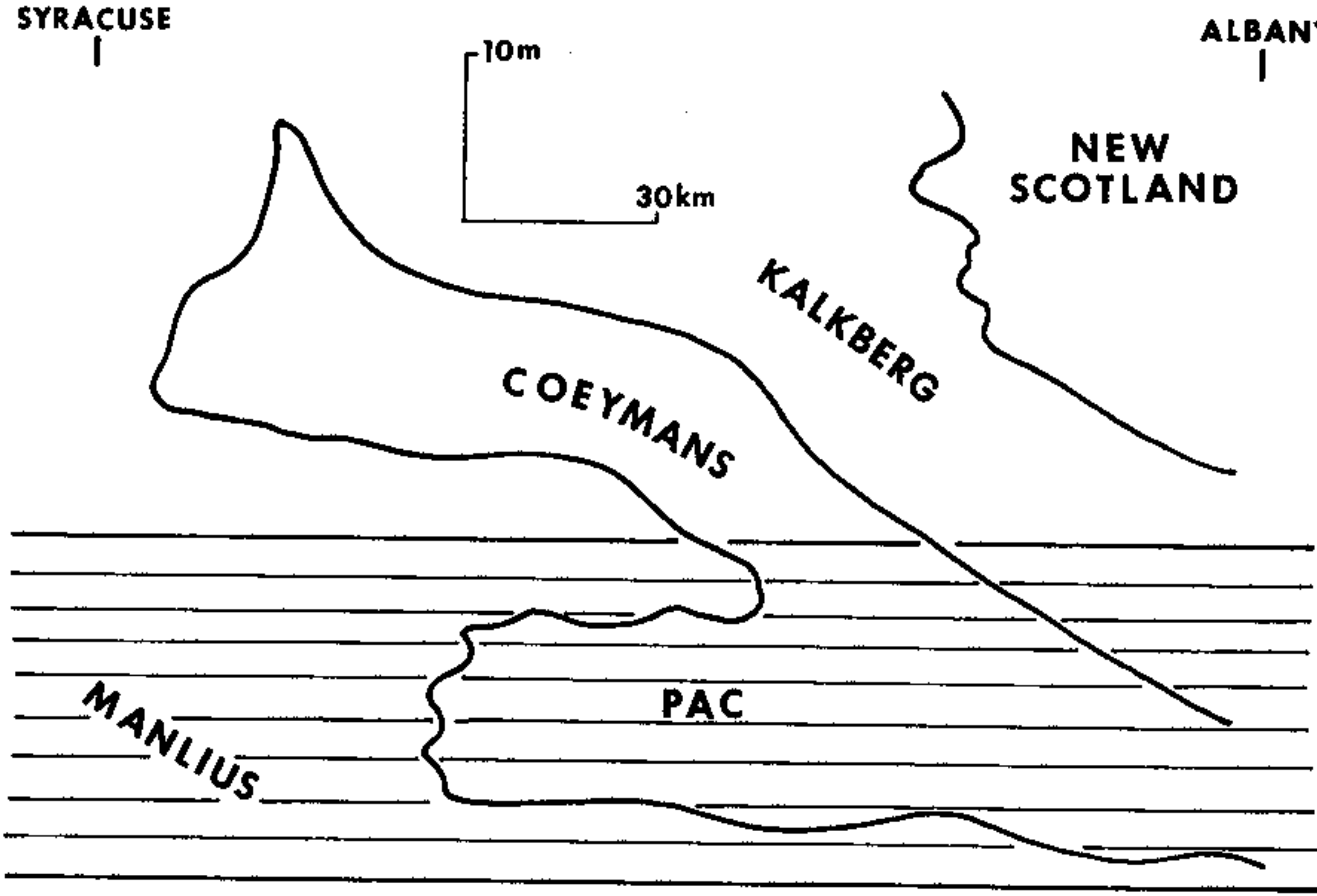
INTRODUCTION

Numerous thin and distinctive faunal zones characterized by an unusual concentration of one or more faunal elements have been described in the stratigraphic literature (e.g. Bowen, 1967, p.9; Rickard, 1962, p. 101-105). These zones, referred to as epiboles, acme zones, or peak zones, have been interpreted by some workers as thin time-stratigraphic units and used as a criteria for rock correlation (e.g. Rickard, 1962, p. 105).

The existence of one such zone in the Helderberg Group appears to be a consequence of episodic rather than gradualistic stratigraphic accumulation (Connor, Goodwin, and Anderson, 1983). An episodic theory of stratigraphic accumulation, the Hypothesis of Punctuated Aggradational Cycles (PACs), may provide an explanation for the occurrence of this and other such zones.

The PAC Hypothesis (Goodwin and Anderson, 1981) argues that nearly all sedimentary accumulation occurs in asymmetric, upward-shallowing (aggradational) cycles that range from 1 to 5 meters in thickness. These cycles are bounded by non-depositional or erosional surfaces that represent abrupt sea-level rises. These sea-level rises are hypothesized to be at least basinwide in extent and geologically instantaneous. Therefore the bounding surfaces are considered isochronous and an individual PAC unit is a time-stratigraphic unit (fig. 1).

Figure 1:
This diagram illustrates the time-stratigraphic nature of the PAC unit compared with the diachronous formational boundaries observed in the Helderberg Group (Anderson and Goodwin, 1980).


SYRACUSE
ALBANY
10m
30km
NEW SCOTLAND
KALKBERG
COEYMANS
MANLIUS
PAC

The PAC Hypothesis (Goodwin and Anderson, 1982) states that the best means of correlating basinwide is by correlating cyclothemic PAC sequences. PAC sequences are on the order of tens of meters thick and are composed of a series of individual PACs that result in a net shallowing (fig. 2). These PAC sequences are defined by major punctuation events that can be recognized basinwide by major facies change.

Purpose of Study

This study is designed as a two part test of the PAC Hypothesis. The first objective of this study is to recognize and define PACs in the shallow shelf carbonate facies of the Lower Devonian Kalkberg Formation. The second purpose is to examine the stratigraphic relationship between PACs and the *Dicoelosia* Zone, a thin faunal epibole within the Kalkberg Formation that has been recognized as being time-stratigraphic (Rickard, 1962).

The limited stratigraphic interval chosen for this study includes portions of the two members of the Kalkberg Formation: the top of the Hannacroix Member, a fossiliferous bioturbated calcisiltite (wackestones, packstones, and minor amounts of mudstones and grainstones); and the lower portion of the overlying Broncks Lake Member which consists of thin (1"-3") blue-gray calcisiltites (wackestones and packstones) interbedded with gray calcareous shales (fig.3).

The top of the Hannacroix Member is recognized at Kingston, New York, as the *Dicoelosia* Zone which typically

Figure 2:
This diagram illustrates the Cyclothemic PAC Sequence Model. The left side of the diagram shows a stratigraphic section composed of several PACs. The right side of the diagram shows the relative water depth interpretation of the facies described in the stratigraphic section (after Anderson and Goodwin, 1980).

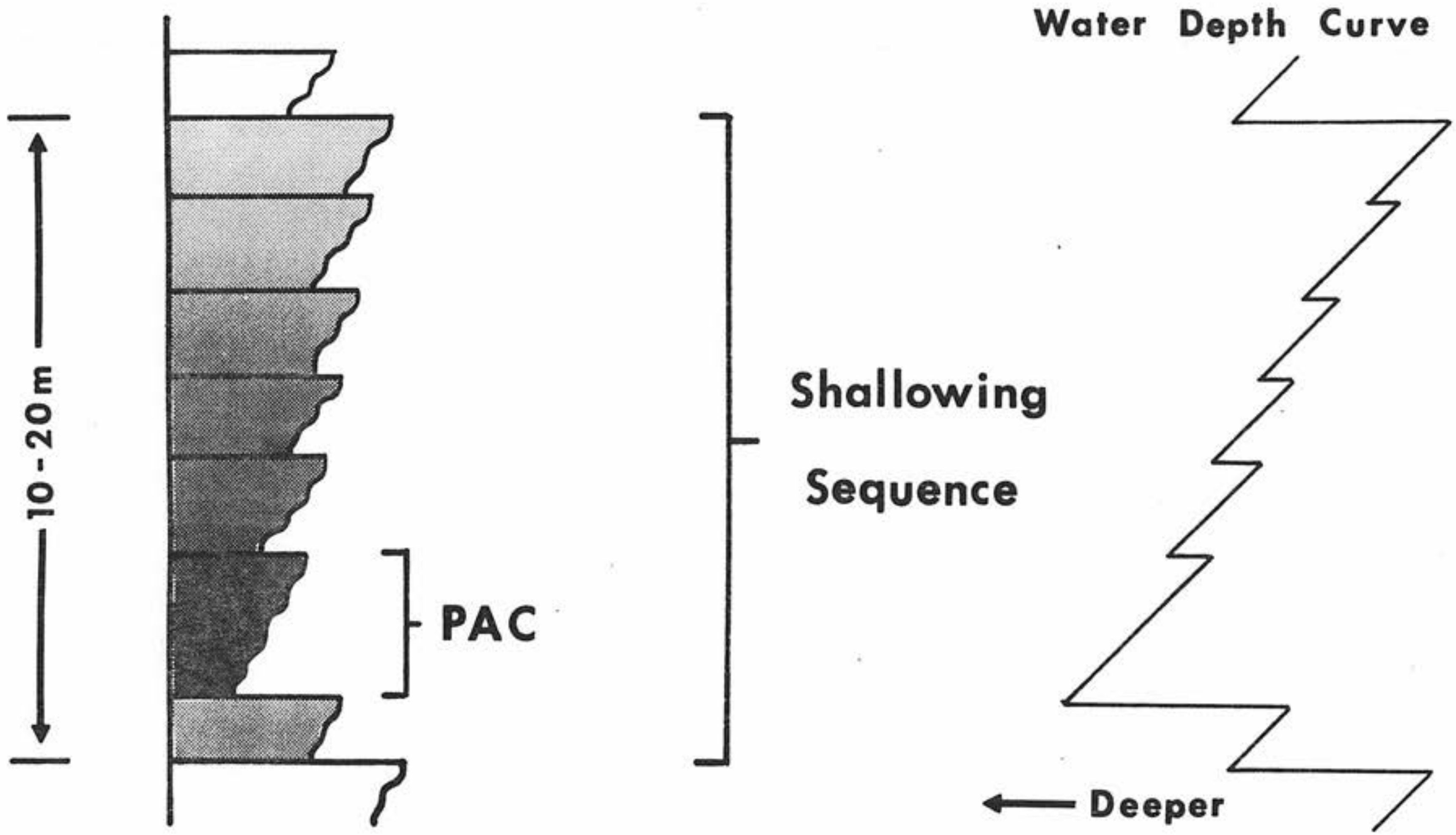

Water Depth Curve
10-20 m
PAC
Shallowing
Sequence
Deeper

Figure 3:
Diagram showing the age of the interval and generalized stratigraphic descriptions of the two members of the Kalkberg Formation.

Group	Formation	Member	Description
Helderberg Group	Kalkberg Formation	Broncks Lake Member	Upper: Argillaceous siliceous fine-grained limestone, medium gray, weathers tannish, 4"-8" beds, abundant rugosans, 3-4 layers of chert lenses near base.
			Lower: Argillaceous siliceous fine-grained limestone, medium dark gray to dark gray, weathers light gray with occasional buff-tan, 2"-4" limestone beds interbedded with 1/4"-1/2" shale beds, abundant encrusting bryozoans, Dicoelosia.
		Hannacroix Member	Upper: Argillaceous siliceous fine-grained limestone, massive (1'-2') sub-bedding, dark gray to medium dark gray, shale streamers (1"-3") resulting in "tennis net" weathering, small Gypidula, siliceous crinoids, Dicoelosia.
			Lower: Cherty fine-grained limestone, massive (1"-12" bedded) dark gray to medium dark gray, weathers light medium gray, transitional fauna similar to Coeymans, Gypidula less common.

is characterized by being two feet thick and consisting of shaly calcisiltites. The specific objectives of this study are to compare the stratigraphic position of the Dicoelosia epibole with the PACs defined in the interval in order to analyze the utility of the Dicoelosia epibole as a time-stratigraphic horizon and to understand the stratigraphic dynamics responsible for its origin.

Previous Work

Stratigraphic and paleoenvironmental investigations of the Helderberg Group in general, and of the Kalkberg Formation in particular, have established a framework and foundation for testing the PAC Hypothesis in this interval. The general stratigraphic framework was constructed by Rickard (1962) and utilized by Laporte (1967, and 1969) and Epstein (1968, and 1971) as a basis for paleoenvironmental investigations.

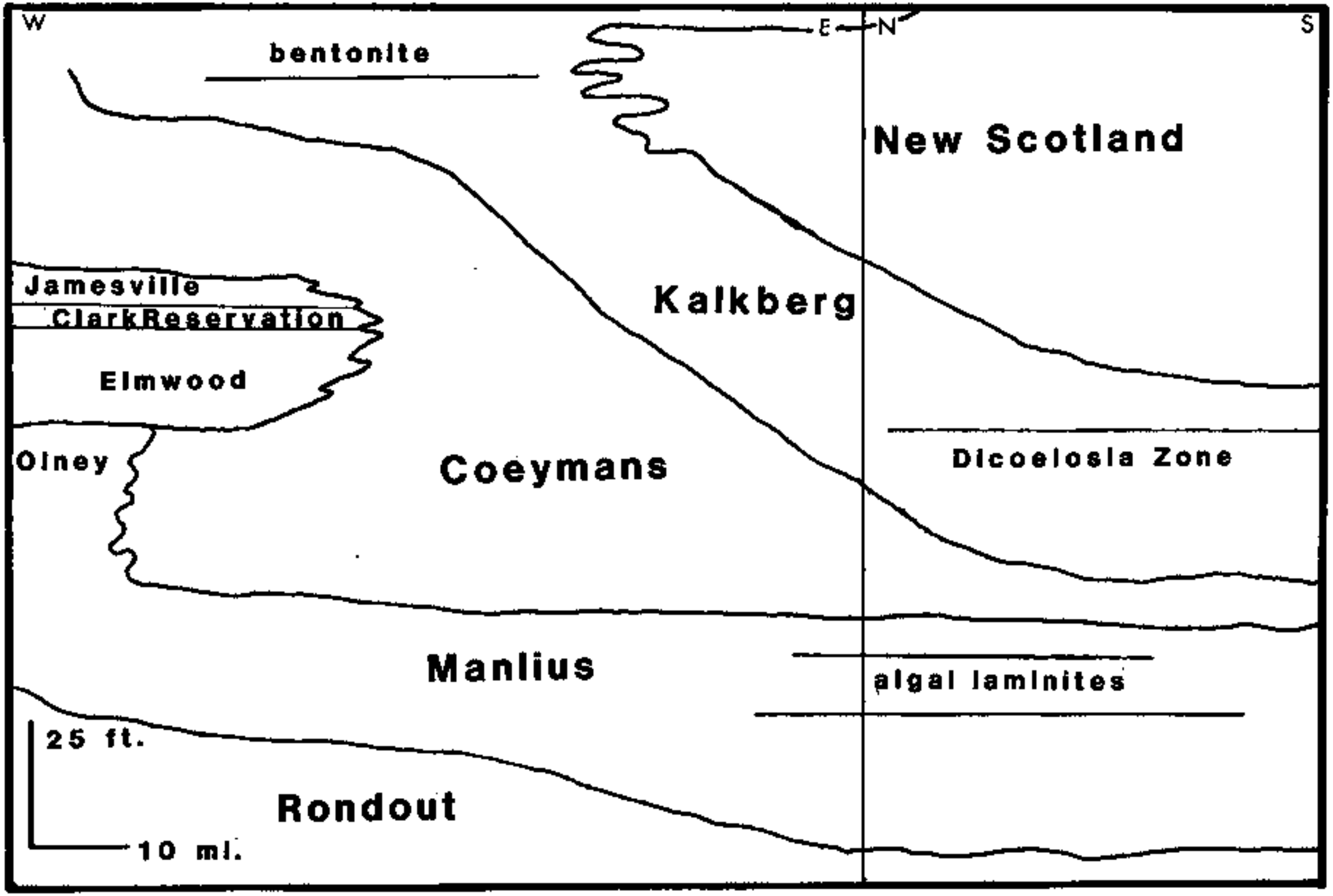
Rickard (1962,p. 98) described the Kalkberg Formation as consisting entirely of the "cherty-calcisiltite facies" which is characterized by an "abundant and normal marine fauna". With these criteria Rickard interpreted this facies as representing the shallow neritic zone of deposition, not far beneath wave base.

Fundamental to Rickard's correlation of the Helderberg Group is the recognition of several biostratigraphic and lithostratigraphic units which Rickard interpreted as chronostratigraphic horizons. One of these units he terms the *Dicoelosia* epibole (1962, pp. 101-105). Throughout the Hudson River Valley this thin unit is recognized at or near the top of the Hannacroix Member of the Kalkberg Formation. Rickard's correlation of Helderbergian stratigraphy shows this unit to parallel other demonstrable time lines and to cut across the diachronous Kalkberg Formation (fig.4). Among the time horizons Rickard utilizes to construct his correlations (1962, pp. 101-105) are a bentonite horizon in the New Scotland Formation, several thin distinctive units in the progradational Manlius "tongue" in Western New York, most notably the Clark Reservation Member of the Manlius Formation, and several traceable (approximately 40 miles) algal laminite beds in the Thacher Member of the Manlius Formation in the Hudson Valley.

Prior to Rickard's correlation of Helderbergian stratigraphy it was believed that each formation in the Helderberg Group existed as a contemporaneous unit throughout its extent (Cooper et al, 1942). In contrast to this, Rickard's correlations demonstrated the time-transgressive relationships of the formations within the Helderberg Group. The resulting stratigraphic configuration suggests that several of the formations were being deposited contemporaneously.

Finally, Rickard concluded that the stratigraphic relationships of the Helderberg Group conform to the implictions of Walther's Law (Rickard, 1962, pp. 101-102). This law states that "only those facies can be superimposed

Figure 4:
Rickard's (1962) lithostratigraphic correlation of the Helderberg strata and several key time horizons used in the correlation.


W
E
N
S
bentonite
New Scotland
Kalkberg
Jamesville
ClarkReservation
Elmwood
Olney
Coeymans
Dicoelosia Zone
Manlius
algal laminites
25 ft.
10 mi.
Rondout

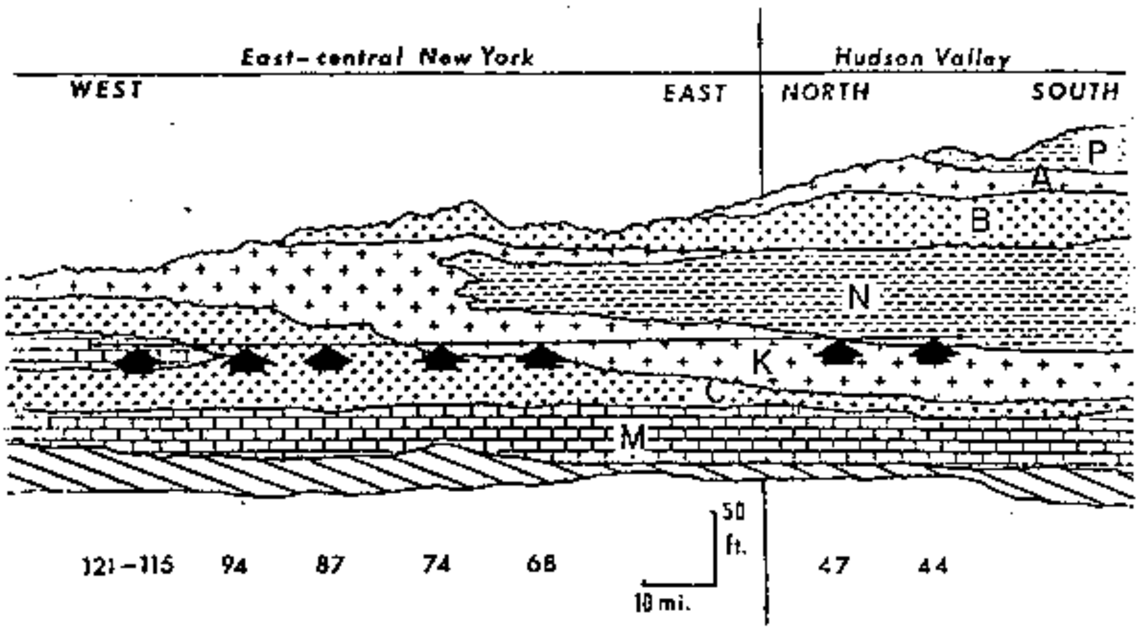
primarily which can be observed beside each other at the present time" (Middleton, 1973). Rickard recognized seven "main facies" within the Helderberg Group that when correlated could be shown to be superposed upon one another in vertical section, and also in part could be demonstrated as existing lateral to one another.

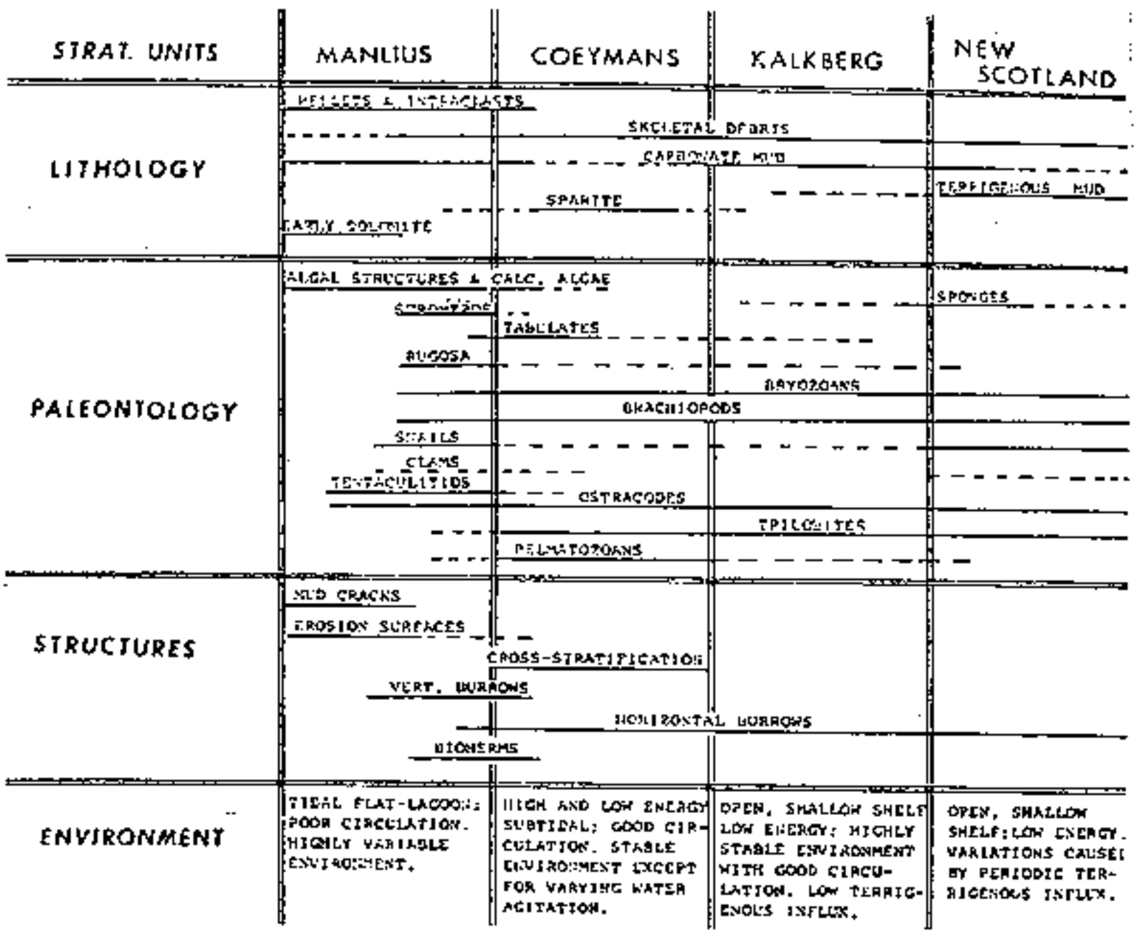
Laporte (1969) offered a refinement to the paleoenvironmental understanding of the facies present within the Helderberg Group. Utilizing Rickard's correlation diagram, Laporte projected a hypothetical time horizon across the four lower formations of the Helderberg Group (fig.5). Sampling three feet on either side of this datum, Laporte documented the major faunal and lithological elements of each of the main facies (formations) through which this datum cut (table 1). The results of this documentation demonstrated an onshore to offshore facies change trending west to east along the Helderberg outcrop belt.

Laporte concluded that the lateral facies changes observed along his stratigraphic datum combined with the stratigraphic configuration of the Helderberg Group supported Rickard's conclusions that the facies relationships conform to the implications of Walther's Law. Applying the theories of Shaw (1964) and Irwin (1965) to the Helderberg Group, Laporte concluded that the contemporaneously deposited onshore to offshore facies predicted by these gradualistic models are present within the Helderberg

Figure 5:
Diagram used by Laporte (1969) showing the hypothetical time horizon in the Helderberg Group that he used to sample laterally "co-existing" facies (from Laporte, 1969).

Table 1:
The results of Laporte's (1969) facies analysis along the time-horizon diagramed in figure 5 (from Laporte, 1969).


East-central New York
Hudson Valley
WEST
EAST
NORTH
SOUTH
P
A
B
N
K
C
M
50 ft.
10 mi.
121–115
94
87
74
68
47
44


STRAT. UNITS
MANLIUS
COEYMANS
KALKBERG
NEW SCOTLAND
LITHOLOGY
PELLETS & INTRACLASTS
SKELETAL DEBRIS
CARBONATE MUD
TERRIGENOUS MUD
SPARITE
EARLY DOLOMITE
PALEONTOLOGY
ALGAL STRUCTURES & CALC. ALGAE
SPONGES
TABULATES
RUGOSA
BRYOZOANS
BRACHIOPODS
SNAILS
CLAMS
TENTACULITIDS
OSTRACODES
TRILOBITES
PELMATOZOANS
STRUCTURES
MUD CRACKS
EROSION SURFACES
CROSS-STRATIFICATION
VERT. BURROWS
HORIZONTAL BURROWS
BIOHERMS
ENVIRONMENT
TIDAL FLAT-LAGOON; POOR CIRCULATION. HIGHLY VARIABLE ENVIRONMENT.
HIGH AND LOW ENERGY SUBTIDAL; GOOD CIRCULATION. STABLE ENVIRONMENT EXCEPT FOR VARYING WATER AGITATION.
OPEN, SHALLOW SHELF LOW ENERGY; HIGHLY STABLE ENVIRONMENT WITH GOOD CIRCULATION. LOW TERRIGENOUS INFLUX.
OPEN, SHALLOW SHELF; LOW ENERGY. VARIATIONS CAUSED BY PERIODIC TERRIGENOUS INFLUX.

Group and that the resultant Helderbergian stratigraphy must be the result of the combined effects of a slowly transgressing sea and regional subsidence (1969, pp.117).

Epstein's (1968) paleoenvironmental studies of the Kalkberg Formation of central New York State and the Helderberg shelf facies in general (Epstein 1971) documented in detail the faunal and lithological elements of the facies present within the Kalkberg Formation. His lithological analysis of the lower Helderberg shelf facies (represented by the Coeymans, Kalkberg and New Scotland Formations) was based wholly upon measurement of the bulk-rock sedimentological characteristics and the degree of bioturbation as seen in thin-section. The results of this analysis demonstrated that each of the formations representing the Helderberg shelf was composed of individual and distinct lithofacies. The two members of the Kalkberg Formation were described as both consisting of the same lithofacies, termed the "silty bottom environment", with the only obvious lithological differences being the location and concentration of the shale partings (1971, p.31). Faunally, however, Epstein demonstrated that although the two members consisted of essentially the same lithofacies, each member of the Kalkberg Formation contained a distinct biofacies (1971, p.33) (table 2).

Epstein's documentation of the Helderberg shelf facies combined with the stratigraphic descriptions and correlations of Rickard (1962), Laporte (1967), Anderson (1967),

Table 2:
This table shows the faunal elements of the two members of the Kalkberg Formation. Brachiopod data is from Epstein (1971) (asterik denotes greater abundances in the Broncks Lake Member).

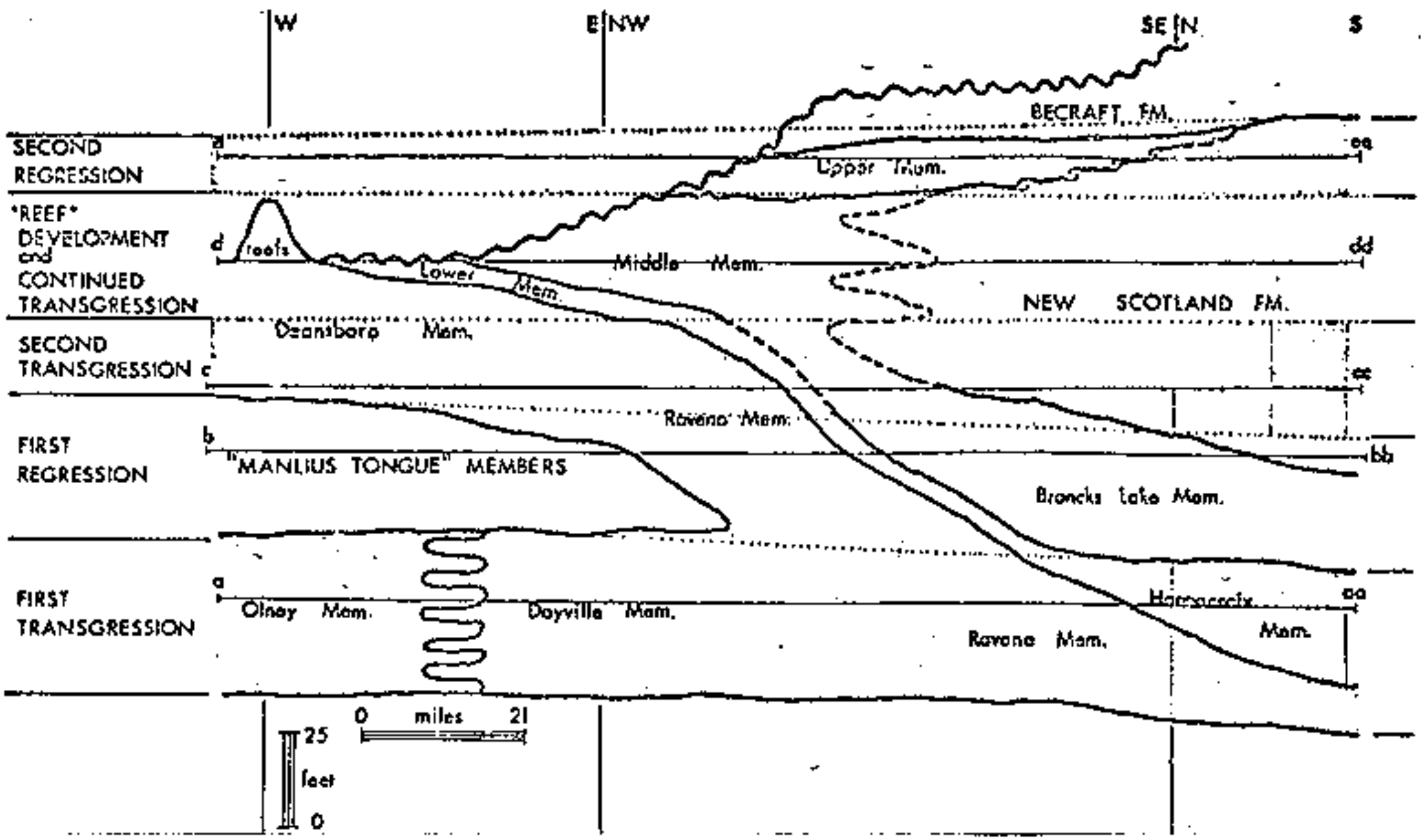
PHYLUM	HANNACROIX MEMBER	BOTH MEMBERS	BRONCKS LAKE MEMBER
Brachiopoda	*Anastrophia vernuili* *Gypidula coeymanensis* *Uncinulus nucleolata*	*Atrypa reticularis* *Atrypina imbricata* *Coelospira concava* *Cupulorostrum transversa* *Cyrtina dalmani* *Dalejina oblata* *Dicoelosia varica* *Eatonia medialis* *Howellella cycloptera* *Leptaena rhomboidalis* *Meristella leavis* *Nucleospira ventricosa* *Strophonella punctulifera* *Trematospira perforata* *Uncinulus mutablis*	*Hedeina macropleura* *Isorthis perelegans* *Kozlowskiellina perlamellosa* *Leptostrophia beckii* *Levenea subcarinata* *M. varistriata arata* *Platyorthis planoconvexa* *Rhynchospirina formosa* *Rhynchospirina globosa* *Schuchertella woolworthana* *Strophonella leavenworthana* *Trematospira deweyi* *Uncinulus Abrupta* *Uncinulus pyramidata*
Coelenterata	Tabulata *Favosites helderbergaie* Rugosa *Enterolasma strictum* *Spongophylloides sp.*		
Bryozoa		ramose/fenestral forms*	
Arthropoda		Ostracoda* Trilobita* Dalminitids *Phacops logani*	
Echinodermata		Crinoidea* *Mariacrinus stoloniferus* Cystoidea*	

and Head (1969) enabled him to recognize several transgressive and regressive episodes (fig.6). These episodes are used by Epstein to define basinwide time-stratigraphic units (1971, pp.43-46). Within each of these units Epstein reconstructs the environmental configurations and demonstrated that the three major shelf environments existed lateral to one another. Consequently, Epstein concluded that these shelf facies were persistent throughout Helderberg time (1971, pp.61-64).

Application of the PAC Hypothesis to Helderberg stratigraphy has resulted in the documentation of numerous PACs that have been grouped into cyclothemic PAC sequences (Anderson and Goodwin, 1982). As reflected by the relative water depth curve on figure 7, these PAC sequences reflect a net shallowing and are bounded by surfaces produced by major punctuation events. Anderson and Goodwin (1982) have recognized two PAC sequences at Kingston, New York. The lower PAC sequence (PAC Sequence A) extends from the top of the Manlius Formation to the base of the <u>Dicoelosia</u> Zone. PAC Sequence B extends from the base of the <u>Dicoelosia</u> Zone to the New Scotland Formational contact.

A preliminary correlation of these PAC sequences at Kingston with PAC sequences recognized at Perryville (locality 144 on fig. 8) New York indicates a time equivalency between two key beds each of which Rickard recognized as time-stratigraphic units (Rickard, 1962). These beds are the Clark Reservation Member of the Manlius Formation and

Figure 6:
Epstein's correlation of regressive and transgressive sequences (the sequences are bounded by dotted lines) in the Helderberg Group (from Epstein, 1971).



W
E
NW
SE
N
S
BECRAFT FM.
SECOND REGRESSION
Upper Mem.
"REEF" DEVELOPMENT and CONTINUED TRANSGRESSION
reefs
Lower
Mem.
Middle Mem.
NEW SCOTLAND FM.
SECOND TRANSGRESSION
Deansboro Mem.
Ravena Mem.
FIRST REGRESSION
"MANLIUS TONGUE" MEMBERS
Broncks Lake Mem.
FIRST TRANSGRESSION
Olney Mem.
Dayville Mem.
Ravena Mem.
Mem.
a
aa
b
bb
c
cc
d
dd
ee
0 miles 21
25 feet 0

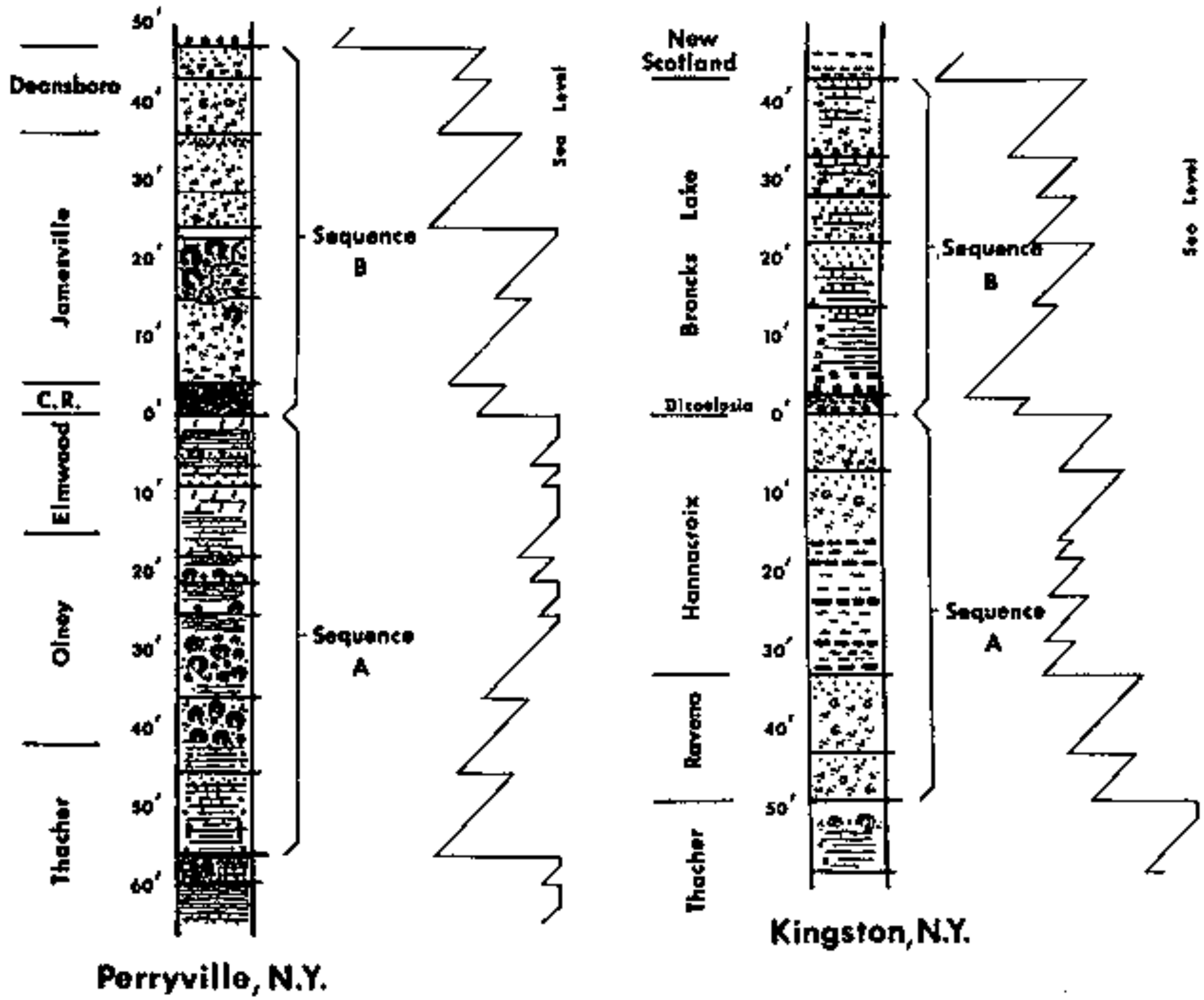
and the *Dicoelosia* Zone of the Kalkberg Formation (fig. 7). This correlation differs significantly from those constructed by Rickard (fig. 4) and Epstein (fig. 6). In Rickard's lithostratigraphic correlation the *Dicoelosia* Zone is correlated 15 ft. below the Clark Reservation Member and Epstein's semi-episodic correlation of transgressive and regressive sequences he correlates the *Dicoelosia* Zone with the base of the "Manlius tongue" or approximately 20 feet below the Clark Reservation Member.

Detailed studies by Lee (1981) and Busch (1981) in the near shoreline and tidal flat facies of the Manlius "tongue" Members in Central New York State have resulted in the documentation and regional correlation of several PACs at the top of PAC sequence A. Documentation of these PACs was based upon detailed microfacies studies and paleoenvironmental reconstruction. Once defined, each of these PACs was then correlated through-out the Central New York State area for distances of approximately 40 miles.

This study is an analysis of the rocks at the top of PAC sequence A in the Hudson Valley, the correlative interval to the Manlius "tongue" Members of Central New York State. These rocks are represented by the shallow shelf facies of the Kalkberg Formation. Similar techniques as used by Lee (1981) and Busch (1981) are utilized to examine the effects in the Kalkberg Formation of the same punctuation events recognized in the western correlative section.

Figure 7:
Correlation of PAC sequences between Kingston and Perryville, N.Y. (from Anderson and Goodwin, 1982).

Correlation of Cyclothemic PAC Sequences



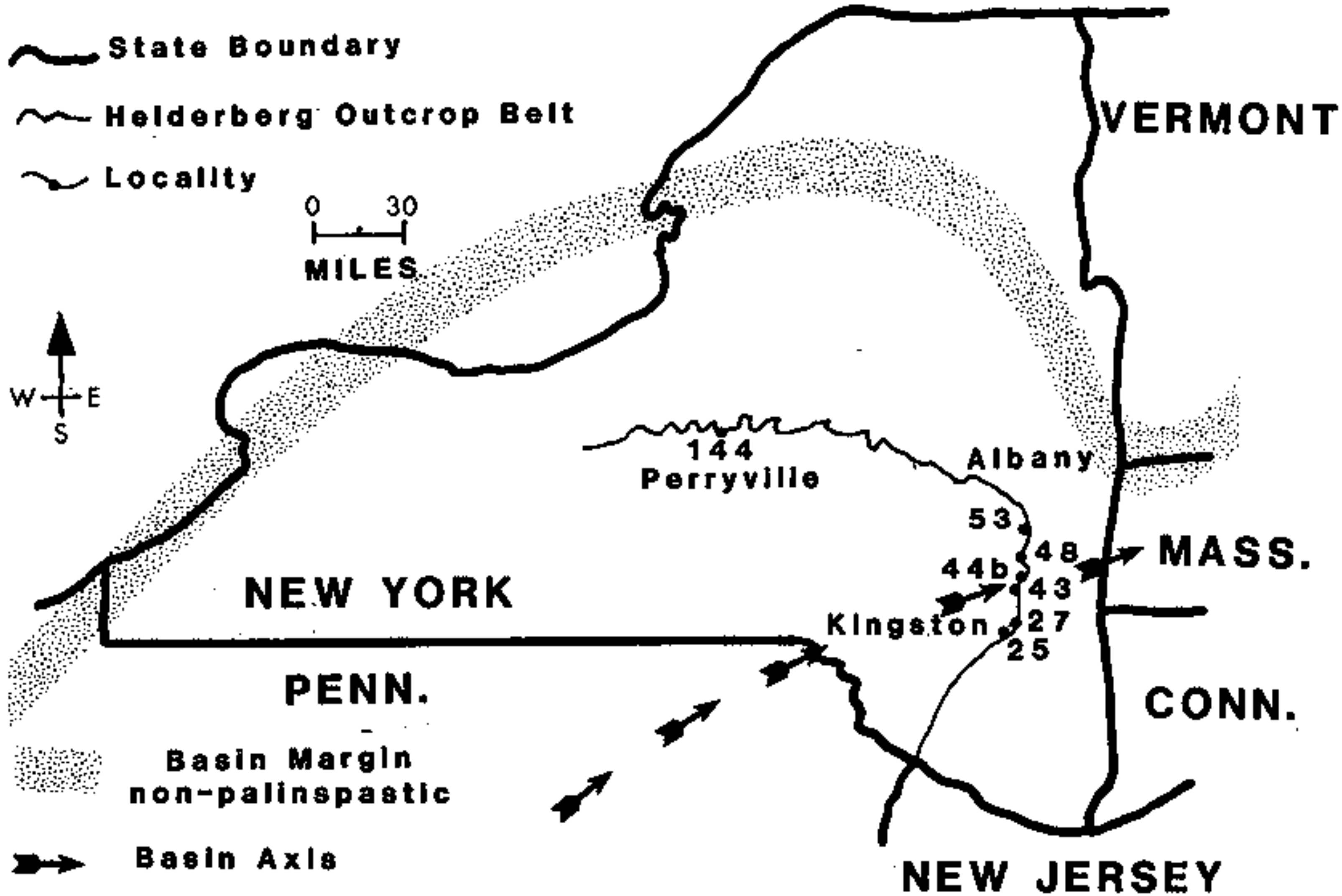
METHODS

Field work for this study required two field seasons, including six weeks during the summer of 1981 and two more weeks during the summer field season of 1982. The time spent in the field was utilized to locate, measure, describe, photograph and sample six individual localities between Kingston, New York, and the Callanan Quarry in South Bethlehem, New York, a distance of approximately 50 miles (fig.8).

Rickard (1962) provided the location and locality number of four of the six sections described in this study. The remaining two localities (localities 27 and 44b) are more recent roadcuts and were numbered to indicate the approximate location of these sections relative to those of Rickard.

Oriented whole-rock samples were taken at closely spaced intervals from fifteen feet below to ten feet above the Dicoelosia Zone and the locations of these samples were marked on the stratigraphic columns using the Hannacroix-Broncks Lake Member contact as a datum. In particular, all varying lithologies and both sides of PAC boundaries were sampled. Because of the extreme effects of bioturbation in the Hannacroix Member, many PACs appeared to be homogenous units. In these PACs, samples were taken at one-foot intervals through the PAC even where no discern-

Figure 8:
Map of New York State showing the Helderberg age outcrop belt and the location of the localities described in this study (with the exception of Perryville, locality 144, which is shown here because it is used in Anderson and Goodwin's (1982) correlation of cyclothemic PAC Sequences), and the non-palinspastic location of the basin margin and basin axis relative to the study localities (adapted from Head 1969).


State Boundary
Helderberg Outcrop Belt
Locality
0 30
MILES
W E
S
VERMONT
144
Perryville
Albany
53
48
44b
43
MASS.
NEW YORK
Kingston
27
25
PENN.
CONN.
Basin Margin
non-palinspastic
Basin Axis
NEW JERSEY

ible lithological variation was obvious.

Where possible, three shale samples were collected at each locality, one from the shaly calcisiltite at the top of the Hannacroix Member (generally containing the Dicoelosia Zone), a second from the well developed calcareous shale at the base of the Broncks Lake Member, and a third from an interbedded shale typical of the Broncks Lake Member and generally taken about three feet above the Hannacroix-Broncks Lake Member contact.

Approximately one hundred rock samples were sliced and mounted on 46 x 27 x 1.2mm petrographic glass slides with Conap epoxy and polished with 1000 grit silicarbide grinding compound. Using binocular and polarizing microscopes, grains were identified, their relative abundances were determined, and sedimentary structures were described. These rocks were then classified according to Dunham's carbonate classification system (Dunham, 1962). All thin-section photographs used in this thesis are photonegatives, resulting in a reversal of colors (i.e. the sparry lithologies appear dark and the silt-rich lithologies appear light). All photonegatives are oriented with the up direction towards the top of the page. The shale samples were split by use of a hydraulic rock splitter. The faunal components of these rocks were then identified and tabulated on a presence-absence basis.

PACS IN THE KALKBERG FORMATION

At each of six localities in the Hudson Valley (fig. 8) there are three complete Punctuated Aggradational Cycles (PACs) recognized in the interval immediately below and including the Dicoelosia Zone. These PACs are labelled, in vertical succession, PAC A, PAC B, and PAC C, with the top of the uppermost PAC, PAC C, corresponding to the Hannacroix-Broncks Lake Member contact in the Kalkberg Formation.

East Kingston Quarry, Locality 25

East Kingston Quarry, an inactive quarry owned by the Hudson Cement Company, is located 0.3 miles south of East Kingston along the Hudson River in the East Kingston 7½" Quadrangle. The quarry contains 18 feet of the Ravena Member of the Coeymans Formation and 31 feet of the Hannacroix Member of the Kalkberg Formation (figures 10 and 11).

Pac A begins 6 feet 9 inches below the Broncks Lake Member contact and is a total of 3½ feet thick. PAC A consists entirely of coarse-grained laminated packstones and wackestones that weather massive and contain an abundance of Atrypa, Eatonia, crinoid columnals, and one specimen of Gypidula. Thin-sectioning (fig. 12) reveals the alternating packstone and wackestone laminations to be composed of brachiopod fragments, echinoderm fragments, and

Figure 9:
Key to field descriptions of study localities as used in figures 10, 17, 26, 33, 41, 51, 57, and 58.

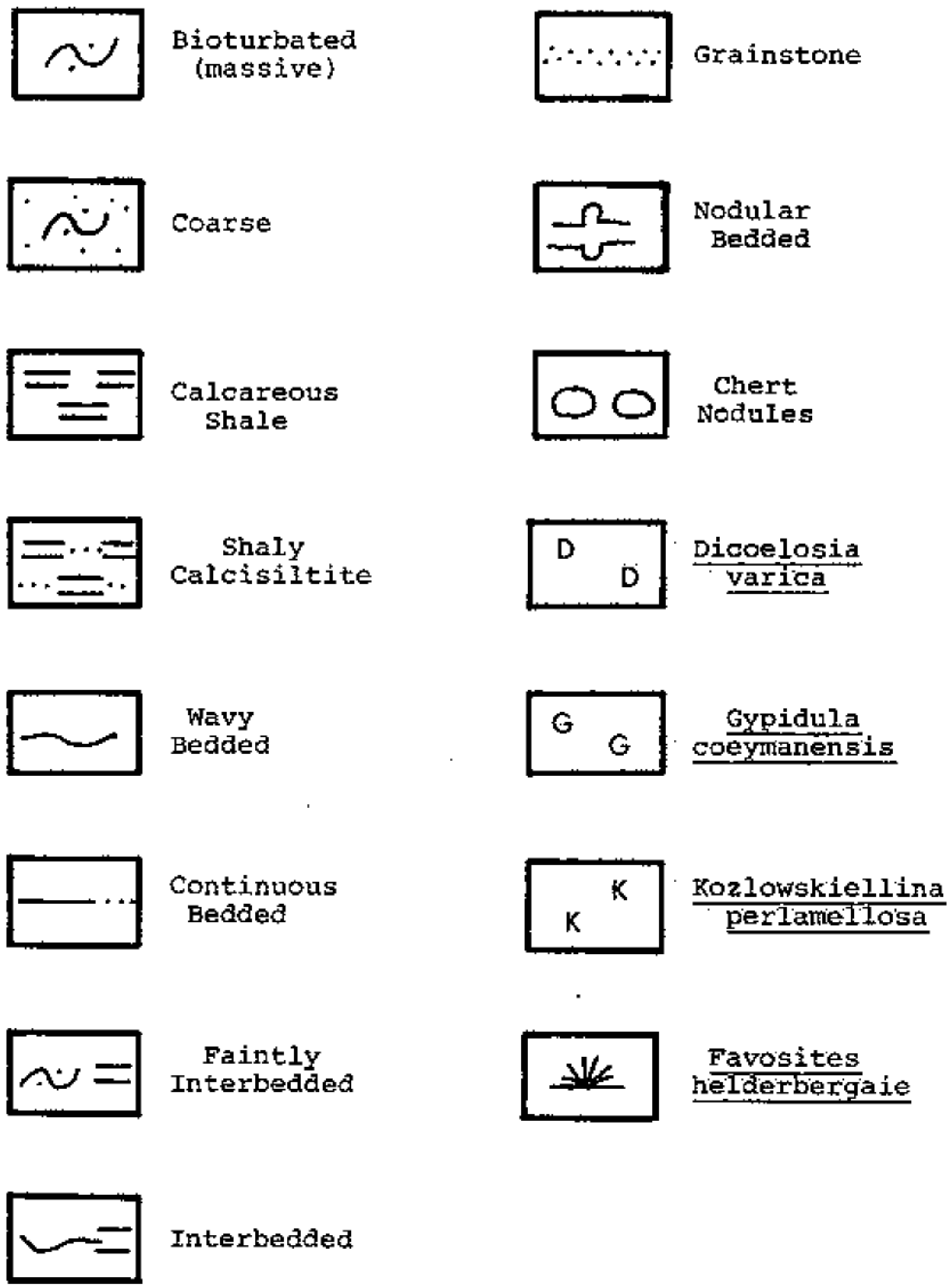
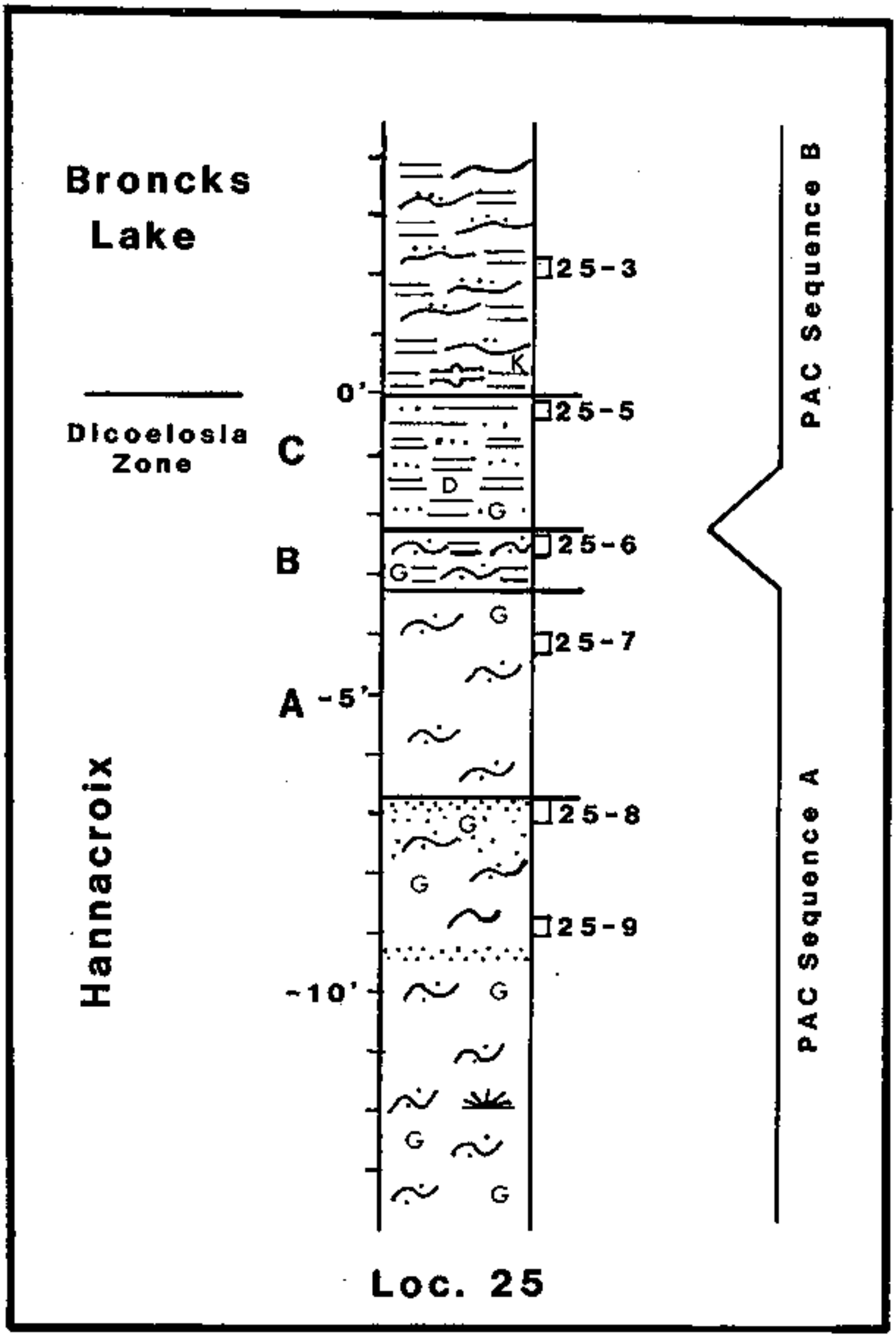

Bioturbated (massive)
Coarse
Calcareous Shale
Shaly Calcisiltite
Wavy Bedded
Continuous Bedded
Faintly Interbedded
Interbedded
Grainstone
Nodular Bedded
Chert Nodules
Dicoelosia varica
Gypidula coeymanensis
Kozlowskiellina perlamellosa
Favosites helderbergaie

Figure 10:
Field description of locality 25 at East Kingston Quarry. PACs are labelled A, B, and C and are bounded by the horizontal lines. Sample locations and numbers are marked on right side of column.


Broncks
Lake
Dicoelosia
Zone
Hannacroix
C
B
A
0'
-5'
-10'
D
G
K
25-3
25-5
25-6
25-7
25-8
25-9
PAC Sequence B
PAC Sequence A
Loc. 25

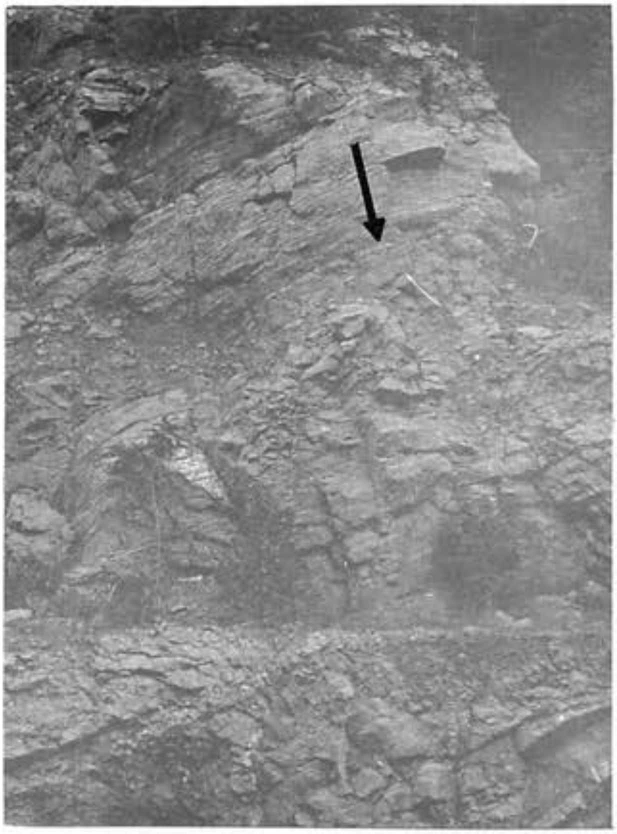
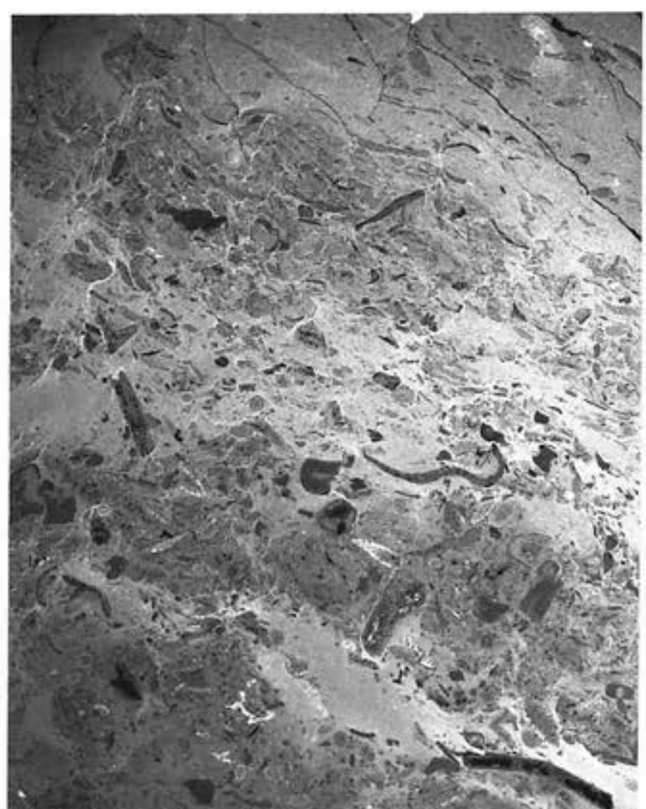


Figure 11:
Outcrop photograph of the interval at East Kingston Quarry. The Hannacroix-Broncks Lake Member contact is denoted by the arrow.

Figure 12:
Thin-section photonegative of sample 25-7 showing the well developed alternating wackestone and packstone laminations of PAC A (X3).



bryozoan fragments.

PAC A is bounded on the top and bottom by sharp surfaces. The surface at the base of PAC A (-6 feet, 9 inches on fig. 10) corresponds to a facies change from the laminated wackestones and packstones of PAC A to bioclastic packstones beneath PAC A. These bioclastic packstones are coarse and bedded (c.a. 6 inches thick) and contain an abundance of Gypidula coeymanensis, Atrypa reticularis, and disarticulated crinoid columnals. Within these packstones are two continuous bedded 3"-4" grainstones. The uppermost grainstone bed is located immediately beneath PAC A with the lower grainstone bed being 2½ feet below the upper bed. A thin-section across the upper contact of the upper grainstone bed (fig. 13) demonstrates that this bed is composed of ramose and encrusting bryozoans, brachiopod fragments, and echinoderm fragments.

The bedding surface at the top of PAC A (-3ft. 3 inches on fig. 10 corresponds to a significant facies change. This facies change is represented by a change from the laminated coarse packstones and wackestones of PAC A to dark gray faintly interbedded silty rocks of PAC B. PAC B is a total of one foot thick and consists of 3 or 4 dark gray faintly interbedded wackestones and thin (c.a ¼" to ½") calcisiltite beds. Many of the wackestone beds are boudinaged and because of the combined effects of the high silt fraction in the wackestone beds and the effects of bioturbation, the compositional differences between these wackestone beds and the thin silt beds are slight. Therefore these beds weather as what is termed here as faint interbeds. In thin-section, these wackestone beds are upward-fining, commonly grading from packstones at the base to wackestones at the top of the bed (fig. 14). The grain constituents of these rocks include brachiopod and echinoderm fragments. The macrofossils of PAC B (as determined by field observation) include Gypidula and several small thin-shelled spiriferids. The interbedded aspect and the upward-fining patterns in these rocks suggest a turbiditic origin for these beds. In contrast to PAC A, these rocks do not demonstrate a strong lamination and do contain a greater amount of calcisiltite and are therefore interpreted to be the result of a relatively deeper depositional environment than the rocks of PAC A.

The bedding surface at the top of PAC B (-27" on fig. 10) corresponds to an abrupt lithological change from the interbedded wackestones and calcisiltites of PAC B to the shaly calcisiltites of PAC C. PAC C is a total of 27" thick and is composed of two units; a lower shaly calcisiltite, and an upper grainstone bed. The dark gray to black shaly calcisiltite is a total of 20" thick. This unit contains Dicoelosia and a few specimens of Gypidula coeymanensis. The grainstone bed at the top of PAC C is 7" thick. This grainstone is composed of fine-grained, well sorted, bioturbated angular brachiopod fragments, ostracode fragments, and trilobite fragments (fig. 15).

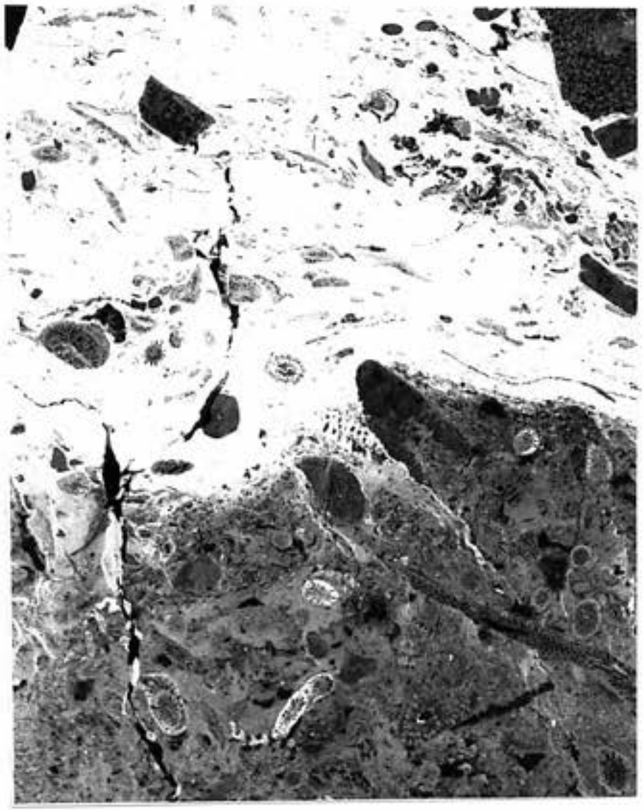


Figure 13:
Thin-section photonegative of sample 25-8 across the upper contact of the upper grainstone bed and marking the base of PAC A. Note the high contrast between the sparry lithology composed predominantly of bryozoan fragments at the base and the silt-rich lithology at the top of the photo (X3).

Figure 14:
Thin-section photonegative of sample 25-6 showing the upward-fining wackestones of PAC B (X3).