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Stratigraphy and paleoecology of the Miamitown shale (Upper Ordovician): Ohio, Indiana, and Kentucky

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Stratigraphy and Paleoecology of the Miamitown Shale (Upper Ordovician): Ohio, Indiana, and Kentucky.

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hereby submit this as part of the requirements for the degree of:

Doctor of Philosophy

in Geology Department

It is entitled Stratigraphy and Paleoecology of the Miamitown Shale (Upper Ordovician): Ohio, Indiana, and Kentucky.

Approved by:

ABSTRACT

The Miamitown shale has been considered an enigmatic unit in the upper part of an Edenian-Maysvillian shoaling upward sequence. A new look at Cincinnatian sequences reveals that this unit is actually an integral part of a more complex sequence architecture. Three fourth-order sequences at the base of the Upper Ordovician in the Cincinnati area are formally named in stratigraphic order: 1) the Brent Sequence, comprising the Edenian Kope Formation; 2) the Riedlin Sequence comprising the Maysvillian Fairview, Miamitown and Bellevue formations; and 3) the Stonelick Sequence comprising the Maysvillian Corryville and Mt Auburn formations. A detailed study of the Riedlin Sequence in outcrops, cores and well logs between Cincinnati, Ohio, Ft Wayne, Indiana, and Indianapolis, Indiana, (13,000 km^2), reveals stacking patterns within the Riedlin Sequence that are comparable to those of a type-2 sequence. This interpretation contrasts with previous interpretations wherein Cincinnatian third- and fourth-order cycles are dominated by highstand systems tracts with thin or absent lowstand and transgressive deposits, or where these cycles are interpreted as parasequences or parasequence sets rather than sequences. This cycle suggests that Cincinnatian fourth-order cycles are examples of typical systems tract architecture. The fact that this architecture was apparent only after detailed examination of stacking patterns suggests that the interpretation of sequences in the Cincinnatian may have been strongly influenced by *a priori* assumptions about cycle form. The Miamitown Shale provides a testing ground for a new integrated cyclic, lithologic, and quantitative faunal method of correlating meter-scale fifth-order cycles.

This has been accomplished within the 12 m interval surrounding the Miamitown Shale in the upper part of the Riedlin Sequence. First, using lithologic criteria alone, six shale-to-limestone cycles bounded by flooding surfaces were delineated and correlated between seven 12 m outcrop sections within a 30 km radius. Unusual fossil occurrences constrained correlations of cycles 3 & 4, and the limited presence of a dalmanellid, *Heterorthina fairmountensis*, showed that the flooding surface above cycle 3 lay 10 cm below the lithologic contact. Quantitatively-defined faunal clusters constrained correlations between all cycles, and revealed a major transition at the top of cycle 2, again below the lithologic contact. Finally, depth gradient fluctuations interpreted from ordination of faunal data suggests that the major transition at the top of cycle 2 is a transgressive surface, and that the middle part of cycle 3 includes the interval of maximum depth.

Acknowledgements

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CHAPTER 1: INTRODUCTION

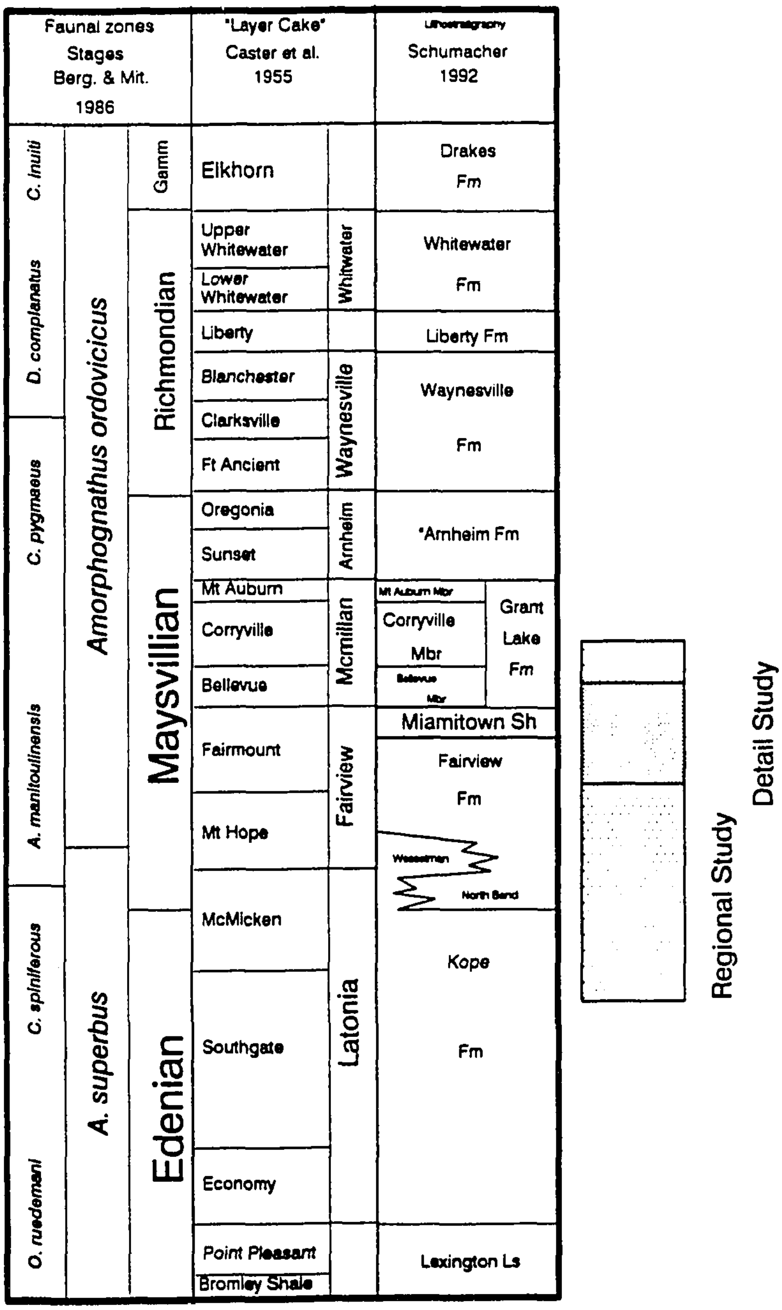
Problem

The Miamitown Shale is a Maysvillian unit that crops out around Cincinnati in Ohio, Indiana, and Kentucky. Long viewed as an enigma, both in terms of lithology and faunal content, it is a thin, mollusc-dominated interval between the Fairview Formation and the Bellevue Member of the Grant Lake Limestone (Fig. 1-1), both of which are considerably more limestone-rich and brachiopod-dominated. The interval is intriguing because of the faunal and lithologic contrasts, as well as the relatively complex geometry of the rapid Miamitown-Fairview facies transition.

Tobin (1982) and Jennette (1986) suggested that Upper Ordovician rocks of Cincinnati were deposited during three major cycles of sea-level regression in a storm-dominated environment. More recently Holland (1990, 1993) recognized five, or possibly six, such cycles that record stratigraphic transitions from deep-water shale to shallow-water limestones, then back to deep-water shale. Within this framework the Miamitown Shale is enigmatic for four reasons: 1) it is an unusual "out-of-place" recurrence of shale in the first cycle, 2) it may not have been storm-dominated, 3) it apparently crosses other formational boundaries (Tobin, 1982), and 4) it contains a bivalve-and gastropod-dominated fauna of apparently low diversity which contrasts sharply with the bryozoan-brachiopod-dominated faunas of surrounding strata.

The Late Ordovician was a time of rapid diversification of the bivalve and gastropod mollusks (Sepkoski, 1979, 1981, 1984; Hallam and Miller, 1988; Miller & Sepkoski 1988), and the Miamitown Shale contains a fauna dominated by these

Figure 1-1. Stratigraphic position of the Miamitown Shale and study intervals in reference to Cincinnatian Stratigraphy.



elements. Although Frey (1987) reported offshore bivalve-dominated communities from the Ordovician, these mollusks appear to have at first diversified more rapidly in nearshore, terrigenous environments; only later did they become widespread and diverse offshore (Miller, 1988b). The fact that Miamitown Shale contains a molluscan-dominated fauna makes it an interesting case study of the ecological conditions surrounding the Ordovician molluscan radiation, and it affords an opportunity to further study the ecological constraints on both bivalves and gastropods.

Simply stated, the aim of this study was to determine just what the Miamitown Shale *is* from the perspective of stratigraphy and depositional environment. To accomplish this goal, I examined the interval of the Miamitown Shale on two different scales: (1) Sequences ten to hundreds of meters thick, were traced over an area around Cincinnati 200 km across; (2) Parasequences 2 to 5 m thick were correlated for 50 km across Cincinnati. The purpose of this dissertation is to present the results of these investigations, which include a revised concept of Cincinnatian sequence stratigraphy and a detailed understanding of the distribution of fossils within the Miamitown interval (an overview of the unique contributions of this study is presented following the descriptions of geologic setting and previous work).

Geologic Setting

The Upper Ordovician strata of the Cincinnati Region of Ohio and Indiana were deposited on a shallow shelf with a low-angle regional slope dipping to the northwest (Gray 1972; Weir *et al.* 1984; Tobin 1982). The basal, lower Edenian part

Figure 1-2. Generalized regional Cincinnatian Paleogeography (Peterson IN PREPARATION).

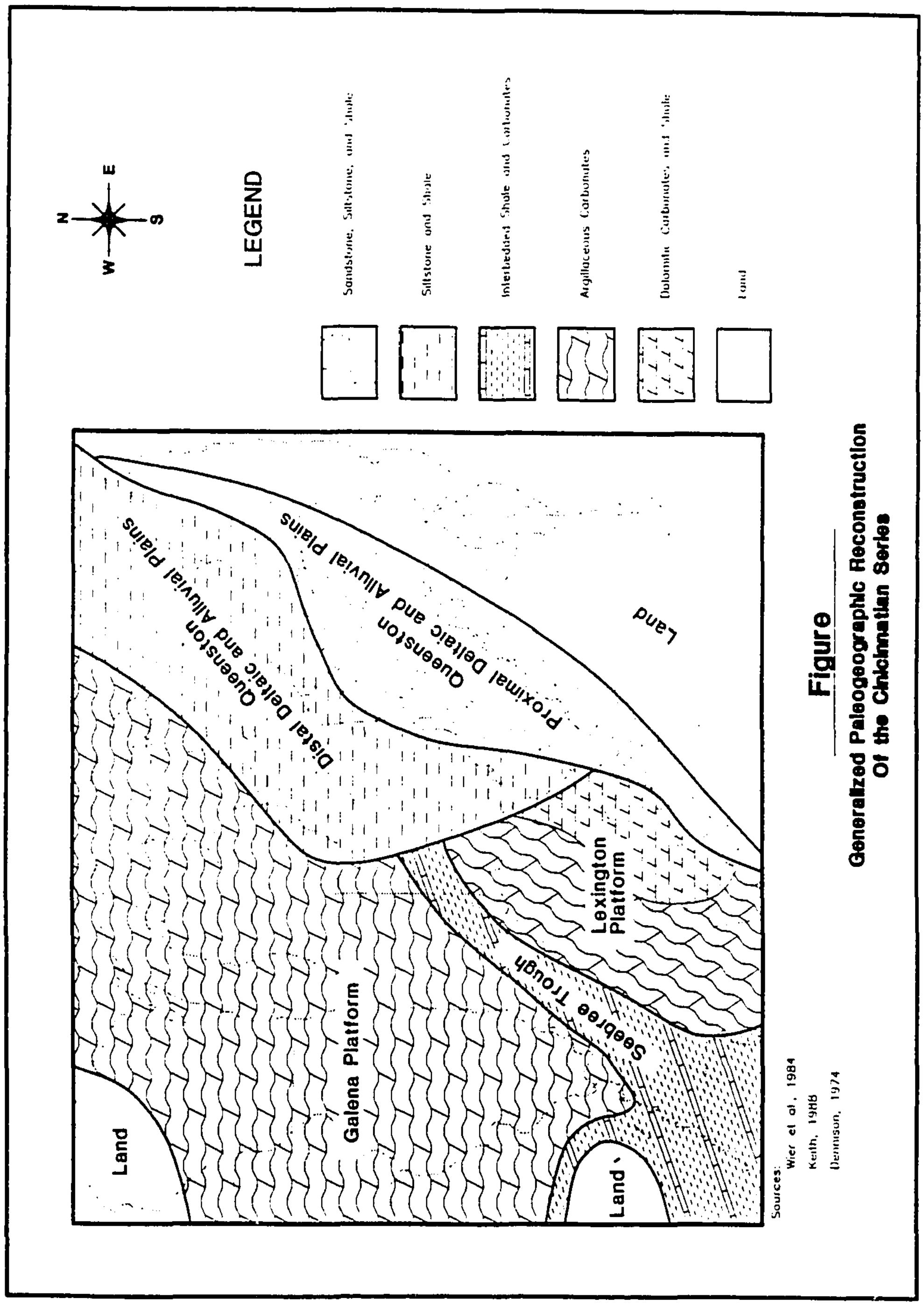
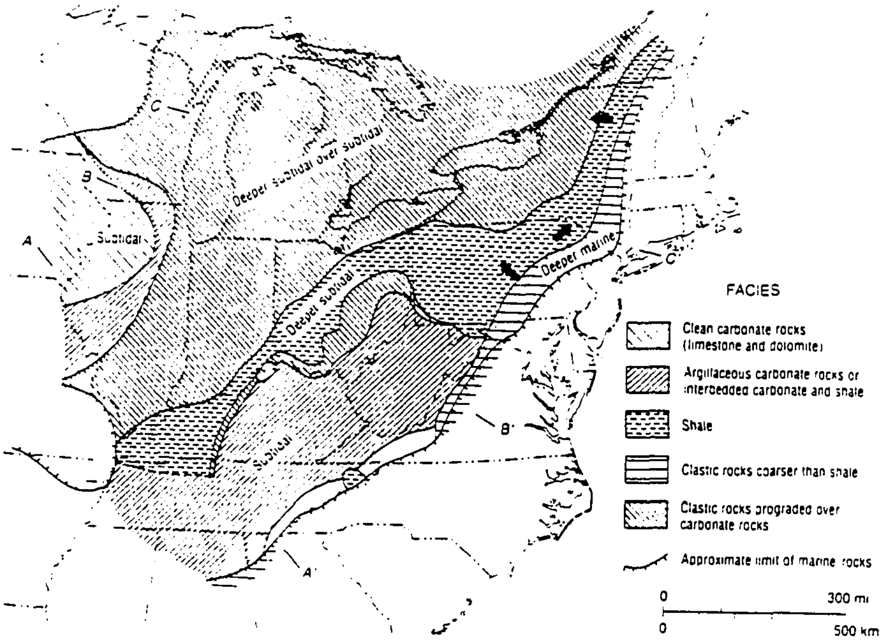


Figure 1-3. Development of Cincinnatian paleogeography. A. Edenian, and B. Maysvillian time (from Keith 1991).



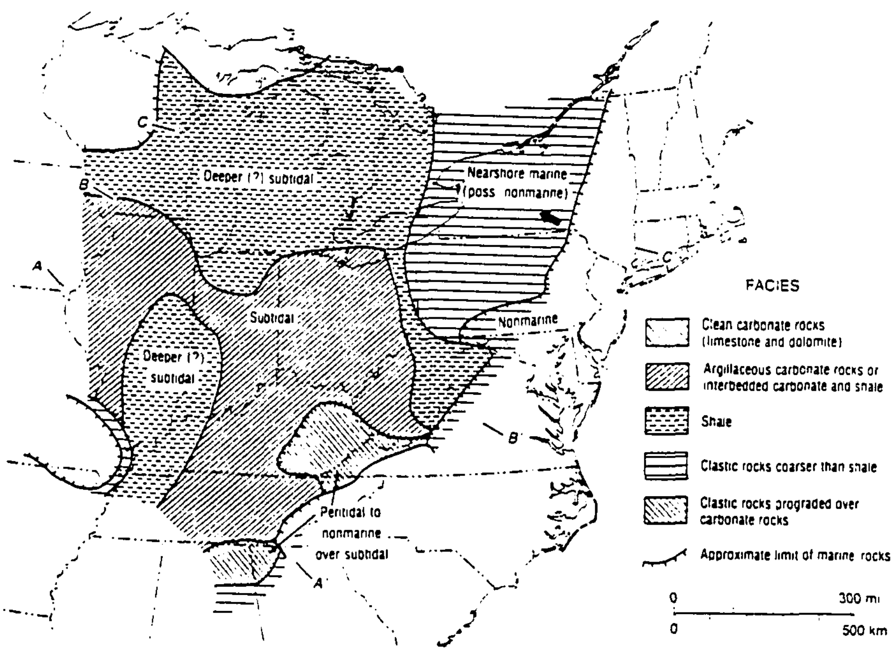
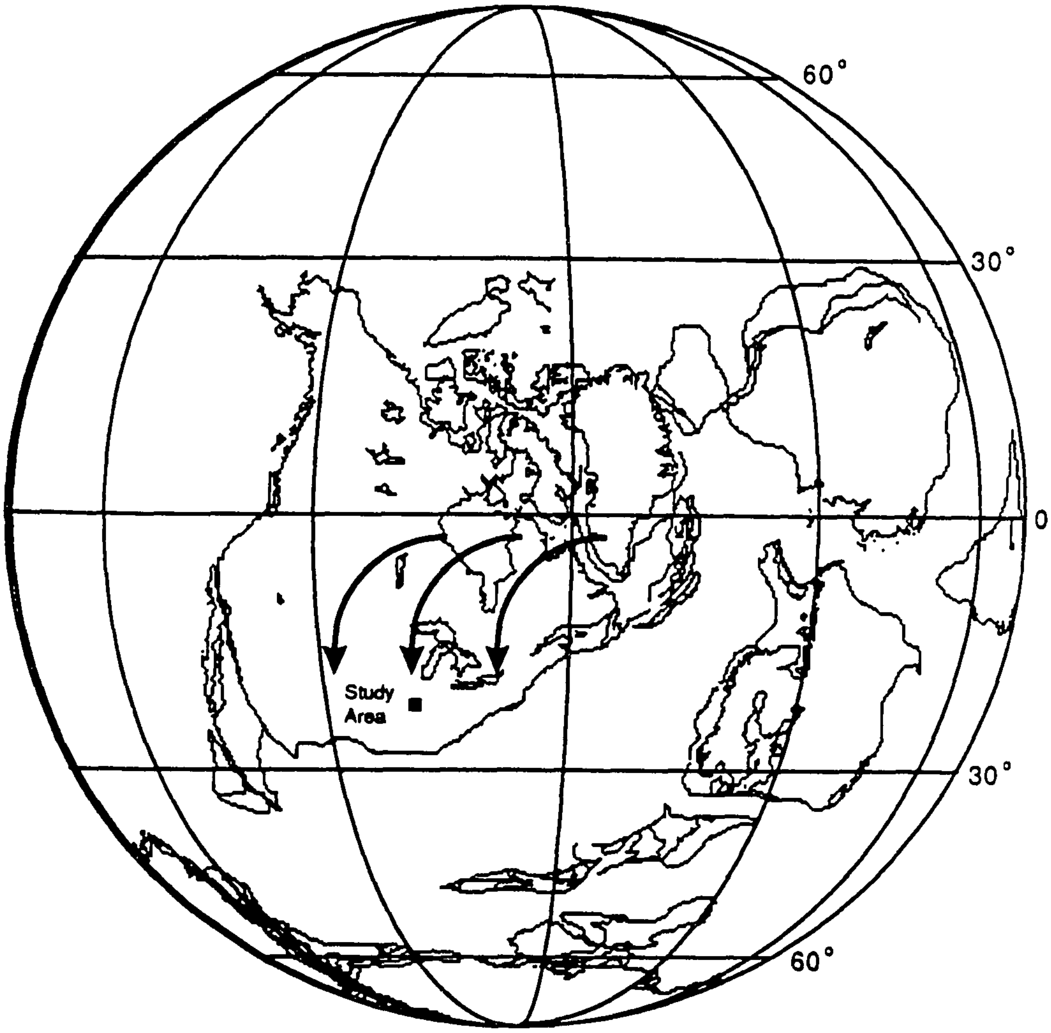


Figure 1-4. Global paleogeographic reconstruction showing the position of the study area during the Cincinnatian.



of these strata may have been affected by a linear structural feature, the Seebree Trough, that ran in a NE-SW direction and lay a few kilometers to the northwest of Cincinnati (Fig. 1-2, 1-3; Keith 1988). Younger Edenian and Maysvillian strata do not indicate the presence of this feature (Fig. 1-2, 1-3). During Edenian-Maysvillian time the Cincinnati region was situated at approximately 25° south latitude (Fig. 1-4); Scotese & McKerrow 1990), within the inferred belt of tropical-storm influence (Kreisa 1981a; Tobin 1982; Jennette 1986; Jennette & Pryor 1993). Cincinnatian sediments in the immediate vicinity of Cincinnati consist of alternating thin- to medium-bedded bioclastic grainstones, packstones, and terrigenous calcisiltites as well as thin- to thick-bedded shales, mudstones and fossiliferous mudstones. These beds show many of the structural and fabric characteristics of storm deposits in general (e.g. Kreisa 1981b; Aigner 1985) and have been interpreted specifically as such (Kreisa 1981a; Tobin & Pryor 1981; Tobin 1982, Jennette 1986; Jennette & Pryor 1993). Facies interpretations (Tobin 1982; Tobin & Pryor 1981; this dissertation) indicate that deposition in the study interval occurred from just below storm wave base to just above fair-weather wave base.

Previous Work

A brief history of Cincinnatian fine-scale stratigraphic nomenclature will acquaint the reader with the complexities of the Miamitown interval in Cincinnati. The Miamitown was formally named by Ford in 1967, but a perusal of largely unpublished manuscripts and theses reveals that the gastropod-rich shale has been recognized since the 1930's and perhaps longer.

First Mention

The Miamitown Shale unit was recognized at least as early as 1914 by Ulrich and Bassler as the "*Stigmatella irregularis* zone" (Fig. 1-5). They described the zone as a shaly interval in the upper Fairview Formation just below the Bellevue with a fauna atypical of the Cincinnati area. They also reported a zone of black (phosphate?) pebbles, a fact of considerable stratigraphic interest, from this unit near Cumminsville. Interestingly, the unit is not apparent in an earlier description of the Bellevue Hill locality (Nickles 1902), an outcrop at which it is clearly present.

Cincinnati School

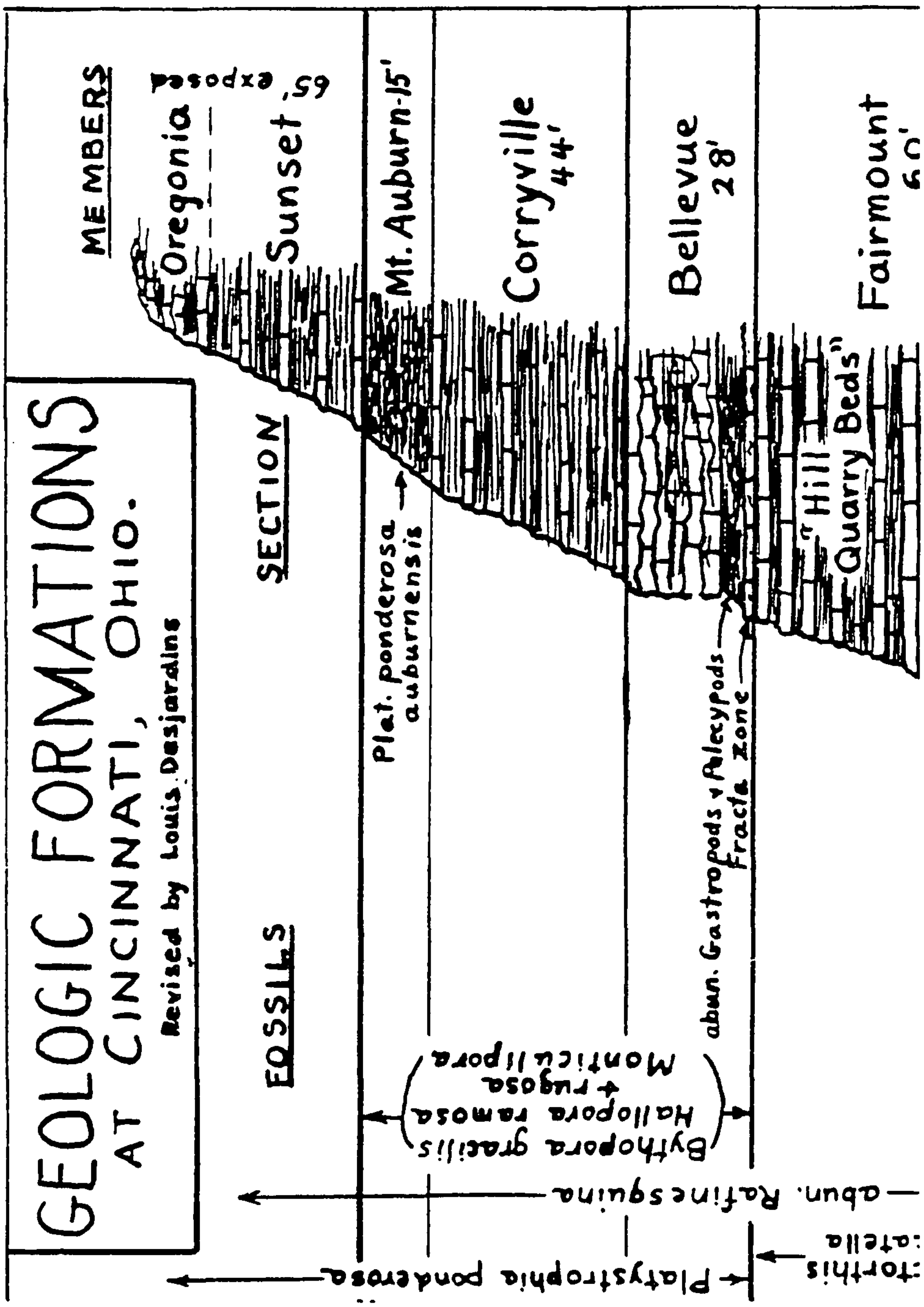
Possibly because of its easy accessibility and distinctive stratigraphy, the interval surrounding the Miamitown Shale was apparently studied in more detail than other Cincinnatian units. Desjardins studied the physiography of the Cincinnati area (1933, 1934, and 1935), but also made detailed notes on the bedrock stratigraphy of the area (see Forsyth, 1946). Unfortunately, the only published Desjardins stratigraphic column yet located is the generalized one in Bucher, Caster, and Jones (1939, 1945) (reproduced in part in Fig. 1-6). In this column, what is now known as the Miamitown Shale is clearly delineated just above the "*fracta* Zone" in the lowest part of the Bellevue Member. A second shaly horizon, is also visible in this rather coarse overview.

Forsyth (1946) described these units in more detail. At the top of the Fairmount Member there are three "*fracta*" or "shingled" zones, each 0.7 m (2 ft) thick; each successive pair is separated by approximately 1.5 m (5 ft) of more shaly,

Nickles 1902	Ulrich and Bassler 1914	Desjardins *fide* Forsyth 1946			Hyde 1959		Ford 1967	This paper (informal)
Corryville	Corryville	Corryville Member			Undesignated		Unamed	
Bellevue Limestone	Bellevue Limestone	Bellevue Limestone	upper massive shelly/rubbly horizon	5'-8'	Bellevue Limestone	"A"	Bellevue Limestone	6
			medium light-buff-yellow shaly horizon w/ large full *Rafinesquina alternata*	5'		"B"		
	?		lower very massive shelly/rubbly horizon	7'-8'		"C"		5
Fairmount Member	*Stigmatella irregularis* Zone	Fairmount Member	gastropod zone light buff-yellow very shaly horizon w/ many gastropods and pelecypods	5'-7'		"D"	NW Miamitown Shale	4
	?		first *"fracta"* zone	2'		"E"		3
	Fairmount Member		undescribed	5'	Fairmount Member	undesignated		
			second *"fracta"* zone	2'		2nd shingled	Fairview Formation	2
			undescribed	5'		undesignated		
			third *"fracta"* zone	2'		3rd shingled	SE	1

Figure 1-5. Summary of stratigraphic classification of the Miamitown Shale interval.

Figure 1-6. Section of early stratigraphic column showing that the unique lithology and fauna ("abun. Gastropods & Pelecypods" in the Bellevue) of the Miamitown Shale was recognized by Desjardin and other Cincinnati workers (Bucher, Caster & Jones 1945).



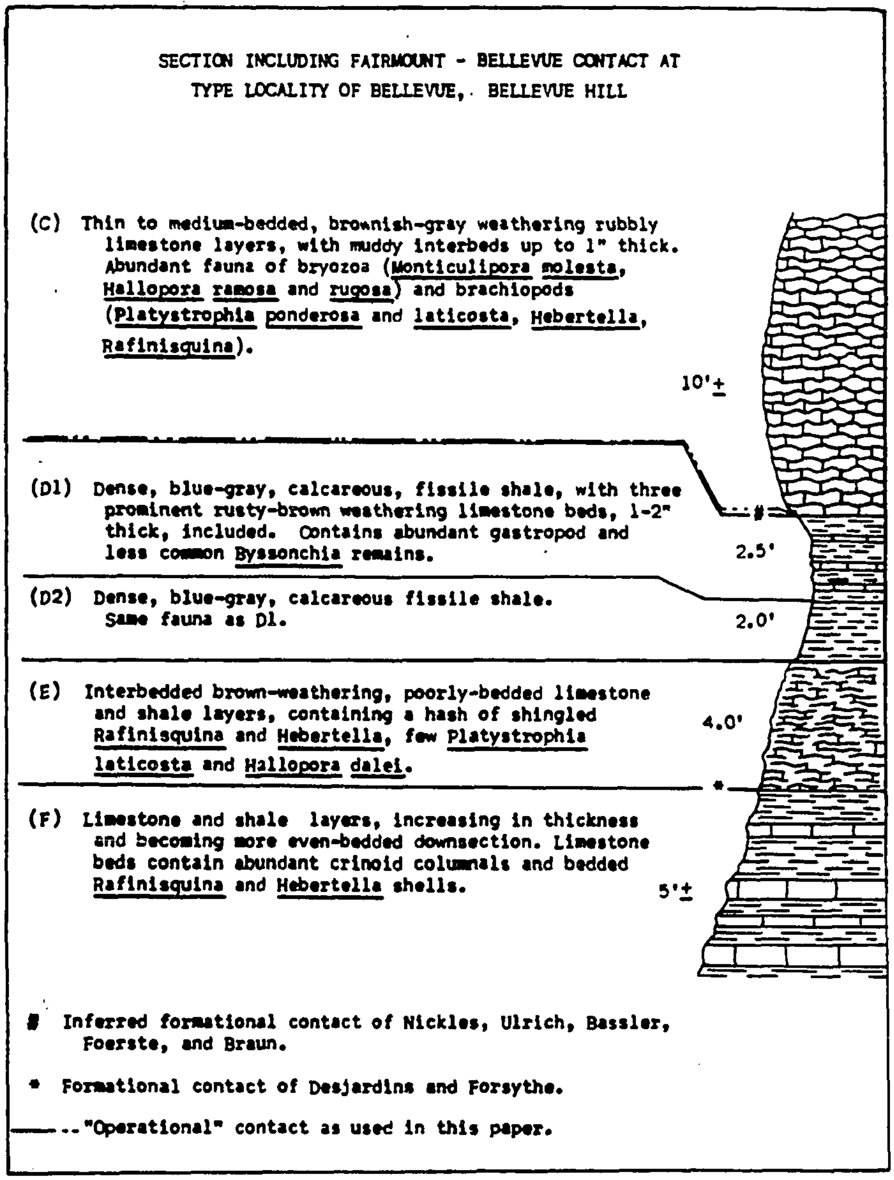
even-bedded strata. These zones are characterized by abundant fragmented valves of *Rafinesquina alternata*, *Hebertella occidentalis*, and *Platystrophia*. The uppermost ("first '*fracta*' zone" or "upper shingled") is the most extensive and continuous, whereas the lowest ("third '*fracta*' zone" or "lower shingled") is the least continuous.

Above the shingled zones is a shaly interval 2 m (5 to 7 ft) thick with a few gastropod-rich limestones called the "gastropod zone" or "gastropod shale" or "zone of abundant gastropods and pelecypods" (Forsyth, 1946). This zone is capped by the 2- to 3-meter (7- to 8-ft) "lower very massive shelly/rubbly" or "lower massive" horizon, which consists mostly of limestone and contrasts markedly with the underlying units. The base of the Bellevue was drawn by Desjardins at the base of the first shingled zone, because all of the shingled zones were recognized as being fundamentally Bellevue-like. Nickles (1902), however, placed the base of the Bellevue above all three "*fracta*" or "shingled" zones, at the bottom of the "lower very massive shelly/rubbly horizon", as did Hyde (1959) and Ford (1967).

Above the "lower very massive shelly/rubbly horizon" is a shaly horizon 3 m (5 ft) thick characterized by large, "full" *Rafinesquina alternata*. Overlying this *Rafinesquina*-bearing shale is an "upper massive shelly/rubbly horizon", the top of which is recognized as the top of the Bellevue.

These same units were used later by Hyde (1959; Fig. 1-5, 1-7) to identify precisely a stratigraphic horizon on which to base a structural contour map of the area. It is interesting that stratigraphy at this fine a scale was not again conducted in the Cincinnatian until much later (e.g., Tobin 1982; Jennette 1986; Jennette & Pryor

Figure 1-7. Stratigraphic section presented by Hyde (1959) showing the great detail to which the Miamitown Shale interval was described in Cincinnati.



1993).

Lithostratigraphy

The stratigraphy of Ford (1967) in this interval differs from that of Nickles (1902) in the recognition of the Miamitown Shale as a lithofacies that thickens to the northwest. Beyond recognizing the Miamitown Shale as a lithostratigraphic formation, Ford (1967) also noted the important intertonguing relationships between the Grand Avenue Member of the Kope Formation, the North Bend Tongue of the Fairview Formation, the Wesselman Tongue of the Kope Formation and, finally, the Miamitown Shale (Ford 1967; Fig. 1-8). The relationship between the Miamitown and Fairview was examined more extensively by Hay (1981, IN PRESS), who showed that the Miamitown Shale is thickest where the Fairview is thinnest and vice versa (Fig. 1-9), suggesting that the Miamitown Shale is in part time equivalent to the upper part of the Fairview Formation.

Cyclic Stratigraphy

Although always noted for its unusual fauna and used as a marker horizon, the enigma of the Miamitown Shale was not discussed in the context of early Cincinnatian stratigraphy (Ulrich & Bassler 1914; Hyde 1959) or in more recent lithostratigraphic studies and transgressive-regressive models (Ford 1967; Hay 1981, IN PRESS). However, in the context of more recent sequence stratigraphic work (Tobin 1982; Holland 1993), the Miamitown appears as an exceptional case. As discussed in Chapter 2 of this dissertation, Tobin (1986) interpreted the Cincinnatian as being divided into three third-order progradational shoaling-upward sequences punctuated by

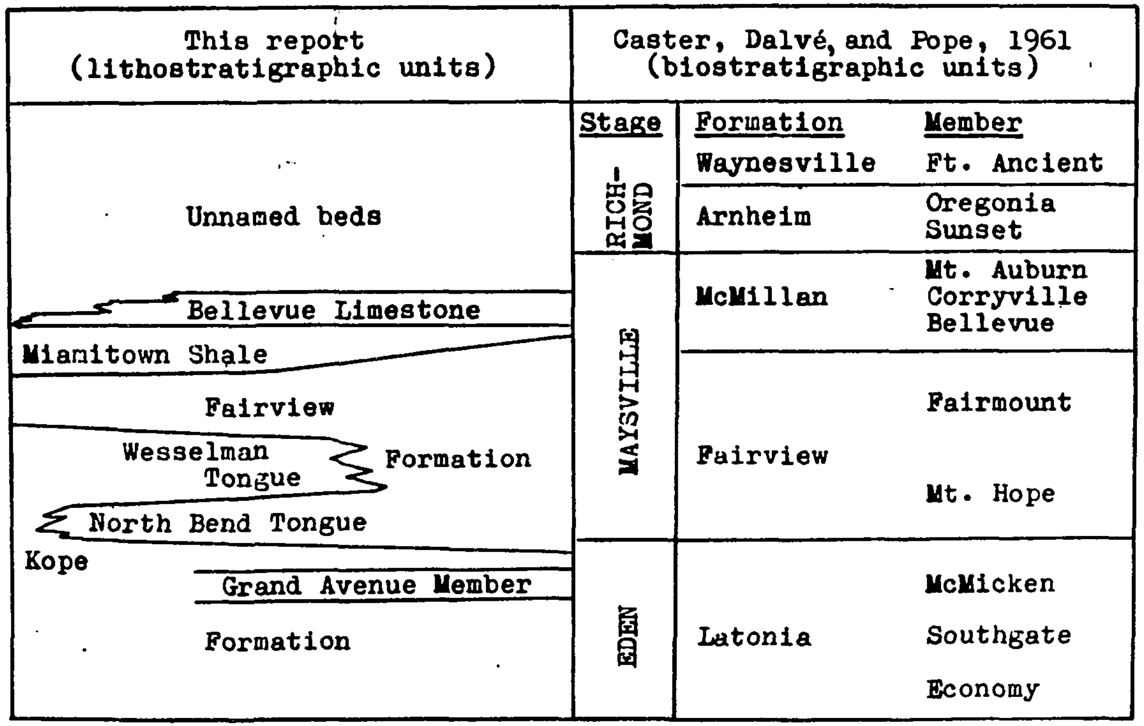


Figure 1-8. Intertonguing facies as interpreted by Ford (1967).

Figure 1-9. Regional isopachs of the Fairview Formation and Miamitown Shale. The complementary relationship between the Miamitown shale and the Fairview Formation is evidence that the two formations are contemporaneous. Note that the Fairview disappears to the northwest where the Miamitown Shale consequently merges with the Kope Formation (Hay 1981; IN PRESS)

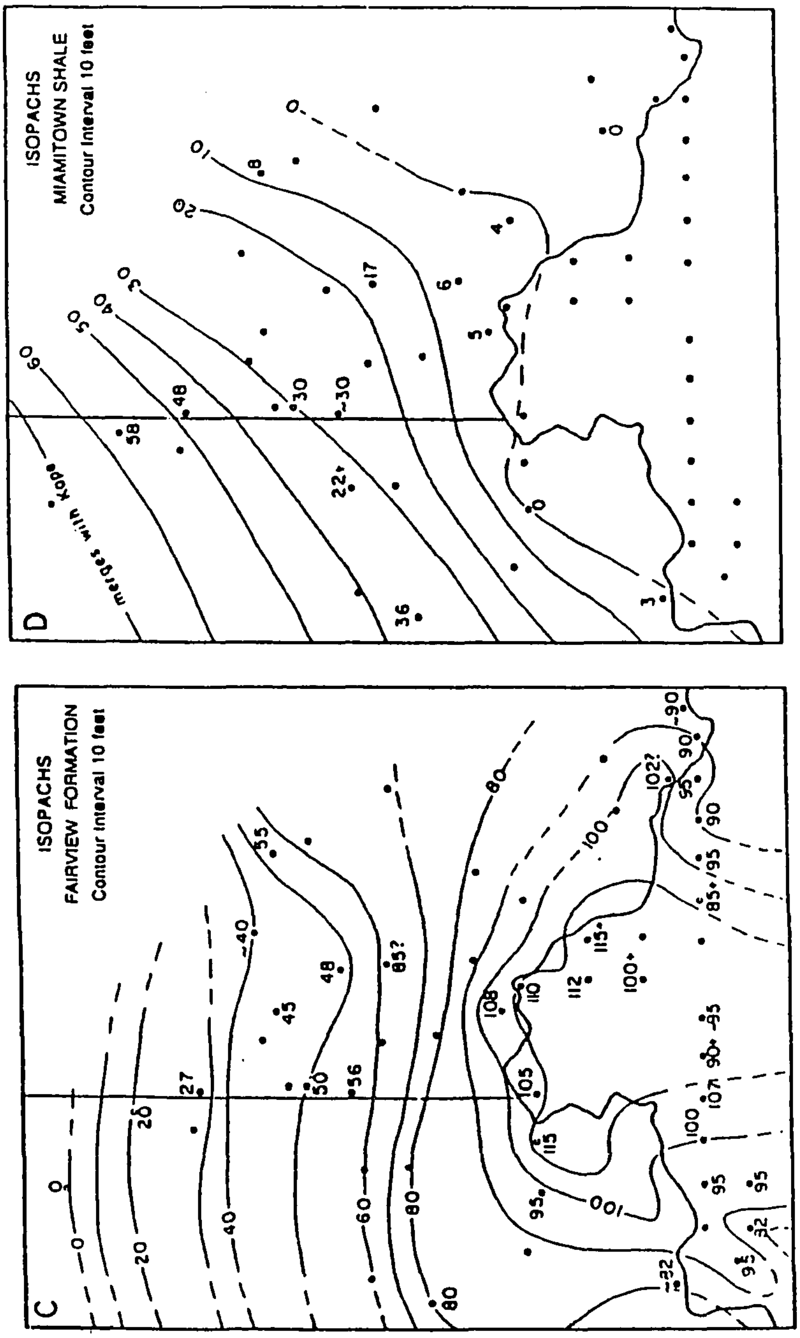


Figure 1-10. Simplified stratigraphic column showing Tobin's (1985) interpretation of the Kope Formation-Bellevue Tongue interval as a shoaling upward shelf sequence. The Miamitown Shale is clearly anomalous in light of this interpretation.

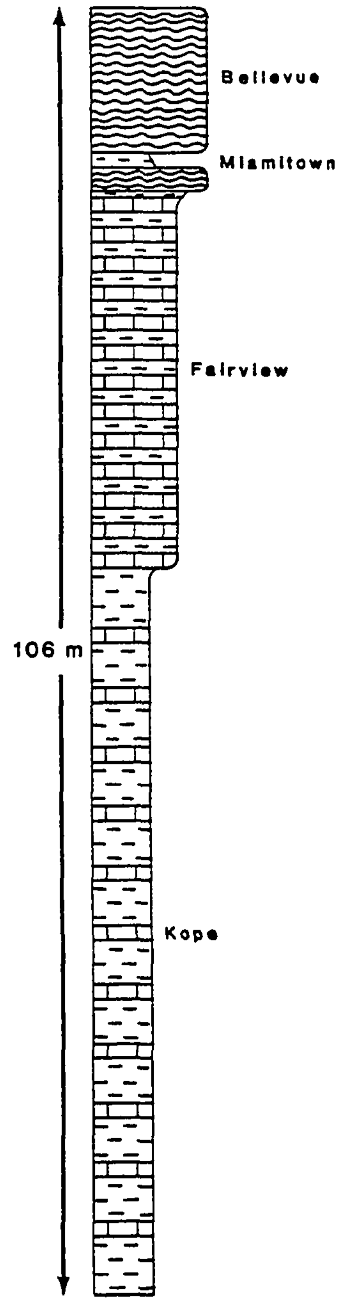


Figure 1-11. Stratigraphic cross section of Miamitown Shale interval showing Tobin's (1985) correlation across Cincinnati. In this interpretation the Miamitown Shale clearly crosses facies lines.

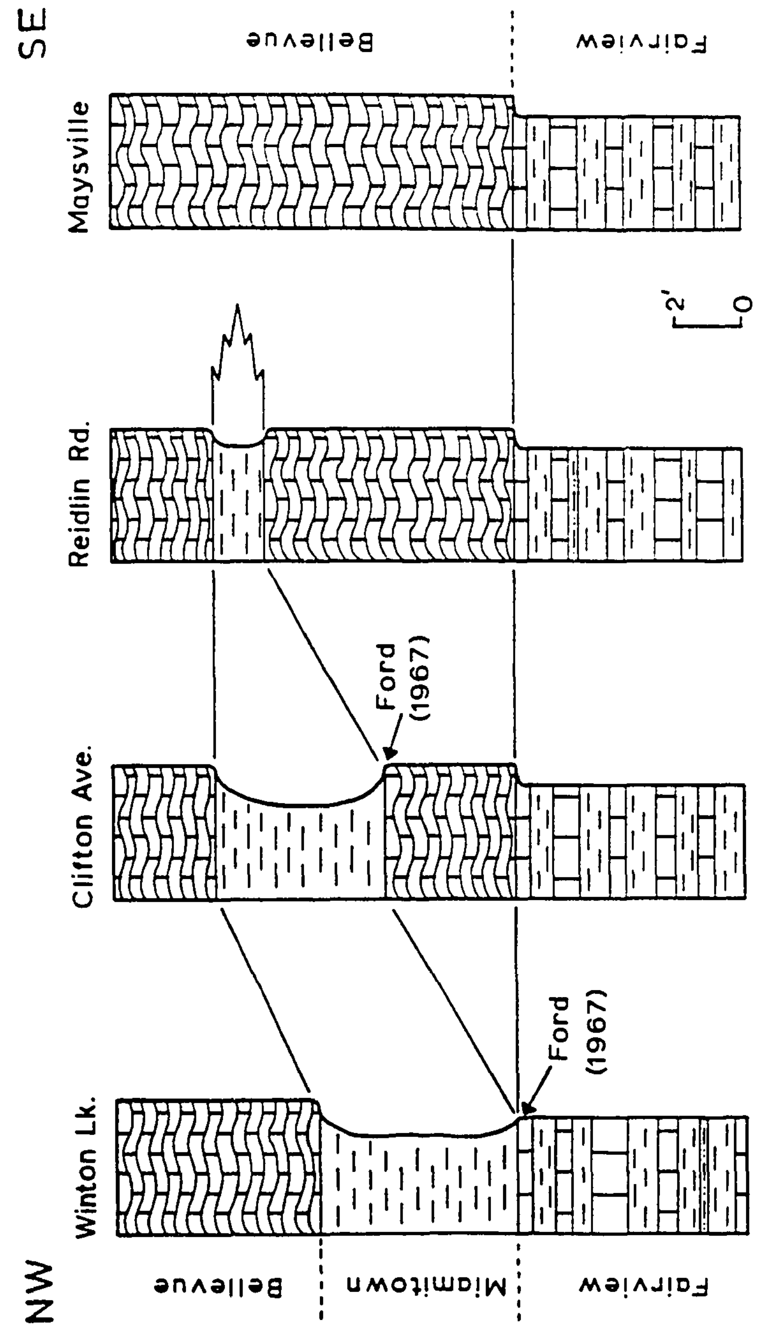


Figure 1-12. Block diagrams showing the interpretation of the Miamitown Shale as an anomalous event that interrupted the normal progradational pattern of sedimentation in the Kope-Bellevue Sequence.

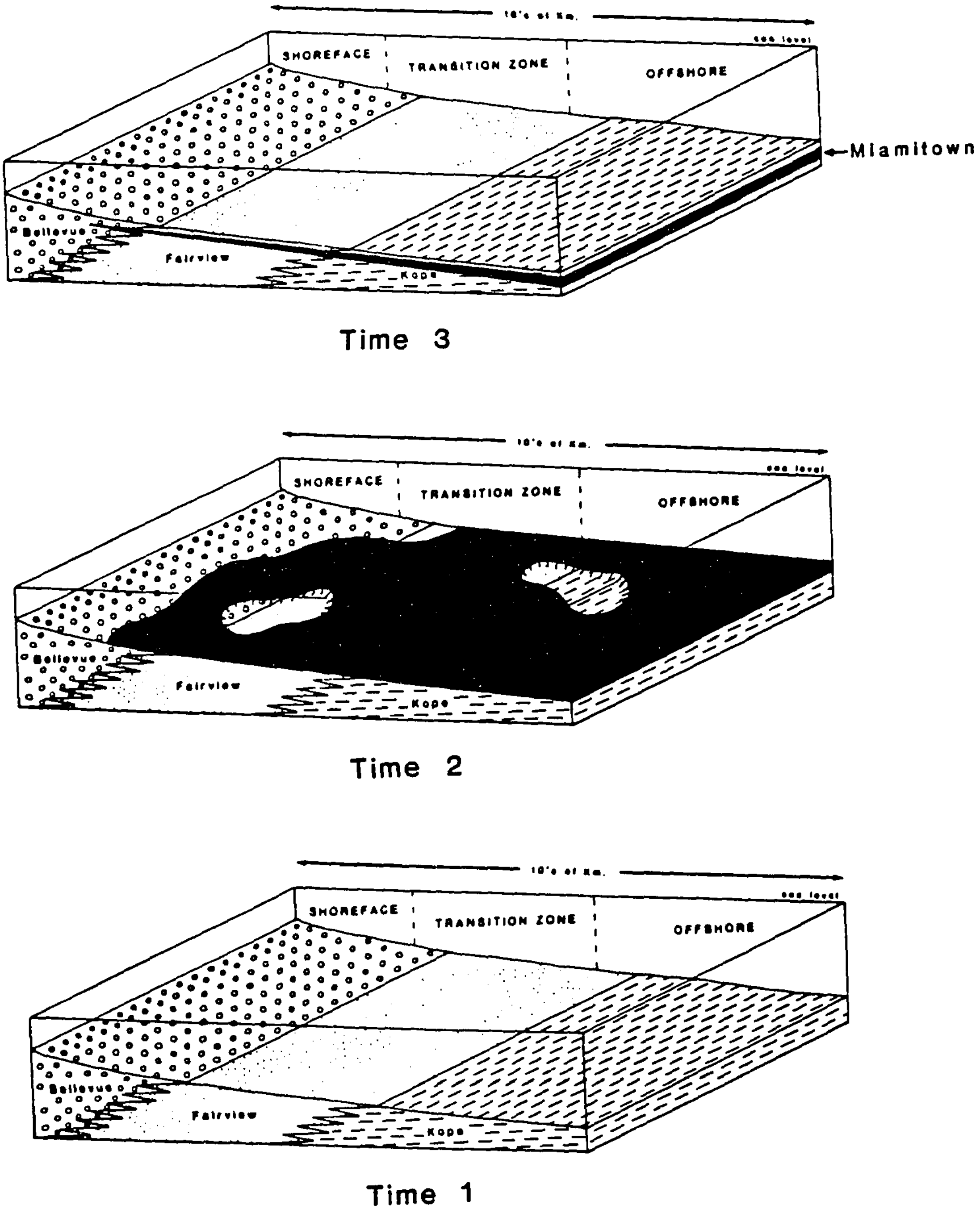
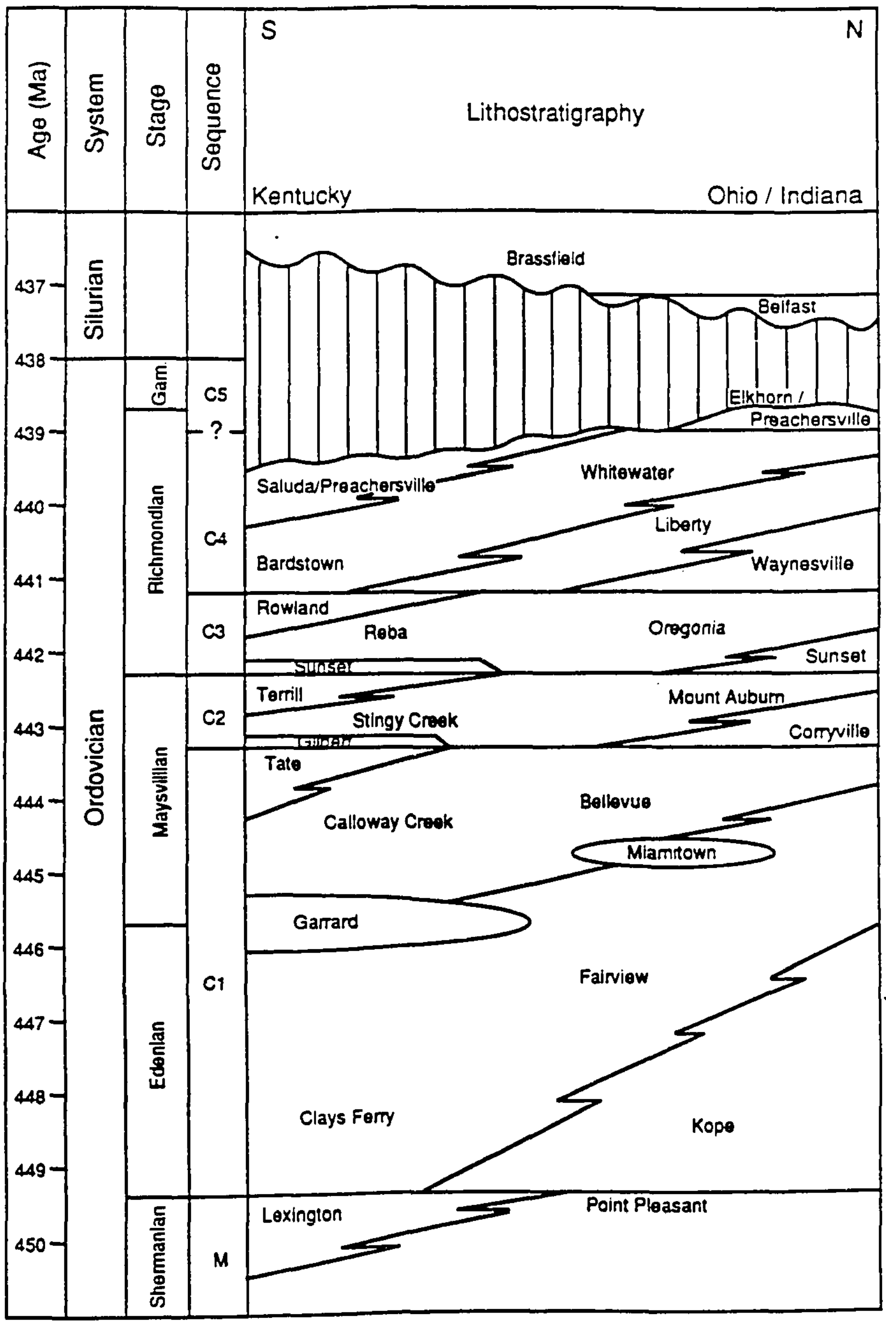


Figure 1-13. The anomalous position of the Miamitown Shale is shown in this interpretation of Cincinnatian sequences (Holland 1990, 1993).



flooding surfaces. The Miamitown Shale represents an out-of-place occurrence of shale in the upper, limestone-dominated part of the sequence (Fig. 1-10). Additionally Tobin (1985) found that the Miamitown Shale crosses the Fairview-Bellevue facies contact (Fig. 1-11); thus it is enigmatic. The best solution to the problem of interpreting the Miamitown Shale was to view it as an unusual event-deposit largely unrelated to the progradational system that deposited the surrounding sediments (Fig. 1-12); Holland (1990, 1993) simply left the deposit unexplained (Fig. 1-13). These studies leave unanswered the fundamental question: *what is the Miamitown Shale?*

New Contributions

The three remaining chapters of this dissertation deal with different aspects of the character of the Miamitown Shale. Large-scale stratigraphic geometries are discussed in Chapters 2 and 3, while details of finer-scale cyclicity and faunal distribution are discussed in chapter 4.

More specifically, the information contained in Chapter 2 shows that the Miamitown Shale is not actually enigmatic, but fits in well with currently accepted sequence-stratigraphic models, if the Kope-Bellevue Sequence (C1 of Holland 1993) is split into two parts. The sequences presented in this chapter differ from previously defined Cincinnatian sequences (Tobin 1986; Holland 1990, 1993) in that they are not primarily progradational, but contain a full complement of systems tracts. The approach used to arrive at this conclusion differs from previous investigations (Tobin 1986; Holland 1990, 1993) in that facies stacking patterns were determined from an extensive network of closely-spaced outcrops and wells rather than from widely scattered outcrops. This allowed for an evaluation of stacking patterns from actual horizontal data rather than simply from vertical successions of facies.

Parts of three sequences are correlated in Chapter 2. In Chapter 3 these sequences are formally named; these are, in stratigraphic order, the Brent Sequence, the Riedlin Sequence, and the Stonelick Sequence. A new set of formal names is given because other naming systems applied to the Cincinnatian can lead to confusion later on.

Chapter 4 reports on a more detailed look at the 17 m of section immediately surrounding the Miamitown Shale as it is found in the Cincinnati area. The main contributions of this chapter involve more than the high-resolution correlation of this interval; the methodology used to arrive at and refine the correlations is itself a significant contribution. In general the method involves application of quantitative paleoecologic analyses of macroinvertebrate fossil samples collected from the different outcrop sections at close stratigraphic intervals. The results were then used to correlate meter-scale cycles from section to section.

CHAPTER 2: ANATOMY OF THE RIEDLIN SEQUENCE

Introduction

The underlying tenets of cyclic stratigraphy, particularly in the context of sequence delineation have undergone considerable development in recent years. Forward, base-level models of the effects of eustatic sea-level fluctuations on siliciclastic sedimentation along subsiding continental margins are now particularly well developed (Posamentier *et al.* 1988; Posamentier & Vail 1988) and backed by extensive data from seismic and field exposures (e.g. Van Wagoner *et al.* 1988, 1990; Shanley & McCabe 1991); purely carbonate sequences are also relatively well understood (e.g. Goldhammer *et al.* 1990; 1993; Sarg 1988).

These studies have generated basic criteria for the recognition and delineation of sequences in the stratigraphic record (Van Wagoner et al. 1988; 1990). Among these definitions (Van Wagoner *et al.* 1988), unconformity-bound sequences and marine flooding-surface bound parasequences are fundamental and rigidly interrelated. Sequences are composed of three systems tracts (lowstand or shelf margin, transgressive, and highstand), each of which is in turn composed of one or more parasequence sets. Each parasequence set consist of one or more parasequences which together define a uniform stacking pattern. The implication is that sequences and parasequences are fundamentally different, and that if a sequence is recognized at one scale, then higher order cycles must be parasequence sets or parasequences.

Conflicting sequence stratigraphic interpretations of the mixed carbonate-siliciclastic Upper Ordovician strata in the region of the Cincinnati Arch (Holland, 1990; 1993) and Illinois basin (Guthrie *et al.* 1993; Hohman & Keith IN PRESS; Hohman & Leonard 1993) underscore the power of this *a priori* assumption in shaping the interpretation of real stratigraphic sequences. The conflict concerns the identification of Cincinnatian third-order and fourth-order (Jennette and Pryor 1993; usage of Goldhammer *et al.* 1993) cycles as either sequences (Holland 1990; 1993; Jennette & Pryor 1993) or parasequence sets within a larger scale Maquoketa sequence (Hohman & Leonard 1993; Hohman & Keith IN PRESS). Although Hohman & Leonard (1993) argue that the structure of Holland's (1993) fourth-order sequences is parasequence-like, the heart of the disagreement lies in the logical implications of a rigid sequence-parasequence structure application; if one point of view is correct, the other must be incorrect.

This does not lessen the importance of sequence structure; Holland's (1993) sequences are parasequence-like in that their transgressive systems tracts are thin to absent, leaving thick, shoaling-upward highstand systems tracts, capped by major flooding surfaces (Hohman & Leonard IN PRESS). While Holland (1993) used this trait to argue that Cincinnatian sequences are exceptional, more detailed work within some of these sequences (Jennette & Pryor 1993; Holland *et al.* 1993; Dattilo *et al.* 1993; Goldman 1993) has led to the preliminary conclusion that the shoaling upward pattern is an oversimplification; these particular sequences have much thicker transgressive systems tracts than once thought. As discussed below, the delineation of these sequences, and particularly of their internal architecture (Holland 1990, 1993), may have also been influenced by expectations of shoaling-upward cycles; while

Cincinnatian fifth-order (Tobin 1982; Jennette & Pryor 1993) and fourth-order and larger (Holland 1993; Hohman & Keith IN PRESS) cycles have been individually delineated, smaller-scale stacking patterns that comprise third- or fourth-order cycles have not been documented thoroughly. The detailed evaluation of such stacking patterns, while not contributing to the evaluation of the Maquoketa sequence (Hohman & Keith IN PRESS), would help determine whether fourth-order cycles can be considered sequences according to the criteria set forth (Van Wagoner *et al.* 1988).

The Miamitown Shale is an apparently enigmatic terrigenous unit within the upper, limestone dominated part of the Edenian-Maysvillian Kope-Bellevue (C1 of Holland 1993) shoaling-upward sequence. In the course of my investigation of this unit and the surrounding strata, stacking patterns and systems tract architecture emerged that closely resemble the theoretical ideal of a type-2 sequence (Van Wagoner *et al.* 1988): a thick shelf margin systems tract, a transgressive systems tract, and a highstand systems tract. This architecture supports the division of the C1 (Holland 1993), Kope-Bellevue sequence at the lithostratigraphic contact between the Kope and Fairview formations, creating two fourth-order sequences, a change which has also been suggested by other workers (Jennette & Pryor 1993; Holland & Patzkowski IN PRESS; compare Schumacher IN PRESS).

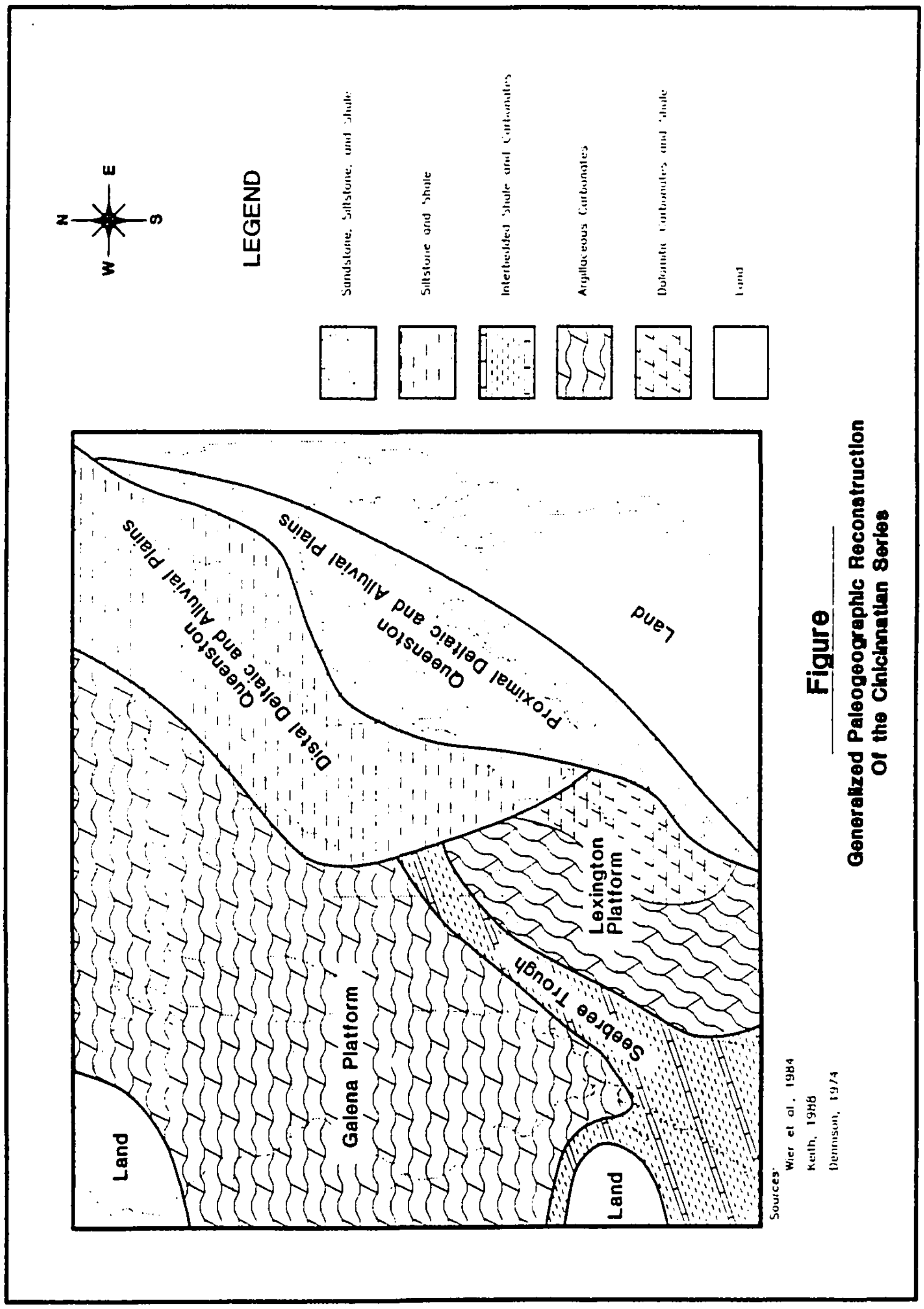
In this paper, I will use new informal stratigraphic names, corresponding to "type" localities to refer to the lower three fourth-order cycles of the Cincinnatian. Such new names are superior to sequential numbers (Holland 1993; which must be completely recast with every revision), and to previously occupied lithostratigraphic names (Hohman & Keith IN PRESS; which might lead the reader to confuse lithostratigraphic units with cycles). These three sequences are referred to, in stratigraphic order as: 1) the Brent sequence, 2) the Riedlin sequence, and 3) the Stonelick sequence.

The purpose of this paper is to document the type-2 sequence architecture of the Riedlin sequence through vertical stacking patterns of fifth-order cycles in outcrop and subsurface sections, and through lateral stacking patterns established from correlations between well logs in the subsurface of part of southwestern Ohio and of southeastern Indiana. I present vertical stacking patterns, correlations between outcrop and subsurface sections, and subsurface correlations and stacking patterns in detail. Finally, I use these data to explore a series of important questions concerning Cincinnatian sequence stratigraphy and their implications for sequence stratigraphy in general: 1) Do Cincinnatian fourth-order sequences differ as much from siliciclastic sequences as once thought (Holland 1993)? 2) Are fourth-order Cincinnatian cycles actually sequences (Holland 1993; Tobin 1982; Jennette & Pryor 1993) or are they parasequences or parasequence sets (Hohman & Leonard 1993; Hohman & Keith IN PRESS)? 3) What is the chronostratigraphic significance of these surfaces with respect to Cincinnatian stratigraphy?

Geologic Setting

The Upper Ordovician strata of the Cincinnati Region of Ohio and Indiana were deposited on a shallow shelf with a low-angle regional slope dipping to the northwest (Gray 1972; Weir *et al.* 1984; Tobin 1982). The basal, lower Edenian part

Fig. 2-1. Regional Ordovician paleogeography in relation to the Cincinnati area.



of these strata are affected by a possible linear structural feature, the Seebree Trough, that ran in a NE-SW direction and lay a few kilometers to the northwest of Cincinnati (Fig. 2-1; Keith 1988). Younger Edenian and Maysvillian strata do not indicate the presence of this feature. During Edenian-Maysvillian time the Cincinnati region was situated at approximately 25° south latitude (Fig. 2-1; Scotese & McKerrow 1990), within the inferred belt of tropical-storm influence (Kreisa 1981a; Tobin 1982; Jennette 1986; Jennette & Pryor 1993). Cincinnatian sediments in the immediate vicinity of Cincinnati consist of alternating thin to medium bedded bioclastic grainstones, packstones, and terrigenous calcisiltites as well as thin to thick bedded shales, mudstones and fossiliferous mudstones. These beds show many of the structural and fabric characteristics of storm deposits in general (e.g. Kreisa 1981b; Aigner 1985) and have been interpreted specifically as such (Kreisa 1981a; Tobin & Pryor 1981; Tobin 1982, Jennette 1986; Jennette & Pryor 1993). Facies interpretations (Tobin 1982; Tobin & Pryor 1981; discussed below) indicate that deposition in the study interval occurred from just below storm wave base to just above fair-weather wave base.

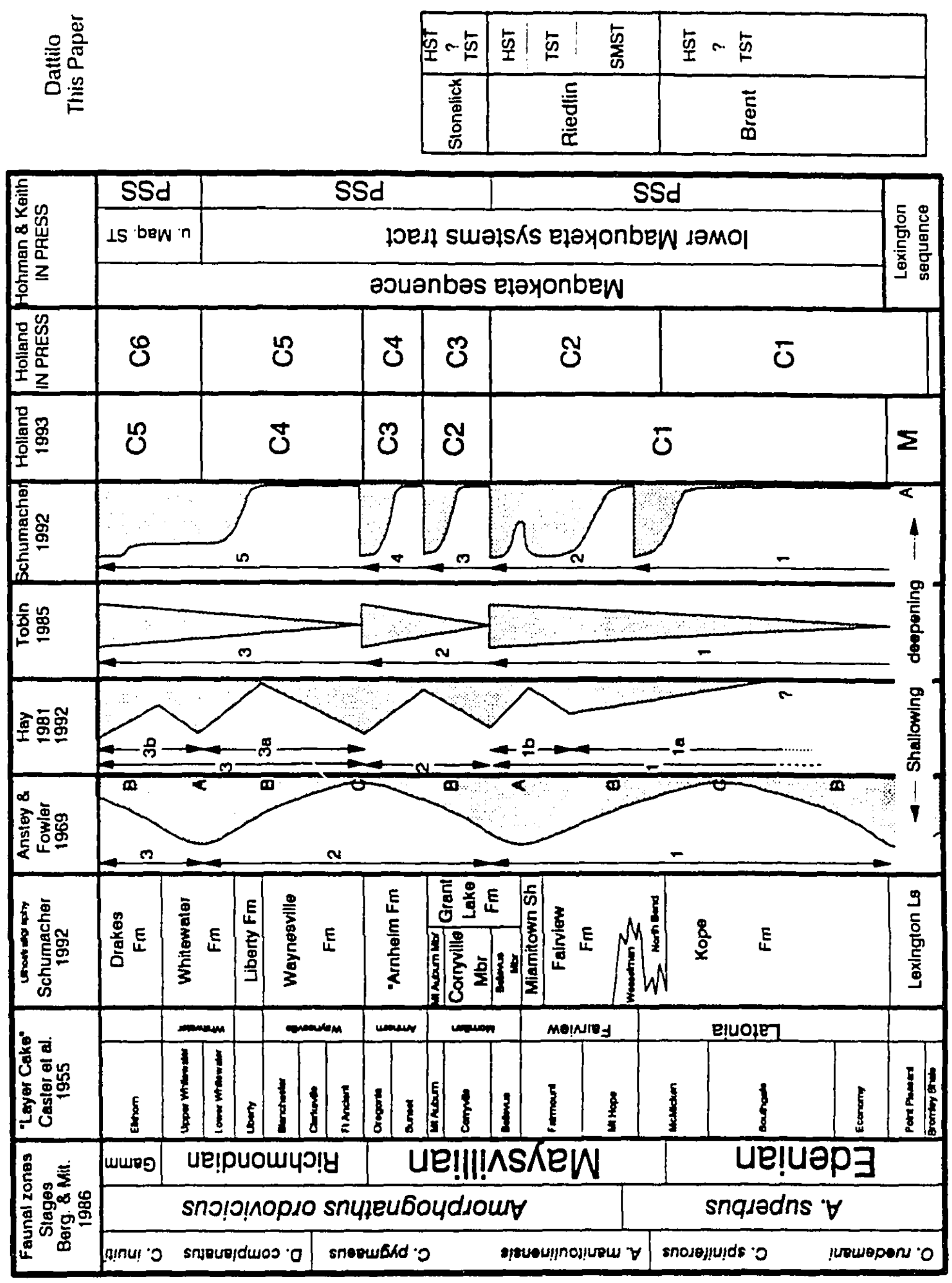
Previous work

Historically Cincinnatian strata, like those in much of the United States, have been classified under the auspices of three separate paradigms: 1) "layercake" stratigraphy, 2) lithostratigraphy and 3) Cyclic or sequence stratigraphy. This paper deals most specifically with cyclic or sequence stratigraphy, but the other classifications, along with biostratigraphic zonations are represented for reference in

Figure 2-2, because both "layercake" and lithostratigraphic systems are well known to students of Cincinnatian stratigraphy. The evolution of cyclic thinking in the Cincinnatian is relevant to the problem of sequence architecture, because it illustrates that different expectations can lead to different interpretations of small scale cycles. More specifically, the idea of shoaling-upward fourth-order "sequences" traces its origin to an older sequence concept (Tobin 1982), which has influenced the way Cincinnatian cycles have been recently interpreted (Holland 1993).

The effect of assumptions on the interpretation of stratigraphic cycles is illustrated by the fact that earlier interpretations of Cincinnatian cyclicity do not show the shoaling-upward pattern evident in more recent work. Even as lithostratigraphic work was underway in the Cincinnatian, an interpretative cyclic scheme was laid out from a composite section by Anstey & Fowler (1969), who considered increased limestone content to indicate shallower water, and assumed a series of uniform sinusoidal cycles. They recognized three such cycles in the Cincinnatian and marked them at their shallowest points: the Lexington Limestone, the Bellevue Limestone, and the Whitewater Formation (Fig. 2-2). The idea of transgressive-regressive cycles led Hay (1981, IN PRESS; Hay *et al.* 1981) to subdivide the Cincinnatian into three cycles (1 through 3; Fig. 2-2), which at some localities are further subdivided (1a, 1b, 2, 3a and 3b). Several of these cycle boundaries correspond closely with Holland's (1993) sequence boundaries such that Hay's 1 is the approximate stratigraphic equivalent of Holland's C1, 3a corresponds to C4 and 3b corresponds to C5. However, Hay's cycles are represented as virtually symmetrical or complex,

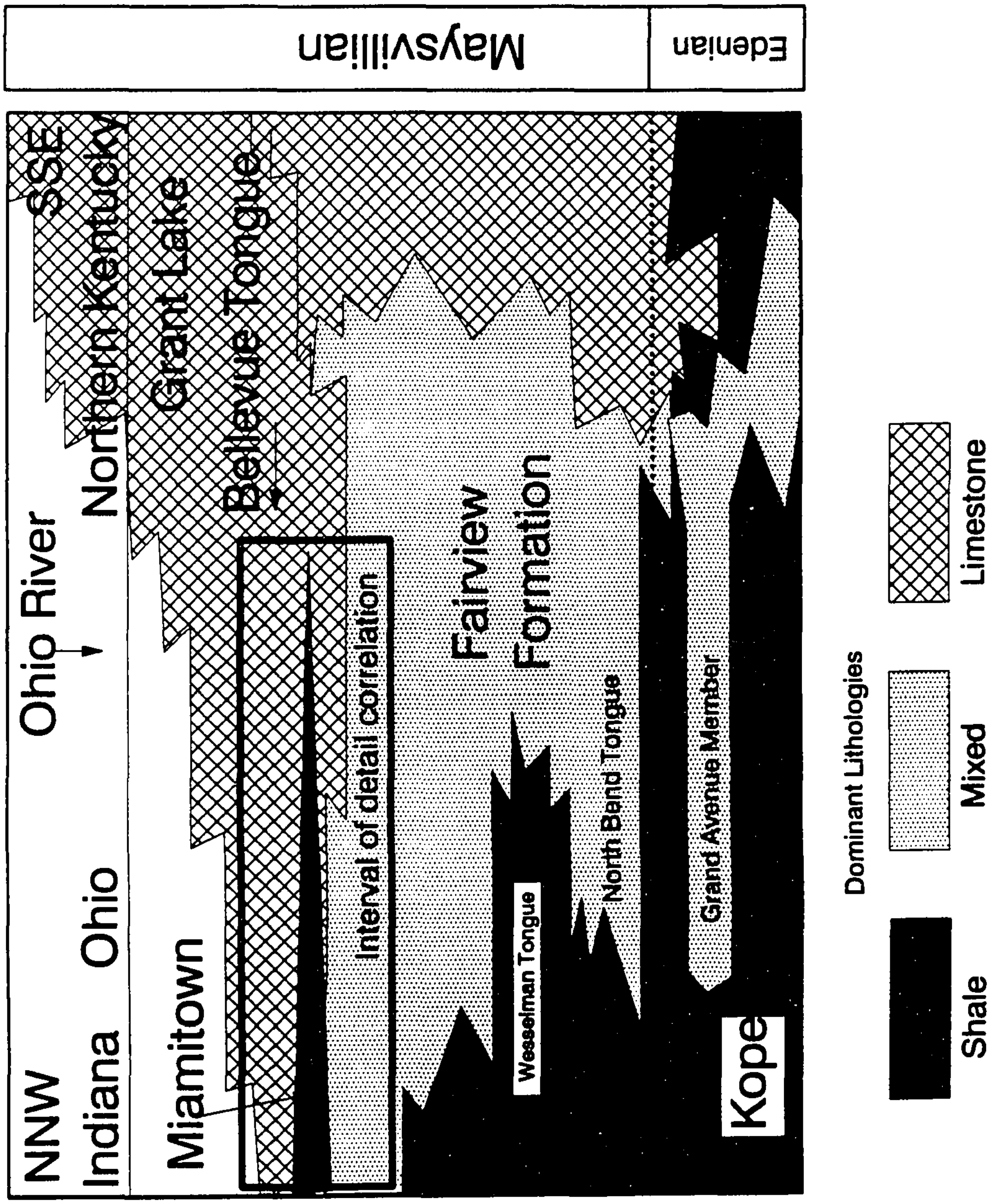
Fig. 2-2. Summary of stratigraphic interpretations of the Upper Ordovician rocks of the Cincinnati area, with emphasis on the recent developments of cyclic and sequence stratigraphic concepts.



while Holland's shoal upward.

Tobin (1982) revised the interpretation of these cycles based on a then contemporary understanding of "sequence-stratigraphy". Starting with the definition of a "vertical sequence" as a "succession of vertically stacked rock strata which are genetically related", Tobin applied the Waltherian concept to the assumption that facies generally prograde, which led to a series of unconformity-punctuated shoaling-upward sequences. A model for this kind of cyclicity was provided by the "shoaling-upward shelf cycles" of Wilson (1975). Tobin (1982) recognized three such sequences of different thicknesses (Fig. 2-2): 1) the Kope-Bellevue sequence, 2) the Corryville-Arnheim sequence, and 3) the Waynesville-Whitewater sequence. The interpretation that these 50 to 100 meter cycles are shoaling-upward has since become entrenched as part of Cincinnatian cyclic stratigraphy. Holland (1993) later took Tobin's (1982) observations a step further by looking closely at the entire Cincinnatian interval over the Cincinnati arch and correlating it with the Appalachian Basin. Using an updated approach to sequence stratigraphy, Holland (1993) recognized even more sequences (C1 through C5), but retained the interpretation of shoaling-upward cycles in that he recognized only very thin transgressive systems tracts and relatively thick highstand systems tracts. In a discussion of Holland's (1993) paper, Hohman and Leonard (1993) argued that, based on Holland's own description, these cycles are actually parasequences, or parasequence sets, which have been correlated into the subsurface of the Illinois basin and define part of a larger single Maquoketa sequence (Hohman & Keith IN PRESS; Fig. 2-2).

Fig. 2-3. Cross section showing lithostratigraphic units under study within their outcrop area around Cincinnati.



From its inception, this concept of large-scale shoaling-upward Cincinnatian cycles has had difficulty accommodating one notable, anomalous unit: the Miamitown Shale (Ford 1967; Fig. 2-3). This unit is a very shaly tongue that occurs enigmatically in the upper, limestone-dominated part of the Kope-Bellevue (C1 of Holland 1993) shoaling upward sequence. Tobin (1982) hypothesized that it represents an unusual event, perhaps deposited by a sudden influx of terrigenous material unrelated to the genesis of underlying and overlying sediments of the sequence. Likewise, Holland (1993) was unable to accommodate the Miamitown shale in the context of his sequence architecture.

Interpretation of the extremely limestone-rich Northbend Tongue of the Fairview Formation (Fig. 2-2) as a relatively shallow-water deposit led Schumacher (IN PRESS) to divide the basal Cincinnatian Kope-Bellevue cycle into two cycles (Fig. 2-2). The first cycle comprises the Kope Formation and the Northbend Tongue, and the second cycle includes the rest of the Fairview Formation, Miamitown Shale and Bellevue Tongue. In recognition of the paleobathymetric implications of the Miamitown shale, Schumacher (IN PRESS) interpreted the Fairview-Bellevue cycle as more complex but still shoaling upward.

Holland & Patzkowski (IN PRESS) recognized a similar need to split the basal Kope-Bellevue Sequence, and placed this division at the base of the North Bend tongue. Because of this split, They chose to renumber the sequences of the Cincinnatian previously recognized by Holland (1993). Such changes in numbering are cumbersome, so, for present purposes, informal names are assigned to each of first three sequences (C1-C3: Holland & Patzkowski IN PRESS) in a new classification scheme, based on the geographic locations of prominent exposures of each. From bottom to top, these are the Brent, Riedlin, and the Stonelick sequences (Fig. 2-2).

Approach and methods

The procedure for establishing the stacking patterns of the Riedlin sequence involved three major tasks: 1) establish sound, sequence-based correlation between Cincinnatian outcrop sections and subsurface cores and well logs, 2) evaluate the vertical succession of biofacies, lithofacies, and well-log signatures in and around the outcrop area to establish stacking patterns and important stratigraphic surfaces, and 3) correlate the network of well logs and reconstruct facies from well-log signatures in order to establish areal stacking patterns and sequence architecture.

The initial correlations between outcrops and nearby subsurface cores were performed in approximately 20 m of strata surrounding the Miamitown Shale, while the final correlations were done through the interval of the upper Kope through lower Corryville formations (or upper Brent sequence through lower Stonelick sequence) in the subsurface, using closely spaced (5 to 30 km) Gamma, neutron, sonic, and electric well logs and cores distributed over the 13,000 km^2 area between Cincinnati, Ohio and Muncie and Indianapolis, Indiana. The methods used in establishing these correlations and stacking patterns, specifically the measurement and of core and outcrop sections, the delineation of biofacies and lithofacies, and the lithofacies interpretations of well logs are discussed below in more detail.

Measurement of cores and outcrop sections

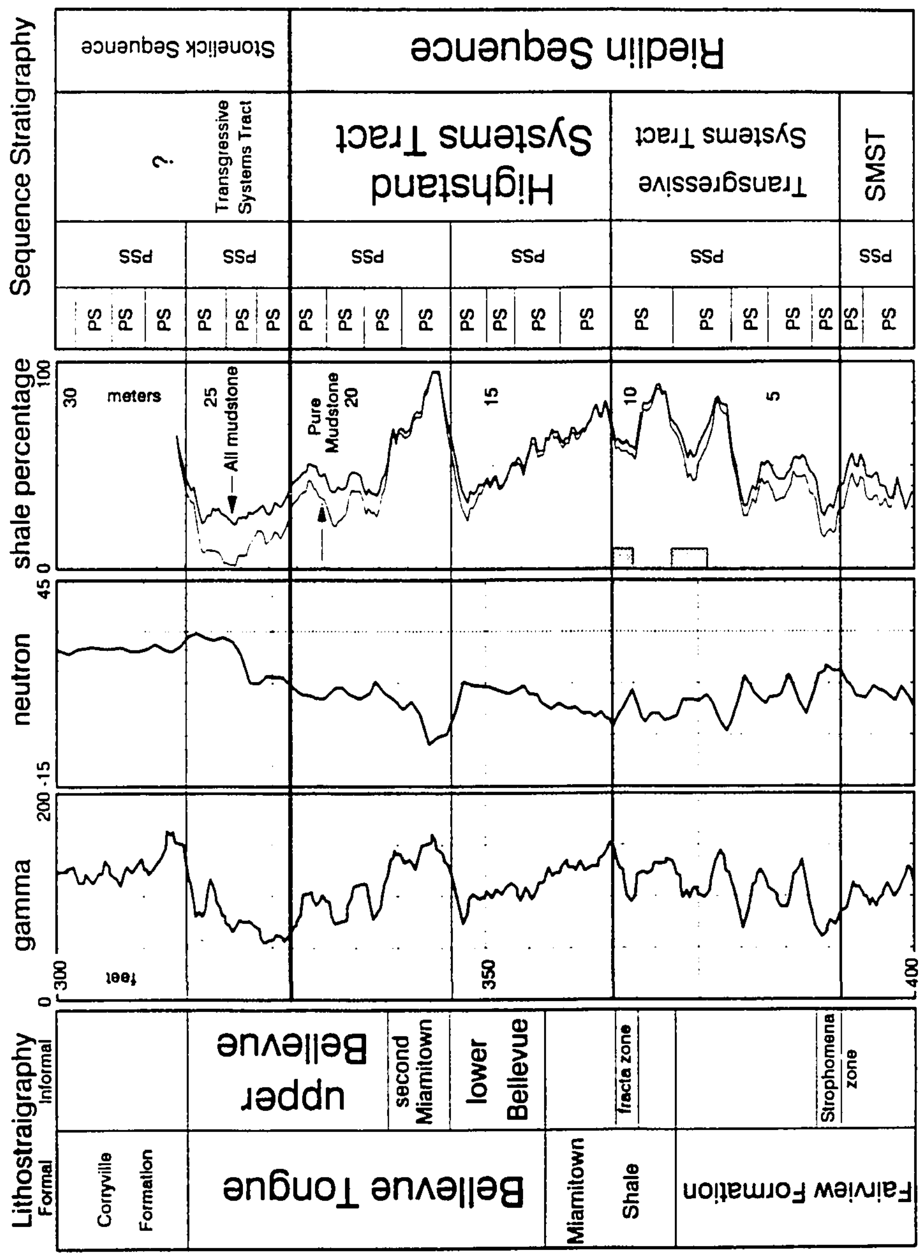
Section measuring in the field and on cores was conducted at a resolution of *ca.* 1 cm; i.e., beds greater than 1 cm thickness were recognized and described. Lithologies recognized included mudstones, fossiliferous mudstone, terrigenous calcisiltites, and the Dunham (1962) limestone classes of wackestone, packstone, and grainstone. Phosphatic content was also noted.

Shale-percentage curves of the outcrop and core sections were prepared by computer processing of measured section data to facilitate correlation with geophysical logs. (Fig. 2-4; see Grey 1972; Schumacher *et al.* 1991). These curves represented a ten point running average of the percentage of shale in a meter of stratigraphic section. The shale percentage curves consist of two different measures of shale; one includes only those beds described as non-fossiliferous, while the other includes fossiliferous intervals. Fossiliferous mudstones were weighted at 0.5 because laboratory analysis of components of these shales shows them to be approximately 50% mudstone and 50% skeletal material.

Biofacies

Because individual genera of benthic organisms have limited environmental tolerances, it is well understood that the fossil assemblage, or biofacies of a given body of sedimentary rock can contain valuable information about the conditions of the original sedimentary environment. This study utilizes previously established biofacies and stratigraphic fossil distribution patterns to aid in the reconstruction of sedimentary environments and thereby support interpretations of vertical stacking patterns. The

Fig. 2-4. Portion of Ohio Geological Survey core 2981 showing responses of gamma ray logs, shale percentage logs, lithostratigraphic and "layercake" nomenclature, and sequence stratigraphic interpretations.



four major biofacies discussed below were compiled by Holland (1990, IN PRESS), and represent convenient divisions in a continuum of biofacies variability in the Upper Ordovician (see Springer & Bambach 1985). These biofacies represent a compilation of several years of paleoecologic work in the Upper Ordovician of Cincinnati (Fox 1962, 1968; Hay *et al.* 1981), the Appalachians (Bretsky 1969, 1970a; Springer & Bambach 1985), and New York (Bretsky 1970b). Although the environmental factors affecting organism distribution can be complex, these Ordovician faunal gradients have been interpreted principally to reflect variations in depth (Fox 1962, 1968; Bretsky 1969, 1970a, 1970b; Springer & Bambach 1985; Holland 1990) and secondarily variations in terrigenous sediment supply (Bretsky 1969, 1970a, 1970b; Miller 1988, 1989). The following biofacies divisions are interpreted as representing variations in depth, and are described briefly, in order, from the deepest to the shallowest.

Graptolite-trilobite assemblage (distal offshore).- The graptolite-trilobite assemblage is dominated by graptolites and the blind trilobites *Cryptolithus* and *Triarthrus*. Small, flat *Onniella* and inarticulate brachiopods, as well as small, delicate crinoids *Cincinnaticrinus* and *Ectenocrinus* are also present, but bryozoans are rare (Holland 1990). Beyond its association with the black-shale turbiditic facies of the Appalachians which indicate a distal offshore depositional environment (Holland 1990; IN PRESS), the small, thin shelled flat brachiopod morphologies have been interpreted as an adaptation to soft substrates (Thayer 1975), while rounded and flattened *Onniella* are found in other deep-water deposits (Hurst 1978).

***ONNIELLA* Assemblage (offshore).-** The *Onniella* assemblage is characterized not only by abundant *Onniella*, but also bryozoans that are generally thin to thick ramose growth forms; trilobites include *Flexicalymene*, *Isotelus*, and *Cryptolithus* (Holland 1990; IN PRESS). Many additional forms, such as the bivalve *Ambonychia*, the brachiopod *Rafinesquina* or the crinoid *Ectenocrinus* may be somewhat smaller or flatter in this biofacies than in others (Alexander 1975; Daley 1993), apparently an adaptation to quiet water and soft substrates (Thayer 1975; Alexander 1975). The subcircular to subquadrangular outline of *Onniella* (Holland 1990; IN PRESS) is thought to be a response to shallower conditions within the relatively limited deep-water range of the genus (Hurst 1978), and thin ramose bryozoans with low or absent monticules are thought to represent deeper-water deposition (Schopf 1969). This represents an offshore depositional environment of deeper, quieter water, presumably at or below normal storm wave base (Holland 1990; IN PRESS), and is equivalent to the *Onniella-Sowerbyella* community of Bretsky (1969, 1970a), the *Onniella* zone of Fox (1962), and the *Onniella-Zygospira* zone of Hay *et al.* (1981).

Mixed Brachiopod-Bryozoan Assemblage (transition zone).- The mixed brachiopod bryozoan assemblage is characterized by high diversity and high equitability of fossil genera (Holland 1990; IN PRESS). Brachiopods include *Rafinesquina*, *Plectorthis*, smaller forms of *Platystrophia*, and *Strophomena*. Abundant bryozoans show a full range of colony morphologies and monticule development. Molluscs, including the bivalves *Ambonychia*, *Modiolopsis* and

Caritodens, and the gastropods *Loxoplocus*, and *Cyclonema* are less abundant. Trilobites are dominated by *Flexicalymene* and *Isotelus*, and crinoids are common. The larger size and higher frequency of geniculation in *Rafinesquina* in this biofacies suggests higher energy environments (Alexander 1975; Daley 1993), as do the more robust and ribbed brachiopod genera (Rudwick 1970), and the diversity of bryozoan growth forms and monticular morphology (Schopf 1969). However, the bivalve *Ambonychia* remains relatively small in this facies through the Brent, Riedlin, and Stonelick sequences (Daley 1993) suggesting that optimum energy conditions (if size is an indication of optimum conditions) for this organism are yet higher. Overall, Holland (1990; IN PRESS) observed that morphologies are intermediate between those of the *Onniella* assemblage and those of the *Hebertella* assemblage, and concluded that this assemblage occupied the transition zone environment. This biofacies is equivalent to part of the *Sowerbyella-Onniella* and *Zygospira-Hebertella* communities (Bretsky 1969), the *Dalmanella-Sowerbyella* community (Bretsky 1970a), the *Leptaena* and *Thaerodonta* zones (Fox 1962), and the *Platystrophia-Leptaena*, *Thaerodonta*, and *Strophomena planumbona* zones (Hay *et al.* 1981).

***HEBERTELLA* Assemblage (shoreface).-** *Hebertella* assemblage brachiopods are characterized by larger brachiopod forms of the genera *Hebertella*, *Platystrophia* and *Rafinesquina*, and bryozoans are abundant (Holland 1990; IN PRESS). Molluscs are similar to those of the mixed brachiopod-bryozoan assemblage. Individual assemblages are frequently dominated by one or two brachiopod taxa (Holland 1990; IN PRESS). The brachiopods of this assemblage are robust and thick shelled, which could be an adaptation to high energy environments (Rudwick 1970); the coarse ribs of *Platystrophia* are also interpreted as reinforcement against breakage in high-energy environments (Holland 1990; IN PRESS). The large size of *Rafinesquina* as well as its high rate of geniculation and alation in this biofacies are similarly interpreted to serve to stabilize these shells under high current conditions (Alexander 1975; Daley 1993). Finally, massive bryozoan colonies and sharp monticules are very common, indicating additional adaptations to strong currents (Schopf 1969). The *Hebertella* assemblage is interpreted as representing deposition in relatively shallow water at or near fair-weather wave base (Holland 1990; IN PRESS), and is equivalent to parts of the *Orthorhynchula-Ambonychia* and *Zygospira-Hebertella* communities (Bretsky 1969), the *Homotrypa wortheni* zone (Fox 1962), and the *Platystrophia* zone (Hay *et al.* 1981).

Lithofacies

Recognizing and interpreting lithofacies is critical for the establishment of stacking patterns that can be used to delineate systems tracts (Van Wagoner *et al.* 1988, 1990). In this present study it is important that shale percentage be an integral part of lithofacies determination, because, as discussed below, gamma ray and sonic well logs are primarily sensitive to the variations in the ratio between limestone and shale in the study area. Although it is a rather simplistic facies criterion, in all of the facies classifications of the Cincinnatian, where four to fifteen facies have been recognized (Hay 1981, IN PRESS; Hay *et al.* 1981; Tobin 1982; Weir *et al.* 1984; Holland 1993), shale percentage is always a major distinguishing feature; it is also an

Table 2-1. Summary of lithofacies characteristics.

Lithofacies	Lithologies	Bedding	Sedimentary Structures	Distinct Body Fossils	Taphonomy	Trace Fossils
Phosphatic Grainstone and Packstone	Packstone and grainstone(80%), fossiliferous mudstone (20%)	Medium to thick, tabular to irregular and uneven	Megaripples, small scale trough cross lamination, amalgamation surfaces	Variable *Hebertella* through *Onniella* facies.	Highly abraided, broken and bored bioclasts; abundant phosphatic steinkerns of small gastropods ("*Cyclora*") pelecypods and bryozoans	Absent
Wavy bedded/nodular limestone	Packstone (70%), fossiliferous mudstone (30%)	Very thin, even but irregular	Mostly proximal storm beds, wave ripple lamination, gutter casts	*Hebertella* assemblage: large thick-shelled brachiopods *Hebertella occidentalis*, *Platystrophia ponderosa*, large *Rafinesquina alternata*; thick ramose, frondose, and massive bryozoans.	Variable/mixed breakage and abrasion, generally moderate to severe. abundant boring and bryozoan encrustation	Pervasive bioturbation; mixed *Skolithos*/*Cruziana* ichnofacies
Limestone-dominated mixed limestone/shale	Packstone, grainstone (60%), mudstone (40%)	Medium to very thin, evenly bedded	Medial to proximal storm beds, Amalgamation surfaces, wave-ripple lamination	Mixed brachiopod-bryozoan assemblage with large with significant numbers of *Hebertella* assemblage elements; *Rafinesquina alternata*, *Plectorthis fissicostata*, *Platystrophia cypha*, *P. laticosta*; thick and thin ramose and frondose bryozoans; high diversity of trilobites, molusca, and echinoderms	Moderate breakage and abrasion; some boring and encrustation; rare articulated multielement skeletons.	Mixed *Skolithos*/*Cruziana* ichnofacies: *Trichophycus*, *Paleophycus*
Mixed packstone-shale	Mudstone (60%), packstone (40%)	medium to very thin, evenly bedded	Mostly medial storm beds, some amalgamation surfaces, wave-ripple lamination, planar lamination	Mixed brachiopod-bryozoan assemblage with mixed elements of the *Onniella* assemblage: *Rafinesquina alternata*, *Platystrophia hopensis*, *P. laticosta*, *Plectorthis plicatella*, *P. fissicostata*, *Onniella emacerata*, *Zygospira modesta*	Slight breakage; rare encrustation; common articulated multi-element skeletons	Mixed *Cruziana*/*Skolithos* ichnofacies: *Chondrites*, *Diplocraterion*, *Trichophycus*, *Paleophycus*
Shale-dominated	Mudstone (70%), packstone and wackestone (25%) calcisiltite/calcareous silt (5%)	Thin to thick.	Mostly distal storm beds, megaripples, small-scale trough and hummocky lamination, gutter casts, groove casts, runzelmarken.	*Onniella* assemblage: *Onniella emacerrata*, *Heterorthina fairmountensis*, small *Rafinesquina*, thin ramose bryozoans, trilobites, crinoids, graptolites.	Moderate breakage, low abrasion; common to abundant articulated multi element skeletons	*Cruziana* ichnofacies. *Chondrites*, *Diplocraterion*, *Trichophycus*, *Rusophycus*, *Diplichnites*

important indicator of depth in these storm-dominated sediments of the study area (Aigner 1985; Jennette & Pryor 1993). However, for a full coverage of important environmental facies indicators, wavy bedded/nodular limestone and phosphatic grainstone and packstone facies had to be recognized with the aid of core samples. The facies used in this study (Table 1) are those of Holland (1993), with the exception that Holland's (1993) mixed packstone/shale facies has been supplemented with an additional "packstone-dominated" facies. This was necessary to show more detail within the relatively narrow range of facies variability within the study area as compared to the entire Cincinnatian.

Shale dominated (offshore).- The shale-dominated lithofacies is characterized by a preponderance of medium to thick beds of mudstone (>70%) and by minor thin beds of packstone and wackestone (<25%) and thin bedded terrigenous calcisiltites or siltstones (5%). These represent mostly distal storm beds (Tobin 1982; Holland 1993) and contain elements of the *Onniella* assemblage, usually well preserved. This represents the deepest water of the study interval, below wave base of most storms (Tobin 1982; Holland 1993; Jennette & Pryor 1993). This facies is equivalent to facies A of Tobin (1992), group 1 of Hay (1981, IN PRESS; Hay *et al.* 1981), and facies D, Shale and fossiliferous limestone of Weir *et al.* (1984).

Mixed packstone/shale (lower transition zone).- This facies is characterized by an almost even mixture of 40% very thin to thin packstone beds interbedded with 60% thin to medium shale beds. The packstones are mostly medial storm beds showing some amalgamation, wave-ripple lamination and planar lamination (Tobin 1982, 1986; Holland 1993). The fossils consist of a mixture of the mixed brachiopod bryozoan assemblage and elements of the *Onniella* assemblage which show generally good preservation, frequently of multielement skeletons. Trace fossils include *Chondrites* and *Diplocraterion* as well as *Trichophycus* and *Paleophycus*. This facies results from deposition at or near storm wave base (Tobin 1982, 1986). Equivalent facies include parts of facies B (Tobin 1982, 1986), parts of group 2 (Hay 1981, IN PRESS; Hay *et al.* 1981), parts of facies B and C (Weir *et al.* 1984), and parts of the mixed packstone/shale facies of Holland (1993).

Packstone dominated (upper transition zone).- The packstone-dominated facies consists of >60% packstone and grainstone interbedded with <40% mudstone in medium to very thin even beds showing characteristics of medial to proximal storm deposits, amalgamation surfaces and wave-ripple lamination (Tobin 1982; 1986; Holland 1993). Fossils represent elements of both the mixed brachiopod-bryozoan assemblage and of the *Hebertella* assemblage, and are generally moderately well preserved. *Trychophycus* and *Paleophycus* are conspicuous parts of the ichnofauna (Tobin 1982, 1986; Holland 1993). Together the characteristics of this facies suggest some affinity to the wavy-bedded limestone facies except for the absence of the irregular bedding and fossiliferous mudstone. The facies is interpreted as reflecting deposition below fair-weather wave base but within the influence of relatively frequent storms (Tobin 1982). The packstone-dominated facies is equivalent to facies 3a and 3b (Hay 1981, IN PRESS; Hay *et al.* 1981), parts of facies B. (Tobin 1982, 1986), facies A., parts of facies B. and C. (Weir *et al.* 1984), and part of Holland's (1993) mixed packstone-shale facies.

Wavy-bedded/nodular limestone (shoreface).- The wavy bedded/nodular limestone facies is characterized by 70% very thin, irregular wavy or "nodular" beds of packstone interbedded with 30% fossiliferous mudstone. Limestone beds have characteristics of proximal tempestites with wave-ripple lamination and gutter casts (Tobin 1982, 1986; Holland 1993). Fossils of the *Hebertella* assemblage, moderate to severe taphonomic grade and *Skolithos/Cruziana* ichnofacies all support the conclusion that this facies represents deposition in a shallower-water environment; it is certainly the shallowest and highest energy lithofacies in this stratigraphic interval within the study area. In the larger Ordovician interval of the Cincinnati area, the next shallowest lithofacies is the bioturbated carbonate dolomitic mudstone, which shows evidence of restriction (Tobin 1982, 1986; Holland 1993). This means that the wavy-bedded limestone facies is the highest-energy non-condensed, or highstand facies in the Cincinnati region, which would constrain it as a shoreface or shoal-water deposit. This facies is equivalent to facies C of Tobin (1982, 1986), facies 3c and 3d of Hay (Hay 1981, 1992, Hay *et al.* 1981), and facies E., F. and G. of Weir *et al.* (1984).

Phosphatic Grainstone and Packstone (transgressive lag).- This lithofacies contains about 80% packstone or grainstone, and about 20% fossiliferous mudstone in medium to thick tabular, irregular and uneven beds showing megaripples, small scale trough cross-lamination and amalgamation surfaces (Tobin 1982, 1986;

Holland 1993). Body fossil assemblages are variable, and the fossils themselves are characteristically highly abraded and bored. Rare to abundant phosphate occurs as steinkerns of small gastropods, bivalves, and bryozoan zooecia. Given the taphonomic grade of fossils and abundance of phosphate, this facies represents periodic reworking of bioclasts under low sedimentation rates, possibly formed during rapid transgressive intervals (Walter 1985; Brett & Baird 1986b; Brett & Speyer 1990). Thus, the stratigraphic distribution of this relatively rare lithofacies is an important clue to sequence boundaries and architecture. This facies was apparently not distinguished by either by Tobin (1982, 1986) or by Weir *et al.* (1984), but is roughly equivalent to parts of facies 3a of Hay (1981, IN PRESS; Hay *et al.* 1981), and encompasses both the bioclastic packstone and cross-bedded calcarenite facies of Holland (1993).

Facies reconstruction from well logs

The types of logs available in the study area include gamma ray, neutron, electric (SP, R, I) and sonic (interval transit time). In this largely limestone- and shale-dominated interval, gamma ray and interval transit time logs both reflect the important lithologic variations: dense limestones transmit sound rapidly and are relatively free of radioactive material, while mudstones transmit sound more slowly and are more radioactive. Gamma ray logs were used where available and sonic logs were used otherwise.

Preliminary facies interpretation of geophysical logs was accomplished by establishing limestone and shale baselines based on the "Trenton" and the Kope formation respectively. However, there are some problems inherent in using logs in this way, because of biases introduced by these two types of logs. For gamma ray logs the minimum response, which can be interpreted as pure limestone, is relatively stable and is available in all of the wells because of the relatively uniform and pure Trenton Limestone. However the maximum response, corresponding to shale, is variable, because the lower Cincinnatian rocks are the shaliest rocks in the interval and they undergo a transition to more radioactive "black" shale to the northwest in the study area. Because the standard for "pure shale" is not fixed, the logs in the northwestern part of the study area appear more limestone-rich than they really are when compared to logs from the southeastern part of the study area.

Because sound travels faster through rocks buried at greater depths, deeper rocks will appear more limestone rich. This could make a measurable difference over the 70 m stratigraphic interval examined. It is also important to remember that rocks to the northwest are buried at a depth of up to 300 m while the same strata crop out in the Cincinnati area to the southeast.

Core control was valuable for the calibration of well log data to correct for these problems in facies reconstructions; they were indispensable for the establishment of the more qualitative aspects of facies reconstruction such as the determination of phosphate content and the identification of fossiliferous mudstone which are not manifested in a well log.

Results

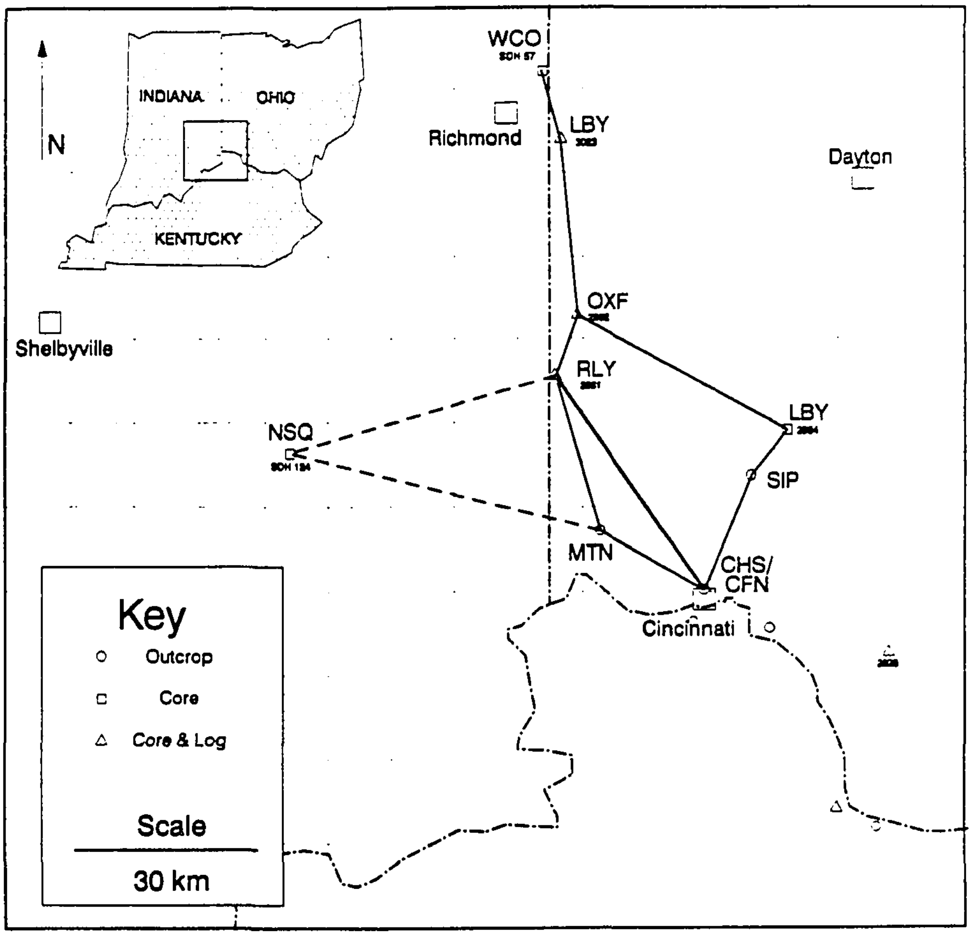
Correlation between surface and subsurface

Correlation from the Cincinnatian outcrop area to the subsurface of Ohio and Indiana was facilitated by the presence of a number of Ohio Geological Survey wells with both gamma ray-neutron logs and core samples (Fig. 2-5) within 70 km of the outcrops. These wells helped to establish that shale-percentage logs are directly comparable to Gamma ray logs to the point that one can be used as proxy for the other in these rocks because they consist primarily of varying amounts of interbedded limestone and shale (Fig. 2-4).

The 20 m interval surrounding the Miamitown shale is ideal for correlation because it contains a number of distinctive surfaces that can be recognized readily from vertical stacking patterns in gamma-ray logs or shale-percentage curves. Below, I provide a sequence stratigraphic interpretation for these surfaces that will be justified further in the remainder of the paper (Fig. 2-4). These surfaces are described in stratigraphic succession:

1) The transgressive surface is drawn at the base of a thick phosphatic limestone in the middle part of the Fairview Formation. This bed historically has been known as the "Strophomena zone" and marked the boundary between the "Mt Hope" beds below and "Fairmount" beds above (Nickles 1902).

Fig. 2-5. Map showing location of cores and outcrops used in correlating surface units into the subsurface.



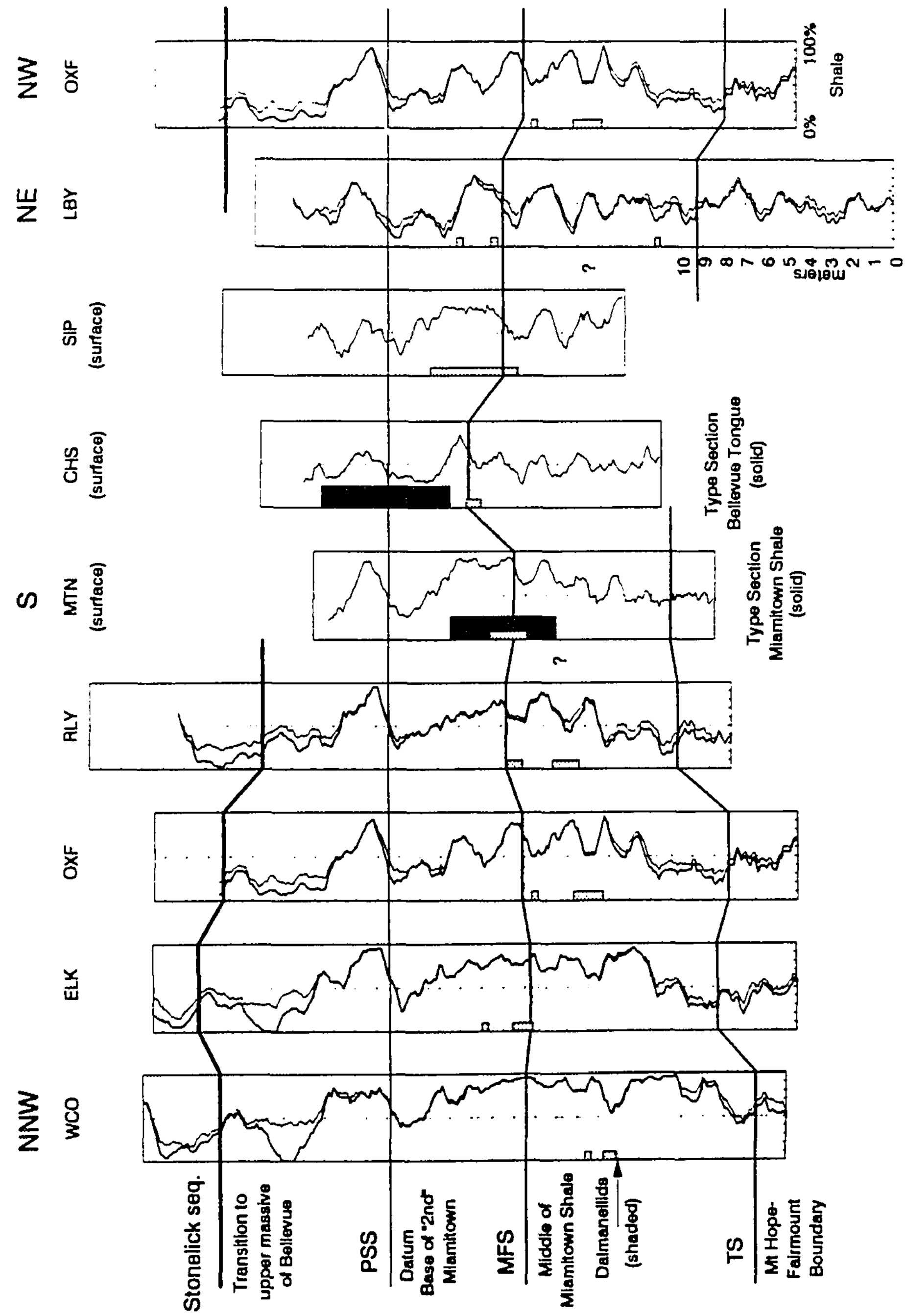
2) The maximum flooding surface occurs in the middle, most shaly part of the Miamitown Shale and is recognized by vertical stacking patterns that are retrogradational below and progradational above. It is also marked by a stratigraphically limited occurrence of the dalmanellid brachiopod *Heterorthina fairmountensis*.

3) The parasequence set above the Miamitown Shale ends in a very distinctive flooding surface boundary that has been recognized as the lower boundary of an intra-Bellevue shale, sometimes referred to as the "second Miamitown" (Schumacher, personal communication 1989).

4) The sequence boundary is drawn in the upper part of the Bellevue Formation at a rather subtle facies transition from wavy bedded/nodular limestone below to phosphatic grainstone and packstone above.

Comparison of percent-shale logs for six cores and three outcrop sections shows a generally straightforward correlation from the surface to the subsurface (Fig. 2-6). One core (Ohio Geological Survey Drill Hole 2981; "Reily Core") and one outcrop section (Bellevue/Clifton Hill reprocessed from Ford 1967; OGS file # 15371) are used to illustrate the correlation of the more complete study interval between the outcrop and subsurface (Fig. 2-7). The core was chosen because it represents the closest cored and logged well to the Cincinnatian outcrop belt; Clifton Hill is a well

Fig. 2-6. Correlation of major flooding surfaces between outcrop and core sections using shale-percentage logs.



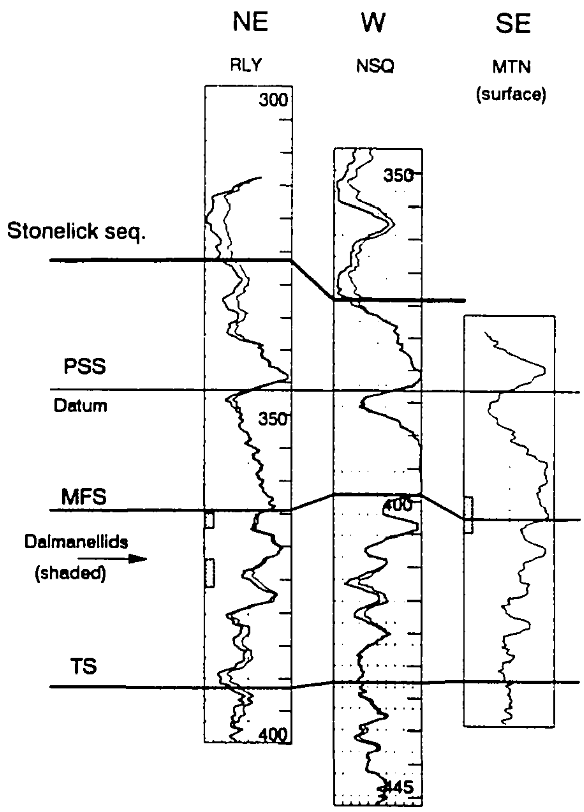
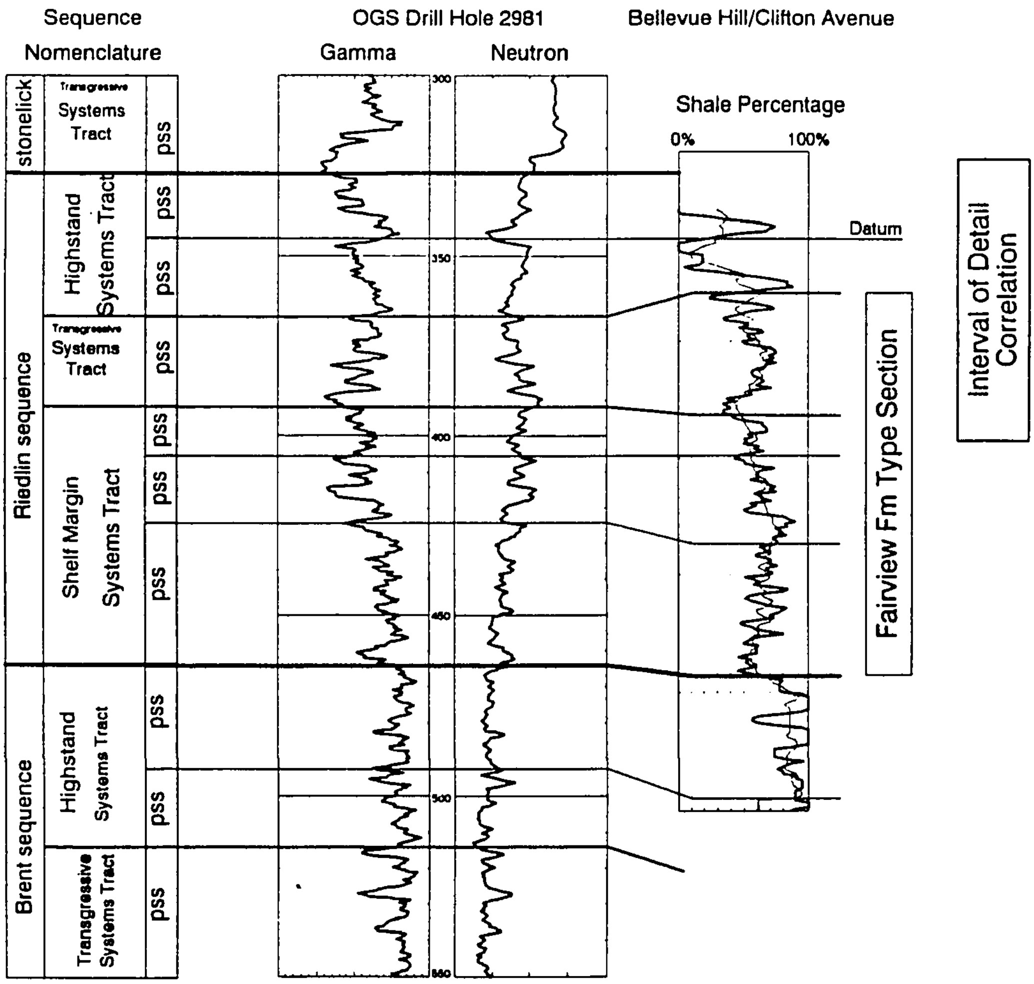

NE
W
SE
RLY
NSQ
MTN
(surface)
300
350
Stonelick seq.
PSS
Datum
350
MFS
400
Dalmanellids
(shaded)
TS
400
445

Fig. 2-7. Correlation of systems tract boundaries between OGS drill hole 2981 and the Bellevue Hill Clifton Avenue outcrop.



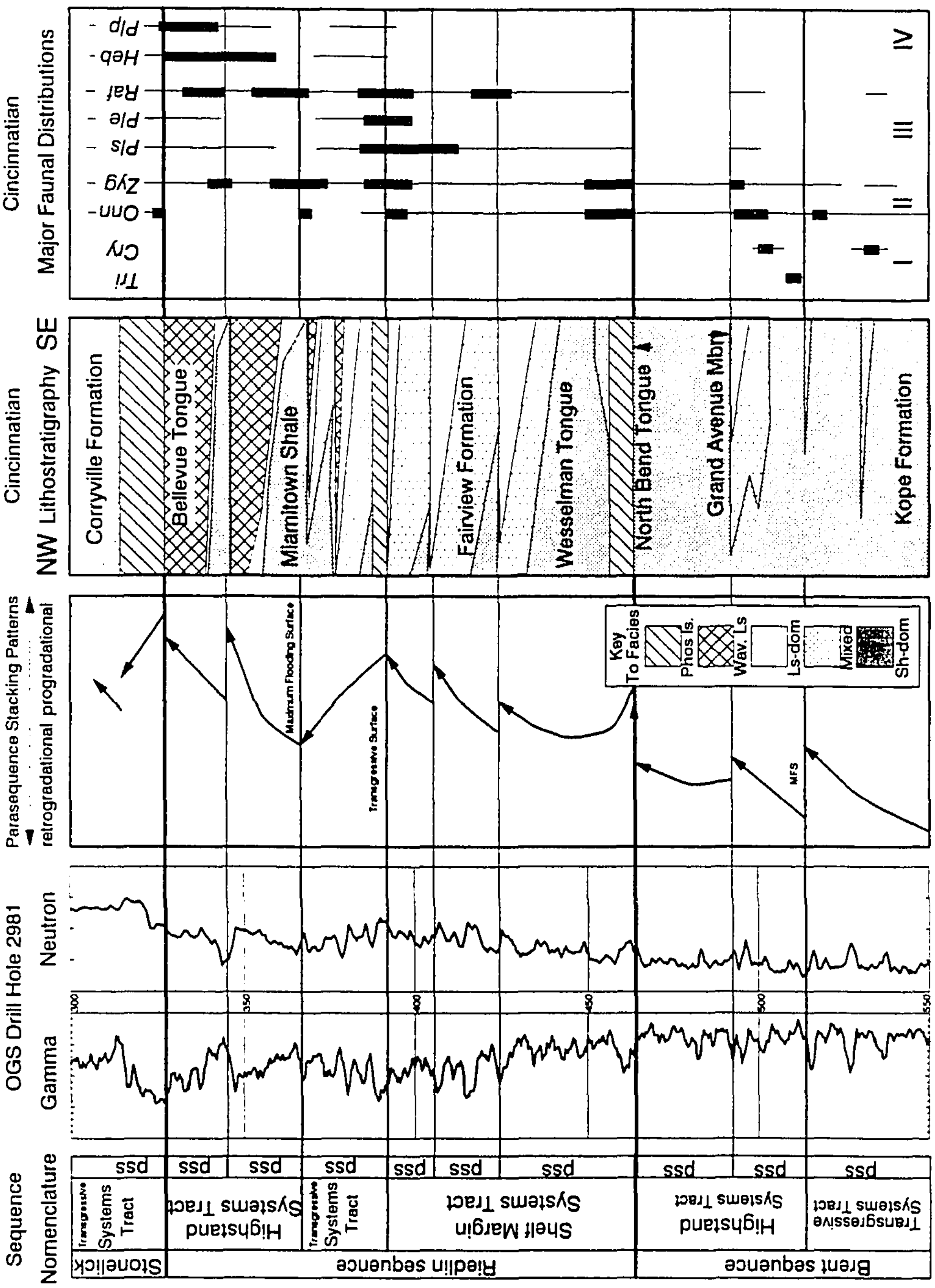
known outcrop that has been used to typify Cincinnatian stratigraphy since 1902 (Nickles 1902; Ford 1967). The correlation is facilitated particularly by the well defined boundary between the Brent and Riedlin sequences which can be readily recognized at Bellevue Hill and correlated to the Reily Core.

Systems tracts from vertical stacking patterns

With the surface to subsurface correlation of the Riedlin and Stonelick sequences established, more detailed parasequence vertical stacking patterns can be established for parts of the three sequences within this interval (Fig. 2-8). This was accomplished with data from core, log, and surface distribution of lithofacies (Ford 1967; Dattilo *et al.* 1993; Holland *et al.* 1993), as well as a generalized succession of biofacies through the interval as found in the Cincinnati area, represented by selected elements of these biofacies drawn from a number of sources (Fig. 2-8; Bucher *et al.* 1939; Caster *et al.* 1955; Diekmeyer 1990, IN PRESS; Dattilo *et al.* 1993).

Brent sequence transgressive systems tract.- The transgressive systems tract of the Brent sequence is not fully covered in this study, but it consists of a few parasequence sets in the Point Pleasant Limestone (see Holland 1993; Holland & Patzkowski IN PRESS) and a little more than half the lower Kope Formation. The retrogradational stacking pattern of the lower Kope has been noted in other studies (Anstey & Rabbio 1989; Jennette & Pryor 1993; Dattilo *et al.* 1993; Holland *et al.* 1993) and is characterized in Cincinnati by the transition from a packstone-dominated to phosphatic grainstone facies at the base to a shale-dominated facies at the top. I have tentatively placed the upper boundary of the transgressive systems tract (i.e the

Fig. 2-8. Derivation of vertical parasequence stacking patterns for the entire interval of the Riedlin Sequence, showing the evidence of gamma and neutron logs (Core 2981), lithofacies distribution in the outcrop area, and vertical biofacies patterns.



maximum flooding surface) at the thin occurrence of the trilobite *Triarthrus*, which represents the deepest deposition in the Cincinnatian.

Brent sequence highstand systems tract.- The Brent sequence highstand systems tract is divided into two parasequence sets. The first is strongly progradational, particularly in the Cincinnati area. This is shown by the rapid faunal transition from the deeper-water *Triarthrus-Cryptolithus* assemblage to the more typical *Onniella* assemblage with elements (*Platystrophia* and *Rafinesquina*) of the mixed brachiopod-bryozoan assemblage. The upper part of this parasequence set is marked by the mixed packstone shale to packstone-dominated lithofacies, comprising the Grand Avenue Member. The second parasequence set appears aggradational, and consist of the shale-dominated lithofacies containing two to three thick grainstone beds and the *Onniella* assemblage biofacies. The upper, possibly progradational part of this parasequence set may be truncated by the overlying Riedlin sequence unconformity.

Riedlin sequence shelf margin systems tract.- The base of the Riedlin sequence is marked in Cincinnati by a relatively abrupt transition from the shale-dominated facies to the phosphatic grainstone and packstone facies at the base of the North Bend Tongue of the Fairview Formation. This surface corresponds to the Kope-Fairview Formation boundary (Ford 1967) in the immediate vicinity of Cincinnati. The presence of a possible unconformity is suggested by the sudden shift in facies, the apparently abrupt truncation of the underlying parasequence set, and the presence of shale ripups in the basal limestone bed of the North Bend Tongue. This unit contains abundant *Onniella emacerata* for which it was once known as the "*Onniella* zone" (Nickles 1902; Bucher *et al.* 1939; Caster *et al.* 1955).

The Northbend Tongue appears to be a transgressive deposit, but above it are three progradational parasequence sets; together, this shelf margin systems tract is aggradational to slightly progradational ranging from the shale-dominated lithofacies to the mixed packstone-shale and packstone-dominated facies. The fauna consists of mixed brachiopod-bryozoan assemblage elements with many elements of the *Onniella* assemblage.

***Riedlin sequence transgressive systems tract.*-** The transgressive surface is marked by another occurrence of the phosphatic grainstone and packstone facies. This limestone-rich unit forms a long-standing stratigraphic marker in the Cincinnatian known as the "*Strophomena* zone" (Fig. 2-8). Fossils of the mixed brachiopod-bryozoan assemblage are abundant, and elements of the *Hebertella* assemblage are also present. The entire transgressive systems tract, comprising a single parasequence set, contains short sections of all lithofacies and the most diverse brachiopod assemblage in the entire study interval. Note particularly that thin units of the wavy-bedded/nodular limestone facies interspersed with intervals of shale dominated facies occur near the flooding surface. This is accompanied by a slight shift in biofacies back to elements of the *Onniella* assemblage, including a thin interval containing the dalmanellid *Heterorthina fairmountensis*. The maximum flooding surface marks the farthest extent of the shale-dominated facies into the Cincinnati area in the Riedlin sequence, and is marked by the lithostratigraphic unit called the Miamitown Shale (Ford 1967). However, the juxtaposition of this shale next to layers of the wavy/nodular bedded limestone lithofacies, and the abundance of the brachiopod *Rafinesquina* with some elements of the *Hebertella* assemblage suggest that this shale does not represent deposition at depths comparable to shales in the Brent sequence or even the shale at the base of the Riedlin sequence.

Riedlin sequence highstand systems tract.- The Riedlin highstand systems tract consists of two progradational parasequence sets each showing rapid facies transitions from shale-dominated facies to wavy-bedded limestone facies in the Cincinnati area. Biofacies consist of the *Hebertella* assemblage with elements of the mixed brachiopod-bryozoan assemblage. Water depth seems to decrease steadily to the sequence boundary. The rapid vertical facies transitions make the Miamitown shale and the "second Miamitown" prominent marker beds that are easily traced over large distances.

Stonelick sequence transgressive systems tract.- The lower boundary to the Stonelick sequence is marked by yet another shift from the wavy limestone facies to the phosphatic limestone facies. This part of the section is not as well exposed in the Cincinnati region as the other parts of the interval; thus the facies and fauna are not well known on the surface. In the Reily core the sequence shows retrogradational stacking within the study interval. Recent work suggests that much of the Corryville Formation is a transgressive systems tract within this sequence (Goldman 1993).

Systems tracts from three-dimensional data

Subsurface correlation.- The sequence stratigraphic surfaces discussed above were correlated in the subsurface using logs and cores from the interval of the Bellevue Tongue down to the top of the "Trenton" limestone in a network that extends between Cincinnati, Indianapolis, and Fort Wayne, covering an area of approximately 13,000 km^2 with an average separation of approximately 50 km (Fig. 2-9).

The correlation of sequence-stratigraphic surfaces in these logs was facilitated by the presence of a number of easily recognizable "marker" beds (Fig. 2-10). The most obvious of these is the top of the Trenton Limestone (not illustrated), which is an unconformity that may mark the base of the Brent sequence in Ohio and Indiana, and can be recognized as a sharp contact between the very clean Trenton Limestone and overlying "Kope" Shale. The phosphatic transgressive lag at the base of the Stonelick sequence marks the second most easily recognizable marker bed and is used as a datum for these sections. The transgressive limestone of the Riedlin sequence is a third important marker bed. Using these marker beds as guidelines, the remaining bounding surfaces were correlated as far as possible over the network (Fig. 2-10).

Facies Distributions in Subsurface.- After the correlations were completed, it was necessary to establish the distribution of facies throughout the area using the available data. Cores near the edge of the correlation network show that the minimum and maximum responses of gamma ray and sonic logs can be used to estimate the shale percentage, an important step in the reconstruction of facies.

Fig. 2-9. Map showing subsurface correlation network. Heavy lines indicate the position of illustrated cross sections. Triangles are cored wells.

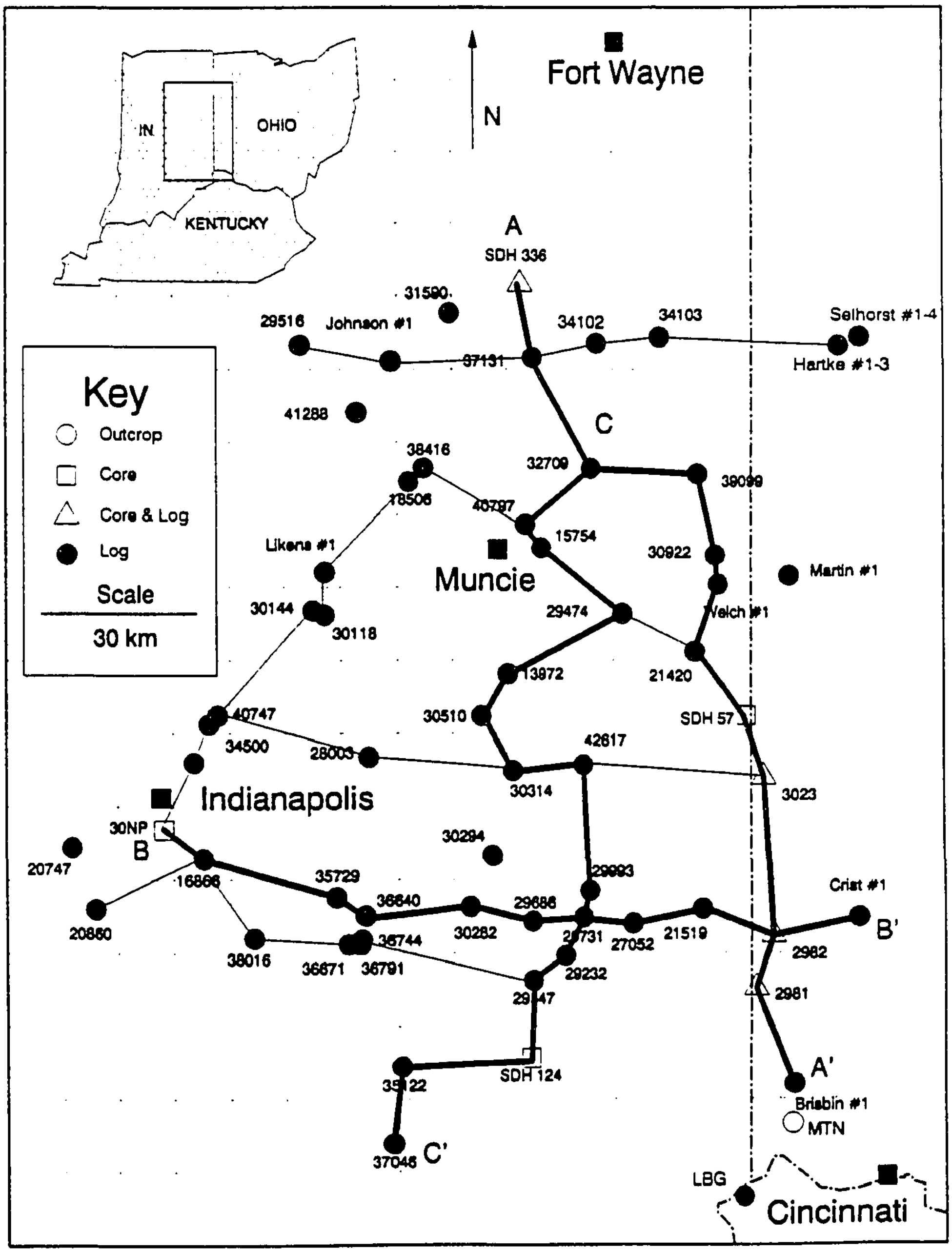
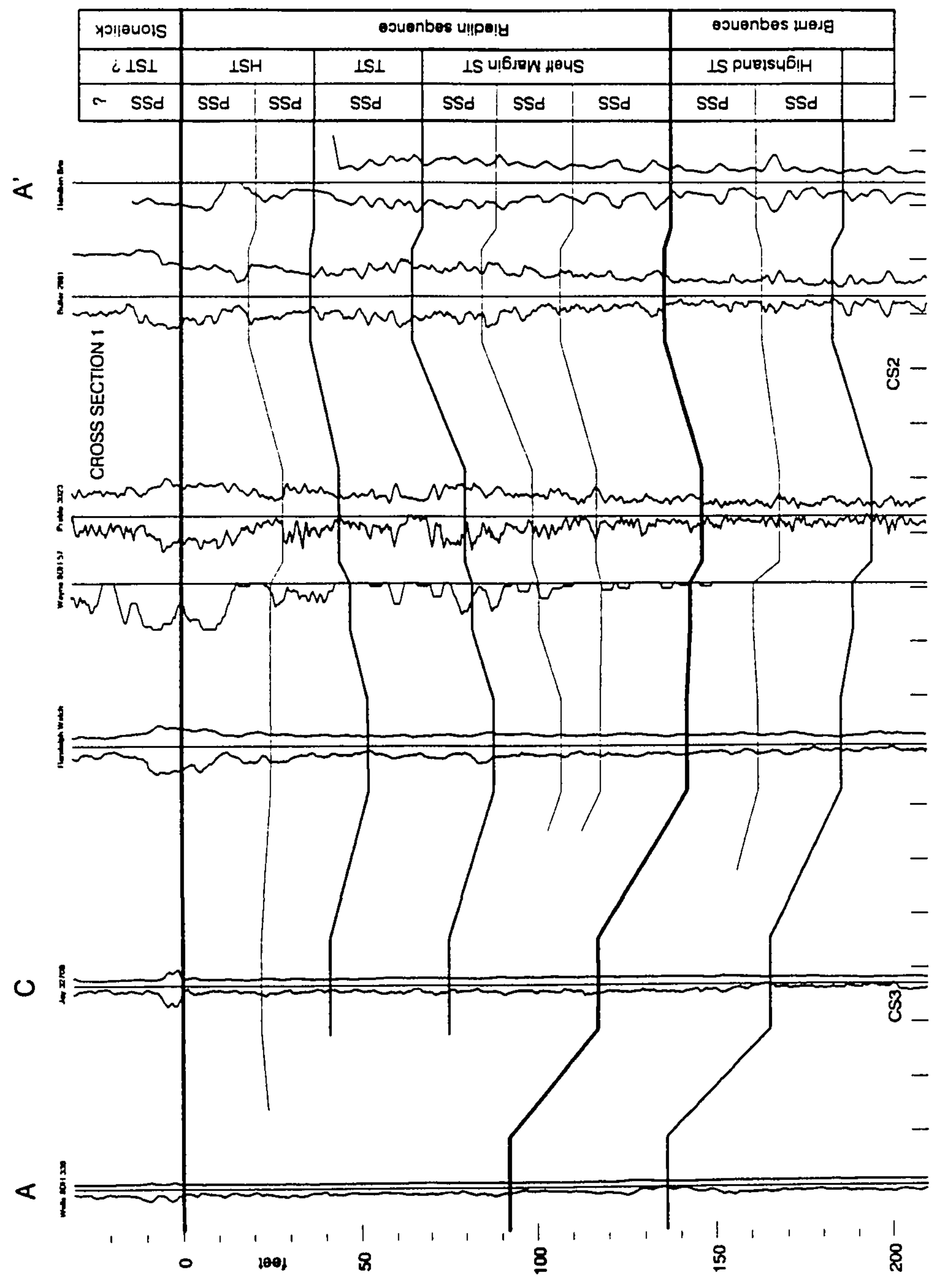
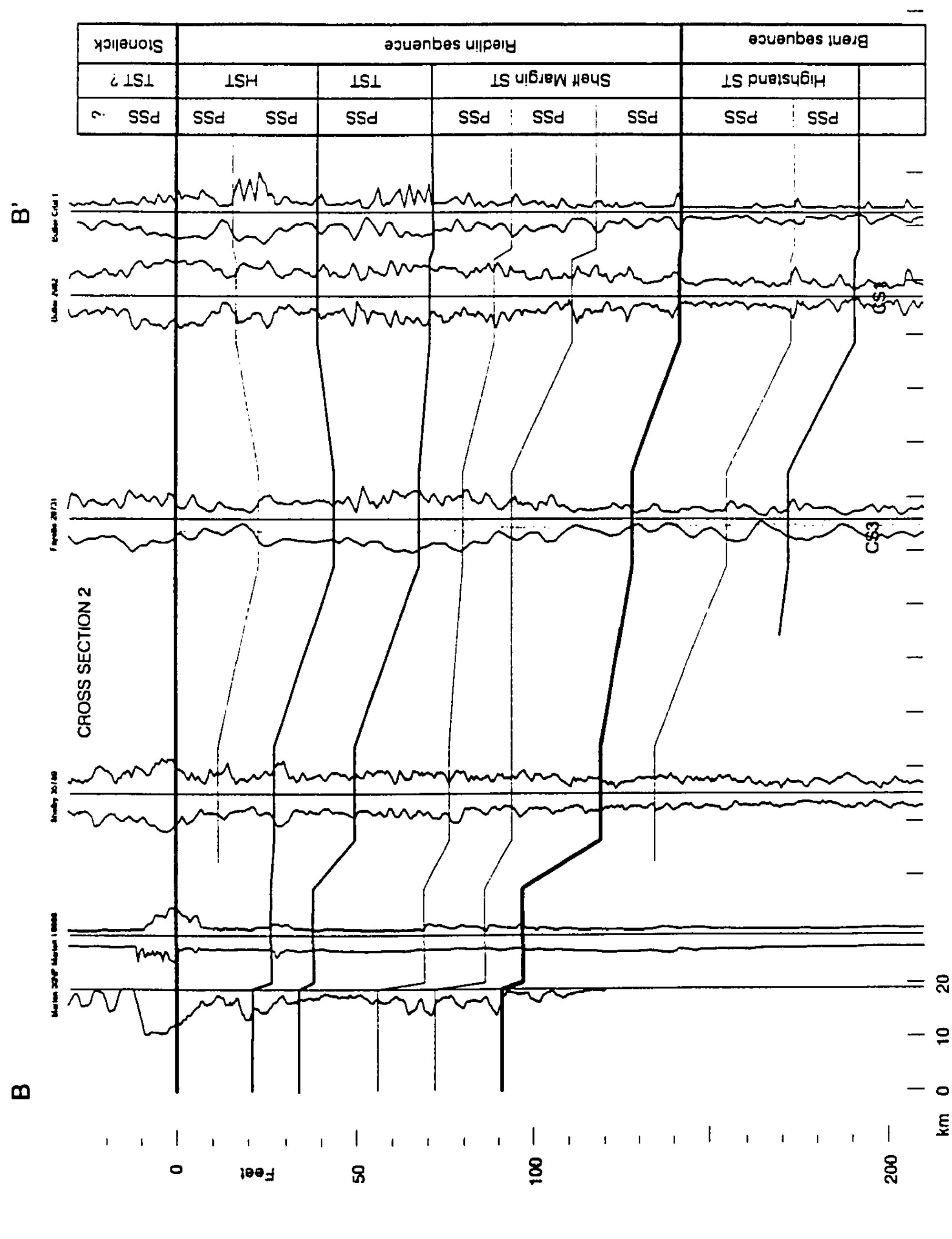
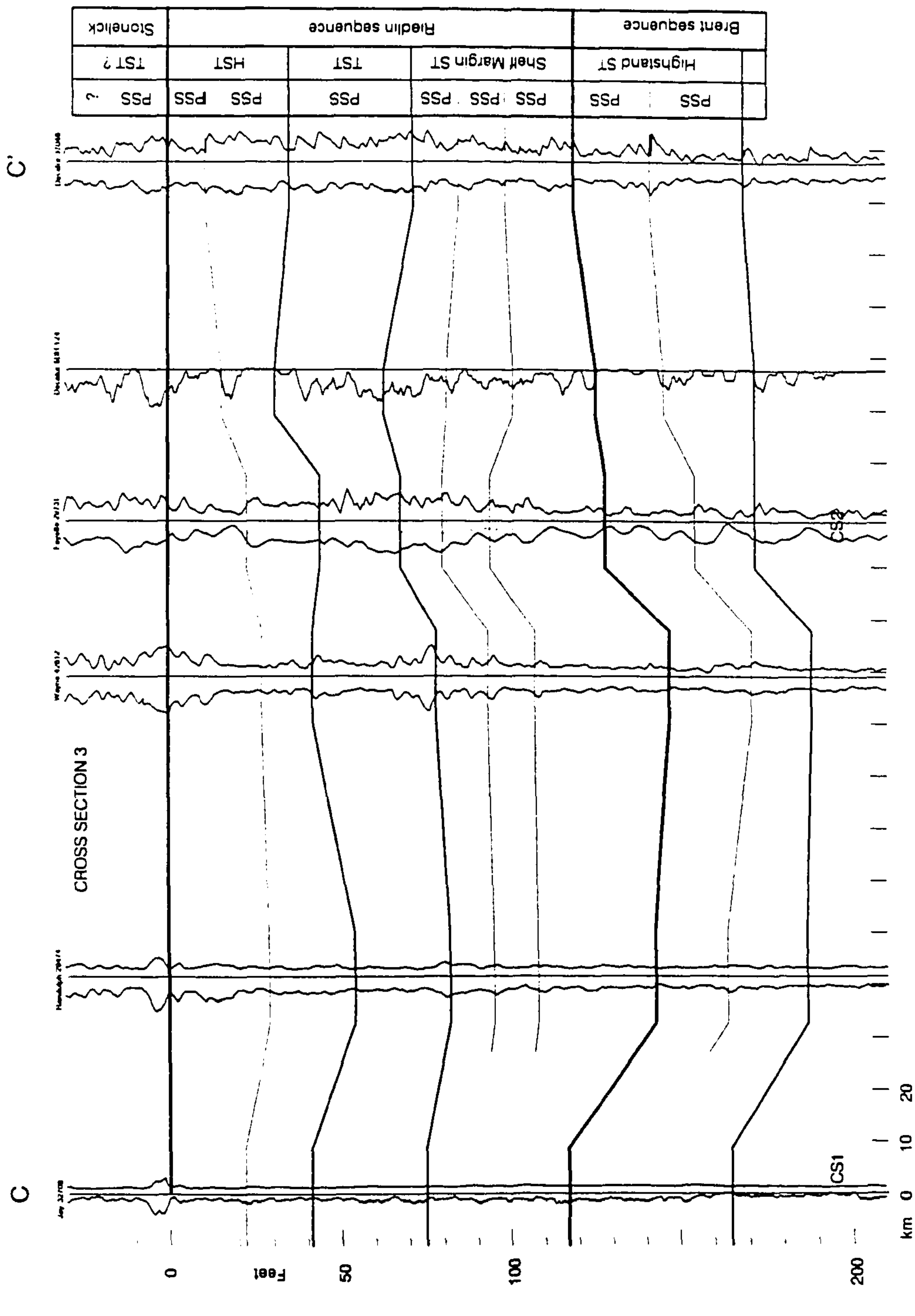


Fig. 2-10. Cross sections showing correlation of important surfaces between selected wells.





CROSS SECTION 2
B
B'
Stonelick
Riedlin sequence
Brent sequence
TST ?
HST
TST
Shelf Margin ST
Highstand ST
PSS
CS3
Feet
0
50
100
200
km
0
10
20


CROSS SECTION 3
C
C'
Brent sequence
Riedlin sequence
Stonelick
Highstand ST
Shelf Margin ST
TST
HST
TST ?
PSS
PSS
PSS
PSS
PSS
PSS
PSS
PSS
PSS ?
CS1
CS2
Feet
0
50
100
200
km
0
10
20

Unfortunately the distribution of cored wells is not very even, so the distribution of the phosphatic and wavy/nodular limestone facies had to be extrapolated from core sample data using the distribution of shale-percentage facies as a guideline.

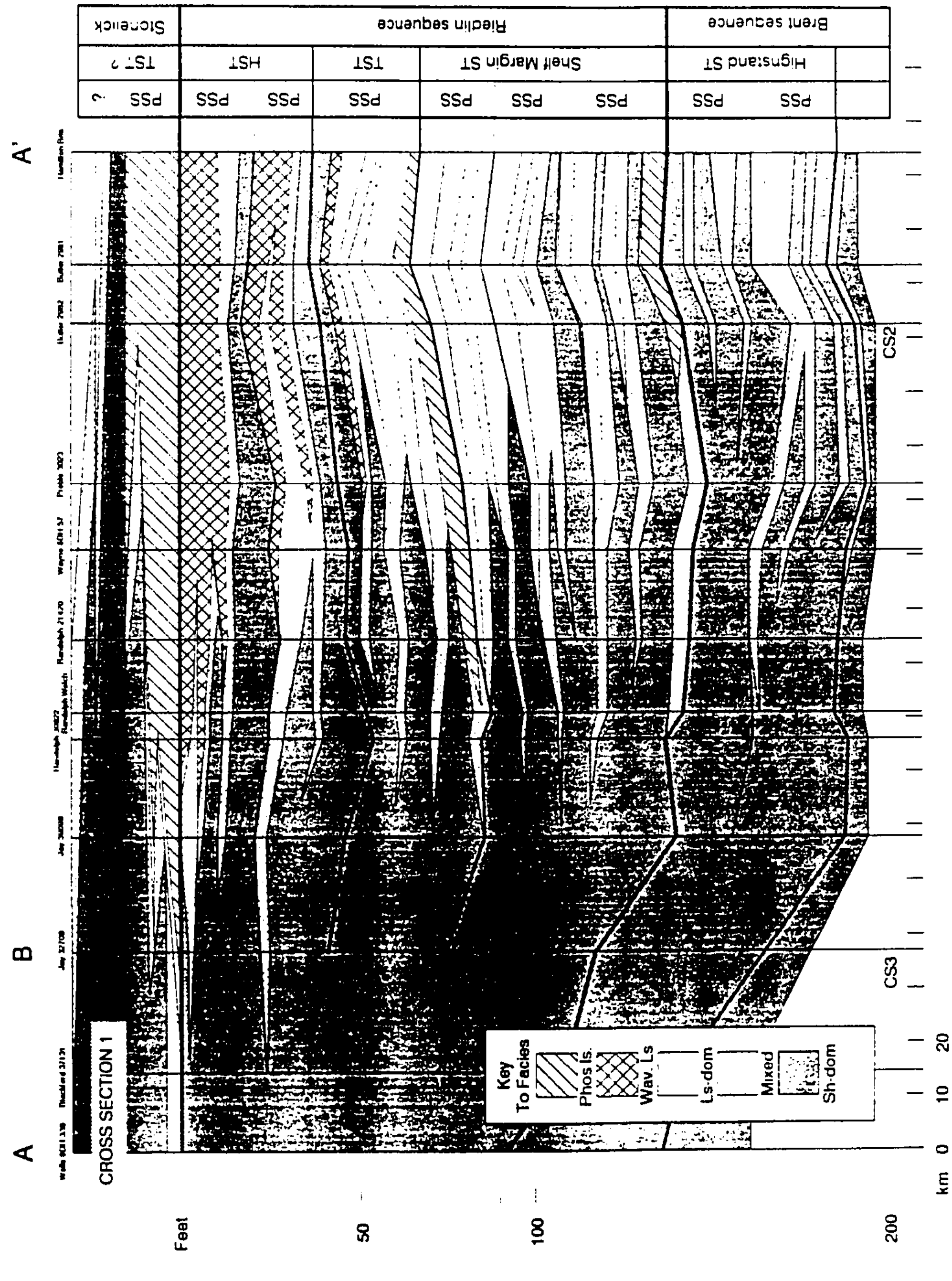
From the distribution of these facies the stacking patterns postulated from vertical sequence are confirmed. Each systems tract is discussed below.

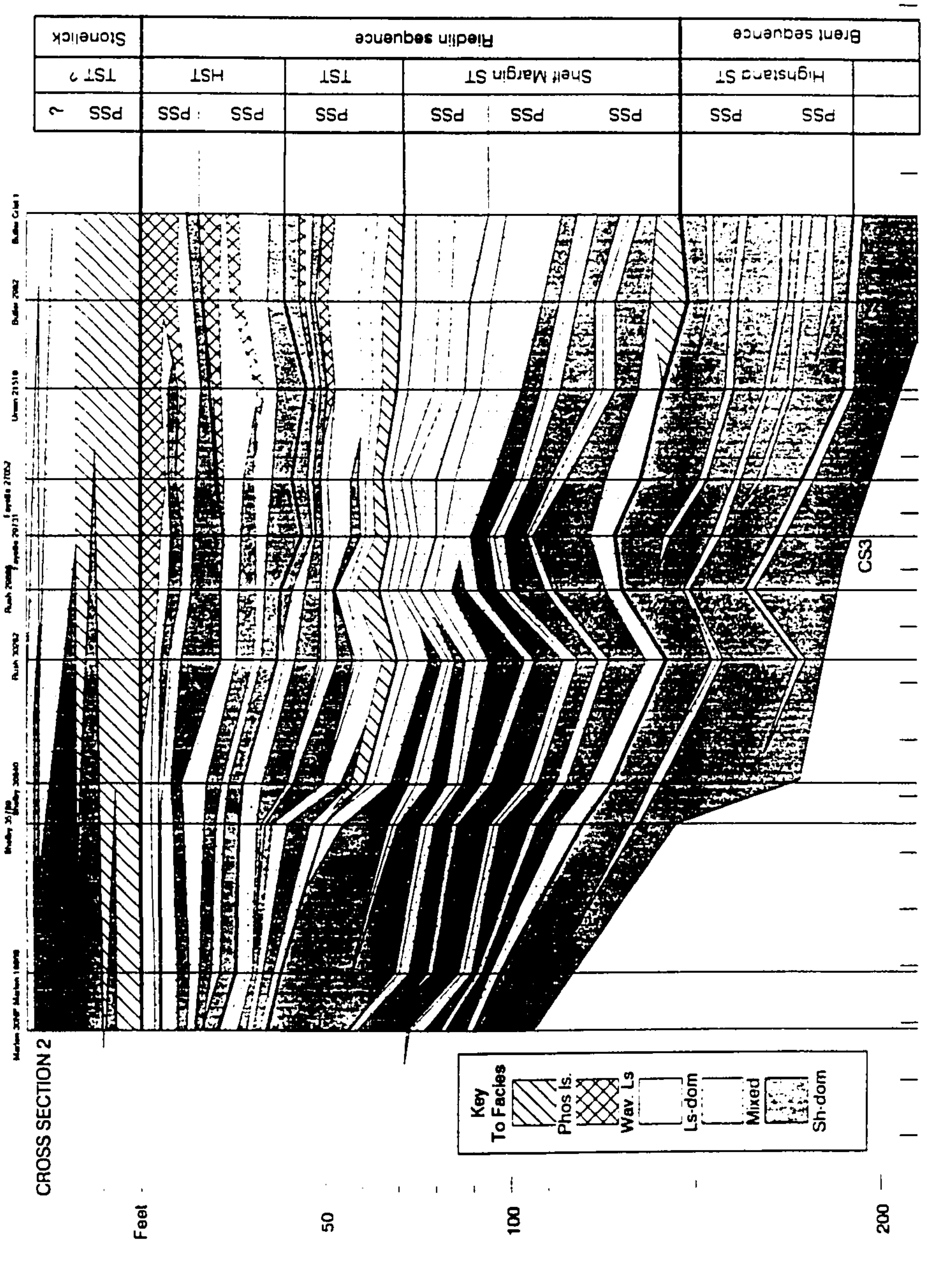
Brent sequence highstand systems tract.- The truncated appearance of the Brent highstand systems tract in vertical succession is also apparent in three dimensions. The entire systems tract seems to be progradational, but at least the lower parasequence set is strongly progradational and its upper surface is widely traceable as the top of the Grand Avenue Member.

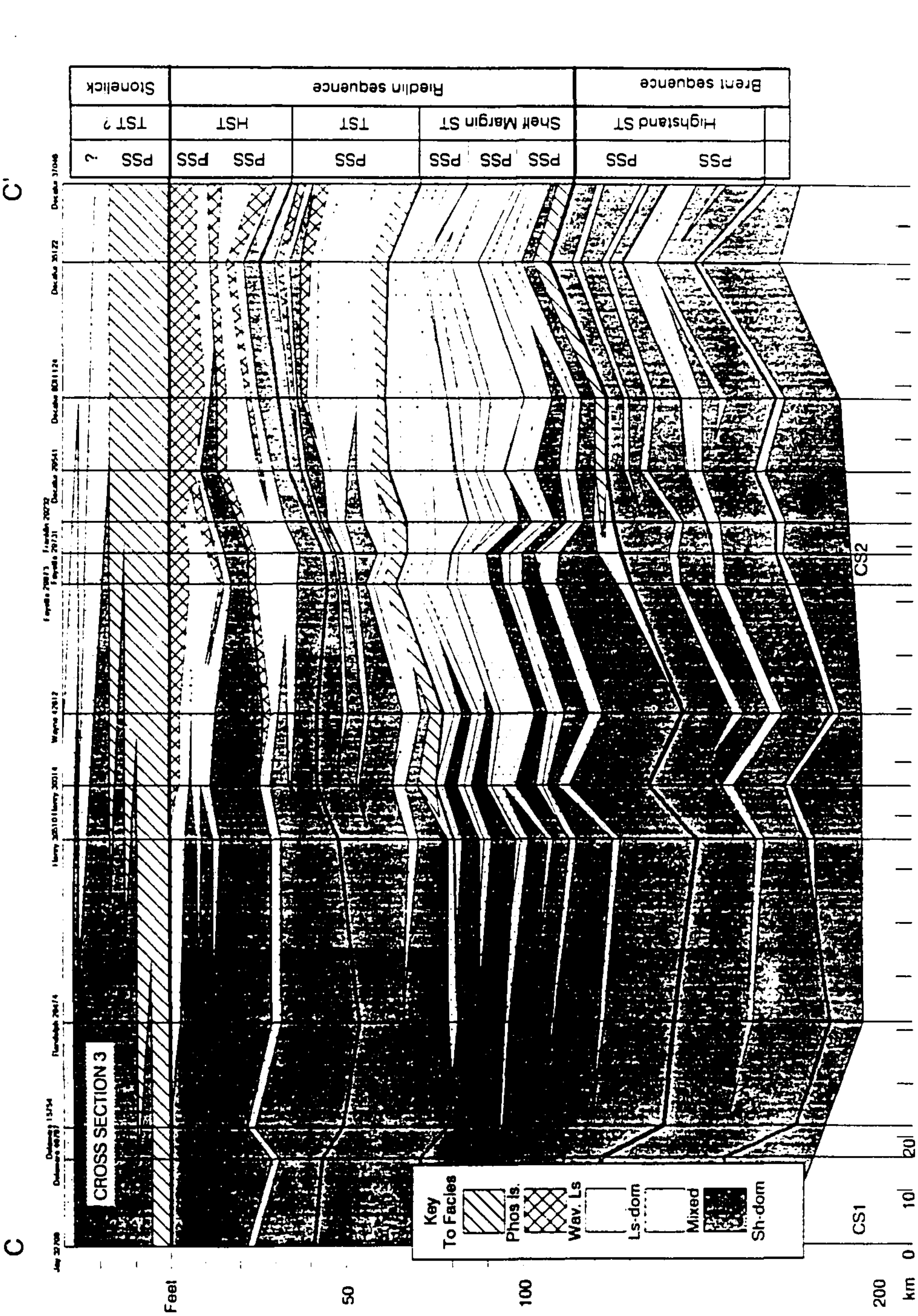
Riedlin sequence shelf margin systems tract.- Each of the three parasequence sets of the Riedlin shelf margin systems tract is progradational, but taken together, the systems tract appears progradational at the base and aggradational at the top. The especially dense phosphatic facies at the base of the sequence does not seem widespread and is restricted to the upramp area in the immediate vicinity of Cincinnati.

Riedlin sequence transgressive systems tract.- The Riedlin transgressive systems tract is clearly retrogradational. The high limestone content at the base seems to be an extensive feature, and it is presumed that the phosphatic aspect to this facies is equally extensive, though core distribution does not allow this to be checked. The distribution of the wavy/nodular limestone facies is limited mainly to the upramp area in the vicinity of Cincinnati.

Fig. 2-11. Cross sections showing reconstruction of facies distribution and stacking patterns over the study area.




CROSS SECTION 2
B
B'
Key To Facies
Phos ls.
Wav. Ls
Ls-dom
Mixed
Sh-dom
Feet
50
100
200
km 0 10 20
CS3
Stonelick
Riedlin sequence
Brent sequence
TST ?
HST
TST
Shelf Margin ST
Highstand ST
PSS ?
PSS PSS
PSS
PSS PSS PSS
PSS PSS


C
C'
CROSS SECTION 3
Key To Facies
Phos ls.
Wav. Ls
Ls-dom
Mixed
Sh-dom
Stonelick
Riedlin sequence
Brent sequence
TST ?
HST
TST
Shelf Margin ST
Highstand ST
PSS
Feet
50
100
200
km
0
10
20
CS1
CS2

An interesting correlation problem is recognized on the line between Marion county Indiana and Butler county Ohio (Fig. 2-11C). Somewhere between the wells Rush 29686 and Rush 30282 there is an apparent reversal in vertical stacking pattern up to the maximum flooding surface; in the Marion County core everything appears to be progradational. It is possible that the limestone that forms at the maximum flooding surface is the result of condensation.

Riedlin sequence highstand systems tract.- The Riedlin highstand systems tract is strongly progradational. As discussed above, the sharp facies contrasts between the bases and tops of parasequence sets are traceable over large areas precisely because of this strongly progradational pattern. The wavy/nodular bedded limestone facies is found in the upper part of the sequence throughout the cores examined, and it is extrapolated farther according to the distribution of high limestone percentages, but there is no direct core control over this interval.

Stonelick sequence transgressive systems tract.- The phosphatic limestone at the base of the Stonelick transgressive systems tract is widespread as determined from core data and probably represents a basal transgressive lag. It apparently intertongues with the overlying shale dominated facies in a number of smaller, possibly parasequence scale cycles. This is evidence that the distal parts of this deposit are not genetically related to the more proximal onramp parts, and they could represent a lowstand wedge rather than part of the transgressive systems tract. There is simply not sufficient well control to resolve this question. One point worthy of note is that to the west, at Marion County Indiana core 30NP (Fig. 2-11B), this basal deposit is highly enriched in phosphate. The top of this deposit in the core is a nearly pure phosphate lag 20 cm thick directly overlain by a black shale. This represents a very prominent flooding surface that is not evident in the upramp cores or in the Cincinnati outcrop (Goldman 1993), but is apparently prominent in the subsurface of western indiana (Hohman & Keith IN PRESS).

Discussion

Sequence architecture--an exception?

Initial attempts at sequence stratigraphic interpretation of the Upper Ordovician rocks of the Cincinnati region have resulted in the recognition of a few shoaling-upward third- and fourth-order sequences or parasequence sets with thin to absent transgressive systems tracts and thick highstand systems tracts (Tobin 1982; Holland 1993). In one study, the transgressive systems tract and the highstand systems tract of each sequence do not even share facies (Holland 1993). This differs significantly from the sequence architecture that might be expected by comparison with other sequences in a variety of paleogeographic settings with either limestone or siliciclastic sequences (e.g. Sarg 1988; Van wagoner et al. 1990). The importance of the present study is that it provides detailed evidence that in at least one of these fourth-order cycles the stacking patterns suggest a sequence architecture which nearly duplicates an idealized model for a type-2 sequence (Posamentier *et al.* 1988; Van Wagoner *et al.* 1988, 1990; Posamentier & Vail 1988). The Riedlin sequence contains a well-developed shelf margin systems tract, a transgressive systems tract and a highstand systems tract; all of these match the idealized model even to the details of relative thickness. With respect to facies, the phosphatic limestone facies seems limited to the basal (lag) part of lowstand, shelf margin, or transgressive systems tracts. Otherwise, there is no limitation on the facies that can occur in a given systems tract of this or the surrounding sequences within the limits of this study.

Sequence architecture in a fourth-order cycle

The importance of sequence architecture in a fourth-order cycle is that it appears to contradict the conclusions of Hohman & Leonard (1993) that these cycles are parasequences or parasequence sets. Admittedly this study was executed on a much smaller spatial scale than those of either Holland (1990, 1993) or of Hohman & Keith (IN PRESS), but the degree of stratigraphic resolution is also higher. The stacking patterns are still clear. As pointed out by Hohman & Leonard (IN PRESS) there is little evidence on the outcrop scale that either unconformities or condensed sections actually exist at their predicted position, but this constitutes a type of negative evidence; the sequence bounding unconformity between the Pleistocene and Holocene deposits of Florida is an example of a virtually undetectable outcrop unconformity surface (Evans & Hine 1991). Admittedly, the Ordovician-Silurian and Trenton-Maquoketa unconformities are more prominent than any surfaces in between (Hohman & Keith IN PRESS), but this does not imply that other unconformities do not exist.

The apparently conflicting results of these studies (Holland 1993; Hohman & Keith IN PRESS; Hohman & Leonard 1993) suggest two problems that need to be investigated further. 1) *Are the differences between parasequences and sequences a* *consequence of differing (eustatic?) genesis, or do they reflect two different ways of looking at the same cycle?* The results of this study certainly suggest that cycles can look like parasequences in the context of a larger scale or in the more distal parts of a basin (Hohman & Keith IN PRESS), while looking like sequences at a finer scale of study and the more proximal parts of the basin, but it does not address the conceptual question of whether both of these interpretations could actually be "correct".

2) *If the differences between parasequences and sequences are artificial, can sequences be recognized within sequences to form a "fractal" pattern of similarity at different scales of observation in stratigraphic cyclicity?* Again, this study, when compared to others (Hohman & Keith IN PRESS) only suggests the possibility and raises the question.

Despite these unanswered questions, it is clear that *a priori* assumptions about shoaling-upward cycle form have shaped the interpretation of cycles in the Upper Ordovician of Cincinnati (Tobin 1982, 1986; Holland 1993; Schumacher IN PRESS) in such a way that further, more detailed studies (Jennette & Pryor 1993; Goldman 1993; Dattilo *et al.* 1993; Holland *et al.* 1993) have resulted in much different interpretations of cycle form, including the Brent and Riedlin sequences in this paper. The differences and relationship between sequences and parasequences may likewise be related more to assumptions derived from seismic stratigraphic studies of passive margins than to relevant observations of core and outcrop data in cratonic deposits.

Chronostratigraphic significance

Rather than being overly concerned about the largely semantic designation of a given package of rocks as either a sequence or a parasequence, it is important to remember that sequence-bounding unconformities, as well as flooding surfaces, may completely separate older strata below from younger strata above (Van Wagoner *et al.* 1988, 1990; Posamentier *et al.* 1988; Posamentier & Vail 1988); i.e. these stratigraphic gaps contain unique, isochronous surfaces. This characteristics makes them useful chronostratigraphic markers. With the recognition of a new sequence boundary at the base of the Riedlin sequence, each of the three North American Upper Ordovician stages is now thought to be bounded by a sequence boundary (see also Holland 1993) in their type area. Thus, stage boundaries may be recognized by the correlation of sequence boundaries in conjunction with biostratigraphic correlation.

The importance of these units, and the surfaces delineated within them is that they may provide finer scale, more precise time control than current biostratigraphic zones (Fig. 2-2) in the Cincinnatian. These surfaces form a framework in which even finer scale fifth-order cycles (Tobin 1982; Jennette & Pryor 1993) may be correlated over large distances. At present, the interpretation of these surfaces in the Cincinnatian leads to conclusions about the chronostratigraphic value of various lithostratigraphic formations within the same interval (Fig. 2-8).

Grand Avenue Member.- The Grand Avenue member of the Kope Formation is the packstone-dominated facies of the upper part of the first parasequence set in the Brent HST. Its upper surface corresponds with the bounding flooding surface and is therefore a useful time marker, while the bottom surface is a simple facies transition and is not useful.

North Bend Tongue.- The basal contact of the Northbend Tongue could be an unconformity and is at least a sequence bounding surface, while the upper surface is not.

Wesselman Tongue.- The Wesselman Tongue is the shale-dominated facies of the Riedlin LST, and does not have contact with a significant surface.

Upper Fairview Formation.- The upper part of the Fairview Formation straddles the transgressive surface of the Riedlin sequence, hence both contacts are diachronous, but the central part of this tongue, the "*Strophomena* zone", can be considered a time marker.

Miamitown Shale.- The Miamitown Shale straddles the Riedlin maximum flooding surface, and both upper and lower contacts are diachronous, but because the unit is so thin is makes a good stratigraphic marker with chronostratigraphic significance. Similarly, the base of the "second Miamitown" corresponds to another flooding surface and also serves as a time marker.

Bellevue Tongue.- The Bellevue Tongue may not be uniformly defined throughout its outcrop area, and may partially straddle the Riedlin-Stonelick sequence boundary; as such, it marks an important time horizon. The limestone content of this interval is high even in very shaly parts of the basin and, thus, represents a useful marker.

Summary and Conclusions

This study presents a fine-scale documentation of a single fourth-order (50 m) Upper Ordovician Maysvillian cycle over a 13,000 km^2 area just northwest of Cincinnati, Ohio based on the correlation of outcrop, core, and well log data. From the stratigraphic and spatial stacking patterns observed within this mixed carbonate-mudstone cratonic cycle a characteristic type-2 (Van Wagoner *et. al* 1988) sequence architecture can be concluded. This sequence, herein informally designated the Riedlin sequence, contains a thick shelf margin systems tract, a thinner transgressive systems tract, and a highstand systems tract based on stacking patterns. Though the existence of sequence bounding unconformities and condensed sections is predicted by this pattern, there is little sedimentological evidence for these in individual outcrops or cores.

These more detailed observations shed light on several questions about sequence stratigraphy in the Cincinnati area as well as larger questions concerning the nature of stratigraphic sequences. First, these findings show that at least one Cincinnatian fourth-order sequence is not so different from other sequences, as had been postulated previously (Holland 1993). Specifically, the transgressive systems tract is not particularly thin or absent, and it does contain the same facies found in the highstand systems tract. This means that Cincinnatian sequences may not point the way to any significant revisions or additions to the sequence model as applied to cratonic mixed carbonate-terrigenous systems.

However, these observations do raise a question about scale in the recognition of sequences. This question concerns the compatibility of two different sequence stratigraphic interpretations of the Cincinnatian strata. On the one hand, the entire Cincinnatian can be interpreted as a sequence and the component third- and fourth-order cycles as parasequences (Hohman & Keith IN PRESS; Hohman & Leonard 1993), or the fourth-order cycles can themselves be considered sequences (Holland 1993; Holland *et al.* 1993). This study provides more definitive evidence that the architecture of these sequences can indeed be interpreted as truly sequence-like, and raises the question of whether there might not be a difference between parasequences and sequences.

While calling a given cycle a sequence or a parasequence is a matter of judgement, it seems that the correlation of sequence boundaries and flooding surfaces carries with it much more confidence. The strength of the sequence stratigraphic approach lies in the use of genetically significant surfaces for correlation. What the present study has shown is that a significant amount of internal sequence anatomy can be established from well log correlations and reconstructed stacking patterns in the Upper Ordovician of the Cincinnati region, suggesting that the difficult correlation of fifth-order cycles (Jennette & Pryor 1993; Dattilo 1991) can be constrained using this larger-scale framework. This sets the groundwork for precise chronostratigraphy at unprecedented scales.

CHAPTER 3: NAMING CINCINNATIAN SEQUENCES

Introduction

As sequences or cyclic stratigraphic units are recognized and delineated in the Upper Ordovician rocks of the Cincinnati region, the question of whether these units should be formally recognized and named or whether a more informal naming system should be retained must inevitably be addressed. Specifically, should a numbering system be retained (i.e C1 through C5 Sequences: Holland 1990, 1993; C1 through C6 sequences: Holland & Patzkowski IN PRESS; Fig. 2), or should lithostratigraphic names be applied informally to cyclic or sequence-stratigraphic units (i.e. Trenton systems tract, lower Maquoketa systems tract: Hohman & Keith IN PRESS; Fig. 2)?

The problem with both of these informal approaches is that they can lead to further confusion. For example, when units are lettered or numbered consecutively, it is impossible to divide one unit without renumbering or relettering all the units. This can cause much confusion when stratigraphic understanding is in a state of flux, as is the Cincinnatian (i.e. compare Holland 1993 and Holland IN PRESS). This problem is not encountered when using lithostratigraphic names in the context of sequence stratigraphy (Hohman & Keith IN PRESS), but such a practice can lead to confusion over concepts. For example, the lower Maquoketa Systems Tract (Hohman & Keith IN PRESS) is not the same as the lower part of the Maquoketa Shale, because this systems tract can be recognized in regions where the Maquoketa Shale is not recognized.

A third option is to name sequence units according to an entirely new and independent formal system. This paper presents three such new names for the basal Cincinnatian sequences of Holland & Patzkowski (IN PRESS) from base to top: The Brent Sequence, The Riedlin Sequence, and the Stonelick Sequence. These Sequences are named according to rules for naming allostratigraphic units as published in the North American Code of Stratigraphic Nomenclature (NASC; 1983). The justifications for using a new system of formal names rather than numbers or previously used or occupied stratigraphic names fall into two broad categories:

(1) *Sequences and cycles are simply not the same as formations; the assumptions and approaches that underlie the delineation of these units are different.* A review of the history of stratigraphic nomenclature reveals that, in fact, there are three different types of lithologic units recognized within the Cincinnatian strata. Though different stratigraphic units can contribute to a whole understanding, to use formation names in a sequence stratigraphic context can only lead to confusion.

(2) *Despite the differences between sequences and formations, the protocols outlined in the NASC for naming rock units in general and allostratigraphic units in particular can be applied without significant alteration to the naming of sequences.* Objections to the use of formal names which center largely around lithostratigraphic aspects of the North American Stratigraphic Code

(NASC) and currently accepted lithostratigraphic usage are discussed below. Careful consideration of these objections demonstrates that slightly different protocols can be developed by those who work with sequences and similar units without compromising the sequence stratigraphic approach or the NASC. Thus protocols for naming sequences are readily available, which precludes the necessity of informal names or cumbersome numbering systems.

Sequences or Cycles Differ from Formations

Stratigraphic nomenclature in the United States has undergone evolution through three distinct ideological phases: "layercake" stratigraphy, lithostratigraphy, and sequence stratigraphy. To emphasize the importance of considering these as separate systems with separate naming systems, each is discussed with regard to basic tenets, application in the Cincinnatian, and confusion of ideas.

Layercake Stratigraphy

Early stratigraphic classification of the Cincinnatian rocks is known colloquially as "layer cake" stratigraphy. This approach was not merely descriptive but involved the use of many lines of evidence to establish a reconstruction of diastrophic events. Because of this, the formations were recognized and defined on faunal ranges, lithofacies, thickness and unconformity evidence, and were considered to have chronostratigraphic value.

This approach suffered from a lack of complete understanding of the concept of facies. Thus, facies changes in contemporaneous deposits were recognized, but only as exceptionally clear cases, leaving many more subtle facies transitions to be interpreted as unconformities. For example, Ulrich & Bassler (1914) noted that the Bellevue Member (actually the wavy-bedded nodular limestone facies) of the McMillan Formation is lacking at Hamilton, Ohio; from this they concluded that the Bellevue had not been deposited there, and that a hiatus of variable duration exists between the Fairview Formation and the Bellevue Member. This idea that rock types represented temporal variations in depositional conditions rather than spatial variations in depositional environment led to an over utilization of a single Cincinnatian type section, which represented details of the stratigraphic succession over a broad region (e.g. Bucher *et al.* 1933; Caster *et al.* 1955).

Lithofacies Stratigraphy or Lithostratigraphy

The recognition of the importance of facies led to the concept of a dual stratigraphic nomenclature (Williams 1894), which is the idea that the names of facies (lithostratigraphy) should be distinct from the names of biozones (biostratigraphy) which represent temporal (chronostratigraphic) units. Eventually, the need for separating the two concepts in the Cincinnatian was laid out by Gutstadt (1958). Soon the stratigraphy of the Cincinnatian outcrop belt was revised into a new lithostratigraphic scheme (e.g. Weir & Greene 1965; Weir *et al.* 1965, 1984; Ford 1967; Anstey & Fowler 1969). Meanwhile, the delineation of chronostratigraphic relationships and stratigraphic gaps was left entirely to biostratigraphers (Sweet *et al.* 1959, 1974; Sweet 1984; Bergstrom & Mitchell 1986; Bergstrom 1990). The column represented in figure 2 shows only a small sampling of the lithostratigraphic nomenclature in the immediate vicinity of Cincinnati. On the larger regional scale the lithostratigraphic classification creates a mosaic that in many places is very difficult to interpret genetically (Fig 3). In the worst case, lithostratigraphy is more reflective of state boundaries than of actual stratigraphic structure (Holland, 1993).

Cyclic and sequence stratigraphy

Cyclic and sequence stratigraphy differs from lithostratigraphy in both its aim and approach. While lithostratigraphy involves identification of a continuous body of a particular facies, cyclic and sequence stratigraphy involves delineation of cyclic packages of strata that contain whole suites of facies. These cycles or sequences are thought to be genetically more fundamental than facies because they are assumed to represent the sedimentologic response to basin-wide, regional, continental, or global events such as tectonic movements or sea-level change, rather than simply the stratigraphic and spatial extent of a given paleoenvironment.

Consequently, the recognition and delineation of important facies is just one step in the sequence-stratigraphic approach. Facies patterns, along with the distribution of important stratigraphic horizons such as flooding surface and unconformities go together to create a more complete sequence stratigraphic picture. Additionally, available faunal evidence is used to help recognize and correlate these surfaces.

Cyclic and sequence stratigraphy in the Cincinnati area has undergone considerable development in recent years. This started fundamentally with Tobin (1982) and has been treated by Holland (1993). The sequences delineated have been named either by numbers (Tobin 1982; Schumacher IN PRESS; Holland 1993) or by informal use of lithostratigraphic names (Hohman & Keith IN PRESS; Fig. 2). None have been named formally according to the rules of the NASC.

Stratigraphic confusion

Considering the large number of names applied to the Cincinnatian rocks, it might be suggested that some of the names which already exist could be applied to sequences, rather than inventing new ones. The fact that sequences are intrinsically different from lithostratigraphic or layercake formations makes this practice questionable, because they are a different category of unit (see NASC Article 6), and at least some of the apparent stratigraphic "complexity" of the type Cincinnatian is caused by the inconsistent usage of "layercake" names as applied to lithostratigraphic units. Even if using layercake names for sequences were acceptable, the following examples show that many of the names that might otherwise be available for use as sequences names have already been either rejected or adopted as lithostratigraphic or chronostratigraphic names. Each of these layercake units might have been changed slightly to fit the Brent, Riedlin, or Stonelick sequences.

An example of a unit that has been abandoned is the Mcmillan Formation (Ulrich 1911), which is approximately equivalent to the Stonelick sequence of this paper. On the other hand, the Fairview Formation, close to the Riedlin Sequence in original intent, is an example of an older unit that was redefined as a lithostratigraphic unit (Ford 1967). A third "layercake" unit, the Eden Shale is approximately equivalent to the Brent Sequence of this paper, and is now recognized as a North

American stage. Consequently, the name Eden Shale had to be abandoned as a lithostratigraphic name, and has been replaced by the Kope Formation.

Name recycling creates multiple usages of the same names. For example the Fairview Formation of "layercake" stratigraphy (Nickles 1902) was recognized over a different area and has different boundaries than the lithostratigraphic Fairview Formation of Ford (1967). At a more fundamental level, the new Fairview Formation (Ford 1967) simply represents a different type of stratigraphic unit. It is preferable to use completely separate names rather than add to this confusion.

Advantages of Formal Sequence Names

To avoid the inevitable confusion generated by utilization of preexisting layercake and lithostratigraphic names in a cyclic stratigraphic context, there are two options: 1) sequential alphanumeric system can be used (e.g. C1-C5 of Holland 1993) or 2) a new set of formal names can be applied. The disadvantages of labeling stratigraphic units with sequential numbers or letters, as discussed above, is that units cannot be split or combined without redesignating (renumbering) many or all of the units.

Thus, both the use of sequential alphanumeric systems and of adopted lithostratigraphic names are seriously flawed approaches to naming cyclic stratigraphic units. The best way to name these units seems to be by giving the units completely new names according to the rules of the NASC for the naming of an Allostratigraphic unit, which is defined as "... a mappable stratiform body of sedimentary rock that is defined and identified on the basis of its bounding discontinuities" (Article 58, NASC). Since sequences are recognized and defined on the basis of bounding unconformities, they can be thought of as allostratigraphic units. The usage in this paper follows the NASC except that the units are termed "sequences" instead of "alloformations".

Objections to Naming Sequences

Of all the objections to assigning new names to Cincinnatian sequences, perhaps the most compelling is that there are already too many names applied to the same Cincinnatian rock units. This results from the confusion in the evolution of Cincinnatian "layercake" and lithostratigraphic nomenclature discussed above. However, as also noted earlier, sequences are fundamentally different from formations as different, for example, as are biozones or chronostratigraphic units. The fact that these different types of stratigraphic units apply independently to the same rocks (e.g. the *Amorphagnathus superbus* conodont zone, the *Climacograptus spiniferous* graptolite zone, the Edenian Stage, and the Kope Formation are all partially equivalent in the Cincinnati region) does not raise any questions about the proliferation of names, because they are all fundamentally different types of units and can be kept separated conceptually. Thus the naming of Cincinnatian sequences need not contribute to the confusion in lithostratigraphic nomenclature.

Another objection to the formal naming of sequences is that sequences are recognized in a different way from formations; a sequence cannot be arbitrarily "defined" as a formation might be, but rather is recognized or discovered. This is because the general definition of "sequence" is more rigid than that of a lithostratigraphic "formation". While a lithostratigraphic unit is "distinguished and delimited on the basis of lithic characteristics and stratigraphic position" (NASC Article 22), a sequence is defined more tightly as "a relatively conformable succession of genetically related strata bounded by unconformities and their correlative conformities" (Van Wagoner *et al.* 1988). Beyond the tighter basic definition, the sequence is expected to have a certain internal structure. The practical difference between these two types of units is that lithostratigraphic units, which can grade one into another, can to a certain extent be defined arbitrarily; one lithostratigraphic classification cannot always be clearly held superior to another, because many formations represent divisions of a continuum. Thus, once a unit has been defined, there is little reason to redefine it, unless the original definition is unclear. Because the sequences are thought to exist independently of their recognition, a sequence or sequence boundary is discovered, not defined; given two different possible boundaries to a sequence, at least one must be wrong, not simply inferior to the other. A sequence stratigraphic unit is a falsifiable hypothesis, and not a defined unit. This means that boundaries may frequently be reinterpreted based on new information; sometimes boundaries may be moved significantly. In the case of a small adjustment there is no problem (NASC article 19-revisions). Boundary shifts can also be quite significant, approaching the maximum adjustment of half a cycle. To handle these it would probably be necessary to rename units.

Beyond shifting of boundaries, the precise description of a sequence stratigraphic boundary (NASC article 10) is problematic; an unconformity and its correlative conformity (i.e. sequence boundary; Van Wagoner *et al.* 1988) may not have the same specific characteristics over its regional extent, and in places it may be virtually unrecognizable in a single outcrop, core, or well log. However, lateral correlation can virtually pinpoint such a surface. For this reason a description of unit boundaries in one area may not apply to different areas.

New Names

Taking the foregoing arguments into account, I name the Brent Sequence, the Riedlin Sequence, and the Stonelick Sequence to replace the designations C1, C2, and C3 (Holland & Patzkowski IN PRESS). The age, dimensions, and lithological characteristics of these Sequences in the Cincinnati region have been described by Holland (1993), and Holland & Patzkowski (IN PRESS). I have presented a thorough overview of this history, age relationships, lithological characteristics, and boundary characteristics of these units in the Cincinnati region (this dissertation). For the purposes of formal naming, stratotype designations and specific boundary descriptions are presented for the Cincinnati area.

Brent Sequence

The Brent Sequence is equivalent to the C1 Sequence of Holland & Patzkowski (IN PRESS). In the Cincinnati area the Brent Sequence comprises roughly the entire thickness of the Kope Formation and part of the underlying Point Pleasant Tongue.

The stratotype for this sequence is designated as a series of roadcuts starting at the intersection of Kentucky Routes 445 and 8 near Brent, Kentucky, and continuing on the north side of Interstate 275, just west of the Ohio River. (Newport, Kentucky-

-Ohio 7.5" Quadrangle, Campbell County, Kentucky). This section has been described by a number of workers (Harrison & Mahan 1981; Tobin 1982; Jennette 1986; Jennette & Pryor 1993; Diekmeyer IN PRESS) This section lacks the lower sequence boundary. A supplementary section showing the lower boundary of this sequence is found at the Point Pleasant locality, which is a stream exposure on the north side of U.S. route 52, 0.3 miles west of the western city limits of Point Pleasant, Ohio. (Laurel, Ohio--Kentucky 7.5-minute quadrangle, Cleremont County, Ohio; 3854'02"N, 8414'13"W).

The lower boundary of the Brent Sequence as described by Holland (1993) coincides with the Point Pleasant-Kope Formation boundary. This will be taken as correct for the purposes of initial naming, but it is quite probable that a few to several meters of the upper Point Pleasant Tongue are actually part of the basal transgressive systems tract or the lowstand systems tract of the Brent Sequence. At least one earlier worker recognized the upper beds of the Point Pleasant as transgressive based on the presence of a reworked fragmental limestone or crinoidal lag and ripup clasts in the outcrops once exposed at Cincinnati (Fenneman 1916). This crinoidal lag is reported to be approximately 60 cm (2 ft) thick, and its base represents a possible sequence boundary. Further work may show the boundary to be even lower in the Point Pleasant Tongue at Cincinnati.

In the type area the Brent Sequence is approximately 82 m (270 ft) thick. At Cincinnati the sequence consists of alternating limestone and shale of the shale-dominated facies; vertical facies transitions are slight, consisting of 20% variations in shale content. Meter-scale cyclicity is pronounced (Jennette & Pryor 1993) and the lower 50 m (160 ft) are interpreted as forming transgressive systems tract based on a gradual upward increase in shale content.

Reidlin Sequence

The Riedlin Sequence is equivalent to the C2 Sequence of Holland & Patzkowski (IN PRESS). In Cincinnati this sequence comprises the Fairview Formation, the Miamitown Shale and the Lower part of the Bellevue Tongue.

The stratotype for the Riedlin Sequence consists of roadcuts along both sides of Riedlin Road/Mason Road at the intersection with and east of Kentucky Route 16. This intersection lies 0.4 mile (0.6 km) north of I-275 (exit 79) (Covington, Kentucky--Ohio, 7.5 minute quadrangle, Kenton County, Kentucky; 3901'15"N, 8430'30"). Descriptions of this section are found in a number of sources (Tobin & Pryor 1981; Tobin 1982, 1986; Jennette 1986; Holland 1990, 1993; Diekmeyer 1990, IN PRESS; Holland 1993, IN PRESS). The Riedlin Sequence is also well exposed at the classic Bellevue Hill cut which lies between the top of the cliff in Bellevue Hill ParK and Clifton Avenue, Cincinnati, Ohio (sec. 13, City of Cincinnati, Covington, Kentucky--Ohio, 7.5 minute quadrangle, Hamilton County, Ohio, 3907'17"N, 8431'14"W). This is the original type section for the Bellevue Limestone (Nickles 1902) and the neotype section for the Fairview Formation (Ford 1967).

As recognized herein, the lower boundary of the Riedlin Sequence corresponds precisely with the lower boundary of the North Bend Tongue of the Fairview Formation as defined in Cincinnati (Ford 1967). This contact is described by Jennette

& Pryor (1993), and is recognized by an abrupt transition from the shale-dominated facies of the highstand systems tract of the Brent Sequence to the basal phosphatic grainstone and packstone facies of the Riedlin Sequence. As shown by the foregoing correlations, the phosphatic facies disappears to the north of Cincinnati, but the limestone-rich interval can be traced a little further. The correlation is nevertheless somewhat problematic north of Wayne County, Indiana (Fig. 11C), where the limestone-rich layer is not present or not visible in geophysical logs.

At the type section, the Riedlin Sequence is about 40 m (131 ft) thick. In addition to the detailed descriptions of the stratigraphic reference and type sections provided by other workers (Ford 1967; Tobin 1982, 1986; Jennette & Pryor 1993), this dissertation provides a detailed description of the Riedlin Sequence across the study area (see Figs 10, 11).

Stonelick Sequence

The Stonelick Sequence is equivalent to the C3 sequence of Holland & Patzkowski (IN PRESS) and to the C2 sequence of Holland (1993). In Cincinnati this sequence comprises some of the uppermost Bellevue Tongue of the Grant Lake Formation, the Corryville Member of the Grant Lake Formation, and at least part of the Mount Auburn Formation.

The Stonelick Sequence stratotype is a series of stream exposures along Stonelick Creek beginning 0.6 mile upstream of the Belfast-Owensville Road bridge and continuing upstream (north) of the Ohio Route 131 bridge (Newtonsville, Ohio and Goshen, Ohio 7.5 minute quadrangles, Stonelick Township, Cleremont County, Ohio; 3910'40"N, 8406"43"W--at Ohio Route 131 bridge). Partly because of its exceptional fossil content, this section has been studied in its various aspects by a number of workers (Meyer *et al.* 1981; Pojeta 1982, 1987; Schumacher 1984; Schumacher *et al.* 1991; Diekmeyer 1992; Goldman 1992, 1993)

Of all the sequence boundaries encountered in the study interval, the basal Stonelick Sequence boundary is the most extensively recognizable. At Stonelick Creek it is manifested as a rather abrupt transition from the wavy-bedded nodular limestone facies to the phosphatic grainstone and packstone facies (Table 1) all within the lithostratigraphic Bellevue Tongue of the Grant Lake Limestone. A similar facies transition is recognizable in Cincinnati and to the north and west of the study area; although the phosphate content is unknown, an isolated limestone bed or bedset can be correlated from the base of the Stonelick Sequence 200 km north of Cincinnati into an interval where surrounding strata are extremely shale rich (Fig. 10A, 11A). The upper boundary of the Stonelick Sequence was not correlated in this study, but was placed by Holland (1993, IN PRESS) at the transition between the wavy bedded/nodular limestone of the Mt Auburn Formation, and the mixed packstone-shale of the overlying "Sunset" Formation.

In the type section the Stonelick Sequence is approximately 23 m thick (data from Goldman 1993, IN PRESS). Based on these data (Goldman 1993, IN PRESS), the sequence can be tentatively divided into a transgressive systems tract (15 m) and a highstand systems tract (8 m). The transgressive systems tract consist of a basal 2 m of phosphatic limestone, followed by 6 m of packstone-dominated mixed packstone shale facies, and 7 m of mixed packstone shale facies. The highstand systems tract contains at its base 3 m of shale-dominated facies followed by 2m of mixed packstone-shale facies and 3 m of the wavy-bedded/nodular limestone characteristic of the Mt Auburn Formation.

Summary

With particular reference to the Cincinnatian section, there are three possible ways to name sequence or cyclic stratigraphic units: 1) number or letter them consecutively (Holland 1990, 1993, IN PRESS; Holland & Patzkowski IN PRESS), 2) utilize pre-existing lithostratigraphic terminology to informally name sequences and parts of sequences (Hohman & Keith IN PRESS), or 3) name sequences formally utilizing new names and new type sections.

In this chapter I have applied new names to the basal three sequences of the Upper Ordovician in the vicinity of Cincinnati. These three sequences are, in stratigraphic order, the Brent Sequence, the Riedlin Sequence, and the Stonelick Sequence, and they correspond respectively to the C1, C2, and C3 sequences of Holland & Patzkowski (IN PRESS).

The arguments that justify this action run in two veins: 1) The use of consecutive numbers or letters as well as the use of previously defined lithostratigraphic names to informally designate sequence units both lead to confusion, and 2) The objections to naming sequences formally can be met by taking into consideration the fundamental differences between sequence stratigraphy and lithostratigraphy and adjusting the approach accordingly.

The confusion that results from consecutive numbering or lettering of any stratigraphic unit is that, since numbers or letters generally connote an order, in this case stratigraphic, all units in a series must be redesignated if a unit is added (split from another) or removed (lumped with another). Thus any revision in the number of units recognized results in a change in designation for many or all of the units. After several revisions, any reference to the number or letter designations is bound to be ambiguous.

On the other hand, the use of lithostratigraphic names in an informal designation of sequence stratigraphic units is confusing because lithostratigraphic units are in no way equivalent to sequences. The use of a lithostratigraphic name, however, suggests some equivalence and thus leads to confusion.

One objection which could be raised to the use of an independent system of names for Cincinnatian sequences is that there are already too many stratigraphic names in the Cincinnatian literature. The answer to this objection is that sequences should always be treated as independent entities from lithostratigraphic formations as far as naming is concerned. If this rule is maintained, then there is no need to confuse the two separate systems of nomenclature.

A second possible objection to the use of the stratigraphic code in the naming of a sequence is that sequences are subject to more revision than can be handled by the NASC. However, despite the greater stability of lithostratigraphic nomenclature, the code does allow for boundary correction, so sequences can be revised formally without violating the code.

CHAPTER 4: A QUANTITATIVE PALEOECOLOGICAL APPROACH TO HIGH-RESOLUTION CYCLIC AND EVENT STRATIGRAPHY

Introduction

Meter-scale lithologic cycles, representing anywhere from 20,000 to 100,000 year periods, have been utilized over the last ten years to establish high-resolution stratigraphic correlations in a number of basins of various ages (Brett & Baird 1985, 1986a; Brett *et al.* 1990; Jennette & Pryor 1993; Kauffmann 1986). This enhanced resolution can greatly benefit paleoecological and evolutionary analyses by clarifying events that occur over periods of thousands rather than millions of years. Many local and regional studies of Cincinnatian and other Paleozoic fossil assemblages have been carried out with stratigraphic resolutions on the order of 1 Ma (e.g. Fox 1962; Bretsky 1969). This means that any recognized spatial and temporal patterns are obscured by 1 Ma of *de facto* time-averaging, regardless of whether time averaging on that scale actually occurs in the sections under study. Assuming cycles are not diachronous, cyclic and event stratigraphic approaches provide intrabasinal time resolutions of 100 to 20 ka, or 10 to 50 times the resolution possible with classical "biostratigraphy".

Where lithologic sequences are fossiliferous, qualitative observations of fossil content have been used in several cases to establish event surfaces for the purpose of correlation (e.g. Kauffmann 1986; Brett & Baird 1986). However, there have only been a few preliminary attempts to use quantitative paleoecological techniques to address stratigraphic questions (Rabe & Cisne 1980; Cisne & Rabe, 1978).

While qualitative observations have proven quite useful in the recognition of evolutionary, preservational, and ecological events (Kauffmann *et al.* 1991), quantitative analysis of relative abundance data offers the advantage of a more predictable and precise simplification of a complex faunal data matrix. This provides the stratigrapher not only with discrete, unusual events, but also with the more subtle stratigraphic signals provided by small but widespread environmental shifts that are reflected in the slight variations of "normal" fossil assemblages. Such variations may not be recognized without quantitative analyses.

The Upper Ordovician of the Cincinnati region ("Cincinnatian") provides a richly fossiliferous natural laboratory for the development of integrated lithology- and fossil-based cyclic stratigraphic techniques. At the same time, partly because of its repetitive, "monotonous", nature, the Cincinnatian has proven difficult to correlate laterally over even tens of km.

Thus, the purpose of this paper is two-fold. First, it presents an integrated quantitative paleontological and lithologic approach to cyclic and event stratigraphic correlations. Second, it illustrates how this approach can be used effectively in one of the more complex and confusing intervals of the Cincinnatian Series, the Fairview Formation-Bellevue Tongue transition.

Concept of cyclicity

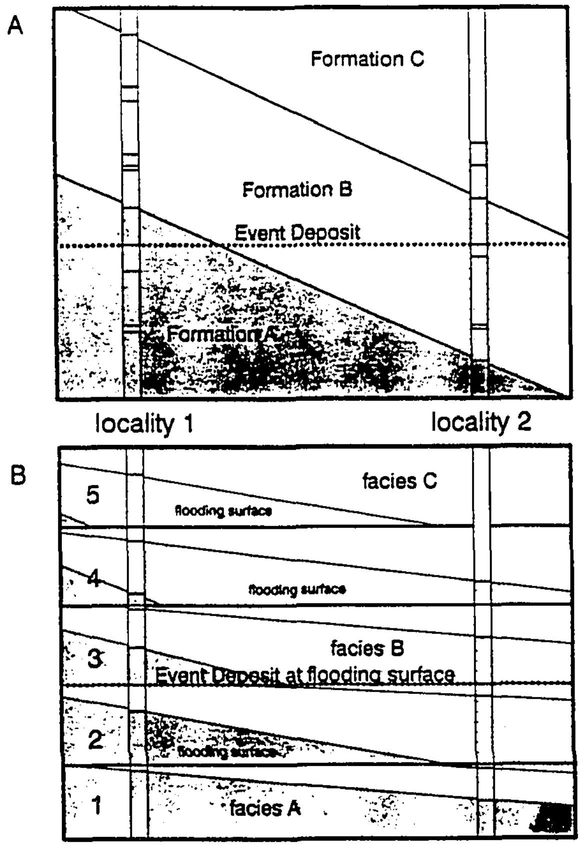
While it is not within the scope of this paper to provide a full review of cyclic and event stratigraphic concepts, simplified schematics (Fig. 4-1A, B) help to illustrate the differences between traditional lithostratigraphy and meter-scale cyclic stratigraphy in terms of stratigraphic resolution and chronostratigraphic significance.

Both Fig. 4-1A and Fig. 4-1B show the same data: two hypothetical localities (locality 1 and locality 2), their respective cyclic sequences of micro-facies A, B and C, and a recognizable event horizon. They differ only in that the two stratigraphic sequences are correlated by generalized facies in Fig. 4-1A (lithostratigraphy), and by cycles in Fig. 4-1B. Some important differences between these two approaches are outlined below.

Lithostratigraphy.- Correlation by facies (Fig. 4-1A) as a technique is relatively simple. The facies (A, B, and C) must first be recognized at each locality. Correlations between the two localities are made by matching equal facies; this is how a Formation is commonly defined.

Facies correlation in cyclic sequences is complicated by the fact that two or more facies are often intercalated for several meters, repeating a sequence (in Fig. 4-1 this sequence is A-B, A-B-C, or B-C) with every meter-scale cycle. Since formations are generally defined on the basis of mapability, they usually exceed 5 to 10 m in thickness. For this reason, formations must commonly be defined with arbitrary boundaries.

Fig. 4-1. Two alternative methods of making stratigraphic correlations between two localities based on the same litho- or bio-facies sequence and unique, widespread events. □A. Lithostratigraphic approach. Facies sequences between localities 1 and 2 are correlated into broad facies belts or formations. □B. Cyclic stratigraphic approach. Correlations are not made by matching identical facies, rather, cyclic alternations in facies are identified at both localities. Unique events serve to narrow the range of possible correlations between the two localities.



For example Ford (1967) defined the lower contact of the Fairview Formation near Cincinnati as "the base of the Limestone overlying the uppermost terrigenous stratum greater than 2 feet [0.6 m] thick.". In another case, Weir *et al.* (1984) working in the Cincinnatian strata of Kentucky, defined the contact between the Bull Fork Formation below and the Drakes Formation above "at the top of the highest persistent fossiliferous limestone bed in a transition zone commonly a few feet [0.6 to 1 m] thick".

Because facies reflect environmental factors, properly defined formations convey important genetic information about the strata. The recognition of such units also relatively uncomplicated, and ambiguities are minimal. It is widely accepted, for example, that facies units are diachronous, and that isochronous events (e.g bentonite beds; see "Event Deposit", Fig. 4-1) cut through facies boundaries. Recognition of facies units is an important preliminary step in the study of a sedimentary basin.

It is also clear that, in many cases, facies distributions are superimposed on a more fundamental stratigraphic pattern. This pattern has received considerable attention in recent years under the heading of "sequence stratigraphy" (see Vail *et al.* 1977), as well as in various studies, hypotheses, and models of smaller-scale cyclicity (Goodwin & Anderson 1985; Kauffmann *et al.* 1991; Brett & Baird 1986; Read *et al.* 1986).

Assuming that such a cyclic pattern or structure exists, a lithostratigraphic unit can really be understood only in the context of that pattern. Unfortunately, many formations have been designated outside of any such context, and their interpretative or descriptive values have been compromised. For example, Holland (1993) showed that formations named in the Upper Ordovician of the Cincinnati region vary widely in their compatibility with sequence boundaries.

Cyclic stratigraphy.- Meter-scale cyclicity represents one of the thinnest correlatable elements of the stratigraphic pattern that underlies facies distributions. Fig. 4-1B illustrates the use of such cycles in correlation. The process entails 4 major steps: (1) establish cyclic alternation of facies at each locality, (2) delineate cycles, (3) establish the identity (i.e. correlation) of cycles between the two localities, largely by the recognition of unique event deposits (Fig 4-1B) and (4) make remaining cycle correlations.

Note that the procedure for correlating cycles is more interpretative than the procedure for correlating facies, but, as illustrated in Fig. 4-1B, facies within a given cycle are matched between the two localities, just as formations would be correlated within a larger-scale sequence. Assuming the stratigrapher recognizes formations as part of a more fundamental pattern, the essential differences between the recognition of formations and the recognition of meter-scale cycles are those of scale.

Meter-scale cyclicity and events in the Cincinnatian

Meter-scale cycles were recognized throughout the Upper Ordovician of the Cincinnati region by Tobin (1982) and Tobin & Pryor (1981), who characterized them as 0.4 to 4.0 m fining-upward cycles consisting of a lower thick grainstone facies, a middle packstone-rich facies, and an upper shale-rich facies.

Recently, Jennette & Pryor (1993) redefined and correlated several cycles near the contact between the Kope and Fairview Formations. The Jennette & Pryor (1993) cyclicity model was based largely on the storm proximality model of Aigner (1985), and they recognized shoaling-upward cycles with a lower, distal, shale-rich facies, and an upper, proximal, grainstone-rich facies. They correlated 22 of these cycles over lateral distances as great as 60 km in the Cincinnati area. Tobin (1982), Tobin & Pryor (1981), and Jennette & Pryor (1993) utilized extensive lithologic data, but relatively little paleontological data to define cycles and accomplish correlations.

Groundwork for quantitative paleoecological study of Cincinnatian cycles was laid by Diekmeyer (1990, IN PRESS). Through analysis of bulk fossil samples taken at 50 cm intervals from an outcrop described by Tobin (1982) (Riedlin Road (RDR) locality of this paper), she was able to show that faunal cyclicity reflects lithologic cyclicity through several meters of section.

Locality and stratigraphy

Fig. 4-2 is a map of the Cincinnati area showing the seven outcrop localities correlated in this study (see locality register in appendix). These outcrops were chosen to cover the area around Cincinnati within the loop created by the construction of Interstate Highway 275 at a maximum radius of 40 km. Fig. 4-3 shows the position of the study interval and area on a schematic lithostratigraphic cross section through Cincinnati. In terms of classic Cincinnatian Stratigraphy, the interval comprises the upper part of the Fairview Formation and most of the Bellevue Tongue; the Miamitown Shale, which lay between the Fairview and Bellevue, was named by

Fig. 4-2. Map of the Cincinnati Area with the locations of the 7 studied outcrop sections and the two stratigraphic cross sections discussed in this paper. MTN = Miamitown, MAF = Mount Airy Forest, CHS = Rice and Gage Streets (Christ Hospital), WYN = Devou Park (Wayne Road), RDR = Riedlin Road, SIP = Sharonville Industrial Park, and LBG = Lawrenceburg.

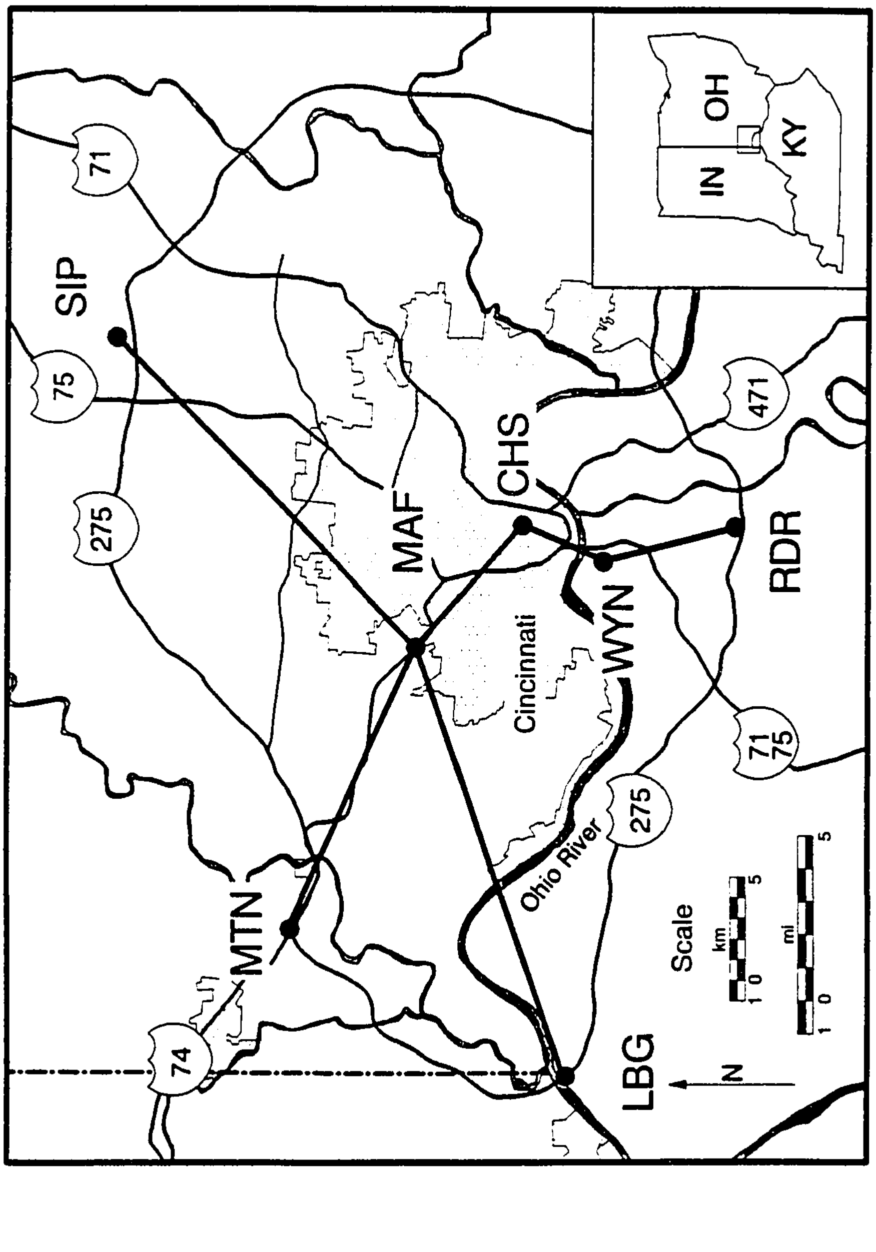
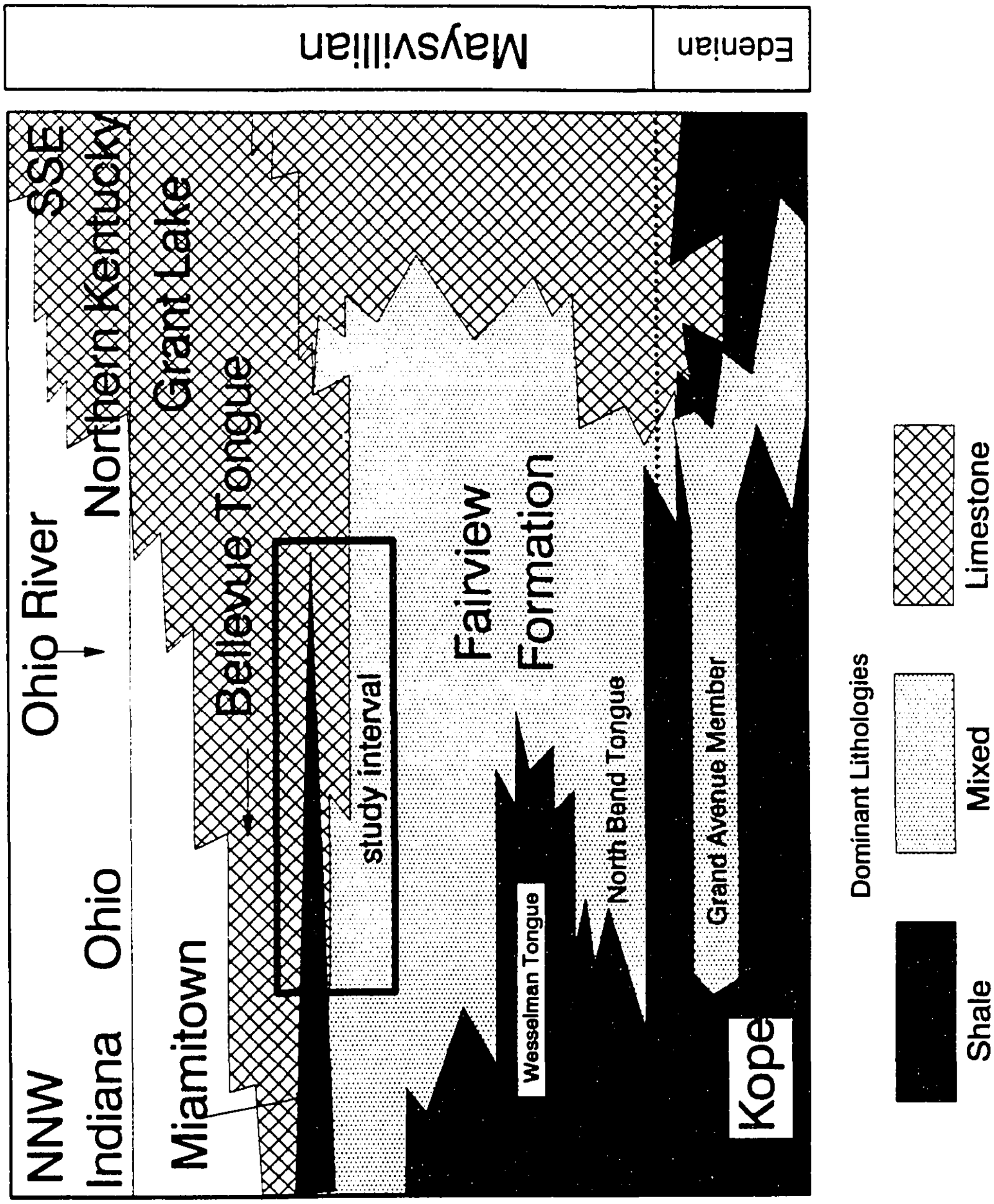


Fig. 4-3. Cross section through the Cincinnati area showing the position of this study with reference to lithostratigraphic classification. Third and fourth order cyclicity are expressed in sequence of lithostratigraphic units (see text). The present study delineates 5th-order cycles within the upper Fairview Formation, the Miamitown Shale, and the Bellevue Tongue in the vicinity of Cincinnati. (Modified from Weir *et al.* 1984).



Ford in 1967.

Anstey & Fowler (1969), Tobin (1982), Jennette & Pryor (1993), and Holland (1993) outlined large-scale (tens to hundreds of meters thick) shoaling-upward cycles in the Cincinnatian. Jennette and Pryor (1993) refer to these as third order cycles after the convention of Goldhammer *et al.* (1990) and Mitchum & Van Wagoner (1991); the same convention is followed in this paper. Fig. 4-3 illustrates the position of the Miamitown Shale near the top of the first such cycle, which can be recognized in the succession from the Shale-rich Kope Formation through the Fairview Formation to the limestone-rich Bellevue Tongue of the Grant Lake Limestone. Jennette & Pryor (1993) recognized further that, in this first major cycle, at least three fourth-order cycles can be identified among the lithostratigraphic "tongues" and "members" of the Kope and Fairview Formations named by Ford (1967). Fig. 4-3 shows that the Miamitown Shale, coupled with the Bellevue Tongue, forms a fourth, capping fourth-order cycle within the third-order sequence.

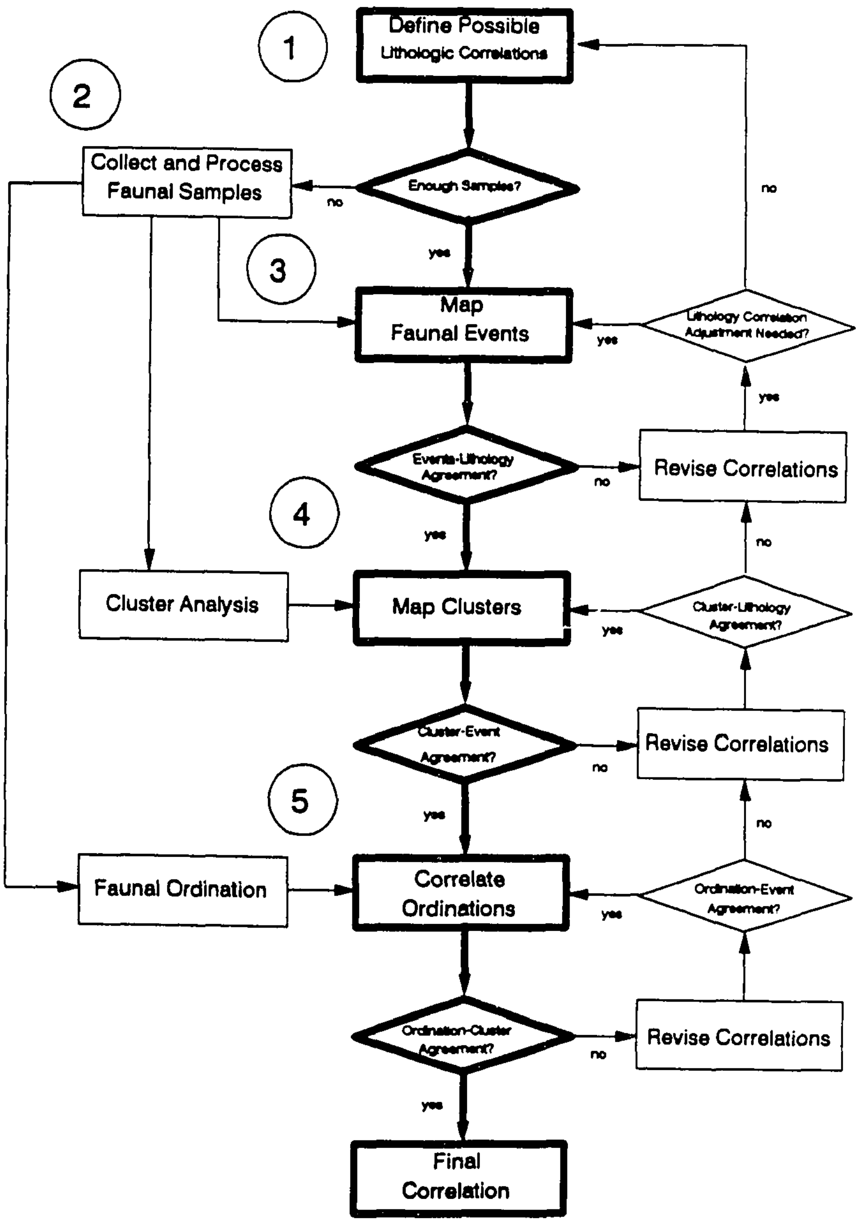
Procedure

The iterative process

The procedure developed in this study incorporates quantitative paleoecological analyses with lithologic data to establish correlations of meter-scale cycles. Fig. 4-4 is a flow chart that summarizes the steps discussed in detail below. The logical sequential process involved in making these correlations is clear (these steps are numbered in Fig. 4-4):

(1) Multiple initial correlations are based on lithologic pattern alone.

Fig. 4-4. Flow-chart outline of stratigraphic correlation procedure presented in this paper. The central column (highlighted with numbered steps) shows a sequential refinement of stratigraphic correlations. The right-hand column illustrates how new data, acquired in the later sequential steps, frequently leads to reevaluations of previous correlations. The left hand column shows that the results of faunal analyses (like lithologic data) are independent of correlations; the interpretation of these results may change.



(2) Sufficient bulk fossil samples are collected to adequately cover the desired interval, and fossil data are collected and processed (independently of the rest of the correlation process, see left-hand column of Fig. 4-4).

(3) Easily recognized, unusual faunal occurrences are used to change or refine some of the initial correlations (step 1).

(4) The distribution of faunally-defined sample clusters is used to further refine correlations.

(5) Faunal-ordination scores are plotted against stratigraphic sample position to refine correlations further.

Because many different types of data are used in this procedure, there are occasions when data used in an earlier step needs to be reevaluated in light of new information. For example, correlations based on individual faunal occurrences (apparent faunal event deposits) may not match correlations based on faunal cluster distributions. At this point the correlations must be reevaluated, and the faunal event may be discounted, or correlations may be revised to conform to the constraints of both the faunal event deposit and the cluster distribution. This iterative process is illustrated in the right-hand column of Fig. 4-4.

Preliminary work

Because of the ambiguity frequently encountered in correlating very thin units, it is advisable to start correlating with larger-scale units. Once a coarse stratigraphic framework has been established, it is a much simpler task to execute the more intensive study of a thin interval or intervals. In the case of the Miamitown Shale, preliminary correlations had been made by Ford (1967). Ford (1967) utilized 9-foot (3 m) running average shale-percentage curves to correlate a significant portion of the interval spanning the Kope Formation through Bellevue Tongue. This resulted in a lithostratigraphic classification of intertonguing facies (Fig. 4-3) that delineate 4th-order (10-m scale) cycles.

Ford's (1967) work permitted selection of several approximately correlative outcrops for detailed analysis in the present study (Fig. 4-2). Each locality includes the Miamitown Shale and several meters above and below, up to a maximum thickness of 19 m, thus insuring a thick interval of stratigraphic overlap.

Lithologic observations in the field

Lithologic correlation (step 1; Fig. 4-4) begins with the measurement of the stratigraphic sequence of lithofacies in the field. Outcrop sections were mark in 10 cm increments using a hand-level mounted on a Jacob's staff (modified from Elder 1989). Bedding and lithology were described at a resolution of approximately 1 cm. The occurrence of shale, fossiliferous shale, siltstone, calcisiltite, wackestone, packstone, and grainstone were recorded as were bedding features such as megaripples, gutter casts, and wavy irregular bedding. The columnar sections in Fig. 4-5 and Fig. 4-6 exemplify these data.

Shale-percentage logs

Columnar sections can be valuable tools for correlation purposes, but thin bedded units are not easily represented. If they are not generalized, columnar section from the Cincinnatian are confusingly detailed. Generalization, on the other hand, must be

Fig. 4-5. Analysis of lithologic sequence is facilitated by reducing data to running-average shale-percentage curves. In this example from the Rice and Gage Street locality (CHS) two such curves are compared with the more traditional columnar section. Shading indicates interval of detailed analysis (Fig. 6).

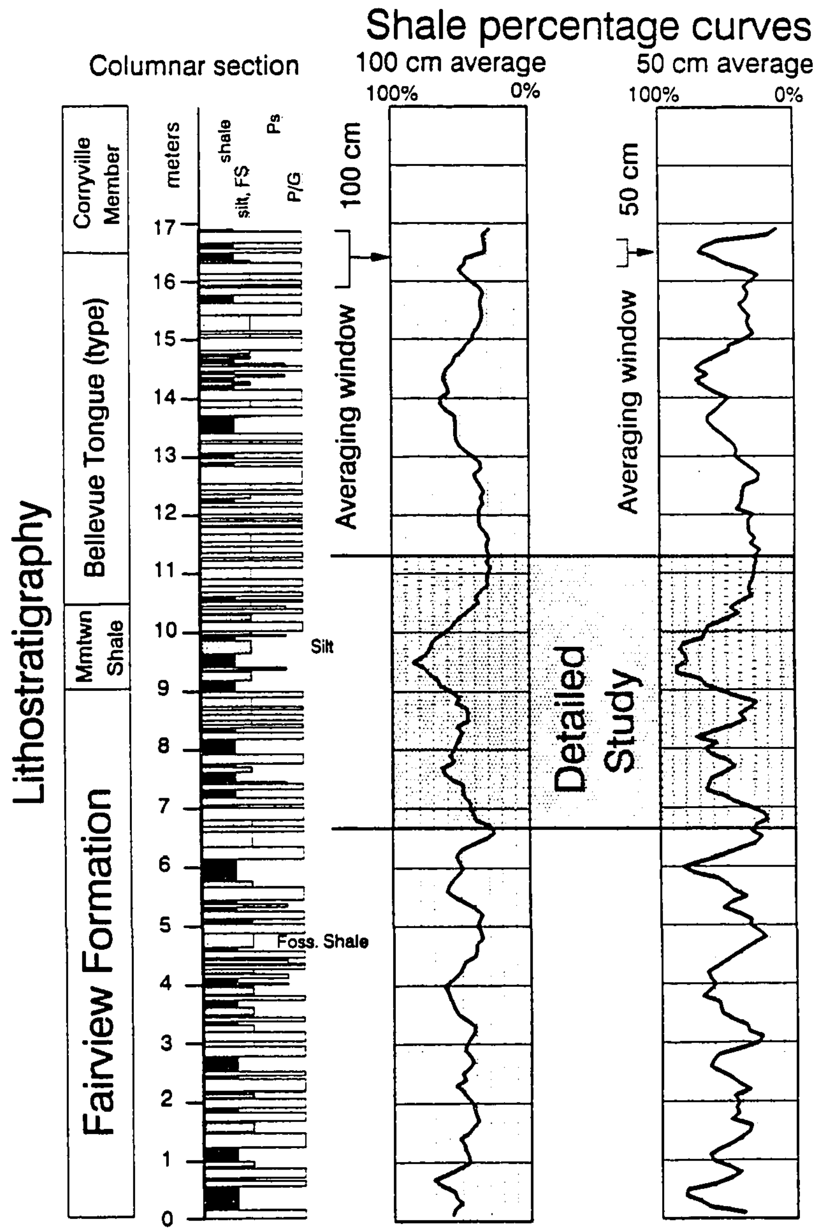
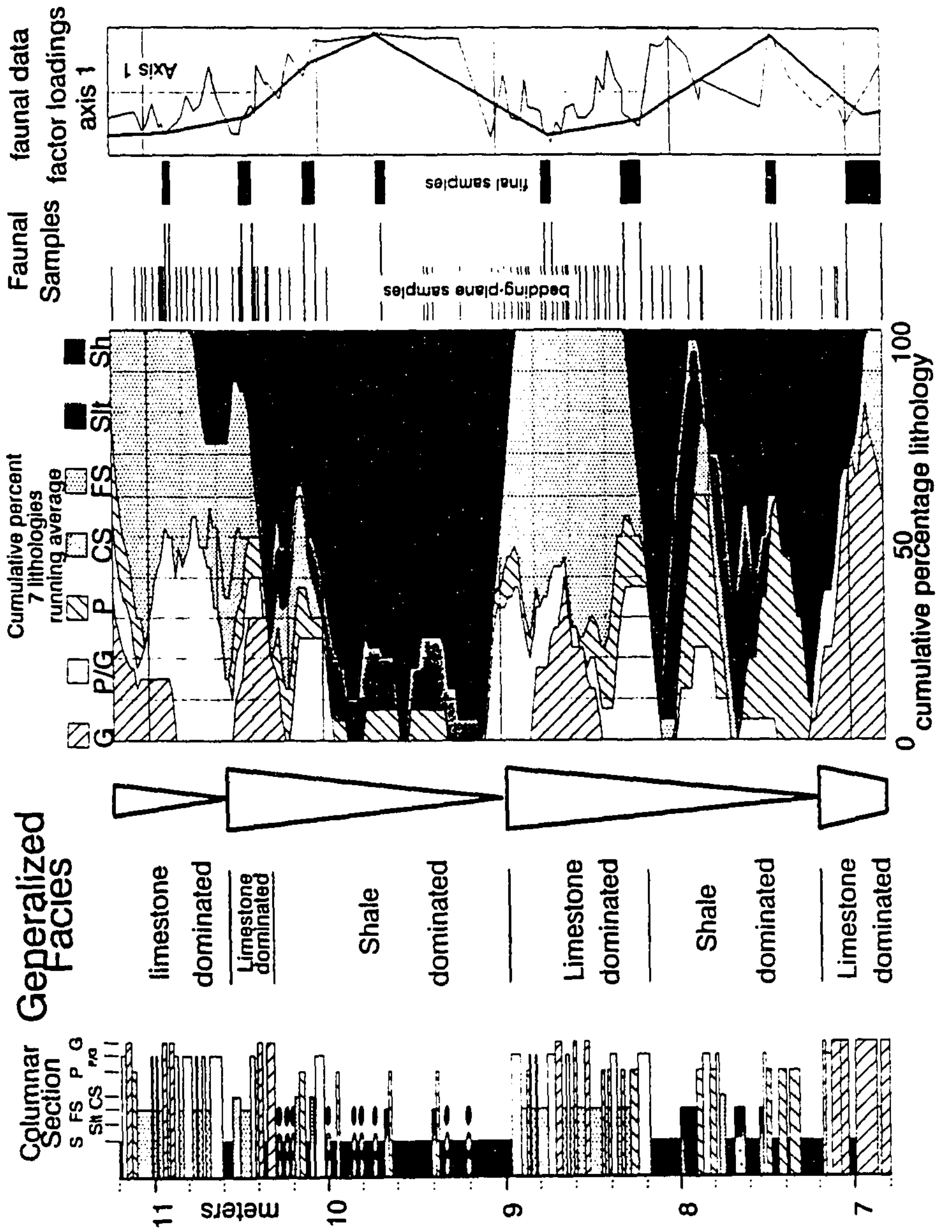


Fig. 4-6. Meter-scale cyclicity is illustrated by detailed lithologic study of two cycles from the Rice and Gage Streets locality (CHS: see Fig. 5). Seven lithologic phases are represented by cumulative running-average percent-lithology curves, generated using a 50 cm averaging window with data points at 2 cm intervals.



done in a subjective manner; too much generalization can render the columnar section useless for correlation.

Shale-percentage logs or curves have been used by Ford (1967), Gray (1972), Sweet *et al.* (1974), and Schumacher *et al.* (1991) to simplify Cincinnatian measured section data objectively. These workers found such logs valuable in correlating distinct intervals for tens or even hundreds of kilometers.

I chose to use shale-percentage curves because they accentuate the shale-rich to limestone-rich cyclic alternations described by Tobin & Pryor (1981) and by Jennette & Pryor (1993). These curves were generated from digitized measured sections of the 7 study localities. Two examples are presented in Fig. 4-5, alongside a columnar section representing the same interval. These shale-percentage logs were generated for each section using 100 cm and 50 cm averaging intervals (labelled in Fig. 4-5). Each curve has a data point every 10 cm stratigraphically; the horizontal position of this point represents shale percentage (thickness of shale/total thickness of interval) in the surrounding averaging interval of 100 cm or 50 cm. Comparison of these curves with the columnar section shows their accuracy.

Delineation of cycles

Cincinnatian cycles.- Cincinnatian lithologic cycles have been delineated in contradictory ways. Tobin & Pryor (1981) recognized fining upward cycles and Jennette & Pryor (1993) delineated coarsening-upward cycles within the same intervals. It is clearly difficult to establish an objective generalization about cycle asymmetry. The question of asymmetry and cycle delineation is important from the standpoint of correlation, because not all facies boundaries within a cycle are isochronous to the same degree. As illustrated in Fig. 4-1B, the boundaries between facies within a cycle do not (and should not) run parallel to boundaries between cycles.

Some examples.- A detailed examination of two cycles, each approximately 2 m thick, from the Miamitown shale interval at the Rice and Gage Street locality (CHS; Fig. 4-6) illustrates the salient characteristics of cycles within this interval. Seven lithologic phases are represented by a columnar stratigraphic section and by cumulative 50 cm running-average percent-lithology curves. Note that these cycles contain two general facies: a shale-dominated facies and a fossiliferous shale-limestone-dominated facies (Fig. 4-6). The boundary above the limestone-dominated facies is abrupt (50 cm averaging obscures the abruptness), while the boundary above the shale-dominated facies is more gradational; washed packstone becomes more abundant toward the top of the shale-dominated facies.

Application to outcrop sections.- Judging from this detailed data, the boundary above the limestone-dominated facies is a convenient first approximation of appropriate cycle boundaries for correlation purposes (inverted triangles, Fig. 4-6). Based on this assumption, I determined cycle boundaries at the seven outcrop localities with the aid of detailed columnar sections and shale-percentage curves. The correlations discussed and illustrated in this paper are correlations of these cycle boundaries.

Lithology based correlations

Cross correlation.- Shale-percentage logs can be compared quantitatively. Cross correlation is a simple method of approximating the position of best correlation between two sequences of values (Davis 1986); the method compares two series (series 1 and series 2) of values by matching them pair-wise at different lags. In this case the lag indicates the difference in stratigraphic position of the elements of each pair. For each lag, a linear correlation is calculated between series 1 and series 2 values. The aim of the analysis is to determine the lag at which the highest linear correlation between the two series is calculated. The chief limitation of cross correlation is that the lag is fixed for the entire stratigraphic interval of comparison; if series 1 is identical in shape, but differs in thickness from series 2, cross correlation will still result in a single best-match lag representing a parallel matching of data points between the two series. Real-world correlations are rarely parallel.

Cross correlations between the study sections are represented in Fig. 4-7 as parallel sets of broken lines. Table 1 lists the lags and correlation values represented by these lines. For illustration, the best correlation (0.64) between the Miamitown (MTN) and Mount Airy Forest (MAF) localities is at a lag of -3.8 m (Table 1). This lag is represented by dashed lines drawn between the MTN and MAF shale-percentage curves in Fig. 4-7. Note that every such line correlates from a point in the MTN section to a point 3.8 m lower in the MAF section.

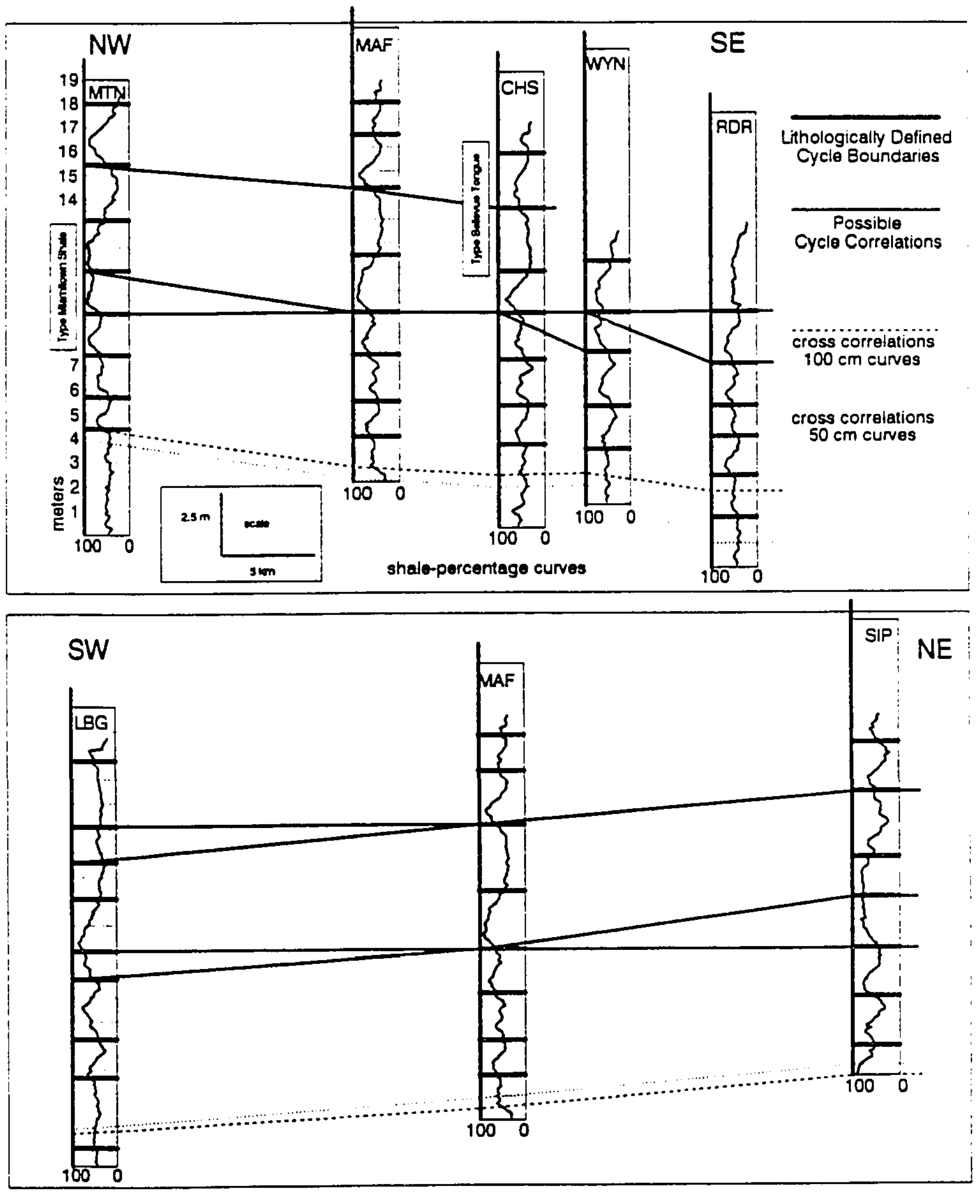
Correlation of cycles.- Shale-percentage curves and columnar sections were used to correlate individual cycles within the constraints of the

Table 4-1. Highest cross correlations between shale-percentage logs. Two or three highest correlations may be included if they are statistically indistinguishable. Cross correlations between standardized, and nonstandardized sections, and between 100 cm and 50 cm averaged percent-shale curves are documented. Positive lag indicates correlation to a higher stratigraphic position in right-hand stratigraphic section. See Fig. 4-2 caption for locality abbreviations.

100 cm		MAF	CHS	WYN	RDR	SIP	LBG	Stan.
Lag C.C. Error		0.0 0.811 0.089	0.0 0.720 0.089	0.0 0.632 0.110	0.0 0.622 0.106	0.0 0.613 0.089	0.0 0.553 0.089	MTN
MAF	-3.8 0.640 0.088		0.0 0.854 0.089	0.0 0.690 0.110	0.0 0.555 0.106	0.0 0.659 0.089	0.0 0.571 0.089	MAF
CHS	-2.4 0.540 0.083	1.6 0.653 0.081		0.0 0.781 0.110	0.0 0.400 0.106	0.0 0.462 0.089	0.0 0.584 0.089	CHS
WYN	-1.8 0.391 0.102	0.7 0.609 0.097	-0.9 0.391 0.098		0.0 0.208 0.106	0.0 0.028 0.089	0.0 0.893 0.110	WYN
RDR	-3.7 0.337 0.097	3.4 0.294 0.095	3.4 0.330 0.095	1.9 0.317 0.089		0.0 -0.079 0.089	0.0 -0.077 0.089	RDR
SIP	-4.2 0.446 0.096	-0.4 0.522 0.083	-1.9 0.391 0.087	-0.8 0.647 0.084	-0.4 0.336 0.083		0.0 0.343 0.089	SIP
LBG	-2.0 0.506 0.080	0.9 0.596 0.077	0.0 0.434 0.075	1.3 0.720 0.078	-6.2 0.291 0.093	2.0 0.569 0.080		
N. S.	MTN	MAF	CHS	WYN	RDR	SIP		

50 cm		MAF	CHS	WYN	RDR	SIP	LBG	Stand.
Lag C.C. Error		0.0 0.758 0.089	0.0 0.684 0.089	0.0 0.557 0.110	0.0 0.630 0.106	0.0 0.572 0.089	0.0 0.480 0.089	MTN
MAF	-3.8 0.567 0.088		0.0 0.761 0.089	0.0 0.595 0.110	0.0 0.525 0.106	0.0 0.650 0.089	0.0 0.553 0.089	MAF
CHS	-2.4 0.484 0.083	1.6 0.582 0.081		0.0 0.752 0.110	0.0 0.438 0.106	0.0 0.455 0.089	0.0 0.514 0.089	CHS
WYN	-3.3 0.301 0.111	0.7 0.482 0.097	-0.9 0.602 0.098		0.0 0.312 0.106	0.0 0.133 0.089	0.0 0.422 0.089	WYN
RDR	-0.6 0.345 0.085	3.5 0.281 0.096	3.4 0.366 0.095	4.4 0.318 0.105		0.0 0.030 0.089	0.0 -0.057 0.089	RDR
SIP	-4.2 0.385 0.096	-0.4 0.457 0.083	-2.1 0.308 0.088	-1.0 0.458 0.085	-0.5 0.284 0.083		0.0 0.397 0.089	SIP
LBG	-2.0 0.396 0.080	0.7 0.437 0.077	0.0 0.364 0.075	1.2 0.559 0.078	2.3 0.289 0.081	1.9 0.424 0.080		
N. S.	MTN	MAF	CHS	WYN	RDR	SIP		

Fig. 4-7. The two intersecting stratigraphic cross sections (see Fig. 2) showing how initial correlations between the seven study sections were made by comparison of shale-percentage logs (100 cm averaged curves illustrated). Broken correlation lines represent the orientations of maximum linear cross correlation values between shale-percentage curves (see Table 1). Dashed lines represent correlations between 100 cm-averaged curves and dotted lines represent correlations between 50 cm curves. Thick solid correlation lines represent possible correlations between cycles. Subsequent stratigraphic cross sections are based on this template.



cross-correlations. This is accomplished in part by matching the shape or "wave form", of shale-percentage curves from section to section. This is not the same as matching points of equal shale-percentage value; from the northwest (MTN) to the southeast (RDR) of that stratigraphic transect (Fig. 4-7), overall shaliness decreases, yet the wave form pattern, as recognized by eye and cross correlation, transcends this facies transition.

Even with the constraints of cross correlations, many cycle correlations were still ambiguous, and were left unresolved. These are represented in Fig. 4-7 by duplicate and triplicate sets of conflicting cycle correlation lines (heavy, solid lines) between localities. For example, the correlations between the lower parts of the Mount Airy Forest (MAF) and Miamitown (MTN) stratigraphic sections are ambiguous because none of these cycles is distinctive lithologically. In particular, a thin limestone-rich interval at 11 m in the MTN section is represented by only a slight wave in the shale-percentage curve; this could correlate to the cycle top at 7 m in the MAF section (showing a dramatic facies change), or it could represent a few limestones near the base of the overlying cycle (demonstrating a dramatic thickening of that cycle). Resolution of this correlation would constrain the correlation of underlying cycles, but it is impossible without additional data.

Faunal data

Sampling strategy. - Because lithologic data alone is frequently not enough to resolve cycle correlation, establishment and implementation of an adequate faunal sampling strategy is an essential second step (see Fig. 4-4) in this approach to high-resolution correlation. After initial, lithology-based cycle correlations are made, the interval of potential correlations between all localities can be determined within a few meters. At this point samples can be collected to adequately cover this interval. Stratigraphic sample spacing should be sufficiently dense to permit recognition of faunal cyclicity and faunally defined facies (if present). Lithologic cyclicity provides a guideline to faunal patterns, but fauna may be more sensitive to environmental fluctuations, and thus show more definite or finer-scale patterns.

To test the correspondence between lithologic and faunal cyclicity in the study interval, I initially collected 77 bulk fossil samples from the 4 m interval illustrated in Fig. 4-6. The faunal content of these samples does show a cyclic pattern that closely mimics the meter-scale lithologic succession shown in Fig. 4-6. Furthermore, the faunal pattern is not strongly affected by the precise lithology of the sample itself; stratigraphic position is more important.

Since the lithologic-faunal cycles in the vicinity of the Miamitown Shale consist of two major facies types which occur in different proportions among different cycles, adequate coverage of a single cycle should require three or four samples, or approximately one sample every 50 cm. In actual collecting, I maintained sample spacing between 30 cm and 70 cm in all but a few cases. The samples, exceeding 400 cm^2 of single-bedding-plane surface area, were collected from limestone and siltstone beds of various thicknesses. Shale samples were not utilized because (1) half of them tend to be only very sparsely fossiliferous, and (2) Shale faunas in this interval tend to be the same as faunas from adjacent limestone and siltstone beds.

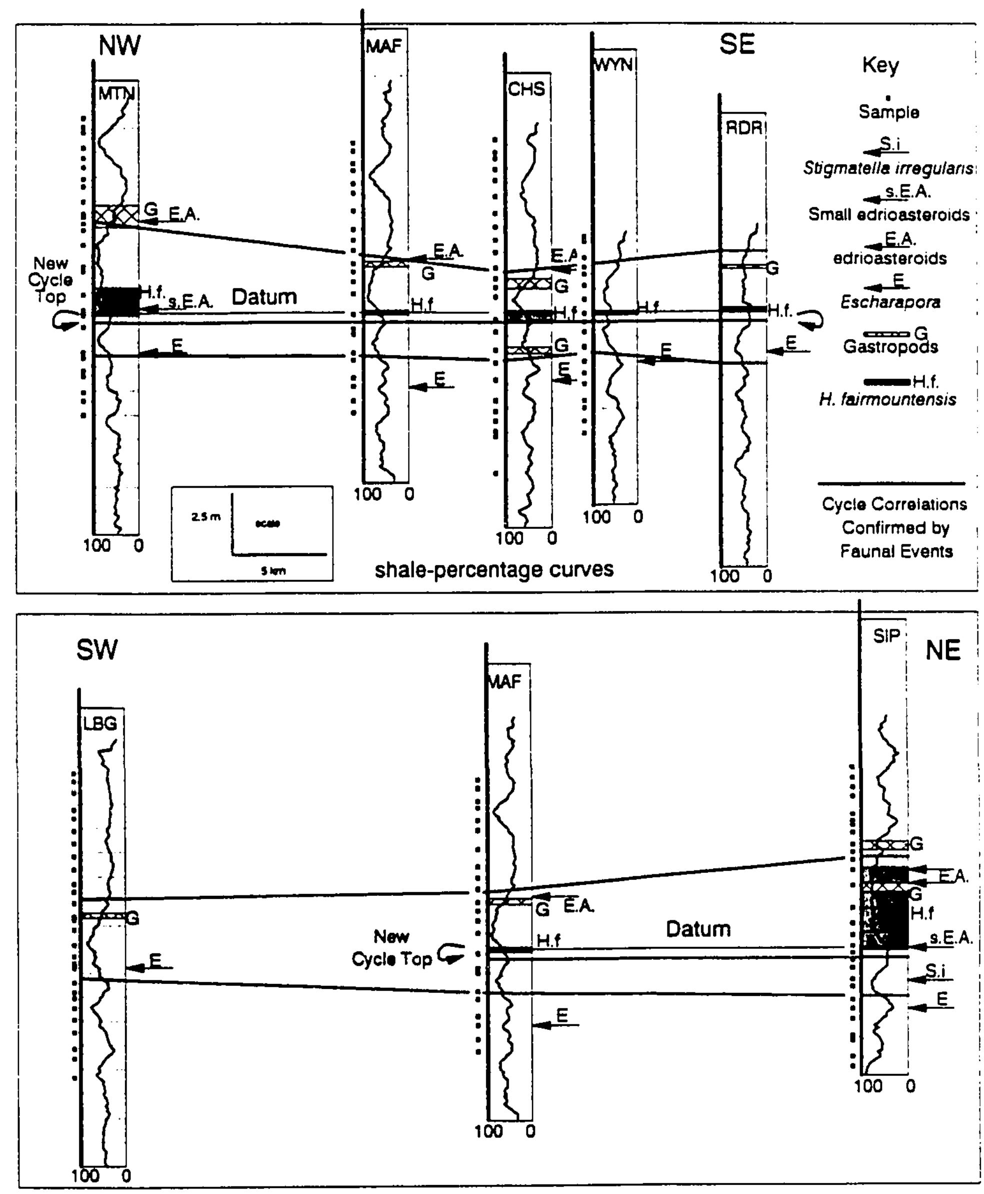
The stratigraphic positions for the 150 bulk samples utilized in the faunal analyses discussed below are illustrated in Fig. 4-8. Note that only eight of the original 77 samples were used in these analyses; the remaining 142 samples were collected separately from different localities or intervals. Additionally, data gathered by Diekmeyer (1990, IN PRESS) was used to constrain the correlations at the Riedlin Road locality (RDR).

Faunal events as chronostratigraphic markers

Importance of events.- The third step in the correlation procedure is to recognize and correlate faunal events (Fig. 4-4). An event is defined here as a short-term change in conditions that affected the sediments or the faunas in some distinctive way. An event deposit is stratigraphically useful to the extent that it is widespread and can be uniquely recognized. Examples of sedimentological events include hurricanes and major winter storms (Aigner 1985), and earthquakes. Epiboles, defined as the brief increase in a normally rare fossil, constitute a class of biotic event deposits as delineated in detail by Brett *et al.* (1990b), who recognized three major types.

Biotic events such as these can easily be recognized and utilized in the field and from samples without employing multivariate analyses (Brett *et al.* 1990a, 1990b; Kauffmann *et al.* 1991). Fig. 4-8 illustrates the faunal events that I have recognized and utilized to narrow the range of possible correlations among localities; these events are described below.

Fig. 4-8. Unusual and unique fossil occurrences are labelled on this stratigraphic cross section and indicated by arrows or patterned rectangles. Solid lines represent those cycle correlations confirmed from faunal event deposits. The first appearance of *Heterorthina fairmountensis* is so consistent across the study area that the cycle top in which it occurs is used as a datum elevation for these stratigraphic cross sections. The last occurrence of *Escharapora falciformis* is not an event in the same sense as the other occurrences, but it did prove useful in confirming correlations to the Riedlin Road locality (RDR).



***Heterorthina fairmountensis*. -** The brachiopod *Heterorthina fairmountensis* (Foerste 1909) probably represents an *incursion* epibole (i.e., the first or only appearance of this species in the basin; Brett *et al.* 1990b. The stratigraphic range of this species thins from 3 m at the Sharonville Industrial Park locality (SIP) in the north to a few cm at the Riedlin Road locality (RDR) (reported by Diekmeyer 1990, IN PRESS as an isolated occurrence of *Onniella*) to the south. At all localities except Lawrenceburg (LBG), were it was not found, *H. fairmountensis* first appears in the limestone-rich upper part of one cycle and in a few cases its range extends into the overlying shale-rich base of the next cycle (Fig. 4-8). After multivariate analysis (discussed below) I found the lowermost occurrence of this brachiopod to be so consistent that I used the top of that cycle as a datum level for stratigraphic cross sections (labelled in Fig. 4-8).

At two localities, Miamitown (MTN) and Sharonville Industrial Park (SIP) the *H. fairmountensis* epibole is associated with a possible taphonomic epibole (i.e., unusually good preservation of a fossil that is normally poorly preserved; Brett *et al.* 1990b): small edrioasteroids attached to small *Rafinesquina* valves.

STIGMATELLA IRREGULARIS. - Ulrich and Bassler (1914) described an interval between the Fairmount Member of the Fairview Formation and the Bellevue Member of the McMillan Formation as the *Stigmatella irregularis* zone. Their description of this interval leaves little doubt that the unit is equivalent to the Miamitown Shale (Ford 1967), and it is also apparent that the bryozoan *Stigmatella irregularis* was used as a unique stratigraphic marker. I recognized this distinctive bryozoan (identified for this study by Roger Cuffey) only from the Sharonville Industrial Park locality, but it may represent another useful incursion epibole.

Gastropod packstone-edrioasteroid association. - The Miamitown Shale (Ford 1967) has been characterized as a unit rich in molluscan remains, particularly the high-spired gastropod *Loxoplocus bowdeni*. These gastropods are heavily concentrated in one or two micrite-rich terrigenous packstone beds, 10 to 15 cm thick, found near the top of the Miamitown Shale at every studied locality. These beds are capped by a *Rafinesquina* pavement on which I observed sparse, well preserved edrioasteroids at all but two localities (LBG and RDR). Together these occurrences may represent an association of an ecologic epibole (i.e., unusual conditions that favor the growth and reproduction of normally rare taxa; Brett *et al.* 1990b) of gastropods and a taphonomic epibole of edrioasteroids; this joint occurrence to confirm another cycle correlation (Fig. 4-8).

Last occurrence of Escharapora falciformis. - First and last occurrences of more long ranging taxa, while not being classified as epiboles, do represent a sort of biotic event which is used in classical biostratigraphy. I include the last occurrence of *Escharapora falciformis* because it was useful for establishing additional correlation lines to the Riedlin Road locality (RDR), which was not included in multivariate analysis. Compared to epiboles, the last occurrence does not occur consistently at the same part of a cycle. For this reason correlations based on the last occurrence must be made somewhat tentatively.

Preparation of data set for multivariate analyses

Multivariate analyses such as cluster analysis (Fig. 4-4; step 4) and faunal ordination (Fig. 4-4; step 5) require precise quantitative faunal data sets. The counting techniques used and the transformations applied to faunal data in this study are explained below.

Faunal counts. - Fossils were counted from the upper and lower surfaces, ~400 cm^2, of each sample. Additionally, some parting-plane surfaces were counted in a few cases. These surface counts were added together for a total sample census.

Most taxa were identified to genus level, though seven supra-generic groups were also counted. These include cryptostomes (all bifoliate cryptostomes except *Escharapora*), smooth encrusting trepostome bryozoans, monticulated encrusting trepostome bryozoans, encrusting cyclostome bryozoans, encrusting inarticulate brachiopods (e.g. *Petrocrania*, *Schizocrania*, and *Trematis*), scolecodonts, cephalopods, and nuculoids. References used for identifications included the University of Cincinnati Geology Museum collections, and several taxonomic works (e.g. Alberstadt 1979; Bell 1976; Bodenbender 1989; Bucher *et al.* 1939; Caster *et al.* 1955; Davis 1985; Hall 1962; Howe 1979; Pojeta 1971; Thompson 1970; Walker 1982).

For counting purposes, I recognized four major types of skeletons: (1) single element, (2) bivalved, (3) Multi element, and (4) colonial. Each type requires a somewhat different counting strategy to assure consistent results, and they are discussed separately.

Those taxa that fossilize as single elements are gastropods, cephalopods, *Cornulites*, and "*Trypanites*". All but *Trypanites* can be characterized as cone-shaped shells with apexes. To avoid duplicate counts of a single organism, only those shells with apices were counted. In the case of *Cornulites*, an encrusting annelid tube, any recognizable fragments remaining cemented on substrate were also counted. Other fragments were counted as one specimen in the absence of apical or substrate-cemented material. Specimens of *Trypanites*, a simple hard-substrate boring, were counted individually.

Brachiopods and pelecypods have bivalved skeletons. As with single element skeletons, duplicate counts of a given valve can be avoided by counting only those fragments which contain the beak, or which remain cemented to a substrate in life position (e.g. *Petrocrania scabiosa*). Unfortunately, each bivalve skeleton can be preserved as a pair of articulated valves or as two separate valves. Clearly each pair of articulated valves can be counted as one organism, but a collection of disarticulated valves represents a number of individuals somewhere between a definite minimum and a definite maximum number of possible individuals. This minimum is simply the number of the most abundant element (left or right, brachial or pedical valves), and the maximum is the total number of valves in the collection. I chose to use this maximum because it is unlikely to find both disarticulated valves of a single organism in a small sample of a storm deposit, and because in many cases shells were partially covered and articulation could not be determined.

Organisms with multi-element skeletons include trilobites, crinoids, and neritid worms (scolecodonts). Some elements of a given skeleton occur singly or in pairs, such as trilobite cranidia, hypostomes, pygidia, librigenia, and genal spines, or certain echinoderm plates. Other elements occur in sets of three to ten, such as crinoid calycal plates, and scolecodonts. For the same reasons noted above in reference to bivalved skeletons, I counted each of these elements as one individual.

For those elements which occur in tens or hundreds, such as trilobite thoracic sclerites or crinoid columnals, calculation of minimum and maximum individuals is useless; a sample of 200 identical columnals could represent as many a 200 crinoids or as few as 1. Another approach would be to estimate the percentage of an organism that one such element represents. I could assume that an average crinoid contains 100 columnals, and calculate that 200 columnals represent, on average, 2 crinoids. Such a calculation may provide an accurate estimate of actual numbers, but since most samples from the study interval contain less than 30 columnals, the resulting crinoid counts would be very low compared to those of other organisms, and a potentially valuable stratigraphic signal might be obscured. In this study I reduced columnal number by a factor of 0.2 (5 columnals = 1 crinoid) and added it to the calycal plate count.

Trilobites are represented by a number of unique components as discussed above, but each trilobite carries about ten thoracic sclerites, a number which varies from species to species and with ontogeny. These sclerites could be left out of the analysis if there were not several samples that contain an abundance of them without other diagnostic elements, and if some trilobite genera, such as *Isotelus* and *Ceraurus* were not usually represented by thoracic sclerites alone. However, thoracic sclerite abundance should not be over-emphasized with respect to cranidia or pygidia, which are relatively common and are frequently found in the same samples. Again, I reduced thoracic sclerite counts by a factor of 0.2 before adding them to counts of other trilobite elements.

Bryozoans are the only colonial organisms included in these analyses. Trepostome fragments were not counted, but encrusting trepostome and cyclostome colonies were . Bifoliate cryptostomes (except *Escharapora falciformis*) consistently occur as fragments 3 to 5 mm in length; each was weighted as a single individual. *E. falciformis* occurs as distinctive blade-shaped colonies about 3 to 5 cm in length, and fragments were counted that exceeded 2 cm in length.

Data transformations. - A few very rare genera or higher taxonomic groups were removed from the data matrix for analytical purposes if they were represented by 15 specimens or less (0.05% of the data set), and if their distribution was neither sufficiently widespread nor consistent enough to contribute to stratigraphic correlation. Removal of all rare taxa reduced the entire data set by 34 specimens, or about 0.001%. The final raw data matrix consists of 150 samples, 29 taxa, and 30,573 individuals.

Depending on the type of multivariate analysis performed, one or two of three data transformations were applied to the final data matrix: (1) percent transformation of samples, (2) log transformation, and (3) percent-range transformation of species.

All samples were initially percent-Transformed to standardize each sample to 100. The intent here was to mitigate for differences in sample size since they can artificially affect the results of cluster and ordination analyses.

Preliminary analyses of partial data sets, including the densely sampled interval illustrated in Fig. 4-6, demonstrated that the distribution of *Zygospira* and *Rafinesquina* was over-emphasized with respect to other taxa. This effect was sufficiently strong that random fluctuations in their abundances overwhelmed cyclic patterns in cluster analysis. Log transformations de-emphasize these most abundant taxa, and emphasize the less abundant taxa without changing their rank abundances. Its application to the percent-transformed data matrix accentuated the meter-scale cyclic patterns and larger-scale transitions.

Before carrying out R-mode cluster analysis, a percent maximum transformation on each taxon was applied following percent transformation of samples: the highest individual sample abundance of a taxon is set at 100% and the abundances of that taxon in all other samples are recalculated as percentages of the maximum abundance sample. This transformation decreases the likelihood that taxa will group together on the basis of comparable overall abundances, rather than their distributions among samples.

Cluster analysis

Justification of cluster analysis. - Cluster analysis is one of many multivariate techniques available to classify ecologic data. When the entities being studied (samples or taxa) occur in natural clusters, a clustering algorithm would ideally be applied to identify those clusters. Most ecologic data sets, however, contain samples and taxa that are distributed continuously, and any classification technique including cluster analysis, must impose a set of boundaries that do not exist in the original data (Gauch 1982; Springer & Bambach 1985). Nevertheless, cluster analysis is still indispensable for the interpretation of ecologic data, because cluster distribution can reveal data structure that might otherwise be overlooked. Thus cluster analysis is a valuable fourth step (Fig. 4-4) in the correlation of meter-scale cycles.

When applied to paleoecologic data and plotted stratigraphically, such clusters reflect biofacies that reveal stratigraphic and spatial patterns similar to those of lithofacies. As with lithofacies, biofacies can be used to detect third, fourth, and fifth order cyclicity in the stratigraphic record. However, biofacies differ from lithofacies in having different sensitivities to environmental parameters, and in reflecting not only the physical environment, but also evolution and migration. Differential sensitivity to environmental parameters may lead to biofacies patterns that are not apparent in lithofacies, while evolutionary or migrational changes in faunal composition can lead to temporal restrictions of biofacies which make them particularly valuable chronostratigraphic markers.

Cluster analysis methods. - Faunal data were analyzed with two-way cluster analysis (Sepkoski & Rex 1974; Springer & Bambach 1985; Miller 1988) using Unweighted Pair-Group Method with Arithmetic Averaging (UPGMA; Sokal & Sneath 1963; Sneath & Sokal 1973). After percent and log transformations in

Q-mode an percent and percent maximum transformations in R-mode, Samples were compared and clustered in Q-mode analysis and taxa in R-mode analysis using the quantified Czekanowski's Coefficient (Sepkoski 1974), as executed by the computer program CLAP written by Sepkoski & Sharry in 1976 and modified for microcomputer by Miller in 1987.

Cluster results.- The resulting two-way cluster analysis (Fig. 4-9) is useful because it combines Q-mode and R-mode analyses in a fashion that allows the assessment of sample clusters on the Q-mode dendrogram with respect to faunal transitions or of faunal associations on the R-mode dendrogram with respect to the sample distribution of component taxa. This is possible because the two-way grid of dots represents the original faunal data matrix sorted into Q- and R-mode dendrogram order. Boxes of various sizes placed on the grid reflect abundances of taxa within samples after percent and percent maximum transformation. A histogram of abundance for selected taxa in each of seven Q-mode clusters (Fig. 4-10) provides additional documentation of the relationship between sample clustering and faunal composition.

The Q-mode dendrogram (Fig. 4-9) is interpreted as showing six major clusters, labelled 1 through 6. There are four additional minor clusters within cluster 3, labelled 3A through 3D. The R-mode dendrogram (Fig. 4-9) contains four major clusters of taxa, labelled I, II, III and IV. Three taxa do not fall within the labelled clusters. The relationship between Q- and R-mode clusters as illustrated in the two-way grid (Fig. 4-9) shows a transition in faunal composition from

Fig. 4-9. Two-way cluster analysis of faunal data. Data matrix of percent maximum-transformed relative abundance (see text) is reordered by Q-mode (sample) and R-mode (taxon) clustering and is represented by a grid of pattern density. R-mode cluster I fauna is concentrated in Q-mode clusters 1 and 2, but extends into clusters 3A and 3B; R-mode cluster II fauna is ubiquitous, but less abundant in Q-mode cluster 4, 5, and 6 samples; R-mode cluster III and IV fauna are concentrated in cluster 4, 5, and 6 samples.

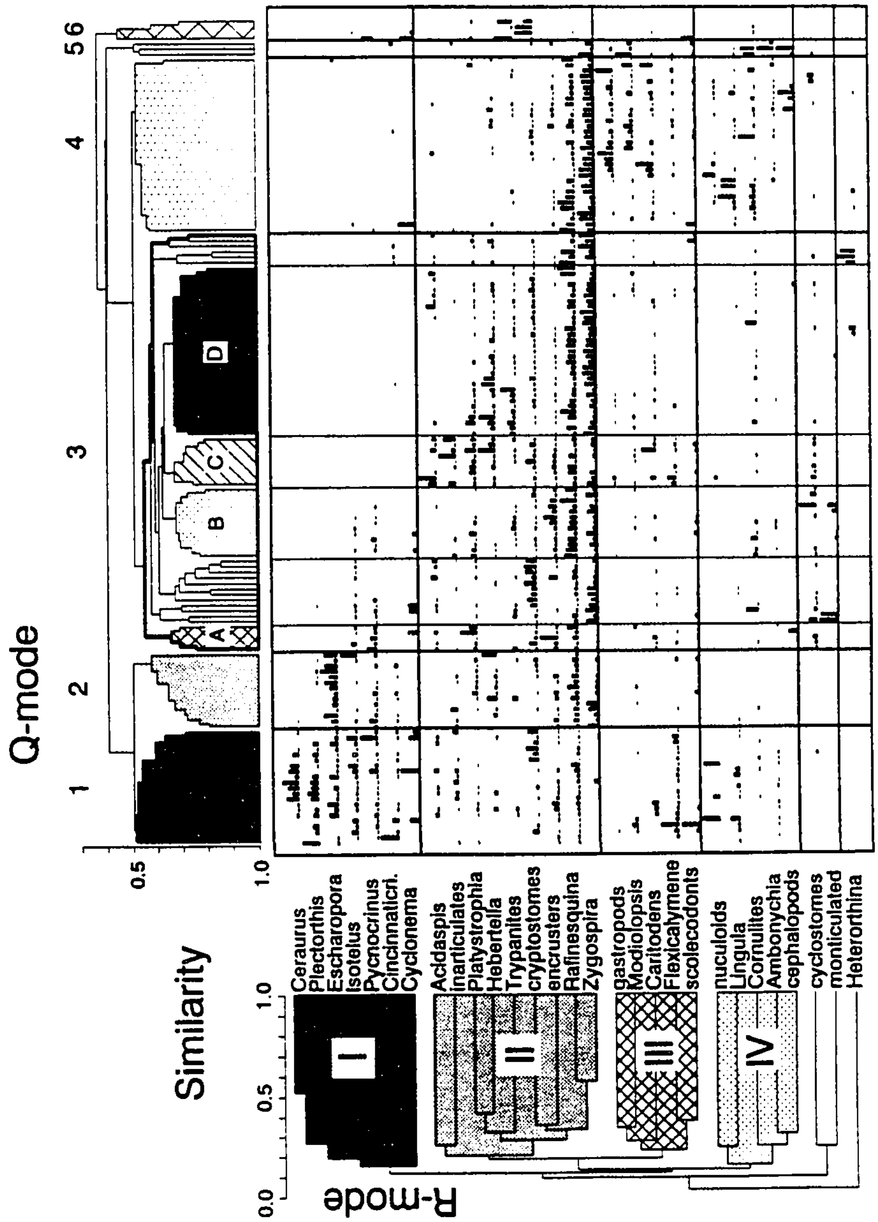
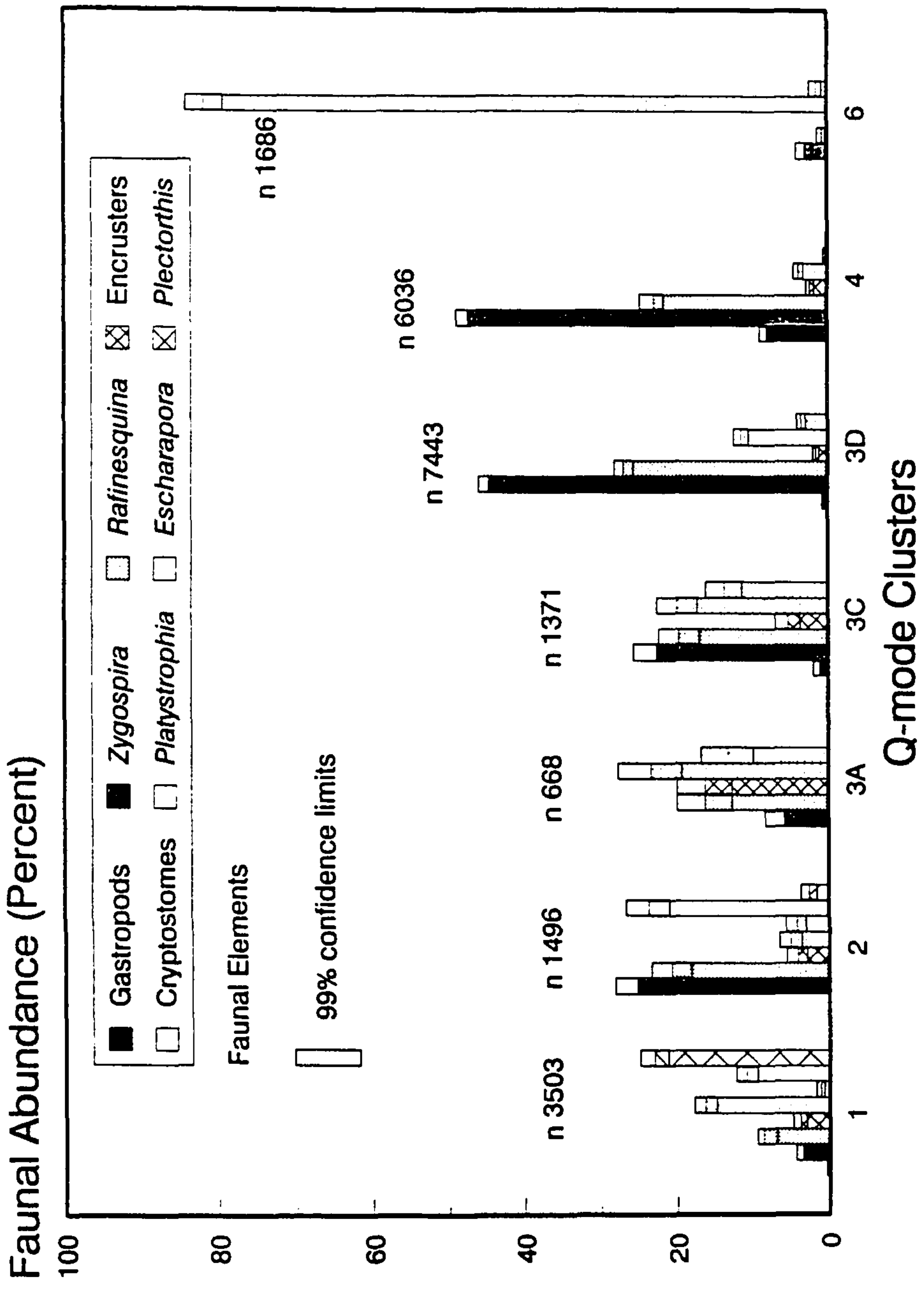


Fig. 4-10. Q-mode faunal composition histogram illustrates the differences between key sample clusters. This is accomplished by combining the samples of each cluster into one sample, and illustrated using eight of the most abundant taxa. Note that each cluster can be distinguished from the others by a statistically significant difference in the relative percent abundance of at least one faunal element.

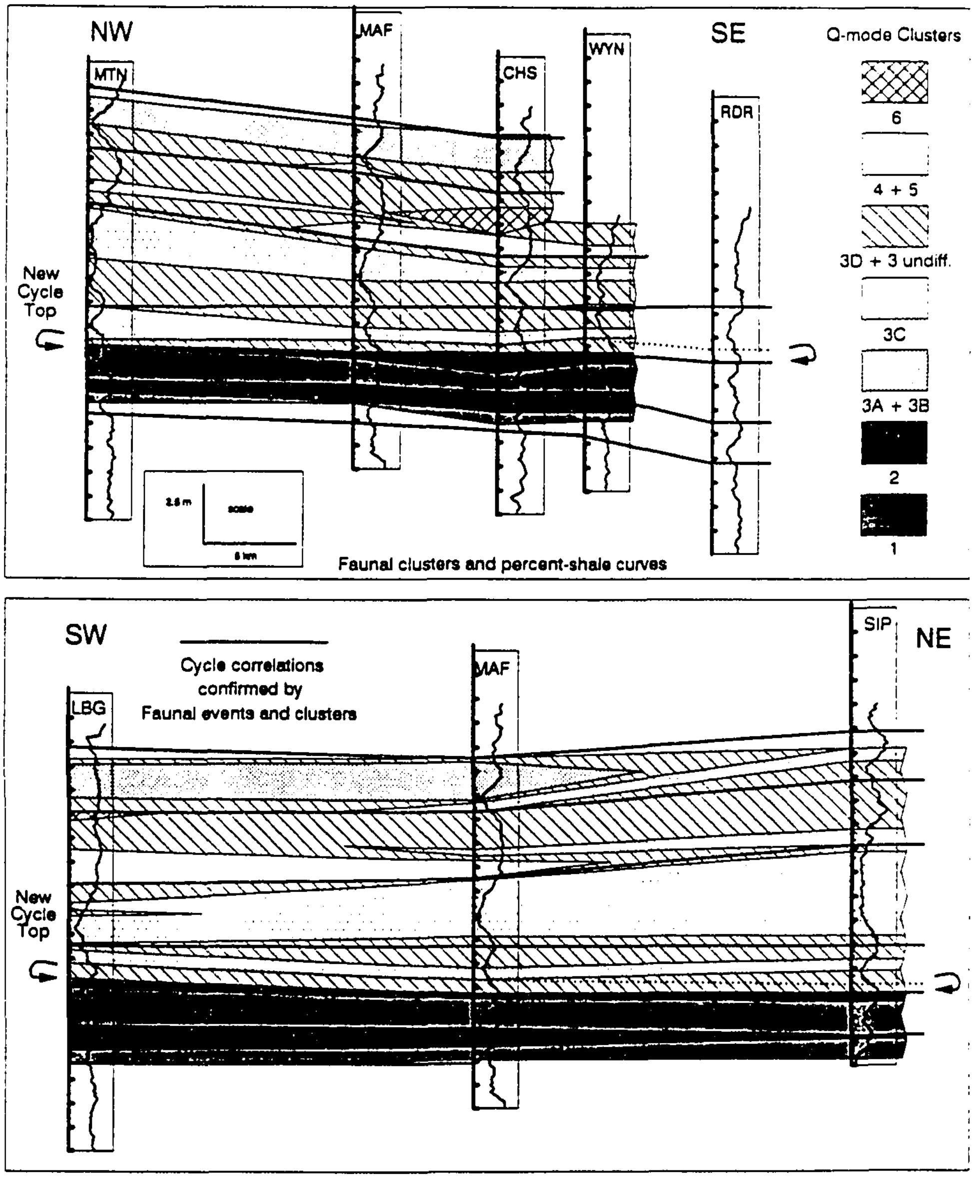


brachiopod-bryozoan-dominated samples in Q-mode cluster 1 to molluscan-dominated samples in Q-mode cluster 5.

R-mode cluster I contains three trilobite genera and two crinoid genera. It is also characterized by the brachiopod *Plectorthis* and the cryptostome *Escharapora*; it cluster I fauna is concentrated in samples of Q-mode clusters 1 and 2. R-mode cluster II contains most of the brachiopods common to the Fairview Formation and Bellevue Tongue, and thus represents a typical Cincinnatian association, typified by *Zygospira*, smooth encrusting trepostomes, cryptostomes, and *Platystrophia*. This fauna is more evenly distributed than other faunas, occurring most sparsely in cluster 1. R-mode cluster III represents the gastropod-bivalve-dominated assemblage typical of the Miamitown Shale, and is characterized by the gastropod *Loxoplocus bowdeni*. This fauna is common in the samples of Q-mode clusters 1 and 3C, and dominates cluster 4. Finally, cluster IV fauna, which includes *Ambonychia* and nuculoid pelecypods, can be described as pelecypod-dominated; it is best represented in Q-mode clusters 4 and 5.

Cluster-based correlations. - Q-mode clusters were placed in a stratigraphic context by mapping them onto the cross sections with lithology- and event-based correlations; the result was that all remaining ambiguities were effectively constrained (Fig. 4-11). For example, the distribution of Q-mode clusters 1 and 2 constrain correlation between the lowermost cycles; within these cycles the relative importance of cluster 1 increases to the northwest: cluster 2 samples are restricted to the upper, limestone-rich facies of each cycle, while cluster 1 samples are restricted

Fig. 4-11. Cross sections showing the stratigraphic distribution of Q-mode (sample) clusters, and additional cycle correlations; compare Fig. 8. Note how the distribution of clusters 1 and 2 constrain the correlation of the lowermost cycles. Clusters 3A and 3B clearly correspond to the upper part of the uppermost cycle in the NW to SE cross section, and at the Lawrenceburg locality (LBG) the distribution of these clusters provides an important correlation key.



to the lower, shale-rich facies. Because the shale component of each cycle thickens toward the northwest (Fig. 4-11, shale-percentage curves), it is reasonable that cluster 1 samples cover a correspondingly thicker stratigraphic range.

However, the abrupt biofacies transition from clusters 1 and 2 to overlying clusters 3 and 4 is not reflected in the distribution of shale or any other observed lithofacies. Since there is no evidence of intertonguing between these two biofacies groups at any of the six outcrop sections, I conclude that this abrupt transition represents an isochronous event surface, at least over the limited geographic extent of the study area.

Clusters 3A and 3B clearly correspond to the upper part of the uppermost cycle in the NW to SE cross section (Fig. 4-11). There the cycle is easily recognized in shale-percentage curves from its shaly base, but at the Lawrenceburg locality (LBG), in the SW to NE cross section, the shale-rich zone is not apparent, and the distribution of these clusters provides an important correlation key.

Faunal ordination

Faunal ordination and ecostratigraphy. - Faunal ordination techniques are used to organize ecological data in such a way that taxa or samples are arranged in a low-dimensional space so that similar entities are close together and dissimilar entities are separated from each other (Gauch 1982). The dimensions of the resulting space are termed axes, and the position coordinates along these axes are termed scores or loadings. The only data used in ordination are the abundances of different taxa among samples, and environmental interpretations are made subsequently.

The scores or loadings of each ordination axis may reflect one or more environmental gradients such as temperature, light intensity, turbidity or substrate type. Many environmental parameters co-vary along a complex gradient controlled by water depth (e.g. Cisne & Rabe 1978); this is frequently reflected in faunal distributions and ordination scores. Plotted stratigraphically, these ordination scores form relative water-depth curves which can be related to glacio-eustatic sea-level fluctuations and used to correlated from locality to locality (Cisne & Rabe 1978; Rabe and Cisne 1980). Because this stratigraphic information is not available from cluster analysis, faunal ordination is a useful fifth step in the iterative correlation approach (Fig. 4-4).

Ordination techniques.- From the point of view of ecological interpretation, an ordination technique or algorithm should ideally arrange samples in an order that reflects an environmental gradient. This is also important for stratigraphic work, particularly if correlation is based on cyclic environmental fluctuations; a distortion of faunal gradient patterns can create erroneous points of correlation.

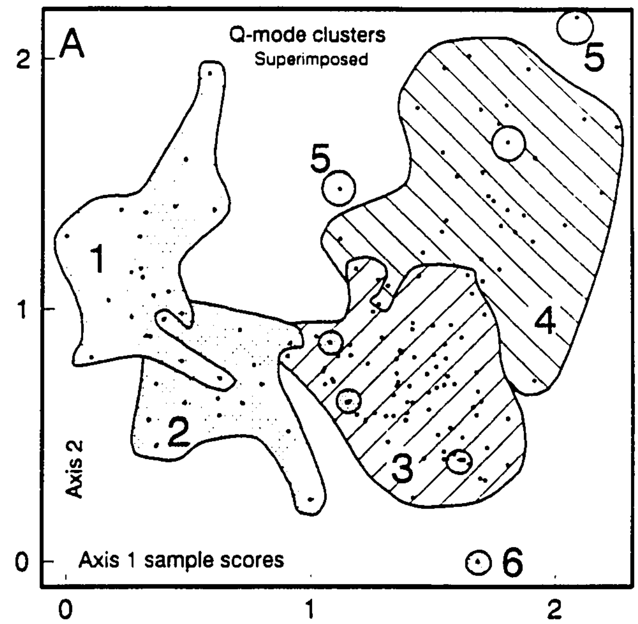
Hill & Gauch (1980) utilized a Gaussian model of ecologic gradients to demonstrate that detrended correspondence analysis (DCA) reflects ecologic gradients better than other ordination techniques available at that time. Despite the diverse factors that may create non-Gaussian fossil distributions (evolutionary change, climatic shifts and migration), detrended correspondence analysis is probably the best ordination technique available for stratigraphic purposes, but this remains untested.

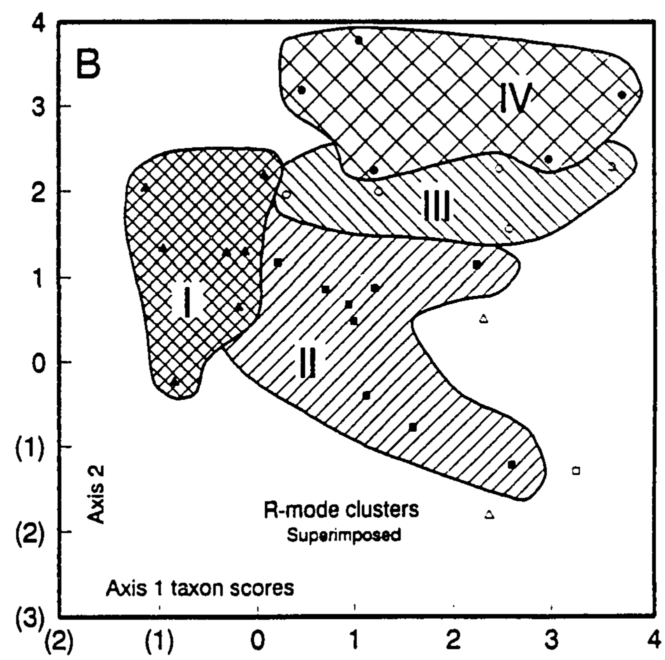
For this reason, I chose to apply detrended correspondence analysis to the percent- and log-transformed data matrix. The computer program CANOCO version 3.10 written by ter Braak, Agricultural Mathematics Group in 1990, was used to execute detrended correspondence analysis (DCA), with a 26-segment detrending; four DCA axes were examined. In this paper I discuss ordination of faunal samples in terms of the first two axes of detrended correspondence analysis; these axes show stratigraphic patterns of cyclicity at two different scales.

Ordination structure. - Together, axes 1 and 2 of detrended correspondence analysis account for 26.8% of the total faunal variability of the data matrix. By relating cluster analysis results (Fig. 4-9) to DCA sample scores (Fig. 4-12A) and taxon scores (Fig. 4-12B), gradient interpretations can be made with respect to each axis. Direct comparisons between sample scores (Fig. 4-12A) and taxon scores (Fig. 4-12B) reflect the relationship between the two: low scoring samples contain more low scoring taxa and high scoring samples contain more high-scoring taxa as defined by the DCA algorithm.

DCA Axis 1 (Fig. 4-12) reflects the same gradient structure shown by two-way cluster analysis (Fig. 4-9); major Q- and R-mode clusters, indicated by patterned areas in Fig. 4-12A and Fig. 4-12B, are arranged in the same order along DCA axis 1 as in the two-way cluster diagram (Fig. 4-9) with minimal overlap between all but Q-mode clusters 3 and 4. The same taxon-sample relationships are

Fig. 4-12. Bivariate Ordination Plots of Detrended Correspondence Analysis (DCA) scores showing distribution of clusters against axis 1 and axis 2. □A. Q-mode clusters in sample ordination space. □B. R-mode clusters in taxon ordination space.





also apparent along this axis as with cluster analysis (Fig. 4-9). For example, the two-way cluster analysis diagram shows that samples of Q-mode clusters 1 and 2 are rich in taxa from R-mode cluster I (see Fig. 4-9); samples and taxa have low ordination scores on axis 1 (compare Fig 4-12A, B). Higher scoring samples of Q-mode clusters 4 and 5 are rich in higher scoring taxa of R-mode clusters III and IV (Fig. 4-12A, B).

Along axis 2, a different aspect of faunal variability is apparent. Here samples from clusters 2, 3, and 6 score equally low and samples from clusters 1, 4, and 5 score high (Fig. 4-12A). Taxon scores (Fig. 4-12B) show that high-scoring samples are rich in mollusks of R-mode clusters III and IV, while low scoring samples contain more of the larger brachiopods of R-mode cluster II.

Further refinements of correlation. - To interpret sample ordination scores stratigraphically, They were plotted them against stratigraphic position at each of the six sampled localities (Fig. 4-13, 4-14). The resulting curves resemble percent-shale logs and can be correlated by similar means; here they were correlated by matching curve shape within the reasonable bounds of previously established correlations. Figs. 4-13 and 4-14 represent these ordination-based correlations. The highest scores at each locality are correlated by heavy dotted lines, and other high-score (seen as "peaks" in an ordination curve) correlations are represented by lighter-weight lines. Similarly, dashed lines represent correlations of low scores (or "troughs").

Fig. 4-13. DCA Axis 1 Sample scores (range standardized between 0 and 1) superimposed on the shale-percentage curve for each of the seven localities. Samples with lowest and highest scores at each locality (recognized as major peaks or troughs in each plot) are correlated throughout the cross sections by heavy dashed and dotted lines respectively. Lighter dashed and dotted lines represent correlations of samples with low or high scores relative to adjacent samples (minor peaks or troughs). Note how well these correlations match the correlations established in previous steps (heavy solid lines).

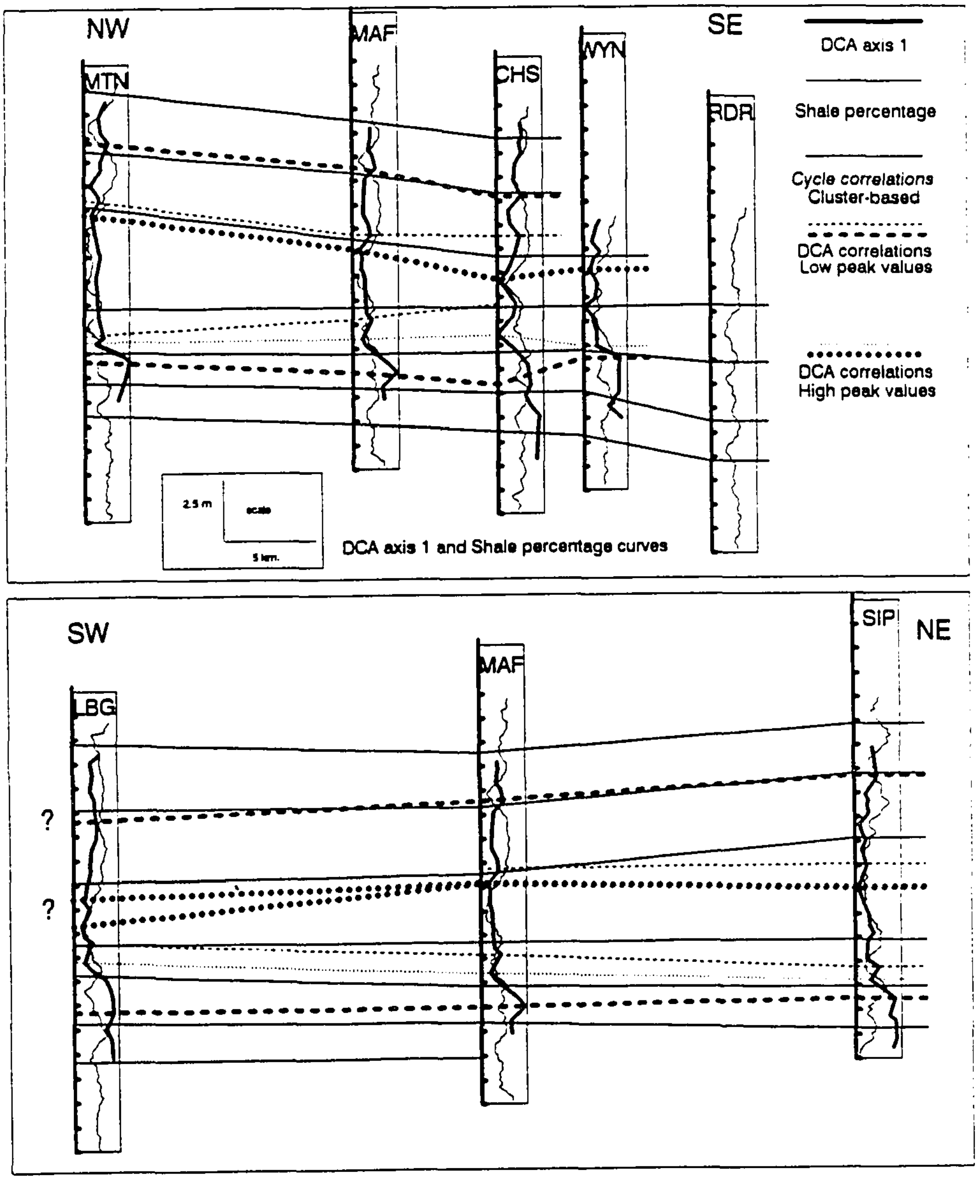
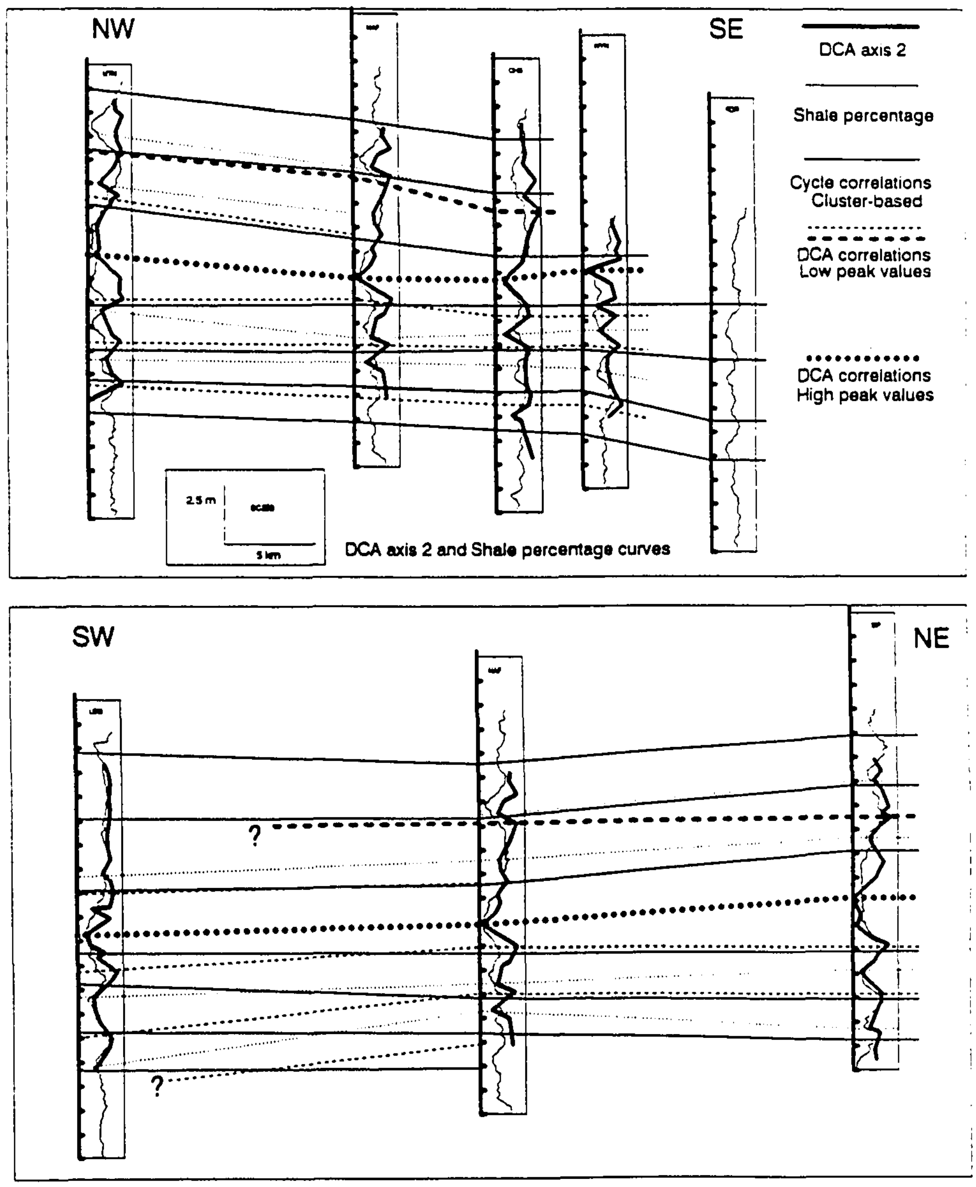


Fig. 4-14. DCA Axis 2 Sample Scores plotted on the stratigraphic cross sections reveal meter-scale faunal cyclicity as well as the larger-scale pattern apparent from axis 1 (Fig. 13). Correlations indicated as in Fig. 13. Note that in the SW to NE cross section the lower correlations between the Lawrenceburg (LBG) and Mount Airy Forest (MAF) localities are discordant with correlations developed through Cluster analysis (solid; Fig. 11) and DCA Axis 1 (Fig. 4-13).



The stratigraphic sequence of axis 1 scores is distinctive and various features are easily recognized at each of the six sampled localities (Fig. 4-13). Scores are very low near the base of the sequence only, and the transition from the low to the high scoring interval is abrupt. Because low sample scores correspond to Q-mode clusters 1 and 2, the same abrupt transition is reflected in the limited distribution of these clusters (Fig. 4-11). Toward the top of the sampled interval, sample scores approach lower values, but do not quite reach those of the basal interval. Geographically, sample scores above the basal interval are generally higher in the southern parts of the study area at the Rice and Gage Streets (CHS), and Lawrenceburg (LBG) localities.

The basal parts of these ordination curves are extremely easy to correlate by eye. The upper part of the section where the pattern is not so distinctive can be correlated by a second occurrence of relatively low-scoring samples. This interval is more difficult to identify at the Lawrenceburg (LBG) section, and the correlation is questionable. The highest scoring samples are generally the gastropod-rich packstones near the middle of the interval (compare Fig. 4-8), and again, the correlation is ambiguous at the Lawrenceburg locality.

The correlation between axis 1 scores and shale logs at each locality is apparent only in a general way (Fig. 4-13), and smaller-scale cyclicity is reflected only weakly. This axis seems to respond to fourth-order cyclicity, and if there is a relative sea-level component to the original environmental gradient that caused this pattern, it seems most reasonable that low scores correspond to shallower water and higher scores correspond to deeper water. This interpretation is derived not only from the larger-scale lithologic cyclicity of the interval (Fig. 4-3), but also from the scores of some key faunal elements. *Heterorthina fairmountensis*, for example, is a dalmanellid with a high axis 1 score, and other dalmanellids are consistently associated with deeper-water facies as interpreted by lithologic and taphonomic criteria--they are particularly abundant in the Kope Formation (see Fig. 4-3), and are relatively rare in the Fairview Formation. If this depth interpretation is correct, then ordination scores reveal a transgressive surface near the base of the interval followed by further deepening to a maximum depth at the interval of the gastropod packstones, and then a rapid but continuous shallowing toward the upper part of the Bellevue Tongue. This interpretation would also suggest shallower water toward the southern part of the study interval, which conforms to independent interpretations of ramp geometry in the Cincinnati area (Ford 1967). Note that these depth interpretations, particularly the transgressive surface, cannot be made from the distribution lithology and faunal clusters alone; ordination is a required step.

Axis 2 sample scores (Fig. 4-14) form a stratigraphic pattern that corresponds more to meter-scale cyclicity than Axis 1 scores. Higher-scoring samples come from the shale-rich lower facies of each cycle, and lower-scoring samples come from the upper, limestone-rich facies. This results in a close correspondence between sample scores and shale-percentage logs at the meter scale. The larger-scale pattern is subdued, and consequently, cycles from different intervals are similar. Thus, in contrast to axis 1 scores, correlations between axis 2 curves cannot easily be made without reference to independent correlation criteria.

With minimal guidance of previously made correlations (lithology, event, and cluster based), a stratigraphic interval of maximum sample scores can be identified near the middle of the study interval (heavy dotted line, Fig. 4-14). Note that this maximum corresponds closely but not precisely with the axis 1 maximum (Fig. 4-13). It occurs in the most shaly, least fossiliferous part of the sections. Minimum scores occur near the top of the interval and are correlated with a heavy dashed line (Fig. 4-14). This correlation line is not extended to the Lawrenceburg locality because the precise interval is not apparent. The remaining correlations are based on comparison of minor curve fluctuations between these first two correlation lines.

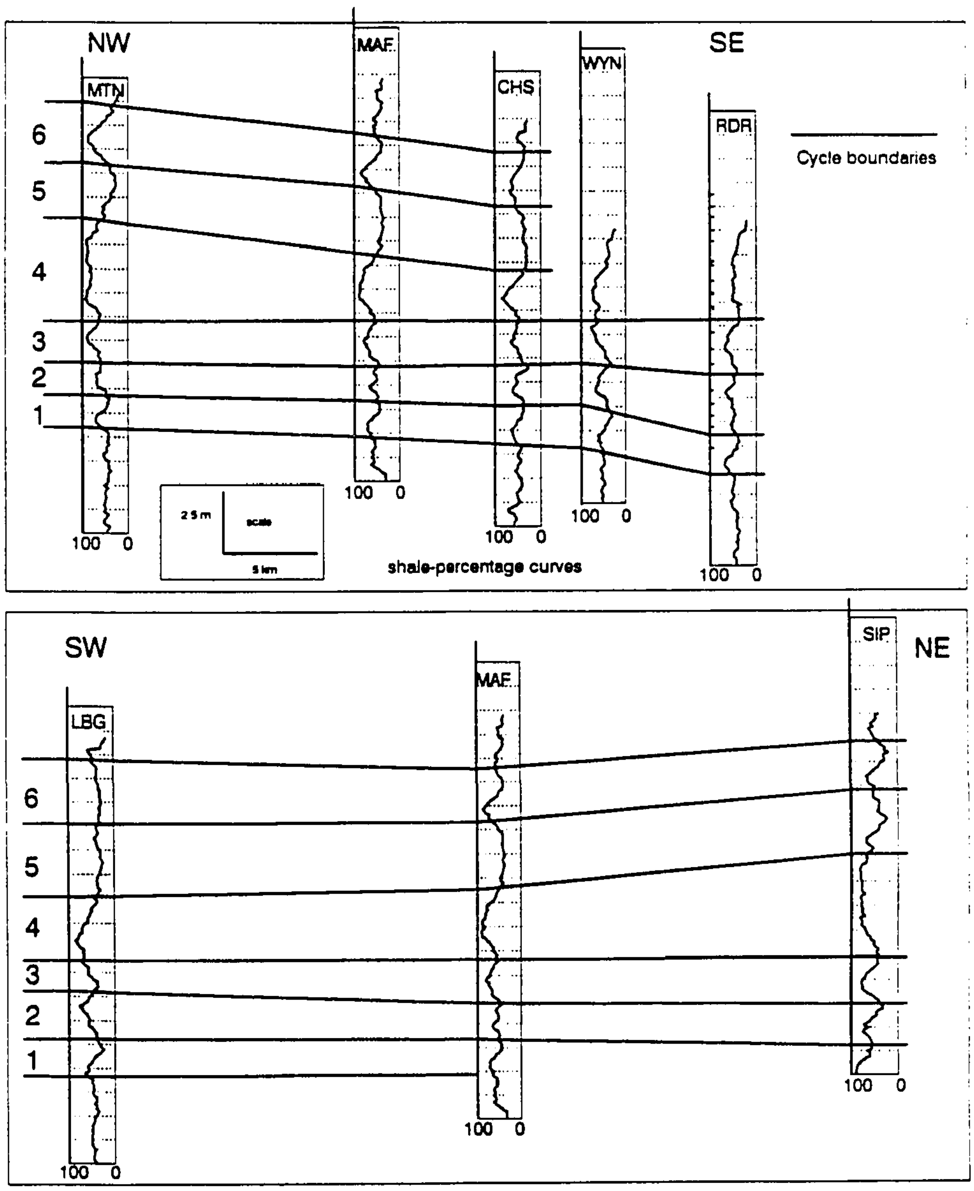
Note that correlations to the Lawrenceburg locality (LBG) in the lower part of the stratigraphic interval (Fig. 4-14) are discordant with correlations based on axis 1 scores (Fig. 4-13) and clustering criteria (Fig. 4-11). The discordant correlations are not based on a distinctive pattern but they were made on the assumption that cycles are of approximately equal thicknesses at different localities. The other correlation criteria require that one cycle (correlated just below the *Heterorthina fairmountensis* datum see Fig. 4-14) should be thinner by a factor of approximately 0.5. This means that the cycle is so thin that it is not clearly expressed by the sample spacing, or it does not contain the same faunal patterns at this locality (LBG). It was concluded that cluster analysis and DCA axis 1 provide a more accurate correlation in this case, but, unfortunately, a thorough searching of the 4 m interval surrounding this surface did not reveal any specimens of *H. fairmountensis* for confirmation.

As discussed above, samples with high axis 2 scores contain an abundance of molluscan fauna, particularly *Ambonychia*, *Modiolopsis*, and *Loxoplocus*. Lingulid brachiopods are a key element in several cases (Fig. 4-12). Depth-related interpretations of this association are problematic. Bretsky (1969) correlated a similar association in the Ordovician Appalachian Basin with shallower depths, but Frey (1987) interpreted a molluscan-rich Cincinnatian interval as being deposited in deeper water. Silt and silty shale are common to these occurrences, and to the Miamitown Shale fauna; thus substrate type may be more important than depth for interpreting the distribution of this fauna (see Miller 1989, 1990 for a more explicit statement of this). The shaly lower facies of each cycle may represent more rapid deposition and more turbid water conditions than the upper limestone dominated facies. Most brachiopods may not have been able to thrive under such conditions while pelecypods and gastropods were better adapted. High sedimentation rates might also favor the preservation of aragonitic molluscan remains, which would otherwise dissolve rapidly on the sea floor.

Final correlations

Fig. 4-15 illustrates the final cycle correlations and designates a numbered sequence of cycles 1 through 6 in the study interval. Together, these cycles represent a framework from which detailed facies interpretations can be made. Shale-percentage curves in this diagram can be compared to evaluate these correlations, but the

Fig. 4-15. Stratigraphic cross-sections showing final cycle correlations (heavy solid lines) and numbered cycles. Note how cycle form, not amplitude, of shale-percentage curve correlates from locality to locality.



differential thickening of cycles can make this comparison difficult.

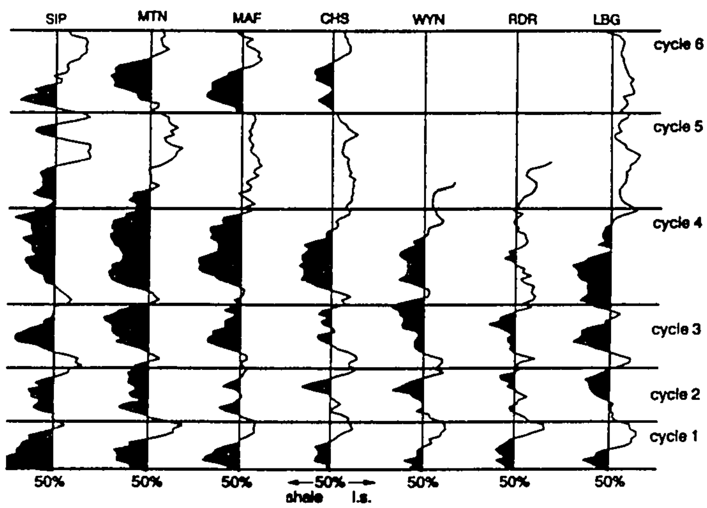
For this reason, measured-section data from each locality were divided into segments representing each of the six cycles delineated in Fig. 4-15. Each of these segments was then stretched or compressed digitally (by multiplication) to match the thickness of the correlative segment at Mount Airy Forest (MAF). When all of the segments of a given locality were thus transformed, I recombined them by addition. This method is geometrically identical to graphic correlation (Edwards 1989; Shaw 1964) where each section is standardized to the composite section (MAF) by line segments such that each cycle is represented by a separate line segment drawn between its lower and upper boundaries.

After each measured section was thus standardized to MAF cycle thicknesses, I generated a 50 cm percent-shale curve using the same methods as with raw measured section data. The resulting curves, graphed side by side, provide both visual and statistical means of comparison (Fig. 4-16). Note, for example, that while the curves show remarkably similar shapes, they contain different total shale contents (i.e. amplitudes differ), showing that curve shape transcends facies.

Table 1 compares maximum cross correlation values obtained from untransformed shale-percentage curves with the cross correlation values obtained from direct (0 lag) comparisons of these transformed curves. In all but a few cases, the correlations between thickness-standardized curves are higher.

Cyclic lithofacies reconstruction

Fig. 4-16. Shale-percentage curves generated from thickness-standardized sections provide a method for evaluation of final cycle correlations among all seven correlated outcrop sections. In this diagram, 50 cm shale-percentage curves are distorted in such a way that a given cycle is the same thickness at each locality. Black shading represents shale content beyond 50%. See text for an explanation of the methodology.

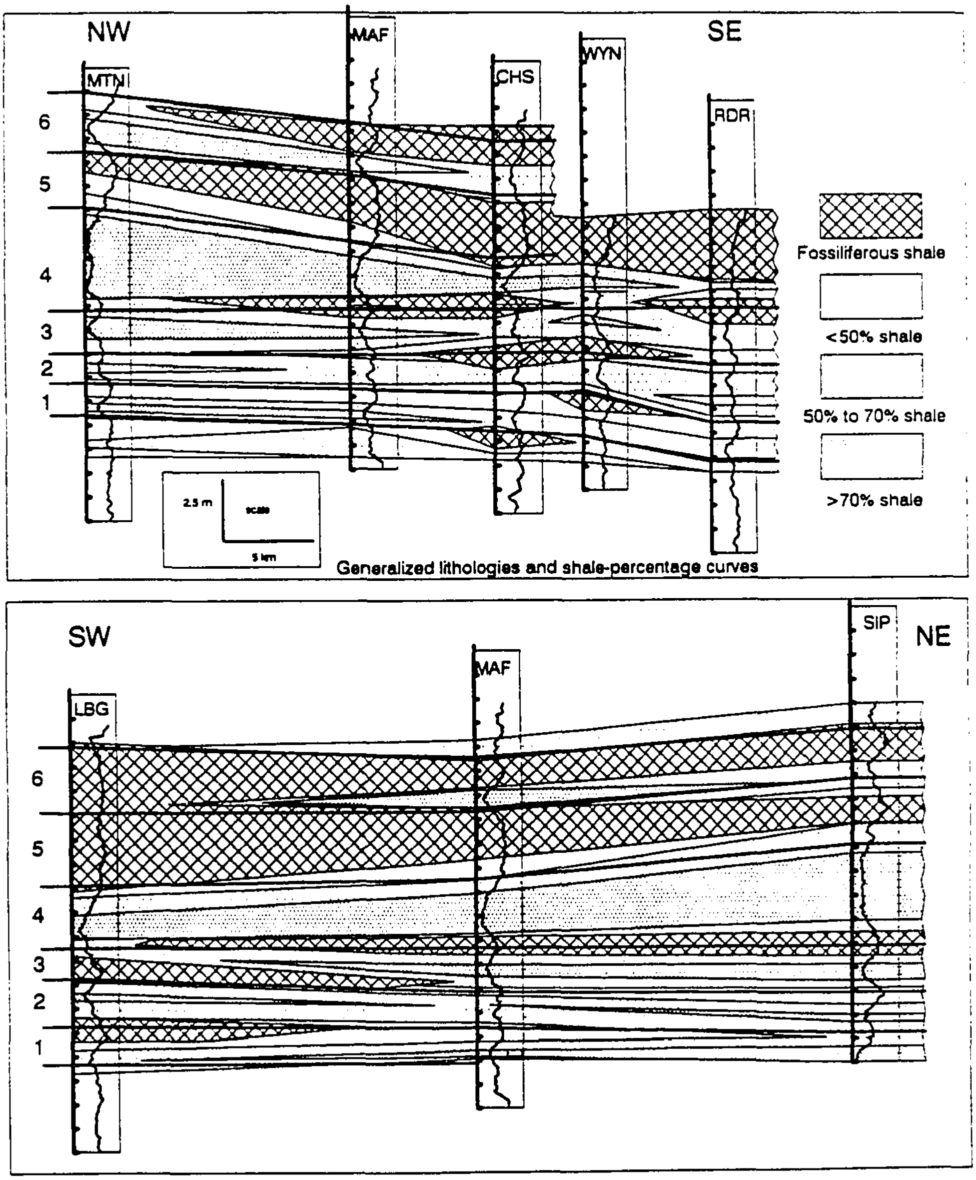


A dramatic demonstration of how cycle correlations transcend facies and how they can be used to better interpret facies is provided by mapping lithofacies within this high-resolution cyclic framework. In Fig. 4-17, shale-percentage facies were reconstructed from the same shale-percentage curves (100 cm averaged) used in correlation. An additional facies, fossiliferous shale, is also included. It was reconstructed from 100 cm averaged curves of fossiliferous-shale percentage. Correlations based on shale-percentage curves and faunal data cross facies established from the same lithologic curves. For example, the top of cycle 3, which coincides with the occurrence of *Heterorthina fairmountensis*, occurs in the Miamitown Shale at Miamitown (MTN), and transverses progressively more limestone-rich facies to the southeast, until at Riedlin Road (RDR) the Miamitown Shale can no longer be recognized. The cyclic signal is independent of facies, and the same cycles could, with care, be traced through even more dramatic facies transitions. More importantly, these high-resolution correlations establish a stratigraphic framework for interpreting the fine-scale distribution of facies and fauna. Thus it can be shown that the fossiliferous shale facies occurs as relatively localized (5 to 10 km) patches as compared to previous classifications (e.g. Fig. 4-3) where facies distribution could only be discussed in a regional context.

Sensitivity of biofacies patterns

Beyond providing constraints that are necessary for the refinement of high-resolution stratigraphic correlations, the faunal patterns of the study interval provide information not available from lithologic data alone. An abrupt ecological transition near the top

Fig. 4-17. Stratigraphic cross section showing distribution of facies types (patterns) and final cycle correlations. Facies types were reconstructed from the same shale-percentage curves used in correlation. An additional facies, fossiliferous shale, overlain on the shale-percentage facies, was reconstructed from 100 cm averaged curves of fossiliferous-shale percentage.



of cycle 2 is reflected clearly by the faunal transition seen in cluster distributions (Fig. 4-11) and in sample ordination scores (Fig. 4-13), but it is not apparent from lithologic patterns (Fig. 4-17). The stratigraphic position, ordination scores, and abrupt nature of this transition suggest that it might be a transgressive surface at the base of a fourth-order eustatic sea-level cycle (indicated in Fig. 4-3). This important surface would be difficult to recognize without faunal data.

Implications

From this analysis of the Miamitown Shale it can be seen that the combination of quantitative faunal analysis with lithology-based cyclic stratigraphy results in a powerful tool for high-resolution correlation within Paleozoic sediments. Sedimentary-faunal cycles can be reliably recognized and correlated through different facies and over several kilometers. The importance of these correlations lies in their chronostratigraphic significance. There have been many arguments set forth as to the temporal significance of meter-scale cycles (Goodwin & Anderson 1985; Kauffmann *et al.* 1991; Kauffmann 1986; Brett & Baird 1985; Vail *et al.* 1977). Jennette & Pryor (1993) have linked Cincinnatian cycles to eustatic changes in relative sea-level through the proximality concept of storm sedimentation (Aigner 1985), and they have suggested that these cycles are also isochronous.

Tobin (1982) and Tobin & Pryor (1981) estimated the duration of an average Cincinnatian Cycle as 57 ka based on sedimentation rates and cycle thicknesses. While this is a rough estimate of actual cycle durations, the conclusion is that the potential resolution of the Cincinnatian stratigraphic record is much higher than has generally been realized. The methods presented in this paper could be used to develop high-resolution correlations across the entire Cincinnatian outcrop area by careful integration with larger-scale studies such as the sequence stratigraphic (third-order sequences) framework provided by Holland (1993). The applicability of this methodology is not restricted to Cincinnatian rocks; it can be applied to any cyclic, fossiliferous sedimentary sequence.

As demonstrated by a simple lithofacies cross section (Fig. 4-17), the ultimate usefulness of high-resolution correlations in any stratigraphic sequence is that they provide a clear distinction between temporal and spatial patterns. This means that lithofacies and biofacies can be more easily interpreted, because they can be evaluated within a more precise framework of spatial variation. High resolution correlations are particularly valuable to the paleontologist who seeks to relate space and environment to evolutionary change. Without fine-scale chronostratigraphic correlations, it may be impossible to distinguish a migrating, evolving lineage from a population of organisms displaying ecophenotypic variation across an environmental gradient.

Summary and conclusions

The main contribution of this study is the development of a new approach to high-resolution cyclic stratigraphy based on a combination of lithofacies analysis, faunal event stratigraphy, and multivariate analysis of fossil abundance data. Correlations are made and improved sequentially, beginning with lithologic data analysis. Lithology-based correlations are constrained and refined by adding information step by step: first faunal events are correlated, then the distribution of biofacies, defined by faunal clusters, is used to further refine correlations. Finally, faunal ordination is used to correct and evaluate the correlations.

The result of this approach is that the final correlations are constrained by a number of independent lines of evidence, and some stratigraphic patterns are recognized that might not be detected without faunal data. Despite the use of lithofacies and biofacies information, these correlations outline a cyclic structure that, paradoxically, transcends facies. The method is effective for correlating meter-scale eustatic cycles over several km distance. The method is generally applicable, and its usefulness is not restricted to the Upper Ordovician of the Cincinnati area.

This approach is illustrated with a correlation of ca 12 m of section encompassing the interval immediately surrounding the Miamitown Shale (Ford 1967) in the Upper Ordovician of the Cincinnati area. As a result of this study, six meter-scale (fifth order) cycles have been recognized (Fig. 4-15) and the basal transgressive surface of a fourth-order cycle has been delineated precisely by faunal transitions (Fig. 4-11, 4-13).

These results show that the approach is effective in recognizing at least two different scales of cyclicity in the Cincinnatian Series, and provides a basis for more extensive work in the Cincinnati region and elsewhere.

CONCLUSIONS

The Miamitown Shale has been viewed as enigmatic because of its anomalous position in the upper, limestone-dominated part of an interpreted Edenian-Maysvillian shoaling-upward cycle, and because of its mollusk-dominated fauna. Consequently, the stratigraphic, environmental, and ecological interpretations of this unit are of interest with respect to the overall interpretation of Cincinnatian stratigraphy. The data and conclusions reported in this dissertation are the results of two separate studies of the Miamitown Shale. The first is a regional correlation of the broader Kope Formation-Bellevue Tongue interval throughout the 13,000 km^2 area between Cincinnati, Ohio, Indianapolis, Indiana, and Fort Wayne, Indiana. The second is a correlation of m-scale cycles within the 12 m interval surrounding the Miamitown Shale at six outcrop sections within a 30 km radius of Cincinnati, Ohio. The purpose of these studies was to shed light on the environmental interpretation of the unit, thus answering the question, *what is the Miamitown Shale?*

As discussed in this dissertation, the direct answer to this question involves a stratigraphic reinterpretation of the surrounding strata (Kope Formation, Fairview Formation, Bellevue Tongue) if not the entire Cincinnatian. The new stratigraphic interpretation is supported by data gathered in the large-scale study:

1) Three fourth-order sequences were recognized. These are named herein the *Brent Sequence* (comprising some of the Point Pleasant Tongue and the Kope Formation), the *Riedlin Sequence* (comprising the Fairview Formation, the

Miamitown Shale, and part of the Bellevue Tongue), and the *Stonelick Sequence* (comprising part of the Bellevue Tongue, the Corryville Formation, and part of the Mt Auburn Formation).

2) These sequences are not shoaling-upward, lacking significant transgressive systems tracts as has been interpreted (Tobin 1982; Holland 1990, 1993), but contain the same lowstand, shelf margin, transgressive, and highstand systems tracts in the same thicknesses that have been observed and generalized from other sequences (Van Wagoner *et al.* 1988).

3) The Riedlin Sequence is a type-2 sequence consisting of a thick shelf margin systems tract (lower half of the Fairview Formation), a transgressive systems tract (upper part of the fairview formation and lower part of the Miamitown Shale) and a highstand systems tract (upper part of the Miamitown Shale and lower part of the Bellevue Tongue).

4) *Thus, the Miamitown Shale marks the maximum flooding surface in the Riedlin Sequence.*

The finer-scale study provides support for this interpretation, and helps clarify the distribution pattern of the molluscan fauna. Beyond the detailed description of the Miamitown Shale interval, this study contributes a refinement of high-resolution ecostratigraphic correlation methods:

1) Faunal patterns confirm a deepening in the lower part of the Miamitown Shale and a shallowing toward the top, consistent with the maximum flooding surface interpretation.

2) Molluscan fauna is associated with higher terrigenous content of sediments, rather than deepening of water. This is indicated by the fact that the molluscan fauna occurs in the shale-dominated parts of m-scale cycles in addition to the Miamitown Shale proper.

3) Detailed correlations through the Miamitown interval reveal a complex of facies not observable at coarser scales.

4) Faunal cyclicity reflects lithologic cyclicity, and adds more information.

5) Abrupt faunal changes at the base of thick grainstone beds suggest that these beds are transgressive deposits rather than "capping grainstones" (Jennette 1986).

6) By combining faunal and lithologic data, m-scale cycles can be uniquely recognized and correlated over gaps of 10-20 km, and over distances of 60 km.

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APPENDIX 1: LOCALITY REGISTER

MIAMITOWN--MTN

Originally a roadcut on I-74 about 1 mile (1.6 km) W of Miamitown, Ohio; subsequently an interchange between I-74 and I-275 was constructed at the location; the locality consists of 6 roadcuts surrounding the various interchange roads; the measured section. Whitewater Township, Hamilton County, Ohio; 39°13'14"N, 84°44'10"W; UTM Zone 16, 4343499 N, 695446 E.

MT. AIRY FOREST--MAF

Series of large roadcuts on either side of I-74, between mile 15.6 and mile 16.8, where it passes through Mount Airy Forest; sec. 4, F.R.2, T.2, Cincinnati West, Ohio, 7.5-minute quadrangle (Ford, 1974), Green Township, Hamilton County, Ohio; 39°10'5"N, 84°34'52"W; UTM Zone 16, 438000 N, 709000 E.

RICE AND GAGE STREETS--CHS

Road cut at the intersection of Rice and Gage Streets, Cincinnati, Ohio, on the grounds of Christ Hospital, under the Christ Hospital Heliport; opposite 2227 Gage St., Cincinnati, Ohio; this locality is on a spur of the hill called Mount Auburn; the Jackson Hill Park locality (OH-HA-0018) is situated on the next spur to the south; sec. 13, R2, T3, city of Cincinnati, Covington, Kentucky--Ohio, 7.5-minute quadrangle (Ford, 1974; Luft, 1971), Hamilton County, Ohio; 39°07'45"N, 84°30'50"W; UTM Zone 16: 4332909 N, 714976 E; elevation at base: 663 ft (202.1 m).

WAYNE ROAD (DEVOU PARK)--WYN

Hill above picnic area west of Wayne Road on northwest corner of Prisoner's Lake, in Devou Park, Covington, Kentucky; Covington, Kentucky--Ohio, 7.5-minute quadrangle (Ford, 1974; Luft, 1971), Kenton County, Kentucky; 39°05'00"N, 84°32'14"W; UTM Zone 16, 4328712 N, 713048 E.

RIEDLIN ROAD/MASON ROAD--RDR

Road cuts along both sides of Riedlin Road/Mason Road, at the intersection with and east of Kentucky Route 16 (Taylor Mill Road); the intersection is 0.4 mile (0.6 km) north of I-275 (exit 79); Covington, Kentucky--Ohio, 7.5-minute quadrangle (Ford, 1974; Luft, 1971), Kenton County, Kentucky; 39°01'15"N, 84°30'30"W.

LAWRENCEBURG--LBG

Road cuts on either side of I-275 in Kentucky, 0.7 km (0.4 mi) south of the Ohio River across from Lawrenceburg, Indiana; Lawrenceburg, Indiana-Kentucky-Ohio, 7.5-minute quadrangle, Boone County, Kentucky; 39°05'46"N, 84°49'04"W; UTM 4329508 N, 688721 E, Zone 16.

SHARONVILLE INDUSTRIAL PARK--SIP

Exposure in upper half of field at Sharonville industrial park, situated at end of 800-foot (243-meter) lane north of Hauck Road and 0.4 mile (0.7 km) east of the intersection of Hauck and Reading Roads; Glendale, Ohio, 7.5-minute quadrangle, Sycamore Township, Hamilton County, Ohio; 39°17'38"N, 84°24'07"W.

BRENT

Composite section of roadcuts at the intersection of Kentucky Route 8 and Kentucky Route 445, and of roadcuts along the north side of I-275 just west of the Ohio River; Newport, Kentucky--Ohio 7.5-minute quadrangle, Campbell County, Kentucky; 3903'15"N, 8426'00"W.

STONELICK CREEK

Stream cuts along Stonelick Creek upstream and downstream of the Ohio Route 131 bridge; Newtonsville, Ohio 7.5 minute quadrangle, Stonelick Twp., Cleremont County, Ohio; 3910'40"N, 8406'43"W.

APPENDIX 2: STRATIGRAPHIC SURFACES IN WELLS

The following table contains specific stratigraphic positions of sequence stratigraphic surfaces in each of the wells used to construct the cross sections in Figs. 2-10 and 2-11. Information given for each well includes the state, county and permit number or farm name, and the datum elevation (generally kelly bushing or ground level) relative to sea-level in feet. Positions to stratigraphic surfaces are given in feet below datum. The following abbreviations for stratigraphic surfaces appear down hole from left to right on the table, and are explained in terms of sequence stratigraphy and Cincinnatian lithostratigraphy:

MFS	Maximum flooding surface for Stonelick Sequence, middle Corryville Formation.
STO	Stonelick Sequence boundary, base of phosphatic facies of upper Bellevue Tongue.
ps1	Parasequence flooding surface.
PSS	Parasequence set flooding surface, base of "second Miamitown".
ps1	Parasequence flooding surface, lower part of Bellevue Tongue.
MFS	Maximum flooding surface for Riedlin Sequence, Miamitown Shale, "*Heterorthina* zone".
ps3	Parasequence flooding surface, upper Fairview Formation.
ps2	"
ps1	", top of "*Strophomena* zone"
TS	Transgressive surface for Riedlin Sequence, base of "Fairmount Member", base of "*Strophomena* zone"
ps1	Parasequence flooding surface.
PSS	Parasequence set flooding surface.
ps1	Parasequence flooding surface.
PSS	Parasequence set flooding surface.
ps2	Parasequence flooding surface.
ps1	Parasequence flooding surface.
RIED	Riedlin Sequence boundary, base of North Bend Tongue of Fairview Formation.
ps1	Parasequence flooding surface, upper Kope Formation.
PSS	Parasequence set flooding surface, upper contact of Grand Avenue Member of the Kope Formation.
ps2	Parasequence flooding surface.
ps1	Parasequence flooding surface.
MFS	Maximum flooding surface for the Brent Sequence, "*Triarthrus* zone".
TRN	Upper surface of the Trenton Limestone.

Stat	County	Designation	Datum	MFS	STO	ps1	PSS	ps1	MFS	ps3	ps2	ps1	TS	ps1	PSS	ps1	PSS	ps2	ps1	RIED	ps1	PSS	ps2	ps1	MFS	TRENT
CROSS SECTION A																										
IN	Wells	sdh 336	853	689	705	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	794	797	NA	NA	NA	NA	841	980
IN	Blackford	37131	894	694	699	NA	723	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	803	807	NA	NA	NA	NA	840	995
IN	Jay	32709	945.1	571	581	NA	603	NA	622	NA	NA	652	656	NA	NA	NA	NA	NA	695	698	NA	NA	NA	NA	746	928
IN	Jay	39099	1063.	728	736	NA	757	767	782	782	NA	819	822	NA	NA	NA	NA	NA	870	876	884	892	902	914	924	1147
IN	Randolph	30922	1117	690	705	NA	730	743	759	NA	776	787	790	NA	NA	NA	NA	NA	838	842	858	867	877	890	894	1118
IN	Randolph	welch 1	1169.	720	738	NA	763	775	790	798	809	821	826	835	845	850	856	865	876	880	892	900	907	917	923	1172
IN	Randolph	21420	1154	636	646	658	674	683	692	708	719	726	730	739	748	758	764	775	785	790	800	807	814	823	832	1110
IN	Wayne	sdh 57	1028	464	483	492	508	520	530	540	552	560	565	576	582	590	600	610	622	628	NA	644	NA	NA	662	1013
OH	Preble	3023	1150	568	580	590	607	615	624	638	645	654	660	667	679	686	697	710	724	729	738	748	757	766	774	1134
OH	Butler	2982	940	276	289	295	306	314	328	337	348	355	360	370	378	391	402	412	427	431	449	462	466	474	480	840
OH	Butler	2981	1012	315	328	335	347	354	364	372	379	388	393	404	413	422	435	447	458	464	481	490	497	504	511	874
OH	Hamilton	brisbin # 1	815	40	48	54	69	76	85	100	105	113	116	130	137	148	156	169	179	186	198	210	219	226	234	565
CROSS SECTION B																										
IN	Hendricks	20747	762.6	946	956	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1220
IN	Marion	30np	737	690	697	NA	NA	NA	718	NA	NA	730	731	NA	753	NA	769	NA	NA	787	NA	NA	NA	NA	NA	989
IN	Marion	16866	842	790	797	NA	NA	NA	823	NA	NA	833	835	NA	866	NA	883	NA	NA	894	NA	NA	NA	NA	NA	1100
IN	Shelby	35789	789.5	512	521	NA	533	NA	548	NA	557	567	571	NA	597	606	615	626	634	640	NA	654	NA	NA	NA	859
IN	Shelby	36640	820.4	498	510	515	521	532	538	550	560	567	571	583	593	602	613	622	631	637	NA	648	NA	NA	NA	866
IN	Rush	30282	964	439	448	456	470	479	485	497	506	514	518	530	536	552	562	572	585	590	NA	603	609	618	626	843
IN	Rush	29686	1065	512	526	537	548	558	564	575	580	584	591	596	602	614	622	635	652	656	665	673	678	685	690	967
IN	Fayette	29731	825	286	300	312	323	332	344	350	360	364	368	374	380	386	394	404	422	428	442	455	460	466	472	792
IN	Fayette	27052	959	340	355	365	376	386	396	404	414	418	421	426	435	445	456	466	481	490	506	516	522	529	534	896
IN	Union	21519	1002	352	363	374	382	395	408	414	424	429	433	443	451	462	471	486	498	504	522	532	538	546	553	821
OH	Butler	2982	940	276	289	295	306	314	328	337	348	355	360	370	378	391	402	412	427	437	449	462	466	474	480	840
OH	Butler	crist #1	990	340	360	366	376	384	399	410	422	428	432	441	454	468	478	490	500	506	523	534	546	555	565	955
CROSS SECTION C																										
IN	Jay	32709	945.1	571	581	NA	603	NA	622	NA	NA	652	656	NA	NA	NA	NA	NA	695	698	NA	NA	NA	NA	746	928
IN	Delaware	40797	958	570	581	NA	610	NA	624	NA	NA	650	652	NA	NA	NA	NA	NA	700	703	NA	NA	NA	NA	738	916
IN	Delaware	15754	983	558	566	NA	588	NA	615	NA	NA	642	645	NA	NA	NA	NA	NA	704	706	NA	NA	NA	NA	743	914
IN	Randolph	29474	1153.	655	663	NA	692	NA	717	NA	730	742	745	NA	758	NA	771	785	804	806	823	827	NA	NA	850	1052
IN	Henry	30510	1032.	569	579	592	608	NA	627	NA	647	658	660	667	677	686	692	705	724	729	738	745	NA	NA	759	943
IN	Henry	30314	1086	526	538	547	554	563	580	592	602	609	614	620	628	633	642	648	670	674	688	695	NA	NA	712	915
IN	Wayne	42612	1021	425	436	446	463	470	478	492	503	510	514	522	528	536	543	555	577	582	596	606	NA	NA	624	858
IN	Fayette	29973	919	307	325	340	348	358	370	376	382	386	390	395	404	412	420	431	448	456	468	480	490	496	500	810
IN	Fayette	29731	825	286	300	312	323	332	344	350	360	364	368	374	380	386	394	404	422	428	442	455	460	466	472	792
IN	Franklin	29232	959	422	440	449	460	469	480	486	496	504	508	514	525	533	543	553	560	566	584	593	600	606	612	947
IN	Decatur	29547	1061	498	506	511	520	532	540	550	560	564	569	578	587	593	601	617	627	630	640	653	660	667	672	973
IN	Decatur	sdh 124	942	348	366	374	380	NA	397	404	420	426	428	437	445	455	467	479	487	490	502	512	523	529	538	860
IN	Decatur	35122	836	435	450	455	462	467	476	488	501	508	513	517	523	528	538	545	554	558	573	579	587	593	600	873
IN	Decatur	37046	791	436	445	450	456	470	480	487	505	512	517	522	530	NA	544	548	556	560	580	587	593	602	614	894

APPENDIX 3: MEASURED SECTIONS

Measured sections are presented as a series of paired numbers: the first number represents the number of meters from the bottom of the section to the top of the unit, and the second represents the lithology of that unit. All measurements, including cores, are given from the bottom to the top of the section. The following key indicates the lithologies coded.

1. Shale.
2. Shale, silty.
3. Siltstone, calcareous siltstone.
4. Calcisiltite, very little terrigenous material.
5. Shale, fossiliferous, extremely calcareous.
6. Packstone, molluscan whole-fossils.
7. Packstone, whole-fossils.
8. Packstone, fragmental, washed.
9. Grainstone, finely comminuted, calcarenite.
10. Grainstone, crinoid rich, encrinite.
11. Grainstone, phosphatic.
12. Packstone, washed, wavy-bedded or "nodular".
13. Shale/siltstone nodules.
14. Calcisiltite, terrigenous.
15. Phosphate, nearly pure.

MTN--MIAMITOWN TYPE SECTION

0.040	1	4.015	1	8.709	8	13.885	8	17.135	7
0.065	3	4.202	8	8.755	1	13.900	1	17.150	1
0.151	1	4.220	1	8.769	8	13.925	6	17.242	8
0.205	3	4.229	8	8.780	3	13.940	1	17.281	5
0.285	1	4.318	1	8.835	1	13.960	8	17.310	8
0.400	11	4.395	8	8.985	8	13.970	1	17.320	1
0.439	1	4.400	1	9.059	5	14.050	8	17.355	8
0.502	10	4.410	8	9.070	8	14.090	1	17.365	5
0.590	1	4.592	1	9.165	5	14.100	3	17.415	8
0.643	8	4.645	7	9.170	8	14.128	1	17.469	5
0.645	1	4.781	1	9.209	1	14.160	3	17.490	8
0.721	8	4.792	3	9.220	8	14.200	9	17.530	1
0.725	1	4.940	1	9.360	1	14.240	1	17.545	8
0.769	8	4.951	4	9.381	3	14.355	8	17.569	1
0.797	1	5.049	1	9.582	1	14.440	7	17.580	8
0.803	8	5.055	8	9.593	3	14.485	8	17.625	5
0.962	1	5.103	1	9.729	1	14.539	5	17.660	8
0.989	8	5.215	8	9.739	3	14.546	8	17.675	1
1.043	1	5.310	1	9.770	1	14.575	1	17.702	8
1.231	8	5.485	8	9.781	3	14.660	8	17.725	1
1.320	1	5.493	1	10.239	1	14.720	1	17.755	8
1.322	5	5.605	8	10.250	3	14.760	8	17.775	1
1.395	1	5.619	1	10.320	1	14.782	5	17.795	8
1.501	9	5.741	8	10.370	8	14.791	8	17.840	1
1.630	1	5.778	1	10.490	1	14.830	5	17.945	10
1.711	9	5.785	8	10.501	3	14.871	8	17.955	1
1.799	8	5.980	1	10.643	1	14.890	3	17.965	8
1.903	1	6.049	3	10.719	3	14.901	8	17.970	1
1.962	9	6.240	1	10.777	1	14.948	3	17.980	8
2.043	1	6.288	5	10.791	3	14.980	8	17.985	1
2.055	8	6.391	8	11.030	1	15.030	5	18.000	8
2.082	1	6.615	1	11.040	3	15.060	8	18.005	1
2.125	8	6.675	7	11.089	1	15.112	5	18.020	8
2.135	1	6.745	1	11.105	3	15.150	8	18.040	1
2.220	8	6.753	8	11.228	1	15.208	1	18.095	9
2.225	1	6.765	1	11.250	6	15.255	8	18.120	1
2.252	3	6.785	8	11.430	1	15.275	1	18.135	13
2.298	1	6.813	7	11.461	6	15.420	8	18.180	1
2.355	11	6.860	1	11.922	1	15.520	1	18.250	9
2.395	1	6.869	3	11.950	3	15.533	3	18.300	0
2.406	8	7.050	2	12.120	1	15.600	1		
2.497	1	7.075	8	12.160	6	15.610	3		
2.555	8	7.095	1	12.380	1	15.630	1		
2.560	1	7.205	8	12.391	3	15.645	11		
2.622	8	7.245	1	12.525	1	15.685	5		
2.635	1	7.253	8	12.531	3	15.700	12		
2.678	8	7.280	1	12.712	1	15.720	5		
2.703	1	7.299	8	12.840	6	15.750	8		
2.801	8	7.305	1	12.960	1	15.783	5		
2.891	1	7.399	8	13.111	6	15.845	10		
2.911	8	7.405	1	13.320	1	16.035	1		
2.930	1	7.415	8	13.331	6	16.045	3		
2.945	8	7.549	1	13.345	1	16.130	1		
2.968	1	7.552	5	13.370	6	16.149	3		
3.101	8	7.585	1	13.435	1	16.215	1		
3.180	1	7.645	8	13.521	6	16.230	3		
3.252	8	7.849	1	13.550	1	16.330	1		
3.288	1	7.856	3	13.630	8	16.340	3		
3.353	8	7.950	1	13.635	1	16.530	1		
3.504	1	7.979	7	13.650	6	16.540	3		
3.517	8	8.109	1	13.700	1	16.811	1		
3.659	1	8.120	3	13.730	8	16.860	7		
3.718	3	8.289	1	13.820	1	17.010	1		
3.732	1	8.293	3	13.840	8	17.015	9		
3.948	8	8.651	1	13.860	1	17.090	1		

MAF--MOUNT AIRY FOREST COMPOSITE SECTION

0.200	8	2.980	1	5.270	8	8.770	1	11.210	1	14.000	1
0.270	1	3.025	8	5.275	1	8.825	3	11.225	8	14.040	8
0.301	8	3.050	3	5.300	8	8.840	1	11.278	5	14.100	5
0.345	1	3.060	12	5.395	1	8.860	13	11.295	12	14.130	8
0.365	8	3.070	1	5.405	8	9.080	1	11.325	2	14.240	5
0.420	1	3.080	12	5.650	1	9.155	6	11.360	8	14.250	12
0.522	8	3.085	1	5.670	8	9.300	1	11.395	5	14.348	1
0.555	1	3.105	12	5.765	1	9.355	8	11.405	12	14.370	8
0.575	8	3.140	5	5.785	3	9.360	1	11.435	5	14.390	1
0.630	1	3.150	8	5.860	1	9.400	8	11.500	8	14.465	8
0.775	8	3.170	1	5.913	8	9.408	1	11.503	1	14.485	1
0.820	1	3.180	8	6.095	1	9.458	8	11.515	8	14.581	8
0.830	3	3.195	1	6.195	8	9.464	1	11.560	1	14.740	1
0.925	1	3.205	8	6.355	1	9.498	8	11.625	8	14.760	8
0.935	3	3.215	1	6.390	8	9.515	1	11.680	1	14.830	1
1.089	1	3.318	8	6.400	1	9.555	8	11.725	8	14.880	8
1.105	8	3.338	1	6.438	8	9.580	1	11.765	1	14.935	1
1.178	1	3.378	8	6.490	5	9.620	8	11.825	8	14.965	8
1.189	8	3.409	1	6.505	8	9.690	1	11.880	1	15.010	1
1.197	1	3.440	8	6.625	1	9.720	8	11.945	8	15.070	8
1.311	8	3.515	1	6.630	12	9.750	1	11.946	1	15.105	1
1.355	1	3.540	3	6.640	1	9.770	8	11.960	12	15.175	8
1.360	8	3.595	1	6.650	12	9.780	1	11.965	1	15.300	1
1.397	1	3.605	8	6.660	1	9.830	8	11.985	12	15.348	8
1.422	3	3.670	1	6.670	12	9.885	1	11.990	1	15.350	1
1.500	1	3.685	8	6.685	1	9.905	8	12.005	12	15.402	8
1.565	8	3.729	1	6.705	5	9.930	1	12.070	5	15.408	1
1.590	3	3.735	8	6.715	12	9.940	8	12.100	1	15.450	8
1.652	1	3.780	1	6.740	5	9.950	1	12.118	8	15.530	5
1.670	12	3.790	8	6.760	12	9.990	3	12.120	1	15.555	8
1.680	1	3.845	1	6.792	1	10.025	1	12.140	8	15.685	1
1.695	12	3.995	8	6.810	12	10.040	3	12.240	5	15.785	8
1.700	1	4.015	1	6.820	1	10.080	1	12.265	8	15.835	5
1.710	12	4.030	8	6.840	8	10.197	8	12.270	1	15.905	8
1.711	1	4.060	1	6.900	5	10.240	1	12.285	8	15.945	1
1.723	12	4.110	8	6.940	1	10.300	8	12.335	1	15.980	8
1.724	1	4.130	1	6.980	8	10.305	1	12.360	6	15.983	1
1.740	12	4.148	8	6.995	1	10.310	3	12.495	1	16.001	8
1.750	1	4.360	1	7.020	8	10.390	1	12.545	6	16.005	1
1.770	12	4.383	3	7.065	5	10.440	8	12.748	1	16.048	8
1.773	1	4.449	1	7.100	8	10.445	1	12.750	5	16.050	1
1.790	12	4.545	8	7.165	1	10.500	8	12.975	1	16.097	8
1.792	1	4.560	1	7.185	8	10.530	5	13.032	6	16.100	1
1.800	12	4.630	8	7.220	1	10.540	8	13.055	1	16.140	8
1.875	8	4.640	1	7.270	3	10.560	1	13.075	12	16.155	1
2.072	1	4.698	8	7.340	1	10.600	8	13.305	1	16.160	8
2.078	3	4.760	1	7.360	3	10.630	5	13.335	8	16.245	1
2.105	1	4.770	8	7.520	1	10.645	8	13.410	1	16.285	8
2.115	3	4.810	1	7.530	3	10.670	5	13.440	8	16.356	1
2.178	1	4.820	8	7.665	1	10.700	8	13.455	1	16.360	8
2.213	8	4.865	1	7.675	3	10.720	5	13.515	8	16.400	1
2.470	1	4.915	8	7.880	1	10.735	12	13.525	1	16.410	8
2.500	8	4.940	1	7.890	3	10.800	5	13.567	8	16.415	1
2.555	1	4.950	8	8.095	1	10.820	8	13.625	5	16.425	8
2.590	8	4.970	1	8.105	3	10.895	5	13.635	12	16.430	1
2.608	1	4.990	8	8.185	1	10.925	8	13.720	5	16.440	8
2.625	8	5.000	1	8.210	3	10.985	5	13.755	8	16.470	1
2.700	1	5.005	8	8.230	1	11.000	8	13.785	5	16.475	8
2.845	8	5.030	5	8.240	13	11.020	5	13.795	12	16.555	1
2.870	1	5.040	12	8.265	1	11.030	12	13.825	5	16.625	8
2.880	8	5.098	5	8.275	13	11.050	5	13.835	12	16.715	1
2.910	1	5.130	8	8.330	1	11.060	12	13.872	5	16.735	8
2.920	8	5.135	1	8.395	6	11.080	5	13.920	8	16.800	0
2.960	1	5.170	8	8.500	1	11.120	2	13.945	5		
2.970	8	5.248	5	8.640	2	11.175	8	13.970	8		

CHS--CHRIST HOSPITAL EXPOSURE, RICE AND GAGE STREETS

0.145	8	3.480	1	6.139	1	9.745	13	11.550	8	12.925	1	14.903	12
0.555	1	3.500	3	6.330	8	9.820	1	11.680	5	12.945	12	14.935	5
0.615	8	3.540	1	6.360	5	9.830	13	11.690	12	12.950	1	14.960	8
0.645	3	3.560	3	6.375	12	9.845	1	11.705	5	12.960	12	14.985	5
0.693	1	3.595	1	6.420	5	9.855	13	11.720	12	12.985	1	15.045	8
0.855	8	3.610	3	6.430	12	9.945	1	11.730	5	13.000	12	15.085	5
0.875	1	3.630	8	6.490	5	9.950	7	11.740	12	13.025	1	15.110	8
0.880	8	3.718	1	6.500	12	9.960	3	11.750	5	13.040	12	15.120	5
0.897	1	3.730	8	6.540	5	10.000	1	11.764	12	13.075	1	15.145	8
0.910	3	3.743	1	6.560	8	10.010	13	11.766	5	13.133	8	15.225	5
0.940	1	3.753	8	6.600	5	10.025	1	11.780	12	13.160	2	15.235	12
0.960	3	3.762	1	6.665	8	10.083	8	11.785	5	13.170	12	15.255	5
1.065	1	3.785	8	6.718	5	10.095	1	11.800	12	13.190	2	15.260	12
1.213	2	3.805	1	6.730	8	10.113	8	11.835	1	13.235	8	15.295	5
1.460	8	3.813	8	6.790	5	10.135	1	11.860	8	13.285	5	15.303	12
1.487	1	3.840	1	6.860	8	10.175	8	11.870	5	13.340	8	15.390	5
1.513	3	3.878	3	6.870	1	10.205	1	11.880	12	13.350	1	15.400	12
1.572	1	3.940	1	7.003	8	10.212	13	11.890	5	13.360	12	15.430	5
1.595	3	3.950	3	7.055	1	10.245	1	11.897	12	13.365	1	15.460	12
1.623	1	4.000	1	7.135	8	10.250	13	11.910	5	13.375	12	15.510	5
1.645	3	4.010	7	7.320	1	10.275	1	11.917	12	13.395	1	15.535	8
1.662	1	4.055	1	7.375	8	10.285	13	11.935	5	13.405	12	15.538	1
1.670	8	4.093	8	7.410	1	10.315	1	11.945	12	13.485	1	15.552	8
1.703	1	4.115	1	7.435	6	10.355	8	11.965	5	13.500	8	15.555	1
1.795	8	4.165	7	7.489	1	10.370	5	11.985	8	13.585	1	15.580	8
1.835	1	4.220	1	7.555	8	10.435	6	12.015	5	13.625	8	15.582	1
1.865	8	4.250	3	7.640	1	10.510	5	12.025	8	13.690	1	15.599	8
1.903	1	4.365	1	7.685	3	10.550	4	12.045	5	13.692	5	15.601	1
2.002	8	4.405	7	7.755	1	10.608	1	12.055	8	13.710	1	15.620	8
2.020	1	4.460	1	7.825	4	10.685	8	12.085	5	13.760	4	15.640	1
2.030	8	4.548	8	7.830	1	10.708	5	12.108	8	13.775	1	15.655	12
2.040	1	4.568	1	7.910	8	10.715	12	12.125	5	13.780	8	15.685	1
2.046	8	4.665	7	8.180	1	10.740	5	12.130	8	13.807	1	15.710	12
2.070	1	4.678	1	8.280	8	10.750	12	12.170	5	13.860	5	15.740	1
2.080	3	4.690	8	8.285	1	10.785	5	12.205	8	13.900	8	15.750	12
2.110	1	4.705	5	8.290	8	10.810	8	12.225	1	13.980	5	15.775	1
2.120	3	4.715	12	8.335	1	10.815	5	12.245	8	13.990	8	15.815	8
2.170	1	4.730	5	8.340	8	10.820	8	12.300	1	14.010	1	15.855	5
2.200	8	4.745	12	8.380	1	10.855	5	12.310	5	14.020	8	15.910	8
2.220	1	4.770	5	8.415	8	10.880	8	12.320	1	14.040	1	15.940	1
2.245	8	4.780	12	8.440	5	10.920	5	12.340	12	14.050	8	16.010	8
2.248	1	4.805	5	8.450	8	10.955	8	12.345	1	14.060	1	16.020	1
2.260	8	4.810	12	8.508	5	10.975	5	12.360	12	14.070	8	16.050	8
2.264	1	4.825	5	8.545	8	10.980	12	12.380	5	14.095	1	16.090	5
2.388	8	4.835	12	8.585	5	11.000	5	12.405	12	14.150	8	16.110	12
2.435	1	4.875	5	8.615	8	11.010	12	12.410	1	14.245	1	16.140	5
2.493	8	4.925	8	8.685	5	11.100	5	12.430	12	14.250	13	16.170	12
2.765	1	4.940	1	8.725	8	11.175	8	12.445	5	14.365	1	16.190	5
2.940	8	5.040	8	8.750	5	11.195	5	12.455	12	14.380	7	16.272	8
2.960	5	5.080	1	8.760	12	11.220	8	12.465	5	14.385	1	16.305	1
2.973	12	5.130	3	8.810	5	11.250	5	12.473	12	14.400	3	16.325	8
3.025	5	5.145	8	8.820	12	11.260	12	12.485	5	14.480	1	16.340	1
3.067	9	5.197	1	8.860	5	11.295	5	12.490	12	14.510	8	16.350	3
3.090	5	5.272	4	8.870	12	11.340	8	12.540	5	14.520	1	16.510	1
3.105	12	5.335	1	8.903	5	11.365	5	12.580	8	14.585	7	16.535	8
3.140	5	5.360	7	8.991	8	11.370	12	12.590	2	14.640	1	16.590	1
3.160	12	5.440	1	9.190	1	11.390	5	12.635	8	14.643	5	16.615	8
3.175	5	5.455	8	9.210	13	11.395	12	12.655	2	14.690	1	16.710	1
3.190	12	5.485	1	9.310	1	11.405	5	12.725	8	14.710	3	16.865	8
3.300	5	5.530	8	9.330	13	11.430	8	12.740	1	14.760	1	16.900	0
3.315	12	5.540	1	9.370	1	11.460	5	12.753	8	14.820	5		
3.330	1	5.660	8	9.395	7	11.475	12	12.765	1	14.850	8		
3.340	8	5.700	3	9.640	1	11.500	5	12.848	8	14.880	5		
3.375	1	5.720	1	9.685	3	11.515	8	12.875	1	14.886	12		
3.450	8	5.745	3	9.735	1	11.525	5	12.900	8	14.895	5		

WYN--DEVOU PARK WAYNE ROAD

0.055	1	3.158	1	5.830	5	8.860	13	11.360	8
0.065	12	3.210	8	5.840	12	8.895	1	11.400	0
0.190	1	3.248	1	5.860	5	8.900	13		
0.215	3	3.255	8	5.870	12	8.950	1		
0.350	1	3.310	1	5.880	1	8.990	3		
0.475	8	3.400	8	5.905	12	9.045	1		
0.480	1	3.410	1	5.950	1	9.055	13		
0.495	8	3.495	8	5.970	12	9.110	1		
0.520	1	3.535	1	5.985	5	9.125	7		
0.535	12	3.570	12	5.990	12	9.195	1		
0.565	1	3.610	5	6.000	5	9.205	13		
0.625	4	3.615	12	6.010	8	9.250	1		
0.695	1	3.650	5	6.070	5	9.255	13		
0.790	8	3.730	8	6.090	8	9.310	1		
0.825	1	3.755	5	6.140	5	9.315	13		
0.895	8	3.760	12	6.200	8	9.380	1		
0.900	1	3.775	5	6.270	5	9.415	8		
0.915	12	3.780	12	6.340	8	9.470	5		
0.920	1	3.800	5	6.550	1	9.510	8		
0.940	12	3.805	12	6.585	8	9.525	1		
1.075	1	3.900	5	6.605	1	9.608	8		
1.110	3	4.085	8	6.670	4	9.670	1		
1.190	1	4.140	1	6.710	1	9.680	8		
1.210	3	4.190	3	6.768	8	9.780	1		
1.225	1	4.325	1	6.780	1	9.895	5		
1.295	8	4.385	8	6.810	8	9.941	8		
1.315	3	4.445	1	6.895	1	9.975	5		
1.390	1	4.470	3	6.905	3	10.025	8		
1.412	3	4.500	1	7.010	1	10.090	5		
1.485	1	4.530	12	7.030	3	10.115	8		
1.575	8	4.590	1	7.175	1	10.150	5		
1.680	1	4.680	8	7.235	8	10.170	12		
1.720	8	4.690	3	7.275	1	10.270	5		
1.755	1	4.730	8	7.310	3	10.310	8		
1.850	8	4.740	3	7.365	1	10.335	5		
1.890	1	4.800	1	7.370	8	10.340	12		
1.910	3	4.815	3	7.610	1	10.360	5		
1.945	1	4.845	1	7.635	3	10.365	12		
1.995	4	4.855	3	7.715	1	10.395	5		
2.020	5	4.890	1	7.780	8	10.405	12		
2.095	8	4.895	3	7.805	1	10.470	5		
2.170	1	5.000	1	7.890	8	10.490	12		
2.185	12	5.010	3	7.910	1	10.530	5		
2.210	1	5.100	1	7.980	8	10.540	12		
2.240	12	5.110	3	8.075	1	10.580	5		
2.250	1	5.280	1	8.085	8	10.590	12		
2.300	8	5.300	8	8.130	1	10.630	1		
2.415	1	5.310	1	8.150	9	10.670	8		
2.440	8	5.395	8	8.255	1	10.680	1		
2.480	1	5.455	1	8.280	3	10.710	8		
2.500	8	5.550	8	8.370	1	10.790	5		
2.580	1	5.555	1	8.410	6	10.795	12		
2.590	8	5.565	8	8.515	1	10.815	5		
2.620	1	5.610	1	8.580	7	10.820	12		
2.645	8	5.680	8	8.640	1	10.880	5		
2.680	3	5.690	1	8.670	7	10.890	12		
2.698	8	5.720	8	8.715	1	10.980	5		
2.760	1	5.745	5	8.725	13	11.010	8		
2.770	8	5.750	12	8.755	1	11.095	5		
2.785	1	5.765	5	8.765	13	11.105	12		
2.820	3	5.780	12	8.795	1	11.190	5		
2.915	1	5.790	5	8.805	13	11.215	8		
3.010	8	5.800	12	8.830	1	11.300	5		
3.120	1	5.810	5	8.835	13	11.320	8		
3.155	8	5.820	12	8.855	1	11.340	5		

RDR--RIEDLIN ROAD

0.025	3	1.795	12	4.010	8	6.910	1	9.490	1	11.935	2	13.715	1
0.055	8	1.805	1	4.103	1	6.930	8	9.510	8	11.945	12	13.730	8
0.125	1	1.810	12	4.125	3	6.950	1	9.680	1	11.980	5	13.750	5
0.130	12	1.820	1	4.155	1	6.965	8	9.750	8	12.000	12	13.755	12
0.145	1	1.945	8	4.175	3	7.000	2	9.780	5	12.060	5	13.790	5
0.150	12	1.955	1	4.225	1	7.060	1	9.795	8	12.100	12	13.795	12
0.225	1	1.960	12	4.230	12	7.065	12	9.830	1	12.190	5	13.820	5
0.240	8	1.985	1	4.270	1	7.085	1	9.858	8	12.205	12	13.875	8
0.305	1	2.000	8	4.295	8	7.090	12	9.890	1	12.240	5	13.890	5
0.345	8	2.090	1	4.310	3	7.150	1	9.915	8	12.250	12	13.895	12
0.350	1	2.153	8	4.389	1	7.155	12	9.980	5	12.280	1	13.920	5
0.390	8	2.165	1	4.460	8	7.170	1	10.010	8	12.300	12	13.930	12
0.400	1	2.185	8	4.485	2	7.185	3	10.090	5	12.315	1	13.955	5
0.415	8	2.203	1	4.500	3	7.210	8	10.100	12	12.350	8	13.960	12
0.450	5	2.215	4	4.710	1	7.260	1	10.120	5	12.360	1	13.990	5
0.510	8	2.240	1	4.725	8	7.375	8	10.125	12	12.385	8	14.000	12
0.565	1	2.250	3	4.770	3	7.400	1	10.155	5	12.420	1	14.040	1
0.615	8	2.260	1	4.860	1	7.405	3	10.160	12	12.430	13	14.050	8
0.625	1	2.280	3	4.925	8	7.435	1	10.180	5	12.480	1	14.090	1
0.630	5	2.352	1	4.940	1	7.440	3	10.190	12	12.490	13	14.110	6
0.640	1	2.575	8	5.100	8	7.520	1	10.205	5	12.530	1	14.135	1
0.645	12	2.610	1	5.130	1	7.540	3	10.260	8	12.580	6	14.170	12
0.665	1	2.613	12	5.235	8	7.630	1	10.275	1	12.600	1	14.200	5
0.703	8	2.630	1	5.250	1	7.645	8	10.305	8	12.635	8	14.240	8
0.760	5	2.660	3	5.255	12	7.700	1	10.340	1	12.660	1	14.245	1
0.770	8	2.680	1	5.280	1	7.760	8	10.350	12	12.670	3	14.280	8
0.810	5	2.685	13	5.455	8	7.763	1	10.387	1	12.690	1	14.285	1
0.820	8	2.700	1	5.540	1	7.800	8	10.505	4	12.700	3	14.310	8
0.835	5	2.705	13	5.550	3	7.803	1	10.520	5	12.725	1	14.400	0
0.845	12	2.775	1	5.590	1	7.865	8	10.550	12	12.765	8		
0.890	1	2.793	8	5.600	3	7.920	5	10.570	5	12.790	1		
0.915	8	2.830	2	5.650	1	7.970	11	10.600	12	12.800	12		
0.950	5	2.880	1	5.700	13	8.030	5	10.630	5	12.815	1		
0.960	8	2.900	3	5.720	1	8.070	8	10.650	8	12.825	12		
0.975	1	2.915	8	5.735	3	8.098	5	10.695	1	12.890	5		
1.020	8	2.930	3	5.783	1	8.105	8	10.705	12	12.910	8		
1.023	1	2.960	1	5.820	8	8.120	1	10.725	1	12.930	5		
1.050	8	2.970	3	5.887	1	8.130	12	10.770	8	12.940	12		
1.055	1	3.140	1	5.910	3	8.190	1	10.800	3	12.960	5		
1.060	12	3.160	12	5.970	1	8.235	8	10.810	1	12.970	12		
1.065	1	3.175	1	5.995	8	8.280	1	10.820	7	13.020	5		
1.080	8	3.380	8	6.005	1	8.300	12	10.835	1	13.100	1		
1.110	1	3.410	1	6.075	8	8.350	1	10.845	7	13.125	8		
1.170	8	3.455	8	6.080	1	8.490	8	10.895	1	13.145	1		
1.240	5	3.470	1	6.083	12	8.510	3	10.965	4	13.185	8		
1.255	3	3.500	8	6.090	1	8.580	1	11.000	1	13.200	1		
1.300	1	3.540	1	6.095	12	8.590	3	11.018	8	13.205	12		
1.310	3	3.570	3	6.195	1	8.635	1	11.080	1	13.280	5		
1.340	1	3.585	1	6.200	12	8.640	3	11.230	4	13.290	12		
1.370	3	3.600	3	6.220	1	8.710	1	11.305	1	13.360	5		
1.375	1	3.620	1	6.290	8	8.770	8	11.320	8	13.385	8		
1.400	3	3.635	3	6.310	1	8.900	1	11.323	1	13.390	1		
1.410	1	3.655	1	6.365	8	8.990	8	11.400	8	13.420	8		
1.425	3	3.670	3	6.395	1	9.000	1	11.600	1	13.425	1		
1.440	1	3.680	1	6.520	11	9.050	8	11.660	8	13.450	8		
1.450	3	3.700	8	6.560	1	9.090	1	11.715	1	13.505	5		
1.470	1	3.730	1	6.570	12	9.110	3	11.740	12	13.515	12		
1.600	8	3.755	12	6.600	1	9.145	1	11.770	5	13.540	5		
1.670	1	3.780	1	6.660	8	9.155	3	11.795	8	13.550	12		
1.695	3	3.820	8	6.700	1	9.240	1	11.810	5	13.570	5		
1.700	1	3.885	1	6.760	3	9.280	3	11.820	12	13.580	12		
1.750	3	3.895	4	6.770	1	9.300	1	11.840	5	13.615	5		
1.775	1	3.910	1	6.775	12	9.310	3	11.855	12	13.620	12		
1.780	12	3.930	8	6.785	1	9.415	1	11.875	5	13.665	5		
1.790	1	3.970	1	6.800	3	9.425	3	11.890	12	13.710	8		

LBG--LAWRENCEBURG

0.040	3	5.360	1	8.790	1	11.425	5	13.620	1	15.240	12	17.400	5
0.205	1	5.380	3	8.870	5	11.480	8	13.630	3	15.270	1	17.445	1
0.285	8	5.438	1	8.967	1	11.530	1	13.645	1	15.280	12	17.625	8
0.286	1	5.442	3	8.995	8	11.570	12	13.650	3	15.295	1	17.633	1
0.475	8	5.490	1	9.010	1	11.610	1	13.670	1	15.305	8	17.655	8
0.477	1	5.510	3	9.050	8	11.630	8	13.700	8	15.315	1	17.660	1
0.580	8	5.540	1	9.080	1	11.670	1	13.720	1	15.340	8	17.680	4
0.590	1	5.560	7	9.090	9	11.675	8	13.740	8	15.341	1	17.705	1
0.620	10	5.562	1	9.110	1	11.685	1	13.780	1	15.438	10	17.730	8
0.622	1	5.600	8	9.120	8	11.700	3	13.790	3	15.440	1	17.770	1
0.640	7	5.602	1	9.190	1	11.720	2	13.820	2	15.460	8	17.790	8
0.648	1	5.642	7	9.200	8	11.740	3	13.835	8	15.570	1	17.805	1
0.680	8	5.760	8	9.215	1	11.760	2	13.870	2	15.580	3	17.825	4
0.700	1	5.780	3	9.330	8	11.775	3	13.890	1	15.620	1	17.910	1
0.740	8	5.870	1	9.370	1	11.788	1	13.895	8	15.630	8	18.015	8
0.760	8	5.908	8	9.380	12	11.850	7	13.910	2	15.685	1	18.030	5
0.810	1	5.963	1	9.450	1	11.853	1	13.965	1	15.730	8	18.040	1
0.868	8	6.000	8	9.460	12	11.880	7	13.990	8	15.780	5	18.050	8
0.870	1	6.140	1	9.500	5	11.915	1	13.992	1	15.930	8	18.055	1
0.907	8	6.235	8	9.510	12	11.940	8	14.020	8	15.975	1	18.070	12
0.940	8	6.280	1	9.670	1	11.955	1	14.024	1	15.990	3	18.088	1
0.941	1	6.320	8	9.680	3	11.965	8	14.057	8	16.035	1	18.103	3
0.958	8	6.325	3	9.770	1	11.980	1	14.060	1	16.045	8	18.130	1
1.018	1	6.392	1	9.930	8	12.010	8	14.090	8	16.110	1	18.155	3
1.104	8	6.523	8	10.090	1	12.035	1	14.105	1	16.150	8	18.210	1
1.106	1	6.528	1	10.170	8	12.040	12	14.150	11	16.205	1	18.300	8
1.167	8	6.635	8	10.225	1	12.075	1	14.155	1	16.230	8	18.325	3
1.169	1	6.665	1	10.245	3	12.085	12	14.240	10	16.255	1	18.340	1
1.238	8	6.720	8	10.275	1	12.095	1	14.290	1	16.265	12	18.347	8
1.240	1	6.765	1	10.300	7	12.115	8	14.320	3	16.280	1	18.365	1
1.302	10	6.798	8	10.350	1	12.175	1	14.355	2	16.300	8	18.385	8
1.840	1	6.895	1	10.370	4	12.200	3	14.380	3	16.315	1	18.420	1
2.020	8	6.910	3	10.400	1	12.270	1	14.400	1	16.320	12	18.440	4
2.030	3	6.960	1	10.420	3	12.340	8	14.405	8	16.335	1	18.460	5
2.350	1	7.010	8	10.425	1	12.345	1	14.425	1	16.430	8	18.470	12
2.380	3	7.015	3	10.450	3	12.350	8	14.445	3	16.505	1	18.500	5
2.435	8	7.300	1	10.530	1	12.365	1	14.490	1	16.610	8	18.510	12
2.620	1	7.340	8	10.555	8	12.370	8	14.510	3	16.620	1	18.515	1
2.642	8	7.345	1	10.580	2	12.530	1	14.610	1	16.680	8	18.530	12
2.835	1	7.380	8	10.600	8	12.560	8	14.620	8	16.690	1	18.535	1
2.937	8	7.460	1	10.815	1	12.650	1	14.675	1	16.755	8	18.560	12
3.060	1	7.508	8	10.825	12	12.740	8	14.700	3	16.770	1	18.570	1
3.090	8	7.740	1	10.840	1	12.765	2	14.710	8	16.805	12	18.575	12
3.095	1	7.780	3	10.850	12	12.775	8	14.750	1	16.825	1	18.585	1
3.180	8	7.795	1	10.880	1	12.890	1	14.760	12	16.850	12	18.630	8
4.040	1	7.805	3	10.895	8	12.985	8	14.780	1	16.870	1	18.633	1
4.075	10	7.828	1	10.910	3	12.990	1	14.810	8	16.905	12	18.680	8
4.270	1	7.840	3	10.940	8	13.000	12	14.880	1	16.950	1	18.682	1
4.328	8	7.865	1	10.995	1	13.045	1	14.900	8	16.965	12	18.738	8
4.330	1	7.870	3	11.010	8	13.050	12	14.960	1	17.005	1	18.740	1
4.370	8	7.890	1	11.040	3	13.075	1	14.985	8	17.020	12	18.810	8
4.390	7	7.910	3	11.125	1	13.090	8	14.995	1	17.050	1	18.820	1
4.480	8	7.960	1	11.180	8	13.120	3	15.010	8	17.170	8	18.824	12
4.595	1	7.965	3	11.190	1	13.315	2	15.020	1	17.185	1	18.830	1
4.665	3	8.000	1	11.200	8	13.320	8	15.050	8	17.210	12	18.834	12
4.800	1	8.010	3	11.210	1	13.370	2	15.070	5	17.250	5	18.850	1
4.820	8	8.055	1	11.215	8	13.380	8	15.090	8	17.260	12	18.855	12
4.935	1	8.070	3	11.235	1	13.395	2	15.100	1	17.280	5	18.870	1
4.970	3	8.100	1	11.250	3	13.400	8	15.125	8	17.305	12	18.895	4
5.070	1	8.290	8	11.277	1	13.420	2	15.135	1	17.315	1	18.950	1
5.115	8	8.365	1	11.300	8	13.424	8	15.145	8	17.320	12	18.970	3
5.200	1	8.520	1	11.360	2	13.470	2	15.175	12	17.335	1	19.000	8
5.248	7	8.565	8	11.380	8	13.490	7	15.200	1	17.340	8	19.080	1
5.252	1	8.620	1	11.390	5	13.580	2	15.210	8	17.360	1	19.100	12
5.295	8	8.740	8	11.400	12	13.600	8	15.230	1	17.375	12	19.170	1

LBG (continued)

19.180	8 20.887	1 22.630	1 25.155	5 27.140	1 30.165	1 31.910	8
19.190	1 20.960	8 22.675	3 25.170	12 27.160	3 30.210	8 31.950	5
19.210	8 20.970	1 22.770	1 25.185	5 27.195	1 30.225	1 31.960	12
19.220	1 20.980	12 22.860	10 25.205	12 27.210	3 30.310	8 31.985	5
19.233	8 20.990	1 22.880	3 25.220	5 27.300	1 30.350	1 31.990	12
19.250	1 21.003	8 22.910	1 25.245	12 27.415	8 30.360	13 32.005	5
19.265	8 21.025	1 22.940	3 25.280	5 27.450	5 30.470	1 32.020	8
19.285	3 21.035	8 23.005	1 25.307	8 27.505	8 30.480	13 32.040	5
19.300	8 21.050	1 23.060	8 25.310	1 27.540	5 30.510	1 32.050	12
19.325	1 21.075	8 23.070	3 25.340	8 27.545	8 30.515	13 32.060	5
19.335	9 21.100	3 23.185	1 25.395	5 27.575	5 30.570	1 32.070	12
19.350	1 21.108	1 23.260	8 25.400	12 27.610	8 30.672	6 32.085	5
19.370	4 21.113	3 23.270	1 25.435	5 27.630	2 30.680	1 32.100	12
19.390	1 21.145	1 23.310	8 25.485	8 27.640	8 30.690	12 32.180	5
19.460	7 21.170	8 23.320	1 25.486	1 27.650	2 30.710	2 32.190	12
19.485	1 21.175	1 23.340	8 25.520	8 27.670	8 30.738	12 32.230	5
19.545	4 21.190	8 23.350	1 25.535	2 27.680	2 30.760	2 32.250	12
19.630	8 21.210	1 23.360	8 25.540	12 27.705	8 30.777	12 32.260	5
19.645	3 21.230	3 23.405	5 25.600	1 27.748	5 30.830	1 32.270	8
19.700	1 21.252	1 23.460	8 25.620	4 27.783	8 30.840	13 32.330	5
19.720	8 21.310	8 23.540	1 25.780	1 27.910	5 30.955	1 32.340	12
19.760	1 21.410	1 23.550	12 25.885	7 27.955	8 30.980	8 32.365	5
19.815	8 21.425	3 23.625	1 25.890	1 27.990	5 30.982	1 32.380	12
19.830	1 21.440	1 23.660	8 25.955	6 28.080	8 31.060	8 32.400	5
19.860	8 21.450	5 23.675	1 26.002	1 28.265	1 31.085	1 32.410	12
19.875	1 21.520	8 23.775	8 26.020	8 28.280	3 31.170	8 32.430	5
19.887	8 21.521	1 23.840	1 26.030	1 28.380	1 31.176	5 32.470	8
19.895	1 21.550	8 23.850	8 26.035	12 28.384	8 31.180	12 32.485	1
19.910	8 21.560	1 23.865	1 26.040	1 28.430	1 31.186	5 32.510	8
19.920	1 21.570	8 23.915	8 26.045	12 28.470	6 31.193	12 32.535	5
19.953	8 21.580	1 23.930	1 26.065	1 28.615	1 31.220	5 32.545	12
19.980	1 21.613	8 23.950	8 26.105	3 28.705	6 31.230	12 32.580	5
20.005	4 21.630	1 24.010	1 26.125	1 28.715	3 31.250	5 32.590	12
20.020	1 21.640	8 24.030	13 26.150	3 28.750	1 31.255	12 32.610	5
20.040	8 21.700	1 24.090	1 26.165	8 28.780	3 31.272	5 32.615	12
20.070	1 21.705	3 24.135	8 26.180	1 28.800	1 31.280	12 32.637	5
20.115	8 21.750	1 24.195	1 26.188	3 28.850	4 31.295	1 32.695	8
20.130	1 21.754	3 24.220	3 26.195	1 28.890	1 31.330	8 32.705	1
20.138	12 21.860	1 24.400	1 26.215	3 28.900	3 31.335	1 32.730	8
20.155	1 21.980	8 24.410	12 26.235	1 28.980	1 31.370	8 32.780	5
20.235	5 21.983	1 24.450	1 26.252	3 28.990	3 31.371	1 32.800	8
20.250	1 21.990	12 24.475	5 26.280	1 29.035	1 31.385	8 32.840	5
20.260	4 21.995	1 24.510	1 26.290	13 29.045	3 31.435	5 32.930	8
20.280	1 22.000	12 24.600	8 26.340	1 29.100	1 31.450	12 32.940	5
20.330	8 22.010	1 24.610	1 26.350	3 29.110	4 31.465	5 32.944	12
20.345	1 22.020	8 24.620	12 26.380	1 29.160	1 31.470	12 32.970	5
20.370	8 22.065	1 24.635	1 26.390	3 29.170	3 31.480	5 33.015	8
20.380	1 22.130	4 24.640	12 26.497	1 29.193	1 31.485	12 33.025	5
20.385	12 22.160	1 24.670	1 26.530	8 29.225	3 31.495	5 33.070	8
20.390	1 22.180	4 24.690	8 26.570	1 29.270	1 31.505	12 33.100	5
20.395	12 22.230	3 24.710	3 26.580	3 29.280	3 31.530	5 33.105	12
20.405	1 22.250	1 24.725	1 26.615	1 29.310	1 31.540	12 33.130	5
20.535	9 22.260	3 24.730	12 26.625	8 29.320	3 31.580	5 33.200	8
20.555	1 22.270	1 24.745	1 26.675	1 29.405	1 31.595	8 33.222	5
20.600	8 22.280	3 24.965	8 26.700	8 29.415	3 31.635	2 33.240	8
20.675	1 22.330	1 24.985	1 26.715	1 29.510	1 31.640	12 33.330	1
20.685	8 22.385	4 24.995	12 26.725	12 29.530	3 31.675	2 33.355	3
20.705	1 22.405	1 25.010	1 26.805	1 29.600	1 31.685	8 33.395	1
20.710	12 22.485	8 25.015	12 26.830	8 29.615	3 31.710	5 33.450	4
20.735	1 22.500	1 25.025	1 26.860	1 29.810	1 31.730	8 33.455	1
20.745	12 22.530	12 25.050	12 26.890	8 29.825	3 31.780	5 33.480	4
20.795	1 22.540	1 25.065	5 26.933	1 30.005	1 31.805	12 33.485	1
20.810	8 22.560	12 25.085	8 26.945	8 30.040	8 31.860	5 33.500	8
20.860	1 22.578	1 25.087	1 26.965	1 30.045	1 31.880	12 33.525	5
20.870	12 22.620	8 25.120	8 26.977	8 30.085	8 31.900	5 33.530	12

LBG (continued)

33.550	5	35.245	12	37.170	1
33.554	12	35.247	1	37.190	8
33.580	5	35.268	12	37.203	3
33.590	12	35.270	1	37.290	1
33.610	5	35.290	12	37.295	8
33.620	12	35.330	5	37.390	1
33.640	5	35.350	12	37.505	8
33.650	12	35.430	5	37.545	1
33.670	5	35.450	12	37.565	3
33.680	12	35.480	5	37.645	1
33.760	1	35.500	12	37.670	8
33.770	12	35.520	5	37.725	1
33.780	1	35.530	12	37.735	8
33.820	8	35.550	5	37.775	1
33.900	5	35.560	12	37.790	4
33.910	12	35.620	5	37.810	3
33.911	5	35.650	12	37.875	1
33.925	12	35.680	5	37.905	8
33.950	5	35.710	12		
33.958	12	35.740	5		
33.980	5	35.750	12		
34.000	12	35.860	5		
34.020	5	35.870	12		
34.030	12	35.890	5		
34.040	5	35.940	8		
34.045	12	36.060	5		
34.130	5	36.070	12		
34.140	12	36.150	5		
34.150	5	36.170	8		
34.160	12	36.200	5		
34.230	5	36.210	12		
34.250	9	36.240	5		
34.260	1	36.250	12		
34.300	9	36.280	5		
34.310	1	36.290	8		
34.350	9	36.330	5		
34.360	1	36.340	12		
34.400	9	36.390	5		
34.460	5	36.400	12		
34.485	8	36.440	5		
34.520	5	36.450	12		
34.535	8	36.480	5		
34.615	1	36.490	12		
34.690	8	36.520	5		
34.720	5	36.530	12		
34.730	12	36.560	5		
34.755	5	36.580	8		
34.785	8	36.620	1		
34.808	5	36.650	8		
34.825	12	36.680	1		
34.850	5	36.710	12		
34.865	12	36.720	5		
34.890	5	36.730	12		
34.915	12	36.740	5		
34.948	5	36.770	8		
34.975	12	36.800	5		
35.015	5	36.810	12		
35.020	12	36.880	5		
35.115	5	36.920	8		
35.155	8	36.940	1		
35.180	5	36.943	12		
35.200	8	36.960	1		
35.201	1	37.060	8		
35.220	12	37.080	1		
35.222	1	37.100	8		

SIP--SHARONVILLE INDUSTRIAL PARK

0.430	1	3.327	3	5.900	1	9.650	1	12.715	8
0.480	8	3.410	1	5.925	8	9.725	6	12.725	1
0.620	1	3.420	3	5.926	1	9.730	1	12.790	8
0.640	8	3.620	1	5.940	8	9.820	8	12.900	1
0.720	1	3.640	3	5.945	1	9.955	1	12.920	8
0.730	3	3.733	1	5.960	8	9.965	12	12.940	5
0.840	1	3.734	5	5.961	1	10.150	1	12.960	12
0.885	8	3.740	1	6.000	6	10.210	8	12.980	5
0.960	1	3.755	3	6.130	1	10.215	5	13.000	12
1.050	8	4.090	1	6.180	6	10.230	12	13.020	5
1.115	5	4.160	3	6.420	1	10.245	5	13.040	12
1.155	8	4.200	1	6.460	6	10.265	12	13.060	5
1.170	5	4.270	3	6.560	1	10.280	5	13.080	12
1.185	12	4.360	1	6.570	3	10.300	12	13.100	5
1.195	5	4.430	3	6.740	1	10.305	5	13.120	12
1.200	12	4.539	1	6.741	5	10.360	8	13.140	5
1.205	5	4.590	8	6.765	3	10.362	5	13.160	12
1.271	8	4.670	1	6.780	1	10.370	12	13.180	5
1.500	1	4.730	8	6.790	3	10.395	5	13.200	12
1.610	8	4.738	5	6.855	1	10.425	12	13.220	5
1.750	1	4.750	8	6.965	2	10.450	5	13.240	12
1.770	7	4.780	5	7.000	3	10.465	12	13.260	5
1.795	1	4.790	12	7.040	3	10.490	5	13.280	12
1.810	3	4.810	5	7.055	3	10.590	8	13.300	5
1.811	8	4.820	12	7.110	3	10.595	5	13.320	12
1.860	1	4.855	5	7.305	1	10.605	12	13.340	5
1.880	3	4.860	12	7.310	3	10.615	5	13.360	12
2.000	1	4.895	5	7.375	1	10.630	12	13.380	5
2.030	3	4.905	12	7.380	3	10.635	5	13.400	12
2.070	1	4.925	5	7.428	1	10.660	12	13.430	5
2.115	8	4.935	12	7.432	3	10.665	5	13.570	8
2.116	1	4.960	5	7.550	1	10.715	8	13.590	5
2.119	8	4.970	12	7.580	3	10.720	5	13.610	12
2.310	1	5.000	5	7.698	1	10.730	12	13.630	5
2.330	3	5.010	12	7.700	3	10.740	5	13.650	12
2.380	1	5.030	5	7.880	1	10.755	12	13.670	5
2.440	8	5.040	12	7.915	4	10.780	5	13.690	12
2.441	1	5.050	5	7.916	1	10.805	12	13.710	5
2.470	3	5.080	12	7.998	8	10.825	5	13.730	12
2.585	1	5.130	5	8.045	1	10.842	12	13.780	5
2.690	8	5.140	12	8.072	8	10.850	5	13.900	8
2.691	1	5.170	5	8.080	1	10.915	8	14.000	1
2.770	8	5.205	8	8.100	8	10.930	5	14.060	8
2.790	1	5.206	1	8.290	1	10.965	8	14.090	12
2.825	12	5.235	8	8.310	8	10.980	5	14.320	1
2.840	1	5.236	1	8.495	1	11.030	8	14.350	8
2.860	12	5.250	8	8.500	3	11.380	1	14.360	1
2.875	1	5.270	1	8.615	1	11.525	8	14.380	8
2.895	12	5.280	12	8.630	8	11.526	1	14.410	3
2.905	1	5.310	1	8.645	1	11.720	8	14.485	1
2.960	8	5.320	12	8.652	5	11.740	5	14.540	8
2.961	1	5.340	1	8.890	1	11.750	8	14.620	1
3.005	8	5.350	12	8.930	8	11.760	5	14.665	8
3.011	1	5.425	1	8.945	1	11.775	12	14.670	3
3.020	12	5,489	8	9.000	8	11.780	5	14.735	1
3.030	1	5.490	1	9.025	1	11.800	8	14.790	8
3.060	12	5.510	8	9.075	8	11.802	1	14.840	1
3.085	1	5.605	1	9.076	1	11.832	8	14.860	8
3.115	12	5.649	8	9.090	8	11.834	3	14.870	1
3.140	1	5.650	1	9.100	1	12.040	1	14.910	8
3.180	12	5.662	8	9.140	8	12.065	6	14.920	1
3.200	1	5.675	1	9.220	1	12.265	1	15.000	8
3.235	7	5.695	8	9.315	3	12.400	5		
3.236	1	5.750	1	9.380	1	12.450	6		
3.325	8	5.770	3	9.390	8	12.590	1		

ELK--ELKHORN CORE, OGS 3023 (bottom, 0 m, at 680 ft; top at 570 ft)

0.022	2	1.782	3	3.320	5	4.500	2	5.680	8	7.892	4	9.830	2
0.025	5	1.810	2	3.338	2	4.505	5	5.710	5	7.928	2	9.890	5
0.065	2	1.812	12	3.345	4	4.555	8	5.730	2	7.940	5	9.910	9
0.090	5	1.828	2	3.368	2	4.570	2	5.732	4	7.945	12	9.915	2
0.140	8	1.832	8	3.372	4	4.590	3	5.790	3	7.950	2	9.920	9
0.142	2	1.855	5	3.388	2	4.655	10	5.810	8	7.990	8	9.950	2
0.195	8	1.880	2	3.392	4	4.685	1	5.845	5	8.005	5	9.960	5
0.210	5	1.885	8	3.410	2	4.690	5	5.885	8	8.015	8	9.980	2
0.220	2	1.900	3	3.435	5	4.718	1	5.900	5	8.028	2	9.990	5
0.230	5	1.930	2	3.455	2	4.720	5	5.910	8	8.050	8	10.030	2
0.290	2	1.945	5	3.460	12	4.732	1	5.920	5	8.090	5	10.035	5
0.300	4	1.968	2	3.470	2	4.740	5	6.130	10	8.095	12	10.090	2
0.340	5	2.018	8	3.545	8	4.770	1	6.170	1	8.110	2	10.092	5
0.355	2	2.038	2	3.560	5	4.780	5	6.225	2	8.120	5	10.140	1
0.360	5	2.045	3	3.630	8	4.785	8	6.255	2	8.140	2	10.220	3
0.378	2	2.055	2	3.700	2	4.802	2	6.260	5	8.150	5	10.260	2
0.380	5	2.058	3	3.710	5	4.810	3	6.300	2	8.170	2	10.265	5
0.452	1	2.080	2	3.718	2	4.815	2	6.310	3	8.185	10	10.300	2
0.455	5	2.082	4	3.720	3	4.820	12	6.325	2	8.210	10	10.305	5
0.468	1	2.200	1	3.730	2	4.835	2	6.330	3	8.220	5	10.360	2
0.475	4	2.212	5	3.795	10	4.840	3	6.385	2	8.240	10	10.460	2
0.500	3	2.252	2	3.818	5	4.862	2	6.400	3	8.245	2	10.500	1
0.530	2	2.272	8	3.822	12	4.870	5	6.412	2	8.305	10	10.550	1
0.600	1	2.298	5	3.838	2	4.950	2	6.420	13	8.325	2	10.570	2
0.630	10	2.330	8	3.842	4	4.960	3	6.440	1	8.350	5	10.630	1
0.640	2	2.342	2	3.851	2	4.965	5	6.460	8	8.392	10	10.640	2
0.730	10	2.349	4	3.855	4	4.985	2	6.470	2	8.412	10	10.660	1
0.745	3	2.390	2	3.868	2	4.990	12	6.540	8	8.425	5	10.661	5
0.758	9	2.410	3	3.870	4	5.000	5	6.550	2	8.442	2	10.810	1
0.770	3	2.425	2	3.882	2	5.015	3	6.585	10	8.500	10	10.855	2
0.898	2	2.440	10	3.888	4	5.045	2	6.600	5	8.515	5	10.925	2
0.902	5	2.485	3	3.925	2	5.070	3	6.645	8	8.530	8	10.930	5
0.928	2	2.500	8	3.988	10	5.072	5	6.670	5	8.540	2	10.990	2
0.930	5	2.515	8	3.998	2	5.110	2	6.810	1	8.560	8	11.000	3
0.945	2	2.530	8	4.002	8	5.120	12	6.885	8	8.580	2	11.072	2
0.950	9	2.540	5	4.022	5	5.132	2	6.940	10	8.620	8	11.075	5
0.968	2	2.582	2	4.028	12	5.180	3	6.950	2	8.662	8	11.120	2
0.972	9	2.610	3	4.040	5	5.215	8	6.985	10	8.685	2	11.130	12
0.988	2	2.638	2	4.065	2	5.240	5	6.990	2	8.692	12	11.205	2
0.992	9	2.642	3	4.100	8	5.250	5	7.105	10	8.965	2	11.220	3
1.120	2	2.715	5	4.110	3	5.270	2	7.108	2	8.980	2	11.315	2
1.125	5	2.752	2	4.120	4	5.300	5	7.135	8	9.005	8	11.345	5
1.155	2	2.810	2	4.140	5	5.308	12	7.175	1	9.090	2	11.355	3
1.180	3	2.850	2	4.150	5	5.322	5	7.190	8	9.100	5	11.423	2
1.200	2	2.860	9	4.165	2	5.330	12	7.225	1	9.172	2	11.425	5
1.202	5	2.890	2	4.200	8	5.335	2	7.275	8	9.180	12	11.455	2
1.245	2	2.902	10	4.210	2	5.395	10	7.295	5	9.192	2	11.460	5
1.250	9	2.930	2	4.222	3	5.410	5	7.300	9	9.195	3	11.490	2
1.270	2	2.933	4	4.255	2	5.415	12	7.308	5	9.225	3	11.500	3
1.280	5	2.950	2	4.265	4	5.420	5	7.312	9	9.280	5	11.530	2
1.282	4	2.955	5	4.275	2	5.425	12	7.395	8	9.410	8	11.570	2
1.296	2	2.975	2	4.278	3	5.445	5	7.408	5	9.460	5	11.580	3
1.302	9	2.985	4	4.288	2	5.470	10	7.412	12	9.480	4	11.612	2
1.345	5	3.028	2	4.290	3	5.520	2	7.430	5	9.490	4	11.620	5
1.410	9	3.050	8	4.310	2	5.525	12	7.460	8	9.530	4	11.650	2
1.450	2	3.070	5	4.355	3	5.530	2	7.475	2	9.540	5	11.670	3
1.452	5	3.100	2	4.388	2	5.532	13	7.560	10	9.550	8	11.752	1
1.522	2	3.118	5	4.390	5	5.548	2	7.570	2	9.595	5	11.820	2
1.590	10	3.130	2	4.410	2	5.555	13	7.580	5	9.630	8	11.822	5
1.600	5	3.180	8	4.420	5	5.560	2	7.620	10	9.640	2	11.830	2
1.670	2	3.195	2	4.430	2	5.585	8	7.730	2	9.650	8	11.832	12
1.692	10	3.200	8	4.435	5	5.608	2	7.840	10	9.665	2	11.890	2
1.712	10	3.212	5	4.460	3	5.612	5	7.850	3	9.670	5	11.892	5
1.728	2	3.232	8	4.478	2	5.620	2	7.870	2	9.745	2	11.995	2
1.765	10	3.310	2	4.482	3	5.650	5	7.890	5	9.755	12	12.020	5

ELK (continued)

12.032	2	13.735	2	15.710	13	17.615	3	19.275	9	20.815	5	22.285	2
12.050	14	13.745	3	15.810	2	17.640	2	19.290	2	20.835	2	22.290	12
12.060	2	13.755	2	15.820	13	17.660	4	19.292	9	20.843	4	22.295	2
12.062	5	13.800	8	15.890	2	17.670	3	19.305	2	20.852	3	22.300	3
12.075	2	13.822	2	15.902	13	17.680	2	19.310	9	20.885	2	22.310	1
12.095	10	13.828	3	15.980	2	17.685	3	19.318	2	20.922	3	22.311	5
12.102	2	13.845	2	16.008	2	17.815	2	19.322	9	20.940	4	22.355	1
12.105	5	13.858	14	16.018	3	17.822	3	19.330	2	20.952	3	22.360	3
12.111	2	13.928	2	16.092	2	17.868	2	19.350	3	20.995	2	22.678	2
12.128	10	13.932	13	16.109	3	17.872	3	19.415	4	21.003	3	22.682	13
12.140	2	13.945	2	16.150	2	17.885	2	19.472	2	21.038	2	22.702	2
12.142	5	13.950	13	16.220	4	17.910	3	19.480	3	21.040	3	22.712	13
12.158	2	14.002	2	16.278	2	17.930	2	19.510	2	21.052	2	22.818	2
12.160	5	14.010	13	16.282	3	17.950	2	19.515	13	21.058	12	22.825	13
12.182	2	14.072	2	16.292	2	17.970	3	19.540	2	21.070	2	22.855	2
12.185	5	14.085	14	16.298	3	17.980	2	19.550	4	21.075	12	22.862	13
12.198	2	14.115	2	16.318	2	17.982	13	19.560	2	21.078	2	22.958	2
12.200	5	14.130	14	16.322	4	18.018	2	19.565	3	21.082	12	23.000	2
12.229	2	14.167	2	16.435	2	18.022	13	19.618	2	21.092	2	23.070	2
12.230	5	14.172	13	16.478	14	18.040	2	19.620	3	21.099	12	23.080	3
12.298	2	14.210	2	16.490	2	18.078	3	19.655	2	21.118	2	23.158	2
12.300	5	14.215	3	16.500	3	18.090	2	19.660	13	21.125	3	23.161	13
12.328	2	14.350	2	16.542	2	18.110	3	19.668	2	21.160	2	23.365	2
12.330	5	14.372	13	16.558	14	18.135	2	19.670	13	21.165	3	23.372	13
12.390	2	14.655	2	16.568	2	18.160	4	19.685	2	21.180	2	23.450	2
12.422	2	14.660	3	16.570	14	18.210	2	19.690	13	21.190	13	23.460	5
12.425	5	14.770	2	16.580	2	18.220	2	19.745	2	21.210	2	23.510	2
12.520	2	14.810	10	16.612	14	18.245	2	19.790	9	21.212	3	23.512	3
12.535	2	14.895	11	16.660	2	18.250	3	19.810	2	21.228	2	23.650	2
12.552	2	14.905	11	16.760	2	18.255	2	19.812	13	21.230	13	23.655	5
12.595	4	14.918	11	16.815	2	18.262	3	19.830	2	21.260	2	23.820	2
12.605	2	14.925	2	16.840	2	18.285	2	19.832	14	21.302	3	23.845	3
12.621	5	14.935	11	16.885	2	18.305	3	19.865	2	21.320	2	23.895	2
12.640	4	14.945	11	16.890	3	18.332	2	19.870	5	21.335	3	23.900	13
12.660	2	14.965	3	16.900	2	18.340	13	19.950	2	21.400	4	23.948	2
12.795	11	14.970	11	16.908	3	18.370	2	19.952	3	21.420	2	23.970	3
12.822	2	14.980	2	16.919	2	18.400	4	19.960	2	21.440	8	23.980	2
12.860	11	14.990	11	16.922	3	18.492	2	19.962	3	21.510	14	24.110	2
12.895	11	15.000	3	16.935	2	18.500	3	19.965	2	21.610	4	24.112	5
12.928	11	15.010	2	16.940	3	18.518	2	19.975	3	21.650	3	24.145	3
12.950	2	15.040	2	16.950	2	18.520	3	19.980	2	21.708	2	24.170	2
12.955	5	15.042	5	16.952	3	18.640	2	20.012	4	21.713	13	24.175	3
12.965	2	15.052	2	16.995	2	18.780	2	20.020	2	21.750	3	24.190	2
12.970	3	15.065	8	17.002	3	18.785	3	20.023	3	21.775	2	24.205	3
13.012	2	15.080	3	17.042	2	18.810	2	20.050	2	21.780	3	24.222	2
13.015	3	15.280	2	17.051	3	18.820	3	20.055	3	21.800	5	24.228	3
13.185	2	15.290	3	17.070	2	18.920	2	20.070	2	21.802	13	24.240	2
13.195	3	15.300	2	17.083	3	18.930	2	20.075	3	21.812	2	24.245	3
13.221	2	15.305	3	17.200	2	18.940	3	20.090	2	21.820	13	24.262	2
13.231	5	15.320	2	17.210	5	18.960	2	20.095	5	21.848	2	24.305	3
13.245	3	15.322	3	17.228	2	18.975	3	20.105	2	21.852	3	24.318	2
13.375	2	15.385	2	17.230	13	18.990	2	20.118	5	21.870	2	24.330	3
13.382	3	15.390	14	17.248	2	19.003	4	20.165	8	21.887	3	24.340	14
13.410	2	15.405	3	17.252	3	19.055	2	20.195	2	21.902	2	24.400	2
13.440	2	15.430	2	17.262	2	19.058	4	20.200	3	21.940	6	24.460	2
13.460	2	15.432	3	17.268	3	19.068	2	20.232	2	22.060	4	24.480	4
13.475	3	15.450	2	17.300	2	19.070	3	20.240	3	22.100	14	24.515	2
13.487	2	15.455	5	17.325	3	19.080	2	20.320	2	22.125	3	24.540	5
13.500	3	15.490	2	17.400	2	19.088	3	20.415	2	22.202	4	24.590	2
13.518	2	15.500	13	17.470	2	19.115	2	20.423	3	22.246	10	24.602	3
13.520	13	15.550	2	17.530	2	19.140	3	20.450	2	22.248	15	24.622	2
13.538	2	15.560	3	17.543	14	19.165	2	20.455	4	22.255	2	24.635	3
13.545	3	15.630	2	17.558	2	19.250	11	20.495	2	22.260	12	24.698	2
13.585	2	15.640	13	17.562	3	19.260	10	20.735	4	22.268	2	24.850	14
13.590	3	15.700	2	17.605	2	19.270	2	20.812	2	22.275	12	24.868	2

ELK (continued)

24.870	13	26.230	5	27.740	12	28.922	12	30.315	5	31.582	5	32.970	12
24.890	2	26.275	2	27.765	5	28.930	5	30.320	12	31.592	12	32.995	5
24.910	4	26.280	12	27.775	12	28.950	8	30.325	2	31.620	5	33.002	12
24.945	3	26.295	5	27.782	5	28.975	5	30.355	11	31.632	10	33.015	2
24.990	14	26.300	12	27.805	8	29.005	2	30.385	5	31.648	2	33.060	11
25.035	2	26.302	5	27.820	5	29.012	12	30.400	8	31.660	10	33.080	11
25.070	4	26.310	12	27.825	12	29.040	5	30.412	5	31.680	5	33.102	10
25.080	3	26.320	5	27.840	5	29.045	12	30.415	12	31.688	12	33.110	2
25.120	2	26.350	8	27.845	12	29.060	5	30.425	5	31.710	5	33.120	12
25.130	3	26.412	8	27.872	5	29.062	12	30.440	12	31.715	12	33.142	2
25.155	2	26.430	5	27.880	12	29.070	5	30.455	2	31.745	5	33.155	8
25.180	2	26.440	12	27.890	5	29.095	4	30.470	12	31.780	10	33.175	5
25.190	2	26.499	5	27.920	10	29.105	2	30.495	2	31.785	5	33.180	12
25.200	3	26.502	10	27.980	5	29.111	12	30.510	12	31.798	12	33.205	5
25.218	4	26.525	5	27.995	8	29.115	2	30.522	5	31.822	5	33.245	8
25.222	4	26.550	4	28.095	5	29.128	12	30.530	12	31.855	10	33.272	2
25.270	2	26.565	5	28.160	8	29.140	2	30.545	2	31.862	2	33.280	5
25.300	2	26.572	12	28.210	5	29.170	10	30.555	12	31.890	10	33.305	2
25.302	5	26.595	5	28.275	11	29.178	2	30.580	2	31.910	5	33.315	8
25.318	2	26.655	4	28.318	5	29.182	12	30.582	5	31.935	10	33.330	3
25.322	3	26.685	2	28.330	10	29.210	5	30.615	5	31.948	5	33.420	5
25.365	2	26.720	5	28.350	5	29.257	8	30.660	2	31.950	12		
25.372	3	26.730	12	28.360	5	29.260	15	30.735	8	31.965	5		
25.390	2	26.825	5	28.390	5	29.315	10	30.755	2	31.995	10		
25.400	3	26.830	12	28.402	8	29.330	5	30.795	4	32.000	5		
25.475	2	26.855	2	28.412	8	29.350	8	30.860	2	32.005	12		
25.490	3	26.880	8	28.425	8	29.378	2	30.870	5	32.018	2		
25.502	3	26.910	3	28.440	5	29.382	5	30.915	2	32.130	10		
25.510	3	26.930	2	28.445	12	29.408	2	30.930	6	32.145	5		
25.540	2	26.970	5	28.465	5	29.460	9	30.940	2	32.155	12		
25.545	3	26.995	8	28.470	12	29.475	5	30.945	12	32.170	5		
25.578	2	27.040	5	28.480	5	29.484	12	30.955	2	32.202	8		
25.587	3	27.050	2	28.482	12	29.510	2	30.985	8	32.218	8		
25.600	2	27.070	5	28.500	5	29.570	10	30.990	2	32.222	5		
25.610	3	27.098	2	28.510	12	29.585	2	31.000	12	32.232	12		
25.670	2	27.102	5	28.525	5	29.592	5	31.015	2	32.240	5		
25.680	3	27.105	5	28.530	12	29.610	8	31.022	3	32.245	12		
25.720	2	27.125	2	28.545	5	29.645	8	31.030	12	32.250	5		
25.735	3	27.140	3	28.550	12	29.675	8	31.040	5	32.260	10		
25.760	2	27.185	2	28.560	5	29.702	2	31.045	4	32.290	5		
25.770	13	27.200	5	28.562	12	29.715	12	31.090	2	32.370	10		
25.795	2	27.215	2	28.578	5	29.720	2	31.125	4	32.390	2		
25.808	12	27.271	2	28.582	12	29.745	4	31.160	2	32.440	10		
25.822	2	27.280	5	28.608	5	29.780	2	31.205	8	32.455	5		
25.830	12	27.295	2	28.612	12	29.808	8	31.225	2	32.500	10		
25.845	2	27.370	8	28.628	5	29.855	1	31.230	12	32.502	15		
25.860	12	27.395	5	28.632	12	29.860	3	31.245	5	32.522	10		
25.875	3	27.405	12	28.655	5	29.895	2	31.255	12	32.578	10		
25.915	2	27.415	5	28.662	12	29.940	8	31.262	5	32.585	2		
25.925	12	27.420	12	28.672	5	29.962	2	31.270	12	32.618	10		
25.950	2	27.440	5	28.678	12	29.965	14	31.292	2	32.630	15		
25.985	8	27.455	12	28.688	5	29.980	3	31.325	9	32.722	11		
26.000	2	27.495	5	28.692	12	30.008	2	31.355	2	32.732	2		
26.010	12	27.520	5	28.698	5	30.045	10	31.395	10	32.750	10		
26.040	5	27.530	12	28.742	11	30.060	5	31.400	2	32.760	10		
26.060	4	27.580	8	28.750	5	30.075	5	31.438	7	32.785	10		
26.070	3	27.590	5	28.760	12	30.095	8	31.450	2	32.808	5		
26.080	2	27.600	12	28.770	5	30.102	2	31.472	4	32.815	10		
26.100	3	27.620	5	28.775	12	30.140	8	31.482	2	32.860	5		
26.155	2	27.625	12	28.782	5	30.150	5	31.490	5	32.882	4		
26.165	12	27.645	5	28.790	12	30.160	8	31.505	2	32.900	5		
26.175	2	27.680	8	28.805	5	30.215	5	31.522	8	32.902	12		
26.190	8	27.695	5	28.840	8	30.228	4	31.545	12	32.920	5		
26.198	2	27.705	12	28.855	12	30.262	5	31.565	2	32.930	4		
26.212	12	27.732	5	28.915	5	30.270	12	31.572	8	32.962	5		

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0.010	3	1.833	1	3.545	2	5.285	2	7.598	5	9.630	10	11.610	1
0.015	2	1.840	3	3.554	8	5.290	12	7.603	4	9.632	3	11.615	4
0.025	3	1.880	1	3.600	5	5.305	2	7.618	2	9.640	10	11.645	1
0.040	4	1.900	5	3.615	7	5.315	8	7.625	4	9.650	5	11.728	8
0.049	3	1.925	1	3.729	1	5.368	2	7.670	2	9.732	10	11.732	5
0.055	1	2.000	8	3.790	10	5.374	12	7.702	5	9.770	5	11.740	8
0.063	8	2.005	1	3.870	8	5.415	2	7.720	3	9.775	4	11.750	5
0.095	5	2.011	12	3.925	1	5.425	5	7.780	2	9.820	5	11.760	8
0.111	8	2.015	1	3.945	3	5.440	8	7.785	5	9.830	8	11.770	5
0.130	1	2.020	8	3.955	12	5.470	2	7.790	2	9.865	5	11.775	8
0.135	5	2.045	1	3.990	5	5.575	8	7.808	3	9.880	5	11.798	2
0.149	1	2.048	5	4.015	2	5.665	1	7.820	1	9.970	8	11.812	9
0.150	5	2.065	1	4.022	3	5.670	12	7.830	4	9.980	2	11.820	5
0.175	1	2.070	12	4.038	2	5.708	1	7.883	2	9.982	9	11.840	2
0.177	5	2.104	1	4.041	3	5.720	3	7.910	3	10.030	2	11.845	12
0.219	1	2.115	1	4.057	2	5.735	5	7.955	2	10.038	3	11.850	2
0.221	5	2.142	8	4.096	5	5.762	3	7.990	10	10.050	2	11.865	9
0.280	1	2.143	1	4.150	1	5.790	3	8.030	8	10.055	3	11.910	1
0.325	5	2.185	8	4.162	3	5.845	4	8.052	2	10.065	2	11.930	4
0.335	1	2.210	5	4.182	1	5.855	1	8.082	3	10.070	3	11.945	1
0.349	3	2.228	10	4.198	3	5.870	3	8.180	1	10.110	2	11.950	4
0.355	4	2.240	1	4.222	1	5.890	4	8.200	3	10.175	10	12.000	1
0.378	1	2.255	10	4.227	3	5.918	3	8.242	1	10.225	10	12.005	4
0.383	4	2.260	1	4.233	2	5.930	1	8.300	10	10.235	3	12.040	2
0.395	1	2.295	8	4.257	8	5.940	5	8.312	10	10.245	2	12.050	12
0.420	5	2.303	3	4.272	2	5.960	3	8.360	10	10.255	3	12.135	2
0.444	2	2.328	8	4.300	2	5.980	2	8.375	1	10.270	2	12.145	6
0.505	8	2.342	1	4.314	1	6.022	1	8.382	8	10.410	2	12.168	3
0.532	1	2.345	5	4.320	5	6.098	8	8.410	1	10.420	5	12.175	2
0.548	5	2.355	1	4.342	1	6.130	8	8.435	10	10.460	2	12.180	12
0.586	1	2.360	5	4.350	5	6.131	1	8.460	1	10.465	3	12.192	2
0.592	3	2.408	1	4.380	5	6.155	8	8.465	9	10.480	2	12.210	12
0.600	1	2.418	3	4.405	3	6.170	5	8.495	1	10.490	3	12.260	2
0.608	3	2.460	2	4.445	1	6.190	2	8.542	8	10.560	2	12.330	10
0.630	1	2.475	5	4.448	5	6.195	5	8.580	1	10.585	6	12.340	8
0.631	8	2.490	3	4.480	1	6.230	1	8.765	10	10.610	3	12.430	10
0.680	1	2.512	10	4.490	3	6.249	3	8.940	1	10.685	2	12.440	2
0.682	8	2.530	1	4.495	2	6.280	6	8.980	5	10.700	3	12.455	5
0.708	1	2.620	10	4.520	1	6.325	5	8.998	8	10.715	2	12.540	2
0.710	4	2.640	5	4.578	10	6.340	8	9.012	5	10.782	5	12.550	5
0.720	1	2.672	8	4.582	1	6.405	2	9.060	8	10.812	4	12.610	2
0.730	3	2.695	5	4.655	10	6.415	3	9.140	1	10.835	5	12.650	4
0.740	4	2.738	10	4.660	1	6.470	2	9.150	5	10.845	8	12.660	5
0.750	1	2.748	5	4.671	10	6.490	5	9.160	2	10.880	5	12.700	4
0.760	3	2.755	12	4.672	1	6.500	3	9.165	4	10.890	12	12.710	3
0.785	2	2.765	5	4.688	10	6.525	5	9.170	2	10.900	5	12.742	2
0.792	3	2.798	10	4.690	1	6.533	7	9.178	10	10.918	2	12.750	4
0.920	8	2.810	5	4.715	10	6.565	5	9.190	3	10.995	10	12.799	2
0.930	4	2.832	1	4.717	1	6.580	4	9.275	2	11.018	5	12.802	12
0.980	3	2.849	7	4.732	8	6.582	1	9.280	3	11.100	10	12.820	3
0.990	1	2.880	1	4.734	1	6.598	7	9.340	2	11.150	8	12.830	2
0.995	3	2.890	4	4.770	8	6.605	5	9.350	3	11.185	5	12.835	12
1.010	1	2.905	1	4.772	1	6.640	2	9.365	2	11.221	2	12.840	3
1.113	4	2.921	3	4.880	10	6.750	10	9.370	3	11.275	5	12.850	12
1.170	3	2.960	5	4.915	5	6.803	9	9.375	2	11.285	12	12.860	3
1.210	2	3.018	1	4.920	12	6.855	10	9.382	3	11.300	2	12.865	4
1.219	1	3.045	10	4.928	5	7.141	1	9.395	2	11.305	12	12.870	3
1.240	3	3.050	3	4.940	7	7.153	9	9.430	10	11.315	2	12.900	2
1.350	1	3.210	10	4.980	1	7.160	4	9.435	1	11.320	12	12.970	10
1.375	8	3.290	1	4.982	5	7.170	3	9.492	9	11.335	2	13.057	2
1.390	3	3.310	5	5.015	1	7.355	2	9.500	5	11.340	12	13.060	3
1.470	1	3.350	10	5.020	4	7.390	6	9.525	10	11.360	2	13.070	2
1.580	8	3.410	1	5.120	1	7.400	3	9.570	5	11.425	8	13.145	1
1.627	1	3.460	5	5.258	2	7.470	2	9.612	10	11.520	1	13.150	4
1.638	3	3.525	8	5.260	5	7.540	1	9.615	2	11.570	5	13.153	3

LBY (continued)

13.190	2	15.105	5	16.885	1	18.555	4	20.220	2	21.700	2	23.095	5
13.192	3	15.150	8	16.890	3	18.565	3	20.225	4	21.730	10	23.105	12
13.240	1	15.160	3	16.970	2	18.645	2	20.235	2	21.740	2	23.110	5
13.255	4	15.175	12	16.980	3	18.650	5	20.240	4	21.800	10	23.155	7
13.315	1	15.180	2	17.010	2	18.712	2	20.225	2	21.810	9	23.180	5
13.320	3	15.185	12	17.015	3	18.720	3	20.235	3	21.842	2	23.205	8
13.420	8	15.187	2	17.035	2	18.738	2	20.310	1	21.860	3	23.218	2
13.430	8	15.192	12	17.075	6	18.742	3	20.335	7	21.870	2	23.225	8
13.440	8	15.197	2	17.265	2	18.785	2	20.409	2	21.895	6	23.242	5
13.465	1	15.220	8	17.290	3	18.790	3	20.411	5	21.910	3	23.300	8
13.490	5	15.222	2	17.320	7	18.890	2	20.440	2	21.980	2	23.325	3
13.520	3	15.260	8	17.390	2	18.892	5	20.463	3	22.030	3	23.392	8
13.530	5	15.330	10	17.400	7	18.910	2	20.495	6	22.040	3	23.400	2
13.560	3	15.335	2	17.440	3	18.911	5	20.545	4	22.058	2	23.410	12
13.685	10	15.348	12	17.450	2	18.935	2	20.562	5	22.062	3	23.430	2
13.775	10	15.400	10	17.500	7	18.940	5	20.612	6	22.070	2	23.435	12
13.777	2	15.405	2	17.530	3	18.965	2	20.670	2	22.072	3	23.445	2
13.805	10	15.430	8	17.550	2	19.000	4	20.672	5	22.085	2	23.475	8
13.815	2	15.480	5	17.560	1	19.055	2	20.695	2	22.110	3	23.488	5
13.840	10	15.510	9	17.565	12	19.060	12	20.702	4	22.135	4	23.560	8
13.860	2	15.520	5	17.580	1	19.080	2	20.715	5	22.140	2	23.570	2
13.887	10	15.550	11	17.605	8	19.085	12	20.740	2	22.155	4	23.600	8
13.892	2	15.597	5	17.610	2	19.095	2	20.750	3	22.160	2	23.615	5
13.915	10	15.630	8	17.630	4	19.120	7	20.808	2	22.190	7	23.630	2
13.920	2	15.770	7	17.655	5	19.130	2	20.861	7	22.200	3	23.660	5
13.982	10	15.798	1	17.660	12	19.155	7	20.883	5	22.235	2	23.690	8
14.012	5	15.805	5	17.682	5	19.160	2	20.902	8	22.240	4	23.698	2
14.042	8	15.830	1	17.700	4	19.180	7	20.922	5	22.255	2	23.748	8
14.103	2	15.835	5	17.745	7	19.205	2	20.935	8	22.265	4	23.765	4
14.107	5	15.860	1	17.755	3	19.210	12	20.960	8	22.300	2	23.775	5
14.125	2	15.880	3	17.765	2	19.220	2	20.990	3	22.370	4	23.780	12
14.130	3	15.895	1	17.772	3	19.225	12	20.992	5	22.410	7	23.800	5
14.145	2	15.905	4	17.780	2	19.275	5	21.000	2	22.420	5	23.805	12
14.150	3	15.920	3	17.788	3	19.282	12	21.025	10	22.440	6	23.810	5
14.335	2	16.050	1	17.815	2	19.305	5	21.035	5	22.450	5	23.815	12
14.350	3	16.060	12	17.818	3	19.325	7	21.055	12	22.482	2	23.830	5
14.360	2	16.070	1	17.825	2	19.370	2	21.068	5	22.493	3	23.905	8
14.380	7	16.075	4	17.830	3	19.390	5	21.072	12	22.520	1	23.920	2
14.435	2	16.105	1	17.895	2	19.450	2	21.100	5	22.545	5	23.930	12
14.438	8	16.110	3	17.962	8	19.455	5	21.180	8	22.600	8	23.950	5
14.448	3	16.215	1	17.972	2	19.495	2	21.190	2	22.628	1	23.955	12
14.463	2	16.225	5	17.978	12	19.500	5	21.240	8	22.695	7	23.970	5
14.473	3	16.260	1	17.985	2	19.545	2	21.245	2	22.705	2	23.980	12
14.480	5	16.262	3	17.990	12	19.555	4	21.280	8	22.715	7	24.010	5
14.490	2	16.275	5	17.995	2	19.615	3	21.295	5	22.755	2	24.062	8
14.525	7	16.335	2	18.035	10	19.779	2	21.332	8	22.790	7	24.065	5
14.690	2	16.360	6	18.050	5	19.780	5	21.350	5	22.840	2	24.075	12
14.700	5	16.399	2	18.065	5	19.829	2	21.355	12	22.855	7	24.085	5
14.718	8	16.455	3	18.080	12	19.831	5	21.362	5	22.865	2	24.095	12
14.721	2	16.505	2	18.115	5	19.862	2	21.380	12	22.870	12	24.125	5
14.740	9	16.538	3	18.120	12	19.868	4	21.389	5	22.878	2	24.180	8
14.750	2	16.570	2	18.135	5	19.875	2	21.480	8	22.881	12	24.210	1
14.802	10	16.580	3	18.145	12	19.880	12	21.482	2	22.895	2	24.270	10
14.815	2	16.590	2	18.175	5	19.920	2	21.515	8	22.930	3	24.305	2
14.855	10	16.600	3	18.190	12	19.945	1	21.535	2	22.945	5	24.310	12
14.870	2	16.635	2	18.230	5	19.950	2	21.540	4	22.952	12	24.330	2
14.940	8	16.640	3	18.240	12	19.960	1	21.548	2	22.970	2	24.340	12
14.985	2	16.700	1	18.287	5	20.031	2	21.580	4	22.980	12	24.360	2
15.000	8	16.730	6	18.292	12	20.035	3	21.595	5	22.987	5	24.363	3
15.005	3	16.787	2	18.315	5	20.145	2	21.610	2	23.000	8	24.380	2
15.030	2	16.810	4	18.325	12	20.170	3	21.615	4	23.015	5	24.390	5
15.050	3	16.840	3	18.370	5	20.178	4	21.635	5	23.035	8	24.400	2
15.055	5	16.850	2	18.410	8	20.190	3	21.675	9	23.068	5	24.430	10
15.070	3	16.860	12	18.445	9	20.210	2	21.682	2	23.082	5	24.440	2
15.085	2	16.870	3	18.500	2	20.215	4	21.691	4	23.090	12	24.478	10

LBY (continued)

24.485	2	26.270	5	27.920	4
24.505	8	26.340	10	27.980	4
24.545	2	26.380	5	27.990	5
24.560	5	26.420	8	28.040	2
24.590	8	26.430	2	28.050	4
24.612	10	26.440	10	28.075	2
24.670	2	26.450	12	28.085	12
24.670	8	26.460	12	28.095	2
24.700	8	26.485	5	28.120	9
24.710	3	26.500	12	28.130	2
24.730	2	26.505	5	28.185	9
24.755	4	26.530	10	28.245	2
24.775	3	26.545	5	28.252	3
24.815	8	26.555	8	28.270	2
24.820	2	26.598	5	28.300	4
24.855	7	26.605	12	28.310	3
24.882	2	26.610	5	28.325	2
24.884	5	26.620	12	28.355	8
24.897	2	26.635	5	28.365	3
24.905	12	26.650	12	28.398	2
24.920	3	26.665	5	28.412	4
24.940	2	26.680	10	28.455	1
24.970	8	26.683	5	28.460	12
24.990	3	26.715	10	28.470	2
25.045	2	26.755	5	28.480	5
25.055	13	26.760	12		
25.100	2	26.780	5		
25.130	2	26.845	8		
25.135	7	26.855	2		
25.160	3	26.905	8		
25.200	2	26.915	5		
25.300	1	26.970	2		
25.360	2	27.005	8		
25.395	7	27.110	2		
25.440	2	27.115	5		
25.475	7	27.135	2		
25.530	2	27.185	6		
25.550	7	27.295	2		
25.610	2	27.300	3		
25.675	8	27.315	2		
25.690	3	27.355	4		
25.700	2	27.370	2		
25.710	12	27.430	9		
25.820	2	27.435	2		
25.830	3	27.440	10		
25.900	2	27.455	2		
25.910	3	27.457	5		
25.920	2	27.469	2		
25.930	5	27.585	10		
25.945	2	27.570	2		
25.955	4	27.580	3		
25.990	2	27.588	4		
26.005	12	27.598	2		
26.032	2	27.655	9		
26.038	4	27.665	2		
26.060	2	27.730	4		
26.065	5	27.755	2		
26.075	2	27.765	12		
26.082	3	27.785	2		
26.172	1	27.800	12		
26.182	12	27.810	2		
26.220	1	27.865	4		
26.230	12	27.885	3		
26.240	1	27.900	2		
26.260	8	27.910	5		

OXF--OXFORD CORE, OGS 2982 (bottom, 0 m, at 370 ft; top at 280 ft)

0.005	5	1.198	3	3.095	3	4.748	4	6.010	5	7.984	2	10.180	10
0.012	12	1.212	8	3.170	8	4.755	2	6.018	12	7.986	5	10.335	2
0.022	5	1.288	3	3.205	2	4.772	4	6.030	2	8.015	2	10.495	2
0.028	12	1.292	9	3.220	10	4.778	2	6.040	12	8.060	8	10.502	3
0.052	2	1.300	3	3.262	2	4.835	10	6.108	2	8.080	2	10.568	2
0.055	5	1.368	2	3.265	5	4.848	5	6.120	5	8.082	5	10.570	5
0.068	2	1.450	10	3.290	2	4.852	12	6.150	10	8.095	2	10.605	2
0.072	12	1.468	5	3.292	5	4.860	2	6.190	5	8.122	3	10.615	3
0.090	2	1.472	12	3.330	2	4.865	12	6.218	2	8.198	2	11.020	2
0.092	5	1.499	5	3.340	4	4.880	2	6.222	12	8.205	6	11.100	3
0.102	2	1.515	12	3.352	4	4.920	10	6.245	2	8.228	2	11.285	2
0.111	12	1.540	5	3.382	8	4.925	2	6.246	8	8.235	3	11.290	4
0.115	2	1.615	8	3.399	5	4.930	12	6.255	3	8.280	2	11.440	2
0.140	8	1.622	5	3.450	8	4.945	2	6.262	3	8.290	3	11.458	4
0.160	3	1.680	2	3.498	5	4.948	5	6.335	2	8.300	4	11.490	14
0.219	2	1.695	8	3.560	8	4.958	2	6.360	3	8.308	3	11.610	2
0.221	5	1.729	2	3.575	5	4.962	12	6.405	2	8.308	2	11.630	4
0.227	2	1.732	5	3.595	4	4.980	5	6.415	10	8.312	12	11.640	3
0.230	12	1.778	2	3.597	15	5.045	10	6.432	2	8.320	2	11.650	4
0.240	2	1.838	9	3.610	4	5.115	2	6.440	10	8.322	5	11.660	3
0.245	12	1.848	2	3.630	5	5.120	3	6.465	5	8.340	2	11.692	2
0.293	2	1.852	12	3.660	8	5.168	2	6.480	2	8.360	5	11.703	4
0.295	12	1.870	2	3.675	5	5.171	12	6.495	5	8.375	12	11.715	3
0.330	2	1.900	10	3.682	12	5.185	2	6.578	10	8.390	5	11.750	2
0.345	3	1.928	10	3.695	2	5.212	5	6.680	10	8.415	8	11.800	3
0.378	2	1.950	5	3.705	12	5.250	8	6.750	10	8.430	5	11.825	2
0.382	3	1.960	3	3.718	2	5.270	1	6.755	2	8.450	2	11.880	3
0.400	2	1.992	5	3.785	10	5.280	4	6.810	10	8.480	5	12.110	2
0.408	3	2.028	2	3.820	2	5.300	2	6.815	2	8.485	12	12.125	3
0.500	2	2.030	5	3.822	12	5.325	2	6.820	12	8.500	5	12.235	2
0.515	8	2.060	2	3.845	5	5.335	8	6.860	5	8.505	12	12.260	3
0.535	5	2.090	2	3.870	8	5.350	5	6.940	10	8.515	5	12.412	10
0.558	2	2.110	4	3.880	4	5.375	2	6.970	5	8.570	10	12.440	2
0.580	3	2.135	2	3.885	4	5.420	2	6.975	8	8.610	8	12.450	10
0.590	2	2.160	5	3.905	5	5.485	8	7.020	5	8.620	8	12.530	2
0.620	3	2.172	2	3.915	9	5.580	10	7.090	8	8.670	8	12.560	3
0.625	12	2.180	12	3.918	15	5.585	11	7.122	1	8.682	8	12.662	10
0.635	3	2.200	2	3.922	5	5.610	5	7.170	1	8.688	2	12.695	2
0.682	2	2.210	3	3.930	12	5.652	10	7.172	5	8.692	12	12.760	8
0.690	5	2.305	8	3.942	5	5.662	2	7.228	1	8.720	5	12.782	5
0.695	12	2.375	8	3.960	8	5.700	8	7.240	14	8.818	1	12.805	2
0.705	2	2.400	5	3.970	5	5.702	15	7.352	2	8.880	2	12.812	12
0.710	12	2.485	1	3.985	8	5.708	5	7.358	12	8.955	1	12.835	2
0.718	2	2.528	2	3.995	5	5.710	12	7.392	2	9.020	2	12.840	12
0.765	8	2.535	3	4.095	10	5.728	5	7.398	12	9.065	1	12.905	2
0.775	3	2.570	2	4.115	2	5.732	12	7.440	2	9.080	6	12.915	12
0.790	8	2.580	12	4.117	5	5.758	10	7.448	3	9.200	1	12.925	3
0.815	5	2.585	2	4.168	2	5.772	5	7.480	2	9.665	2	12.930	2
0.835	2	2.590	3	4.180	3	5.782	12	7.490	5	9.670	4	12.940	3
0.882	8	2.618	4	4.215	8	5.800	5	7.570	5	9.690	2	12.965	2
0.890	3	2.623	2	4.229	2	5.812	12	7.580	2	9.770	10	12.972	3
0.902	3	2.630	5	4.232	10	5.822	2	7.612	8	9.785	3	12.982	2
0.945	2	2.640	2	4.240	3	5.835	2	7.670	2	9.838	10	12.990	3
0.952	3	2.685	8	4.270	2	5.860	10	7.675	12	9.842	2	13.070	2
0.975	2	2.708	5	4.290	5	5.870	2	7.740	2	9.870	8	13.095	3
1.000	5	2.740	10	4.292	12	5.915	10	7.745	3	9.875	2	13.485	2
1.025	8	2.755	3	4.298	2	5.928	5	7.780	2	9.915	8	13.502	4
1.035	2	2.776	11	4.300	12	5.930	12	7.800	8	9.929	2	13.545	2
1.042	12	2.795	2	4.330	5	5.940	5	7.828	2	9.990	8	13.560	3
1.062	2	2.805	5	4.480	10	5.968	10	7.832	12	10.012	8	13.598	2
1.068	12	2.880	2	4.560	2	5.978	2	7.835	2	10.018	5	13.600	4
1.115	2	2.882	15	4.590	5	5.982	12	7.842	12	10.075	8	13.710	2
1.140	8	2.919	8	4.695	8	5.990	5	7.908	2	10.085	5	13.720	3
1.172	2	2.920	15	4.705	2	5.992	12	7.945	2	10.088	12	13.795	2
1.182	2	3.065	2	4.720	5	6.005	2	7.970	8	10.108	5	13.800	12

OXF (continued)

13.820	2 15.512	5 16.798	2 17.948	2 19.255	12 21.280	4 22.902	12
13.845	4 15.590	2 16.805	12 17.952	3 19.260	5 21.320	3 22.930	5
13.910	2 15.600	4 16.815	2 17.990	3 19.325	10 21.360	2 22.940	12
13.950	4 15.648	2 16.822	8 18.012	2 19.345	5 21.428	3 22.968	5
14.085	2 15.650	12 16.840	2 18.020	3 19.360	4 21.470	8 22.972	12
14.090	3 15.672	2 16.870	8 18.030	3 19.378	2 21.485	2 22.988	5
14.105	2 15.675	12 16.900	2 18.038	2 19.382	4 21.492	3 22.992	12
14.112	3 15.700	2 16.930	8 18.040	3 19.430	2 21.538	2 23.020	5
14.195	2 15.702	5 16.945	8 18.055	2 19.435	12 21.545	4 23.062	8
14.202	3 15.725	14 16.950	2 18.060	12 19.450	2 21.562	3 23.078	5
14.255	2 15.750	2 16.955	8 18.088	2 19.512	5 21.605	2 23.082	12
14.310	4 15.755	12 16.970	8 18.092	12 19.550	8 21.612	3 23.092	5
14.365	2 15.760	2 16.980	5 18.112	1 19.570	2 21.630	2 23.100	12
14.370	3 15.770	12 16.995	12 18.130	3 19.580	12 21.650	4 23.110	5
14.395	2 15.782	2 17.008	5 18.145	2 19.586	2 21.680	2 23.145	10
14.402	3 15.790	12 17.020	12 18.180	4 19.630	10 21.700	3 23.175	10
14.410	2 15.795	2 17.028	5 18.210	3 19.680	5 21.715	2 23.180	3
14.495	3 15.800	12 17.055	10 18.230	14 19.695	10 21.720	4 23.208	2
14.595	4 15.805	2 17.062	5 18.250	14 19.710	5 21.748	2 23.215	10
14.610	3 15.810	12 17.065	12 18.260	4 19.800	2 21.770	3 23.230	3
14.640	2 15.825	2 17.070	5 18.270	3 19.850	0 21.855	2 23.260	4
14.650	3 15.880	7 17.072	12 18.285	4 19.945	2 21.860	3 23.270	5
14.670	2 16.005	2 17.095	5 18.292	3 19.950	3 21.878	2 23.290	2
14.690	4 16.010	3 17.100	12 18.370	2 19.980	2 21.882	5 23.310	4
14.770	2 16.020	2 17.103	5 18.372	4 19.985	3 21.938	2 23.340	8
14.780	3 16.022	3 17.120	10 18.390	14 20.150	2 21.940	3 23.348	5
14.785	2 16.035	2 17.122	11 18.400	3 20.188	0 21.951	2 23.350	12
14.795	3 16.045	3 17.170	10 18.430	2 20.270	2 21.955	3 23.355	5
14.810	2 16.088	2 17.172	15 18.575	8 20.290	3 21.990	2 23.362	12
14.820	4 16.092	3 17.212	10 18.590	2 20.318	2 22.040	8 23.415	2
14.820	2 16.110	2 17.220	5 18.620	2 20.320	3 22.045	2 23.440	5
14.875	3 16.112	3 17.225	12 18.640	4 20.380	2 22.080	8 23.505	9
14.900	4 16.192	2 17.250	5 18.650	5 20.387	3 22.150	3 23.520	5
14.915	3 16.200	3 17.260	10 18.672	2 20.420	2 22.180	2 23.523	12
14.930	4 16.235	2 17.265	15 18.680	3 20.470	0 22.220	8 23.540	2
14.940	14 16.240	12 17.318	10 18.690	14 20.510	2 22.230	8 23.545	3
14.960	3 16.248	2 17.330	2 18.695	2 20.518	3 22.260	5 23.592	10
14.980	4 16.252	4 17.335	12 18.710	3 20.612	2 22.290	4 23.600	2
15.020	2 16.270	2 17.340	2 18.720	2 20.620	3 22.309	2 23.640	10
15.035	3 16.275	3 17.360	11 18.728	3 20.685	2 22.320	3 23.670	5
15.060	2 16.340	2 17.380	5 18.748	2 20.690	3 22.348	3 23.720	10
15.065	12 16.345	4 17.410	11 18.750	3 20.778	2 22.380	4 23.745	5
15.080	2 16.360	2 17.420	3 18.770	2 20.782	3 22.415	2 23.768	9
15.145	2 16.365	4 17.530	2 18.840	4 20.795	2 22.460	4 23.780	9
15.160	3 16.405	3 17.550	3 18.860	3 20.802	3 22.480	2 23.810	2
15.172	3 16.410	4 17.565	14 18.880	2 20.870	2 22.515	8 23.815	9
15.190	2 16.428	2 17.600	3 18.898	4 20.905	4 22.540	2 23.830	2
15.200	4 16.450	3 17.620	2 18.910	3 20.950	2 22.582	10 23.850	10
15.210	3 16.460	14 17.622	14 18.920	4 20.965	3 22.610	5 23.885	5
15.230	2 16.485	4 17.635	3 18.935	4 21.003	2 22.640	8 23.890	12
15.235	3 16.500	5 17.668	2 18.952	4 21.008	3 22.645	5 23.900	5
15.245	2 16.535	2 17.695	2 18.960	5 21.020	2 22.652	12 23.938	10
15.285	3 16.537	5 17.698	3 18.968	12 21.025	3 22.680	5 23.942	2
15.300	2 16.545	3 17.728	2 18.982	5 21.042	2 22.685	12 23.952	12
15.302	5 16.555	2 17.730	14 18.990	12 21.085	4 22.705	5 23.958	2
15.320	2 16.560	3 17.770	3 19.010	5 21.130	3 22.720	10 23.960	12
15.355	3 16.600	2 17.795	6 19.012	12 21.158	2 22.760	5 23.965	2
15.360	3 16.615	3 17.815	3 19.040	5 21.160	5 22.795	10 23.980	12
15.400	3 16.640	2 17.840	2 19.050	11 21.178	2 22.800	2 23.985	2
15.415	3 16.680	2 17.875	3 19.075	10 21.180	5 22.848	10 24.015	10
15.420	2 16.690	3 17.885	3 19.100	5 21.198	2 22.852	5 24.035	2
15.422	3 16.705	2 17.895	2 19.150	10 21.202	5 22.860	12 24.060	4
15.470	2 16.710	3 17.905	3 19.165	2 21.218	2 22.868	3 24.065	4
15.495	3 16.735	2 17.918	2 19.190	4 21.222	3 22.880	10 24.090	4
15.508	2 16.790	8 17.930	3 19.250	5 21.240	2 22.895	3 24.110	5

OXF (continued)

24.115	4	25.418	5	26.570	4
24.135	5	25.422	12	26.585	5
24.140	4	25.440	5	26.610	8
24.165	5	25.445	12	26.680	2
24.185	10	25.462	5	26.710	4
24.190	5	25.465	12	26.718	2
24.200	12	25.482	5	26.720	12
24.235	10	25.510	8	26.729	2
24.238	15	25.520	2	26.732	12
24.295	11	25.545	8	26.740	2
24.302	5	25.552	3	26.762	10
24.312	12	25.562	12	26.805	2
24.322	5	25.568	3	26.810	12
24.338	12	25.572	12	26.822	5
24.340	5	25.582	3	26.830	12
24.355	12	25.630	10	26.845	5
24.395	11	25.680	10	26.885	10
24.428	10	25.682	15	26.915	2
24.475	11	25.735	10	26.925	10
24.485	11	25.740	15	26.985	10
24.500	11	25.795	10	27.015	5
24.510	2	25.800	15	27.050	10
24.600	10	25.842	10	27.060	5
24.605	15	25.858	5	27.062	12
24.628	10	25.860	12	27.075	5
24.630	15	25.890	5	27.078	15
24.638	5	25.925	11	27.155	11
24.652	12	25.930	2	27.158	2
24.678	5	25.935	12	27.208	11
24.680	12	25.945	2	27.220	5
24.682	15	25.950	12	27.225	12
24.700	5	25.955	2	27.245	5
24.718	2	26.065	11	27.275	2
24.740	10	26.100	10	27.292	15
24.808	5	26.115	5	27.325	10
24.815	11	26.120	12	27.345	5
24.830	5	26.130	5	27.360	11
24.838	12	26.155	10	27.385	5
24.860	5	26.175	5	27.420	10
24.925	10	26.195	10	27.425	5
24.930	15	26.228	2	27.430	5
24.945	5	26.235	8	27.435	12
24.985	2	26.250	2		
25.035	10	26.260	12		
25.052	5	26.278	2		
25.062	10	26.280	5		
25.085	5	26.300	12		
25.112	9	26.310	2		
25.140	5	26.325	4		
25.142	12	26.325	5		
25.160	5	26.365	2		
25.185	10	26.385	10		
25.210	2	26.395	2		
25.230	3	26.420	4		
25.262	10	26.425	3		
25.265	2	26.450	2		
25.302	9	26.452	12		
25.328	5	26.455	2		
25.333	12	26.470	10		
25.348	2	26.472	11		
25.352	12	26.490	10		
25.360	2	26.505	2		
25.390	10	26.508	15		
25.400	5	26.525	4		
25.408	12	26.530	2		

RLY--REILY CORE, OGS 2981 (bottom, 0 m, at 400 ft; top at 314 ft)

0.075	8	1.805	12	3.512	12	5.120	3	7.275	3	9.370	2	11.155	2
0.090	3	1.845	2	3.530	5	5.130	2	7.280	2	9.380	3	11.158	3
0.115	1	1.855	2	3.550	8	5.180	8	7.282	5	9.392	5	11.220	2
0.125	3	1.860	4	3.555	2	5.220	5	7.348	2	9.400	4	11.225	4
0.240	1	1.880	3	3.570	8	5.250	2	7.395	8	9.420	3	11.250	2
0.248	3	1.912	2	3.580	5	5.260	3	7.410	5	9.440	2	11.280	4
0.260	2	1.930	4	3.585	3	5.280	2	7.432	8	9.455	5	11.310	3
0.280	3	1.940	3	3.600	5	5.300	8	7.438	2	9.465	4	11.350	2
0.290	2	1.975	2	3.605	3	5.360	5	7.450	12	9.480	3	11.360	5
0.310	3	1.985	3	3.615	2	5.390	2	7.480	5	9.494	2	11.375	2
0.350	4	1.990	4	3.660	8	5.400	2	7.495	2	9.500	5	11.385	4
0.371	3	2.035	2	3.665	2	5.410	3	7.505	12	9.508	2	11.450	2
0.385	2	2.040	12	3.695	8	5.420	2	7.520	5	9.512	3	11.460	4
0.405	3	2.060	5	3.715	8	5.435	3	7.525	12	9.528	2	11.490	2
0.418	2	2.082	2	3.780	5	5.445	5	7.560	5	9.535	3	11.495	3
0.450	8	2.087	12	3.782	8	5.487	2	7.570	12	9.608	2	11.525	2
0.500	3	2.105	2	3.845	2	5.494	3	7.600	5	9.612	3	11.565	8
0.530	2	2.185	8	3.855	12	5.498	2	7.625	2	9.635	2	11.610	3
0.548	3	2.195	2	3.894	2	5.505	3	7.660	10	9.670	3	11.645	2
0.690	11	2.200	12	3.905	12	5.520	2	7.665	2	9.702	2	11.650	3
0.697	2	2.245	2	3.940	2	5.526	3	7.675	12	9.710	4	11.710	2
0.740	10	2.330	2	3.945	8	5.555	2	7.685	2	9.712	2	11.715	3
0.790	8	2.350	5	3.982	2	5.565	5	7.690	5	9.720	4	11.840	2
0.820	3	2.360	12	3.987	5	5.610	8	7.715	2	9.730	2	11.850	3
0.855	2	2.400	5	4.110	2	5.660	8	7.720	12	9.760	0	11.860	4
0.860	5	2.490	8	4.130	5	5.705	2	7.760	2	9.780	5	11.890	2
0.930	2	2.520	8	4.218	8	5.720	3	7.780	5	9.810	2	11.918	4
0.940	3	2.550	5	4.270	2	5.770	8	7.795	9	9.820	3	11.945	3
0.975	2	2.555	12	4.280	5	5.780	3	7.840	2	9.880	2	11.955	2
0.990	4	2.568	2	4.295	8	5.810	2	7.865	3	9.885	3	11.962	4
1.047	2	2.572	12	4.335	2	5.820	3	7.875	1	9.940	2	12.022	2
1.070	8	2.590	2	4.355	8	5.860	2	7.930	2	9.950	3	12.030	3
1.080	5	2.599	5	4.365	5	5.905	8	7.935	5	9.982	2	12.065	2
1.100	2	2.605	12	4.375	2	5.908	10	7.965	2	9.990	3	12.070	3
1.125	5	2.620	5	4.390	8	5.910	15	7.992	8	10.115	2	12.080	2
1.200	4	2.640	12	4.395	2	5.938	10	8.022	2	10.160	5	12.090	3
1.215	2	2.650	5	4.400	12	5.940	15	8.029	3	10.210	7	12.112	2
1.225	5	2.690	2	4.450	5	5.965	10	8.035	2	10.280	8	12.150	3
1.230	12	2.740	5	4.480	8	5.970	15	8.042	4	10.290	2	12.200	2
1.240	5	2.750	12	4.490	2	6.060	8	8.052	2	10.293	15	12.205	3
1.248	12	2.755	5	4.500	12	6.070	11	8.060	4	10.340	8	12.232	2
1.260	5	2.790	8	4.510	2	6.085	3	8.088	2	10.440	8	12.240	3
1.290	8	2.820	5	4.555	8	6.097	11	8.092	8	10.530	2	12.242	2
1.295	5	2.885	10	4.560	2	6.205	0	8.100	2	10.540	5	12.250	3
1.300	12	2.895	1	4.630	8	6.215	5	8.115	3	10.568	2	12.260	4
1.310	5	3.000	10	4.645	2	6.222	12	8.180	5	10.572	3	12.280	2
1.320	8	3.035	2	4.650	3	6.235	5	8.205	8	10.620	2	12.320	8
1.340	2	3.045	5	4.670	5	6.245	12	8.225	2	10.630	4	12.350	5
1.415	8	3.075	2	4.745	8	6.255	5	8.290	8	10.680	2	12.370	2
1.442	2	3.125	10	4.760	2	6.285	8	8.308	2	10.690	5	12.380	5
1.445	5	3.130	2	4.770	12	6.300	2	8.312	4	10.740	2	12.400	2
1.472	2	3.150	4	4.800	2	6.355	8	8.348	2	10.750	4	12.400	1
1.480	12	3.155	2	4.805	5	6.390	5	8.350	5	10.780	3	12.440	2
1.490	3	3.200	8	4.820	2	6.435	8	8.370	2	10.790	2	12.470	4
1.510	5	3.220	5	4.830	5	6.450	2	8.372	5	10.800	3	12.520	2
1.520	10	3.230	12	4.875	8	6.460	4	8.392	2	10.825	2	12.540	3
1.540	10	3.260	5	4.900	5	6.880	2	8.505	8	10.830	3	12.578	2
1.598	5	3.270	12	4.930	2	6.882	5	8.925	2	10.840	2	12.582	4
1.630	8	3.290	5	4.940	12	7.040	2	8.940	4	10.845	3	12.600	3
1.645	5	3.352	8	4.948	5	7.042	5	9.020	2	10.860	2	12.605	2
1.690	8	3.355	2	4.952	12	7.180	2	9.025	3	10.865	4	12.612	3
1.720	8	3.365	8	4.967	5	7.235	8	9.112	2	11.040	2	12.695	2
1.740	5	3.380	2	4.972	12	7.250	2	9.130	0	11.042	4	12.730	4
1.790	2	3.480	8	5.068	1	7.260	5	9.265	2	11.048	2	12.740	2
1.800	5	3.510	2	5.080	4	7.270	3	9.270	13	11.052	3	12.760	4

RLY (continued)

12.775	2	14.378	3	15.652	8	16.831	5	18.860	14	20.190	5	21.121	2
12.782	4	14.382	3	15.660	2	17.025	1	18.870	2	20.198	12	21.130	4
12.825	2	14.390	3	15.663	8	17.028	13	18.872	3	20.218	5	21.140	2
12.872	2	14.422	2	15.668	2	17.159	1	18.888	2	20.222	12	21.145	4
12.970	4	14.430	5	15.670	8	17.162	13	18.915	4	20.242	5	21.148	2
12.995	2	14.440	3	15.675	2	17.338	2	18.945	2	20.248	12	21.172	4
13.002	4	14.450	2	15.680	8	17.345	3	18.970	8	20.252	5	21.181	2
13.050	2	14.460	3	15.689	2	17.448	2	19.005	2	20.260	12	21.185	12
13.120	2	14.490	2	15.693	8	17.452	13	19.035	10	20.268	5	21.190	2
13.160	2	14.500	3	15.703	2	17.478	2	19.044	5	20.272	12	21.192	4
13.165	5	14.515	2	15.705	8	17.492	13	19.050	12	20.278	5	21.218	2
13.210	2	14.520	13	15.720	2	17.587	2	19.068	5	20.282	12	21.220	3
13.212	5	14.560	2	15.738	8	17.592	14	19.072	12	20.295	5	21.238	2
13.230	2	14.565	13	15.740	2	17.642	2	19.080	5	20.311	12	21.241	3
13.280	3	14.600	2	15.790	4	17.645	14	19.085	12	20.320	5	21.250	2
13.282	3	14.650	8	15.800	3	17.675	3	19.110	5	20.330	12	21.308	4
13.288	2	14.720	3	15.825	5	17.680	2	19.205	8	20.340	5	21.315	2
13.290	3	14.750	2	15.832	12	17.710	5	19.220	5	20.390	4	21.320	12
13.295	2	14.760	3	15.850	5	17.715	4	19.232	12	20.400	5	21.350	5
13.300	3	14.775	2	15.890	4	17.725	3	19.260	10	20.408	12	21.360	12
13.330	2	14.820	4	15.895	2	17.730	5	19.290	5	20.412	5	21.380	2
13.350	0	14.830	3	15.905	4	17.762	2	19.315	10	20.430	8	21.382	5
13.360	4	14.840	2	15.918	5	17.772	4	19.340	5	20.448	5	21.398	2
13.395	2	14.860	4	15.922	12	17.780	2	19.380	8	20.490	10	21.418	5
13.450	4	14.870	3	15.968	2	17.802	3	19.435	10	20.498	2	21.440	10
13.455	2	14.878	2	16.005	8	17.818	2	19.445	5	20.502	12	21.450	5
13.460	4	14.879	4	16.037	8	17.822	13	19.460	10	20.518	2	21.490	2
13.475	4	14.910	2	16.048	3	17.885	2	19.475	5	20.525	8	21.500	8
13.485	4	14.960	4	16.075	2	17.978	4	19.515	10	20.542	5	21.520	5
13.490	2	14.965	2	16.090	12	17.999	3	19.525	5	20.550	12	21.530	4
13.515	2	14.970	4	16.098	5	18.082	2	19.530	12	20.580	5	21.535	2
13.530	3	15.005	2	16.103	12	18.085	5	19.540	5	20.590	12	21.540	12
13.560	2	15.020	3	16.120	5	18.118	2	19.562	2	20.600	5	21.550	2
13.570	2	15.068	2	16.125	12	18.120	5	19.568	3	20.605	12	21.580	4
13.580	3	15.085	3	16.139	5	18.280	2	19.590	2	20.620	5	21.585	2
13.582	2	15.100	2	16.155	10	18.300	3	19.595	3	20.625	12	21.587	12
13.590	3	15.112	5	16.160	5	18.310	3	19.603	2	20.635	2	21.590	2
13.612	2	15.140	2	16.170	5	18.340	2	19.606	3	20.645	12	21.595	12
13.620	3	15.280	4	16.200	10	18.360	3	19.638	2	20.660	12	21.628	4
13.625	2	15.320	3	16.211	5	18.362	5	19.640	3	20.670	5	21.650	5
13.660	8	15.340	2	16.215	12	18.420	3	19.652	2	20.680	12	21.660	2
13.682	5	15.342	4	16.218	5	18.430	3	19.655	3	20.705	5	21.670	4
13.710	8	15.348	2	16.223	12	18.510	2	19.720	2	20.725	2	21.680	2
13.720	5	15.352	4	16.235	5	18.512	5	19.740	2	20.730	12	21.690	7
13.760	2	15.358	2	16.240	12	18.540	2	19.800	3	20.738	2	21.705	5
13.820	4	15.362	4	16.312	11	18.550	3	19.820	2	20.795	8	21.712	4
13.870	2	15.375	2	16.312	5	18.598	2	19.830	3	20.801	5	21.720	5
13.885	3	15.378	3	16.320	12	18.602	13	19.848	2	20.818	2	21.738	2
13.900	2	15.385	2	16.323	5	18.615	2	19.860	3	20.822	5	21.742	4
13.902	4	15.390	3	16.335	12	18.620	4	19.865	2	20.852	8	21.785	2
13.920	2	15.405	2	16.342	5	18.668	2	19.878	3	20.870	5	21.810	5
13.921	5	15.420	5	16.360	12	18.672	4	19.885	2	20.878	8	21.850	2
13.935	2	15.455	4	16.400	10	18.690	5	19.970	4	20.895	2	21.910	4
13.937	5	15.471	2	16.410	11	18.707	2	20.010	2	20.903	12	21.942	2
13.960	2	15.495	2	16.440	1	18.710	4	20.015	3	20.920	5	21.965	4
13.970	8	15.505	3	16.450	5	18.720	2	20.030	2	20.940	2	21.978	2
14.055	2	15.512	2	16.590	1	18.723	4	20.032	3	20.965	4	21.982	12
14.118	2	15.520	3	16.598	13	18.730	2	20.065	2	20.995	5	21.990	2
14.122	9	15.530	2	16.715	1	18.733	4	20.072	3	21.002	12	22.015	4
14.135	2	15.533	3	16.720	3	18.740	2	20.082	2	21.015	2	22.038	2
14.140	4	15.555	2	16.745	1	18.772	4	20.110	8	21.016	5	22.042	12
14.145	2	15.560	12	16.750	3	18.778	2	20.155	2	21.040	2	22.070	2
14.150	8	15.578	2	16.787	1	18.785	12	20.160	12	21.090	4	22.175	10
14.160	2	15.635	8	16.788	5	18.790	2	20.178	5	21.100	2	22.210	5
14.310	8	15.648	3	16.829	1	18.830	4	20.182	12	21.105	12	22.240	2

RLY (continued)

22.282	10	23.310	9	24.602	12	26.210	2
22.290	2	23.320	5	24.618	5	26.240	10
22.300	10	23.415	10	24.620	12	26.260	10
22.315	10	23.430	5	24.640	5		
22.328	2	23.435	12	24.675	11		
22.332	12	23.455	5	24.678	2		
22.340	2	23.530	10	24.715	10		
22.350	12	23.560	5	24.745	5		
22.360	2	23.590	5	24.750	12		
22.380	12	23.600	5	24.760	5		
22.410	5	23.630	2	24.775	2		
22.425	2	23.640	4	24.782	11		
22.432	12	23.645	2	24.810	5		
22.440	5	23.660	4	24.820	15		
22.445	12	23.670	2	24.850	10		
22.450	5	23.675	3	24.852	15		
22.455	12	23.685	2	24.875	5		
22.470	5	23.720	8	24.935	10		
22.475	12	23.725	5	24.950	5		
22.485	5	23.775	5	24.965	2		
22.555	10	23.790	12	24.980	5		
22.575	5	23.800	2	25.020	4		
22.590	2	23.910	10	25.065	5		
22.605	12	23.930	10	25.072	12		
22.625	5	23.932	2	25.080	5		
22.635	12	23.950	10	25.088	12		
22.650	5	23.960	5	25.100	5		
22.685	10	23.970	12	25.112	10		
22.690	5	23.990	5	25.120	2		
22.702	10	24.005	12	25.125	12		
22.720	5	24.010	5	25.140	2		
22.725	12	24.020	12	25.160	5		
22.748	5	24.025	5	25.190	8		
22.752	4	24.030	12	25.199	2		
22.775	5	24.040	5	25.202	12		
22.780	4	24.050	12	25.220	2		
22.805	5	24.060	5	25.222	12		
22.810	11	24.070	12	25.245	5		
22.830	5	24.080	5	25.255	12		
22.840	10	24.110	10	25.265	5		
22.850	5	24.120	5	25.272	12		
22.908	8	24.130	12	25.285	5		
22.912	2	24.140	5	25.390	11		
22.920	12	24.142	12	25.392	15		
22.925	2	24.160	5	25.398	2		
22.929	12	24.162	12	25.402	15		
22.932	2	24.175	5	25.440	5		
22.990	10	24.180	12	25.460	15		
23.000	2	24.202	5	25.555	10		
23.002	5	24.210	12	25.560	15		
23.020	2	24.235	5	25.570	10		
23.030	5	24.240	12	25.575	15		
23.040	2	24.250	5	25.615	10		
23.090	8	24.300	10	25.635	5		
23.093	15	24.305	15	25.655	10		
23.115	10	24.320	5	25.665	2		
23.140	2	24.325	10	25.678	10		
23.222	10	24.340	5	25.690	5		
23.230	2	24.470	10	25.700	12		
23.240	12	24.473	15	25.728	5		
23.250	2	24.490	5	25.730	15		
23.260	3	24.505	12	25.890	10		
23.262	4	24.525	5	25.895	15		
23.290	2	24.535	11	25.940	2		
23.300	5	24.590	5	25.960	3		

WCO--WAYNE COUNTY CORE, IGS SDH 57 (bottom, 0 m at 593.8 ft; top at 460.9 ft)

0.015	1	2.540	2	5.325	2	7.286	2	9.255	2	11.715	5	16.490	1
0.050	3	2.570	5	5.330	3	7.305	8	9.390	10	11.725	2	16.500	2
0.240	1	2.608	8	5.420	2	7.307	2	9.445	2	11.732	12	16.515	1
0.270	8	2.650	5	5.423	5	7.340	8	9.450	12	11.760	5	16.718	2
0.310	2	2.680	2	5.450	2	7.355	2	9.485	2	11.770	9	16.723	3
0.338	8	2.682	5	5.453	5	7.358	5	9.530	10	11.912	2	16.791	2
0.365	2	3.050	2	5.590	2	7.398	2	9.550	2	11.920	5	16.808	8
0.382	8	3.055	5	5.592	5	7.418	10	9.575	5	12.015	2	16.815	2
0.418	1	3.098	2	5.682	2	7.545	5	9.590	9	12.022	5	16.822	12
0.430	5	3.105	12	5.698	9	7.560	9	9.645	2	12.198	2	16.835	2
0.448	1	3.162	2	5.719	2	7.668	2	9.650	12	12.199	5	16.870	8
0.468	10	3.171	4	5.725	9	7.672	12	9.672	5	12.438	2	16.930	2
0.507	1	3.448	2	5.770	2	7.700	5	9.690	9	12.440	5	16.935	5
0.512	9	3.450	5	5.815	8	7.725	2	9.730	5	12.870	1	16.945	12
0.548	1	3.560	2	5.830	2	7.745	9	9.760	8	12.908	3	16.965	5
0.555	12	3.563	5	5.832	5	7.775	5	9.800	5	13.440	1	16.975	2
0.584	2	3.590	2	5.870	2	7.790	2	9.805	2	13.480	3	17.035	8
0.595	12	3.598	9	5.873	5	7.840	10	9.806	5	13.840	1	17.070	14
0.612	2	3.755	2	5.887	2	7.860	2	9.835	2	14.050	0	17.088	2
0.622	12	3.760	8	5.900	5	7.870	5	9.900	8	14.070	2	17.092	4
0.720	2	3.808	5	5.945	2	7.915	2	10.045	2	14.130	1	17.408	2
0.735	8	3.820	9	5.970	8	7.925	5	10.050	4	14.150	3	17.410	12
0.767	2	3.950	2	5.985	2	7.980	2	10.075	2	14.210	1	17.575	2
0.770	12	3.955	8	6.000	5	7.983	5	10.077	5	14.212	5	17.582	4
0.815	2	4.005	2	6.048	2	8.115	2	10.115	2	14.300	1	17.870	2
0.820	5	4.084	8	6.050	3	8.120	5	10.145	5	14.320	3	17.875	4
0.872	2	4.202	2	6.072	2	8.135	2	10.298	2	14.385	2	17.960	2
0.880	8	4.260	8	6.088	8	8.145	9	10.305	5	14.408	3	17.980	3
0.908	2	4.300	5	6.200	2	8.200	2	10.335	2	14.458	2	18.150	2
0.917	9	4.340	2	6.205	3	8.210	5	10.368	8	14.459	5	18.200	3
0.958	2	4.350	12	6.235	2	8.230	2	10.390	5	14.488	2	18.488	2
0.992	9	4.351	2	6.270	4	8.250	5	10.412	2	14.660	1	18.500	3
1.008	2	4.360	12	6.338	2	8.280	8	10.420	12	14.665	5	18.520	2
1.010	5	4.370	2	6.375	8	8.300	5	10.448	2	14.750	1	18.540	3
1.065	2	4.375	5	6.430	2	8.370	1	10.465	8	14.755	5	18.587	2
1.102	9	4.410	3	6.432	5	8.400	8	10.485	2	14.830	1	18.628	3
1.165	2	4.440	2	6.488	2	8.445	2	10.487	5	14.832	5	18.840	2
1.167	5	4.443	5	6.510	8	8.452	8	10.518	2	14.932	2	18.855	3
1.385	2	4.470	3	6.530	5	8.500	2	10.522	5	14.960	3	18.948	2
1.503	10	4.496	2	6.605	8	8.505	5	10.648	2	14.988	2	18.952	3
1.548	2	4.498	5	6.606	2	8.535	2	10.655	9	14.990	15	19.010	2
1.550	5	4.570	2	6.670	8	8.537	5	10.680	2	15.020	8	19.018	3
1.762	2	4.575	5	6.690	3	8.590	2	10.682	5	15.023	15	19.058	2
1.781	4	4.620	2	6.692	4	8.600	5	11.000	2	15.050	8	19.062	3
1.798	2	4.630	8	6.725	2	8.685	8	11.005	5	15.090	5	19.100	2
1.802	12	4.715	2	6.750	8	8.715	2	11.050	2	15.110	2	19.108	3
1.908	2	4.720	5	6.780	2	8.750	5	11.078	5	15.122	8	19.680	2
1.920	8	4.750	2	6.782	5	8.790	10	11.121	2	15.148	2	19.685	3
1.972	2	4.755	5	6.802	2	8.791	2	11.123	5	15.152	9	19.882	2
2.003	3	4.885	2	6.818	9	8.820	10	11.180	2	15.185	2	19.892	3
2.033	2	4.890	5	6.820	2	8.870	2	11.210	5	15.212	8	19.932	2
2.040	12	4.945	2	6.845	9	8.930	9	11.248	2	15.230	2	19.942	3
2.050	2	4.950	5	6.846	2	8.950	5	11.255	9	15.387	8	20.010	2
2.105	5	4.970	2	6.865	9	9.020	2	11.290	2	15.393	2	20.012	3
2.112	9	4.985	5	7.035	2	9.072	9	11.295	5	15.440	8	20.060	2
2.140	2	5.035	2	7.058	8	9.100	2	11.440	2	15.460	2	20.065	3
2.150	8	5.038	5	7.080	2	9.130	9	11.445	8	15.463	5	20.132	2
2.280	2	5.080	2	7.082	5	9.140	2	11.495	2	15.725	2	20.145	3
2.328	8	5.100	5	7.115	2	9.150	12	11.510	5	15.807	3	20.160	2
2.340	5	5.130	2	7.135	9	9.170	2	11.550	8	16.102	2	20.165	3
2.350	12	5.150	5	7.180	2	9.173	5	11.630	5	16.112	3	20.265	2
2.360	5	5.198	2	7.215	5	9.190	2	11.650	8	16.218	2	20.272	3
2.385	8	5.202	5	7.228	8	9.195	9	11.680	5	16.222	3	20.390	2
2.432	2	5.278	2	7.270	2	9.235	2	11.700	8	16.428	2	20.395	3
2.460	8	5.282	4	7.285	8	9.238	5	11.710	2	16.430	5	20.468	2

WCO (continued)

20.470	5 23.077	8 25.330	3 28.210	2 31.240	5 32.730	2 34.430	2
20.548	2 23.079	2 25.350	2 28.280	3 31.260	4 32.755	4 34.440	10
20.568	3 23.142	8 25.370	3 28.300	2 31.275	5 32.795	2 34.460	0
20.598	2 23.280	2 25.400	4 28.840	2 31.280	12 32.815	11 34.470	4
20.605	8 23.285	5 25.420	3 28.870	2 31.285	5 32.818	2 34.510	2
20.735	2 23.325	2 25.450	3 28.910	5 31.292	12 32.848	11 34.560	5
20.740	12 23.326	5 25.468	8 28.915	2 31.305	5 32.910	5 34.590	2
21.030	2 23.430	2 25.523	11 28.918	5 31.310	12 32.930	9 34.650	8
21.035	3 23.433	5 25.540	2 28.938	2 31.380	5 32.940	2 34.685	2
21.120	2 23.538	2 25.548	15 28.940	5 31.385	12 32.952	9 34.700	12
21.150	3 23.539	5 25.580	2 28.960	2 31.405	5 32.965	2 34.730	5
21.170	2 23.568	2 25.590	5 29.055	2 31.412	12 32.970	12 34.802	10
21.200	3 23.569	5 25.605	3 29.150	10 31.445	5 32.985	2 34.900	15
21.320	2 23.590	2 25.630	2 29.170	10 31.455	12 33.000	4 34.940	9
21.328	3 23.595	5 25.640	9 29.220	10 31.495	5 33.018	2 34.985	5
21.390	2 23.697	2 25.655	3 29.230	2 31.515	8 33.032	4 35.005	10
21.400	3 23.702	12 25.718	2 29.231	5 31.540	5 33.045	2 35.015	2
21.438	2 23.858	2 25.735	5 29.250	2 31.580	8 33.090	4 35.025	12
21.451	3 23.865	8 25.755	3 29.252	5 31.622	5 33.118	3 35.030	2
21.572	2 23.910	2 25.799	2 29.290	2 31.632	12 33.120	5 35.060	10
21.628	14 24.020	4 25.860	8 29.320	3 31.655	2 33.140	3 35.090	5
21.642	2 24.090	2 25.885	2 29.345	2 31.660	12 33.142	5 35.095	12
21.650	3 24.092	5 25.912	3 29.370	2 31.695	2 33.158	3 35.115	5
21.670	2 24.145	3 26.112	2 29.385	5 31.722	8 33.195	2 35.140	10
21.678	3 24.165	2 26.133	3 29.410	2 31.760	5 33.292	2 35.150	2
21.858	2 24.170	9 26.190	2 29.455	8 31.770	9 33.303	3 35.200	10
21.870	3 24.180	5 26.220	5 29.470	5 31.790	5 33.398	2 35.282	10
21.900	2 24.190	2 26.250	3 29.490	2 31.795	12 33.415	8 35.299	2
21.920	3 24.205	3 26.425	2 29.520	10 31.825	5 33.430	5 35.310	12
21.922	2 24.228	2 26.430	3 29.525	2 31.840	10 33.440	8 35.325	1
21.930	3 24.235	4 26.488	2 29.560	10 31.870	2 33.480	2 35.340	8
21.938	2 24.275	2 26.492	3 29.665	5 31.880	10 33.485	4 35.365	8
21.945	3 24.320	8 26.512	2 29.700	8 31.905	2 33.530	2 35.380	8
22.070	2 24.332	3 26.538	3 29.750	2 31.912	12 33.545	8 35.400	8
22.072	5 24.350	2 26.562	2 29.770	5 31.940	5 33.615	2 35.425	1
22.170	2 24.365	9 26.564	5 29.840	2 31.970	10 33.620	12 35.462	10
22.172	3 24.382	2 26.620	2 29.920	8 32.005	2 33.650	2 35.475	15
22.230	2 24.390	3 26.655	2 29.942	2 32.015	12 33.705	8 35.500	10
22.242	4 24.420	2 26.665	3 29.948	12 32.050	2 33.780	8 35.502	15
22.268	2 24.490	14 26.705	2 29.955	5 32.080	10 33.790	2 35.598	10
22.270	3 24.540	2 26.715	3 29.960	12 32.132	4 33.830	8 35.600	15
22.328	2 24.618	3 26.820	2 29.980	2 32.150	5 33.850	2 35.648	10
22.340	3 24.640	2 26.828	3 30.000	5 32.198	2 33.882	10 35.650	15
22.368	2 24.642	5 26.902	2 30.010	8 32.202	5 33.900	2 35.670	10
22.375	3 24.678	2 26.955	3 30.030	8 32.250	2 33.920	5 35.710	2
22.425	2 24.682	3 26.980	2 30.050	8 32.275	9 33.950	8 35.750	10
22.618	2 24.710	2 27.150	0 30.065	8 32.295	2 33.990	2 35.755	15
22.621	5 24.730	14 27.187	2 30.180	5 32.315	9 34.018	10 35.780	10
22.650	2 24.745	2 27.195	3 30.210	8 32.330	2 34.020	15 35.782	15
22.700	10 24.792	3 27.232	2 30.300	5 32.335	12 34.060	10 35.818	10
22.760	5 24.810	2 27.238	3 30.305	12 32.385	10 34.062	15 35.820	15
22.765	12 24.820	3 27.280	2 30.380	5 32.415	2 34.175	10 35.830	3
22.780	2 24.860	2 27.370	3 30.390	10 32.418	12 34.195	2 35.840	12
22.820	8 24.871	3 27.850	2 30.440	5 32.455	5 34.210	10 35.860	2
22.835	2 24.900	2 27.910	5 30.445	12 32.465	12 34.230	2 35.870	12
22.882	8 24.915	2 27.920	14 30.500	5 32.500	9 34.275	10 35.882	2
22.892	2 24.983	3 27.960	5 30.518	10 32.510	2 34.290	12 35.888	12
22.900	12 25.030	2 27.975	2 30.605	5 32.520	12 34.310	9 35.895	2
22.905	2 25.082	3 27.982	9 30.615	12 32.530	2 34.330	5 35.900	12
22.912	12 25.125	3 28.030	2 30.710	5 32.535	12 34.345	2 35.918	2
22.921	2 25.155	2 28.050	9 30.900	0 32.550	2 34.352	12 35.970	10
22.926	12 25.223	14 28.070	14 30.995	5 32.595	11 34.378	2 35.980	15
22.940	2 25.282	2 28.100	3 31.000	12 32.610	2 34.395	10 36.022	10
22.950	12 25.320	4 28.110	2 31.185	5 32.662	9 34.405	2 36.030	15
23.055	2 25.323	2 28.118	3 31.210	8 32.675	3 34.415	12 36.062	10

WCO (continued)

36.070	15	38.225	10
36.095	10	38.230	2
36.175	5	38.320	10
36.180	12	38.335	14
36.197	2	38.570	8
36.202	12	38.590	2
36.215	5	38.620	8
36.245	9	38.720	2
36.250	15	38.740	5
36.270	10	38.808	2
36.295	5	38.830	5
36.305	8	38.840	2
36.340	5	38.845	4
36.380	10	38.925	2
36.390	12	38.928	3
36.405	3	39.015	2
36.415	8	39.040	3
36.480	5	39.075	3
36.550	8	39.282	2
36.555	5	39.290	9
36.560	12	39.535	2
36.575	5	39.540	9
36.582	12	39.650	2
36.590	5	39.655	5
36.595	15	39.792	2
36.650	8	39.800	5
36.665	15	39.840	2
36.810	8	40.100	0
36.812	15	40.165	2
36.830	10	40.178	9
36.909	5	40.235	2
36.910	15	40.255	5
36.930	10	40.325	5
36.950	10	40.330	3
36.960	2	40.380	3
36.990	10		
37.000	2		
37.005	12		
37.020	2		
37.070	8		
37.075	2		
37.090	8		
37.120	2		
37.122	12		
37.150	5		
37.180	10		
37.470	2		
37.500	8		
37.620	2		
37.760	1		
37.810	8		
37.845	2		
37.880	8		
37.910	2		
37.972	11		
38.020	11		
38.040	2		
38.045	12		
38.050	2		
38.060	12		
38.080	2		
38.088	8		
38.110	2		
38.150	8		
38.190	5		

MRN--MARION COUNTY CORE, IGS 30NP (bottom, 0 m, at 820 ft; top at 663 ft)

0.065	1	2.405	5	3.820	2	5.580	4	7.841	2	10.495	3	11.625	2		
0.070	8	2.438	1	3.845	10	5.591	3	7.845	3	10.555	2	11.630	5		
0.091	1	2.450	3	3.863	5	5.618	2	7.860	2	10.585	3	11.648	2		
0.099	12	2.500	2	3.878	8	5.629	3	7.863	3	10.620	2	11.668	4		
0.175	1	2.555	1	3.919	2	5.668	2	7.911	2	10.640	3	11.830	2		
0.180	8	2.556	5	3.930	9	5.669	5	7.915	4	10.690	2	11.838	3		
0.279	1	2.588	1	3.968	2	5.733	2	7.958	2	10.710	3	11.850	2		
0.280	5	2.589	5	3.969	5	5.740	8	7.960	4	10.767	2	11.851	5		
0.415	1	2.629	1	4.000	2	5.753	2	8.025	2	10.769	3	11.870	2		
0.416	5	2.631	12	4.001	5	5.763	4	8.030	4	10.810	2	11.880	3		
0.540	1	2.738	1	4.025	2	5.790	2	8.039	2	10.815	3	11.900	2		
0.550	5	2.739	5	4.071	3	5.800	4	8.042	4	10.830	2	11.908	3		
0.590	1	2.780	1	4.112	2	5.840	2	8.048	2	10.835	4	11.965	2		
0.620	2	2.790	4	4.113	5	5.850	10	8.052	4	10.840	2	11.970	3		
0.712	1	2.820	1	4.140	2	5.869	2	8.060	2	10.845	4	11.990	2		
0.713	5	2.832	2	4.141	5	5.872	8	8.061	4	10.865	2	11.999	3		
0.789	1	2.834	5	4.212	2	5.948	2	8.078	2	10.871	3	12.005	2		
0.790	5	2.848	1	4.213	5	5.957	8	8.081	4	10.892	2	12.012	4		
0.853	1	2.849	5	4.265	2	5.970	2	8.100	2	10.898	3	12.025	2		
0.854	5	2.881	1	4.266	5	6.083	10	8.112	3	10.942	2	12.035	13		
0.904	1	2.883	5	4.469	2	6.115	1	8.402	2	10.948	3	12.042	2		
0.905	5	2.912	1	4.470	5	6.145	8	8.403	5	10.978	2	12.048	4		
0.949	1	2.918	9	4.511	2	6.178	5	8.808	2	10.985	3	12.062	2		
0.950	5	2.949	2	4.512	5	6.200	2	8.811	5	11.020	2	12.070	4		
1.100	1	2.950	5	4.558	2	6.205	8	8.900	2	11.025	3	12.080	2		
1.105	5	2.959	1	4.559	5	6.395	2	8.908	3	11.035	2	12.090	4		
1.146	1	2.960	5	4.597	2	6.397	5	8.969	2	11.045	4	12.095	2		
1.152	9	2.985	1	4.600	8	6.575	1	8.970	12	11.055	2	12.103	3		
1.344	1	3.008	5	4.638	2	6.583	8	8.985	2	11.080	3	12.112	2		
1.345	5	3.026	1	4.643	8	6.725	2	9.043	8	11.087	2	12.115	5		
1.409	1	3.027	5	4.679	2	6.730	12	9.069	5	11.095	4	12.150	2		
1.411	5	3.118	1	4.680	5	6.800	2	9.089	9	11.102	2	12.160	3		
1.430	1	3.119	5	4.785	2	6.805	8	9.120	2	11.108	4	12.183	2		
1.431	5	3.211	1	4.787	8	6.858	2	9.140	9	11.128	2	12.195	4		
1.445	1	3.212	1	4.815	2	6.863	8	9.248	2	11.132	4	12.217	2		
1.446	12	3.245	3	4.816	5	6.893	2	9.253	12	11.168	2	12.280	3		
1.521	1	3.280	1	4.829	2	6.903	8	9.292	2	11.172	4	12.348	1		
1.522	5	3.295	2	4.830	5	6.926	2	9.299	12	11.178	2	12.352	3		
1.620	1	3.300	5	4.840	2	6.932	8	9.339	2	11.182	4	12.395	2		
1.622	5	3.310	2	4.841	5	6.969	2	9.365	3	11.200	2	12.403	3		
1.641	1	3.318	1	4.868	2	6.971	8	9.407	10	11.205	4	12.478	2		
1.642	5	3.322	2	4.870	5	7.130	2	9.445	2	11.225	2	12.485	3		
1.669	1	3.335	1	4.949	2	7.165	3	9.461	3	11.230	5	12.509	5		
1.670	5	3.365	2	4.950	5	7.220	2	9.532	8	11.252	2	12.513	4		
1.779	1	3.390	1	5.040	2	7.225	5	9.565	3	11.255	4	12.532	2		
1.781	3	3.422	2	5.041	5	7.359	2	9.595	8	11.285	2	12.537	3		
1.833	1	3.423	5	5.065	2	7.363	2	9.620	3	11.312	4	12.550	2		
1.840	4	3.462	1	5.067	5	7.398	2	9.657	2	11.329	2	12.554	3		
1.882	1	3.472	3	5.100	2	7.403	3	9.728	3	11.332	4	12.570	2		
1.888	8	3.485	2	5.121	4	7.420	2	9.829	10	11.352	2	12.583	9		
1.995	1	3.498	3	5.210	2	7.440	8	9.851	2	11.358	3	12.630	3		
2.004	8	3.518	2	5.212	5	7.489	2	9.859	12	11.370	2	12.718	8		
2.035	1	3.522	3	5.233	2	7.490	5	9.885	2	11.378	3	12.755	2		
2.036	5	3.545	2	5.240	3	7.540	2	9.891	12	11.400	2	12.760	5		
2.056	1	3.552	3	5.262	2	7.541	5	9.917	2	11.408	3	12.775	2		
2.058	5	3.625	2	5.270	4	7.606	2	9.923	12	11.421	2	12.780	3		
2.218	1	3.627	5	5.288	2	7.618	4	9.925	2	11.430	4	12.830	2		
2.219	5	3.659	2	5.292	5	7.750	2	9.930	5	11.442	2	12.840	9		
2.332	1	3.665	8	5.360	2	7.751	5	10.069	2	11.450	3	12.850	2		
2.350	3	3.687	2	5.362	5	7.760	2	10.070	4	11.490	2	12.865	3		
2.370	1	3.692	3	5.423	2	7.761	5	10.110	2	11.511	4	12.880	5		
2.371	5	3.735	1	5.430	3	7.770	2	10.111	5	11.529	2	12.960	1		
2.381	1	3.736	5	5.510	2	7.771	5	10.410	2	11.531	5	12.970	3		
2.382	5	3.775	2	5.518	8	7.825	2	10.420	3	11.550	2	13.028	1		
2.404	1	3.776	5	5.569	2	7.837	8	10.453	2	11.558	9	13.035	4		

MRN (continued)

13.070	2	14.595	2	16.128	2	17.860	4	19.662	4	22.585	3	25.490	3
13.072	5	14.602	3	16.133	3	17.898	2	19.668	2	22.730	2	25.510	2
13.122	2	14.618	2	16.159	2	17.903	4	19.672	4	22.740	3	25.540	4
13.130	12	14.653	3	16.161	3	17.910	2	19.680	2	22.765	2	25.551	2
13.148	2	14.672	2	16.215	2	17.920	4	19.720	3	22.770	5	25.559	3
13.149	5	14.688	4	16.225	3	17.935	2	19.760	2	22.950	2	25.580	2
13.210	2	14.700	2	16.255	2	17.940	4	19.765	4	22.980	5	25.585	3
13.211	5	14.705	3	16.265	3	17.942	2	19.825	2	23.045	2	25.630	1
13.251	2	14.715	2	16.335	2	17.945	4	19.850	3	23.052	4	25.675	2
13.260	3	14.730	3	16.340	3	17.955	2	19.870	2	23.090	2	25.676	5
13.285	4	14.760	2	16.375	2	17.962	4	19.878	3	23.092	5	25.745	2
13.295	2	14.770	3	16.380	3	18.065	1	19.925	2	23.225	2	25.747	5
13.296	5	14.775	2	16.430	2	18.072	3	19.950	3	23.282	10	25.830	2
13.380	2	14.780	3	16.512	10	18.097	1	20.095	2	23.408	2	25.840	5
13.385	3	14.785	2	16.520	2	18.103	3	20.105	3	23.422	3	25.900	2
13.490	2	14.795	3	16.525	9	18.115	1	20.170	2	23.525	1	25.905	5
13.491	5	14.810	2	16.532	2	18.125	4	20.175	5	23.530	2	25.955	2
13.510	2	14.811	5	16.538	9	18.175	1	20.198	3	23.640	1	25.960	5
13.518	3	14.850	2	16.545	2	18.190	3	20.210	9	23.670	3	25.990	2
13.570	2	14.855	3	16.552	15	18.221	1	20.235	2	23.735	1	26.005	5
13.574	3	14.865	2	16.567	5	18.222	5	20.248	5	23.736	5	26.055	3
13.600	2	14.870	12	16.571	9	18.237	1	20.280	2	23.785	1	26.120	2
13.602	5	14.880	2	16.585	5	18.265	9	20.285	3	23.786	5	26.155	3
13.615	2	14.881	5	16.591	9	18.378	2	20.360	3	23.860	1	26.172	2
13.620	13	14.898	2	16.623	5	18.382	4	20.390	2	23.895	2	26.180	9
13.641	5	14.902	8	16.630	9	18.438	2	20.410	3	23.896	5	26.199	3
13.643	5	14.910	2	16.680	5	18.440	3	20.434	2	23.938	2	26.220	2
13.718	2	14.927	8	16.710	8	18.489	2	20.444	3	23.957	5	26.230	3
13.725	3	14.952	2	16.725	2	18.494	3	20.483	2	23.975	2	26.298	2
13.750	2	14.957	12	16.730	8	18.565	2	20.491	3	23.980	4	26.325	10
13.752	3	14.980	2	16.745	2	18.570	8	20.620	2	24.025	2	26.413	1
13.828	2	14.989	8	16.755	9	18.610	2	20.621	5	24.026	5	26.414	5
13.832	3	15.000	2	16.818	5	18.611	5	20.660	2	24.262	2	26.498	1
13.855	2	15.015	4	16.830	8	18.655	2	20.665	4	24.300	3	26.499	5
13.857	3	15.046	2	16.845	1	18.740	5	20.765	2	24.335	2	26.535	1
13.870	2	15.055	3	16.847	5	18.810	2	20.770	10	24.336	5	26.545	3
13.876	4	15.081	2	16.875	1	18.812	4	20.908	2	24.430	2	26.590	1
13.947	2	15.370	10	16.890	1	18.885	2	20.910	5	24.435	4	26.600	3
13.955	3	15.395	8	16.912	8	18.945	5	20.940	2	24.525	2	26.685	1
13.967	2	15.430	1	16.930	5	18.950	12	20.941	5	24.526	5	26.687	5
13.975	3	15.515	9	16.965	1	18.975	5	21.055	2	24.625	2	26.718	1
14.042	2	15.557	1	16.974	3	18.990	9	21.060	3	24.626	5	26.721	5
14.061	3	15.578	1	17.001	1	19.060	1	21.150	2	24.643	2	26.765	1
14.101	3	15.582	4	17.010	3	19.070	4	21.178	3	24.652	3	26.771	3
14.128	2	15.600	1	17.090	1	19.098	1	21.275	2	24.685	2	26.845	2
14.132	3	15.606	9	17.105	5	19.103	4	21.281	8	24.692	3	26.850	3
14.150	2	15.615	3	17.115	8	19.135	2	21.340	2	24.710	2	26.870	2
14.152	3	15.738	1	17.155	2	19.142	4	21.390	3	24.750	3	26.880	5
14.212	2	15.740	4	17.162	4	19.155	2	21.422	2	24.878	2	26.910	2
14.214	3	15.840	1	17.205	2	19.160	4	21.430	4	24.885	3	27.010	8
14.228	2	15.860	3	17.212	4	19.170	2	21.595	2	24.965	2	27.020	3
14.232	13	15.880	2	17.250	2	19.180	4	21.596	5	24.971	3	27.080	2
14.255	2	15.885	3	17.275	3	19.200	2	21.675	2	25.020	2	27.081	5
14.260	13	15.895	2	17.280	5	19.235	3	21.685	12	25.070	3	27.098	2
14.308	2	15.899	3	17.330	2	19.315	2	21.760	2	25.110	2	27.181	10
14.313	13	15.920	2	17.390	3	19.320	3	21.780	3	25.145	4	27.202	2
14.435	2	15.925	3	17.405	4	19.385	2	21.910	2	25.178	2	27.203	5
14.437	3	15.948	2	17.545	2	19.395	4	21.950	3	25.195	3	27.225	2
14.465	2	15.953	3	17.552	3	19.463	1	22.065	2	25.245	2	27.251	3
14.475	4	16.007	2	17.712	2	19.480	3	22.066	5	25.247	5	27.360	2
14.490	2	16.012	3	17.720	9	19.550	2	22.180	2	25.365	2	27.361	5
14.500	3	16.080	2	17.730	3	19.555	12	22.190	3	25.366	5	27.400	2
14.503	5	16.091	3	17.810	2	19.650	2	22.505	2	25.450	2	27.415	5
14.558	2	16.113	2	17.815	4	19.655	4	22.520	3	25.458	3	27.465	2
14.559	5	16.118	3	17.851	2	19.660	2	22.555	2	25.485	2	27.480	5

MRN (continued)

27.518	2 29.198	2 30.989	2 33.318	3 35.252	3 36.890	2 38.745	10
27.542	8 29.231	4 30.990	5 33.370	2 35.355	2 36.900	12 38.770	5
27.890	2 29.245	2 31.080	2 33.380	3 35.370	5 36.910	2 38.780	12
27.915	3 29.251	11 31.085	9 33.400	2 35.420	10 36.981	8 38.810	5
27.950	2 29.289	2 31.140	1 33.412	4 35.470	7 36.995	2 38.850	10
27.955	3 29.294	11 31.148	3 33.460	1 35.552	2 37.065	10 38.870	5
28.018	2 29.305	2 31.159	1 33.465	4 35.570	9 37.085	5 38.890	3
28.022	3 29.310	11 31.160	5 33.530	1 35.595	8 37.100	12 38.950	10
28.092	2 29.320	2 31.220	1 33.545	5 35.635	7 37.120	5 38.970	5
28.095	5 29.360	4 31.225	3 33.578	1 35.665	2 37.130	12 38.972	11
28.155	2 29.440	8 31.300	1 33.590	3 35.674	3 37.140	5 39.064	10
28.160	5 29.470	3 31.301	5 33.618	4 35.721	2 37.170	11 39.100	11
28.180	2 29.481	2 31.390	1 33.675	2 35.730	3 37.171	15 39.102	15
28.188	3 29.485	11 31.391	5 33.685	8 35.735	2 37.335	11 39.215	10
28.200	2 29.495	2 31.418	1 33.710	2 35.741	3 37.365	1 39.225	15
28.205	3 29.512	9 31.440	3 33.725	7 35.762	2 37.370	8 39.325	10
28.242	2 29.525	2 31.490	4 33.743	2 35.770	3 37.380	1 39.390	10
28.252	3 29.545	4 31.505	1 33.813	10 35.790	2 37.445	10 39.475	11
28.268	2 29.594	8 31.506	5 33.865	2 35.819	7 37.452	1 39.530	11
28.272	3 29.605	1 31.620	1 33.895	10 35.832	2 37.500	10 39.533	15
28.310	2 29.610	12 31.625	5 33.952	2 35.898	7 37.502	15 39.570	10
28.350	4 29.695	1 31.649	1 33.978	8 35.900	0.2 37.545	10 39.810	15
28.385	2 29.710	12 31.650	5 33.992	3 35.921	2 37.555	11 40.710	1
28.390	3 29.715	2 31.752	1 34.048	2 35.960	7 37.580	10 40.711	5
28.395	2 29.720	12 31.760	3 34.055	3 36.004	10 37.585	11 40.940	1
28.402	3 29.730	2 31.799	1 34.070	2 36.008	11 37.620	10 40.941	5
28.428	2 29.772	15 31.800	5 34.080	3 36.012	2 37.627	11 41.730	1
28.440	3 29.805	2 31.830	1 34.102	2 36.095	10 37.685	10 41.731	5
28.452	2 29.812	3 31.831	5 34.110	3 36.097	11 37.697	15 41.895	1
28.457	5 29.855	2 31.869	1 34.158	2 36.105	2 37.755	10 41.918	8
28.465	2 29.860	3 31.872	3 34.178	6 36.130	10 37.760	11 41.925	2
28.471	4 29.875	2 31.935	1 34.248	2 36.160	2 37.786	10 41.931	8
28.530	1 29.880	4 32.025	10 34.255	3 36.255	10 37.790	11 41.945	2
28.582	3 29.915	2 32.027	11 34.298	2 36.278	5 37.820	10 41.960	8
28.630	8 29.935	4 32.105	10 34.315	6 36.290	10 37.822	11 41.972	2
28.650	2 30.010	2 32.107	11 34.352	2 36.315	2 37.845	10 41.985	8
28.662	8 30.022	4 32.125	2 34.358	3 36.324	9 37.850	11 41.992	2
28.695	2 30.065	1 32.130	3 34.367	2 36.338	2 37.860	10 42.025	8
28.705	8 30.070	3 32.158	2 34.374	3 36.342	9 37.890	5 42.048	2
28.725	2 30.150	1 32.161	3 34.397	2 36.375	2 37.900	12 42.080	5
28.732	3 30.151	5 32.187	2 34.421	6 36.420	8 37.930	5 42.090	8
28.770	2 30.190	2 32.191	3 34.447	2 36.425	2 37.950	8 42.125	5
28.785	3 30.201	4 32.199	2 34.454	3 36.448	10 37.952	15 42.148	8
28.818	2 30.230	2 32.201	3 34.500	2 36.455	2 37.975	5 42.155	5
28.821	4 30.245	11 32.230	2 34.530	3 36.488	10 37.985	12 42.160	12
28.829	2 30.250	2 32.235	15 34.576	2 36.500	2 38.020	5 42.235	5
28.832	4 30.260	11 32.250	1 34.582	3 36.585	10 38.115	10 42.250	12
28.839	2 30.270	2 32.252	5 34.652	2 36.586	2 38.117	11 42.260	5
28.841	3 30.280	11 32.310	1 34.661	3 36.639	10 38.118	2 42.270	8
28.881	2 30.292	2 32.362	3 34.720	2 36.642	2 38.150	10 42.285	2
28.882	5 30.329	8 32.533	1 34.730	3 36.682	10 38.151	2 42.290	12
28.925	2 30.348	2 32.540	4 34.830	2 36.708	2 38.355	8 42.315	2
28.935	12 30.368	8 32.605	3 34.840	3 36.712	10 38.390	5 42.345	5
28.955	2 30.402	10 32.660	2 34.850	2 36.728	2 38.425	8 42.360	8
28.960	4 30.410	2 32.712	1 34.860	9 36.734	10 38.430	2 42.375	5
28.975	2 30.440	8 32.720	3 34.885	2 36.747	2 38.433	11 42.380	8
28.981	4 30.460	2 32.798	1 34.962	7 36.784	10 38.440	2 42.435	5
28.990	2 30.520	10 32.805	3 34.965	4 36.790	2 38.450	11 42.445	8
29.038	7 30.545	2 32.885	1 34.973	8 36.815	10 38.465	2 42.500	1
29.060	2 30.555	12 32.891	3 35.000	0.7 36.825	2 38.485	11 42.505	12
29.068	11 30.575	5 32.925	1 35.122	10 36.830	12 38.500	2 42.514	1
29.100	2 30.580	12 32.931	3 35.145	11 36.845	2 38.605	10 42.515	5
29.120	4 30.600	5 33.175	2 35.196	2 36.853	12 38.612	2 42.535	1
29.129	5 30.950	8 33.190	3 35.203	3 36.870	2 38.710	10 42.536	5
29.160	8 30.965	5 33.308	2 35.245	2 36.880	12 38.720	2 42.698	1

MRN (continued)

42.699	5	44.770	2	46.335	5	47.652	5
42.710	1	44.775	5	46.468	1	47.700	2
42.711	5	44.920	2	46.471	5		
42.720	1	44.922	5	46.508	2		
42.721	5	44.945	2	46.515	5		
42.745	1	44.947	5	46.535	2		
42.750	8	44.953	2	46.542	5		
42.760	5	44.955	5	46.550	2		
42.772	8	44.990	2	46.560	5		
42.860	1	44.992	5	46.565	2		
42.861	5	45.095	2	46.566	5		
42.900	1	45.097	5	46.598	2		
42.901	5	45.109	2	46.605	5		
43.090	1	45.111	5	46.615	2		
43.095	3	45.148	2	46.617	5		
43.373	1	45.150	5	46.626	2		
43.373	5	45.160	2	46.627	5		
43.430	1	45.201	3	46.653	2		
43.450	5	45.228	2	46.655	5		
43.535	1	45.230	3	46.719	2		
43.536	5	45.250	2	46.720	5		
43.652	1	45.255	8	46.778	2		
43.653	5	45.272	2	46.785	5		
43.807	1	45.275	5	46.815	1		
43.808	5	45.335	2	46.816	5		
43.850	1	45.350	8	46.835	1		
43.852	5	45.371	2	46.842	5		
43.930	1	45.373	5	46.949	1		
43.933	3	45.385	2	46.950	5		
44.010	1	45.386	5	47.072	1		
44.012	5	45.495	2	47.090	8		
44.043	1	45.496	5	47.110	2		
44.044	5	45.541	2	47.120	12		
44.130	1	45.542	5	47.175	5		
44.140	5	45.561	2	47.198	8		
44.190	1	45.562	5	47.220	2		
44.230	10	45.628	2	47.225	12		
44.235	2	45.629	5	47.245	5		
44.242	12	45.648	2	47.250	2		
44.260	5	45.649	5	47.255	12		
44.278	8	45.700	2	47.270	2		
44.290	5	45.701	5	47.280	12		
44.298	8	45.775	2	47.300	2		
44.310	5	45.776	5	47.310	12		
44.325	12	45.790	2	47.325	5		
44.345	5	45.791	5	47.330	12		
44.350	12	45.840	2	47.350	5		
44.365	5	45.890	3	47.360	12		
44.375	12	45.918	5	47.370	5		
44.400	5	45.952	3	47.380	12		
44.430	8	45.980	1	47.390	5		
44.440	2	45.990	8	47.400	12		
44.478	8	46.020	1	47.435	2		
44.500	3	46.030	8	47.460	5		
44.510	5	46.050	1	47.470	2		
44.550	2	46.063	5	47.500	5		
44.565	5	46.090	1	47.525	2		
44.598	2	46.095	3	47.550	9		
44.610	5	46.103	1	47.565	2		
44.639	2	46.190	3	47.566	5		
44.640	5	46.215	2	47.589	2		
44.650	2	46.245	8	47.590	5		
44.652	5	46.270	10	47.622	2		
44.663	2	46.295	10	47.626	5		
44.668	5	46.315	1	47.648	2		

NSQ--NEW POINT STONE QUARRY, DECATUR COUNTY CORE, IGS SDH 124 (bottom, 0 m, at 500 ft; top at 310 ft)

0.085	1	3.450	8	5.408	1	7.528	1	9.253	1	11.232	5	13.880	1
0.095	8	3.537	1	5.500	8	7.535	8	9.255	5	11.305	1	13.892	3
0.840	1	3.540	8	5.528	1	7.550	1	9.275	1	11.325	3	13.940	1
0.880	5	3.573	1	5.530	8	7.553	5	9.290	8	11.355	1	13.950	2
0.912	1	3.585	2	5.562	1	7.569	1	9.350	1	11.356	5	13.990	1
0.918	10	3.600	1	5.565	8	7.570	5	9.400	8	11.460	1	14.010	8
0.945	1	3.602	5	5.580	1	7.642	1	9.428	1	11.462	5	14.060	1
0.953	10	3.690	1	5.585	12	7.644	5	9.430	5	11.480	1	14.095	8
1.490	1	3.700	8	5.650	1	7.670	1	9.442	1	11.495	3	14.125	2
1.497	8	3.815	1	5.670	8	7.671	5	9.565	8	11.649	1	14.127	5
1.688	1	3.816	5	5.671	1	7.697	1	9.625	1	11.650	5	14.172	1
1.703	3	3.885	1	5.695	7	7.699	5	9.626	5	11.725	1	14.173	5
1.790	1	3.896	8	5.712	8	7.715	1	9.655	1	11.765	8	14.200	1
1.805	3	3.980	1	5.750	4	7.755	8	9.673	3	11.840	1	14.205	9
1.990	1	3.981	5	5.772	5	7.885	1	9.695	8	11.872	5	14.210	1
2.030	3	4.040	1	5.814	8	7.890	8	9.708	1	12.070	1	14.215	9
2.180	2	4.050	3	5.823	1	7.928	1	9.710	8	12.115	8	14.232	1
2.287	1	4.110	1	5.830	12	7.935	8	9.740	1	12.117	1	14.233	9
2.302	8	4.112	5	5.845	1	7.943	1	9.741	5	12.158	8	14.275	1
2.332	5	4.140	1	5.878	8	7.995	8	9.760	1	12.190	5	14.277	5
2.415	1	4.165	3	5.912	1	8.062	8	9.785	8	12.260	8	14.292	1
2.425	5	4.200	1	5.913	5	8.092	1	9.786	1	12.262	1	14.299	8
2.470	1	4.201	5	6.035	1	8.098	8	9.810	8	12.315	8	14.365	2
2.480	5	4.250	1	6.065	8	8.140	1	9.811	1	12.347	5	14.367	5
2.530	1	4.255	7	6.085	1	8.150	3	9.840	8	12.362	9	14.395	2
2.550	5	4.275	1	6.100	8	8.161	1	9.985	1	12.578	1	14.396	5
2.598	1	4.280	7	6.113	1	8.168	3	9.986	3	12.632	8	14.425	3
2.602	3	4.295	1	6.115	5	8.212	1	10.000	1	12.640	1	14.426	8
2.613	1	4.297	5	6.130	1	8.229	5	10.043	8	12.678	8	14.500	3
2.620	8	4.384	1	6.131	5	8.288	1	10.085	8	12.690	1	14.600	2
2.645	1	4.410	8	6.245	1	8.305	8	10.155	8	12.725	8	14.630	1
2.652	8	4.430	5	6.246	5	8.312	5	10.160	1	12.726	1	14.645	5
2.669	1	4.479	1	6.275	1	8.351	8	10.165	8	12.750	8	14.670	8
2.672	8	4.480	5	6.280	8	8.369	1	10.255	1	12.760	1	14.680	3
2.682	1	4.539	1	6.488	1	8.372	8	10.260	12	12.763	8	14.690	8
2.691	8	4.540	5	6.515	5	8.488	1	10.340	1	12.825	1	14.707	1
2.710	1	4.580	1	6.565	1	8.499	8	10.345	3	12.830	8	14.720	12
2.760	9	4.581	5	6.600	8	8.520	5	10.355	1	12.850	1	14.735	2
2.788	8	4.630	1	6.692	1	8.535	4	10.362	8	12.860	2	14.795	1
2.801	1	4.665	3	6.722	8	8.595	8	10.518	1	12.935	1	14.815	2
2.820	9	4.695	8	6.771	1	8.640	8	10.520	5	12.936	5	14.825	5
2.838	5	4.708	5	6.775	8	8.641	1	10.532	1	13.105	1	14.898	11
2.853	9	4.848	1	6.785	1	8.685	8	10.538	12	13.150	8	14.899	3
2.870	1	4.890	5	6.810	8	8.690	1	10.565	1	13.152	1	14.922	11
2.890	8	4.941	8	6.820	1	8.700	8	10.615	5	13.170	8	14.923	3
2.900	5	4.965	5	6.850	8	8.795	1	10.645	1	13.212	1	14.955	11
2.935	8	4.980	1	6.880	5	8.796	3	10.647	5	13.260	2	14.990	2
2.950	5	5.045	8	6.908	1	8.809	1	10.735	1	13.328	1	15.000	8
2.985	8	5.075	1	6.912	8	8.810	3	10.785	8	13.350	2	15.013	1
2.987	11	5.084	8	6.945	1	8.840	1	10.787	1	13.435	1	15.025	3
3.000	8	5.113	1	6.965	8	8.841	3	10.802	8	13.440	5	15.055	2
3.003	5	5.122	8	6.988	1	8.845	1	10.804	1	13.450	1	15.090	3
3.025	8	5.150	1	7.002	5	8.846	3	10.820	8	13.510	8	15.183	8
3.027	15	5.157	8	7.110	1	8.898	1	10.830	3	13.515	1	15.185	2
3.108	8	5.160	1	7.118	8	8.905	8	10.860	1	13.540	8	15.233	8
3.110	11	5.170	8	7.180	1	8.977	1	10.875	3	13.610	1	15.234	2
3.140	5	5.175	1	7.185	8	8.980	8	10.915	1	13.650	8	15.270	8
3.160	8	5.185	8	7.190	1	8.990	1	10.950	2	13.651	1	15.280	1
3.215	1	5.200	5	7.222	7	9.000	8	10.970	5	13.668	8	15.300	8
3.270	8	5.232	8	7.290	1	9.015	5	11.050	1	13.712	1	15.330	3
3.298	1	5.240	1	7.300	8	9.033	8	11.120	8	13.728	2	15.470	1
3.310	8	5.290	8	7.378	1	9.048	1	11.122	1	13.778	1	15.510	3
3.325	1	5.295	5	7.382	5	9.060	8	11.170	8	13.792	2	15.550	8
3.327	5	5.362	1	7.400	1	9.145	1	11.195	5	13.834	1	15.551	2
3.448	1	5.370	8	7.403	5	9.150	8	11.230	1	13.848	2	15.720	8

NSQ (continued)

15.778	1	18.472	2	20.940	4	23.045	4	25.528	8	27.950	2	34.105	3
15.782	2	18.501	11	21.030	2	23.070	8	25.555	5	27.997	6	34.330	2
15.840	1	18.502	2	21.042	8	23.085	3	25.562	12	28.025	4	34.345	3
15.851	8	18.520	11	21.050	2	23.100	4	25.572	5	28.027	2	34.385	6
15.923	1	18.521	2	21.052	5	23.115	3	25.580	12	28.052	4	34.442	2
15.932	3	18.602	11	21.128	2	23.160	8	25.610	5	28.135	2	34.475	4
16.030	1	18.603	2	21.175	5	23.235	2	25.615	12	28.225	8	34.520	2
16.035	2	18.633	11	21.228	8	23.280	4	25.650	5	28.250	2	34.545	4
16.070	1	18.634	2	21.229	1	23.320	2	25.655	12	28.292	8	34.560	2
16.090	8	18.663	8	21.275	8	23.345	3	25.698	5	28.340	2	34.582	6
16.115	1	18.664	2	21.276	1	23.430	8	25.705	12	28.342	5	34.588	2
16.145	3	18.680	8	21.320	8	23.460	5	25.722	5	28.355	2	34.620	6
16.160	8	18.718	2	21.368	2	23.490	8	25.732	12	28.358	5	34.775	2
16.210	2	18.818	8	21.380	8	23.491	2	25.750	5	28.380	2	34.800	8
16.275	3	18.900	1	21.395	2	23.525	8	25.780	8	28.532	7	34.835	3
16.285	9	19.000	2	21.405	12	23.526	2	25.780	3	28.545	3	34.865	2
16.338	3	19.012	8	21.418	2	23.578	8	25.810	8	28.570	8	34.882	3
16.385	9	19.040	3	21.422	4	23.579	2	25.850	2	28.573	15	34.930	2
16.460	1	19.075	2	21.438	2	23.610	8	25.870	8	28.602	8	35.000	6
16.495	2	19.090	3	21.442	12	23.612	2	25.995	2	28.607	2	35.002	2
16.520	1	19.140	2	21.450	2	23.650	8	26.020	3	28.612	12	35.195	6
16.540	2	19.185	5	21.500	4	23.665	5	26.072	8	28.633	2	35.205	2
16.580	5	19.226	2	21.501	2	23.685	2	26.330	2	28.638	12	35.252	8
16.651	8	19.375	8	21.597	8	23.695	12	26.380	5	28.645	2	35.305	5
16.691	1	19.410	1	21.605	4	23.710	1	26.465	2	28.650	15	35.392	8
16.692	5	19.415	8	21.712	8	23.790	4	26.590	10	28.805	8	35.401	2
16.820	2	19.445	2	21.738	1	23.800	5	26.592	2	28.807	15	35.510	6
16.835	3	19.455	8	21.739	5	23.885	1	26.665	8	28.982	2	35.645	1
16.930	4	19.480	2	21.850	1	23.935	8	26.720	5	29.005	5	35.680	3
16.952	1	19.500	4	21.890	8	23.936	2	26.725	12	29.075	2	35.697	8
17.000	3	19.525	2	21.902	4	24.020	4	26.770	5	29.077	5	35.850	2
17.035	9	19.530	12	21.930	8	24.075	1	26.812	8	29.208	2	35.885	8
17.068	2	19.555	5	21.935	4	24.130	4	26.840	5	29.215	9	36.842	2
17.070	5	19.565	2	22.037	8	24.200	2	26.925	8	29.415	2	36.850	4
17.170	2	19.581	4	22.068	8	24.212	8	26.927	2	29.420	9	37.125	2
17.190	8	19.622	2	22.070	2	24.225	5	26.950	8	29.875	2	37.135	3
17.210	5	19.735	8	22.070	8	24.307	1	26.952	2	29.910	8	37.240	2
17.222	8	19.737	3	22.110	2	24.330	8	26.970	12	30.110	2	37.270	3
17.290	2	19.750	8	22.135	3	24.331	2	26.982	5	30.150	3	37.320	6
17.315	8	19.760	3	22.162	15	24.352	8	26.995	12	30.210	8	37.435	2
17.360	2	19.775	8	22.198	4	24.385	2	27.020	5	30.235	3	37.442	8
17.370	3	19.840	5	22.290	1	24.387	5	27.030	12	30.237	5	37.480	2
17.400	4	19.915	3	22.300	12	24.435	2	27.045	5	30.345	3	37.488	3
17.448	3	20.035	8	22.310	5	24.450	5	27.068	12	30.418	9	37.648	2
17.478	2	20.036	2	22.322	1	24.460	9	27.082	12	30.455	3	37.662	6
17.490	3	20.075	8	22.415	11	24.462	2	27.110	5	30.460	4	37.841	2
17.565	2	20.085	3	22.425	1	24.475	9	27.120	12	30.512	3	37.850	8
17.590	1	20.150	11	22.465	11	24.495	2	27.138	5	31.670	2	37.855	2
17.640	3	20.200	1	22.470	15	24.505	8	27.142	12	31.990	0	37.862	8
17.705	2	20.201	5	22.490	11	24.540	2	27.155	5	32.060	2	37.875	2
17.810	8	20.260	1	22.500	1	24.610	3	27.165	12	32.065	12	37.882	8
17.830	2	20.270	12	22.532	8	24.658	2	27.175	5	32.540	2	37.898	2
17.835	12	20.348	2	22.534	15	24.722	3	27.190	12	32.552	3	37.905	8
17.855	2	20.362	9	22.570	3	24.822	2	27.205	5	33.395	2	37.985	2
17.873	8	20.400	5	22.615	2	24.850	4	27.295	8	33.397	5	38.002	3
18.022	2	20.480	2	22.670	9	24.990	2	27.323	2	33.657	2	38.072	2
18.080	3	20.540	8	22.680	3	25.000	3	27.328	12	33.665	4	38.165	8
18.097	5	20.552	2	22.740	9	25.018	4	27.398	2	33.695	2	38.195	2
18.125	4	20.588	8	22.760	2	25.100	3	27.420	8	33.702	4	38.202	5
18.240	2	20.589	2	22.790	3	25.140	2	27.650	2	33.740	2	38.228	2
18.390	11	20.675	8	22.805	8	25.190	5	27.670	3	33.760	3	38.231	5
18.405	2	20.718	2	22.850	3	25.240	8	27.700	8	33.974	2	38.270	2
18.407	5	20.732	8	22.915	2	25.275	1	27.765	3	33.976	5	38.272	4
18.415	2	20.862	2	22.962	3	25.395	8	27.882	2	34.050	2	38.288	3
18.470	11	20.898	8	23.020	2	25.400	1	27.900	4	34.070	6	38.318	2

NSQ (continued)

38.319	5 39.965	12 41.035	5 42.403	2 44.075	2 45.425	5 47.050	2
38.353	2 39.970	5 41.115	8 42.440	8 44.135	4 45.430	12 47.089	5
38.354	5 40.015	8 41.145	11 42.468	5 44.182	5 45.450	5 47.092	11
38.378	2 40.025	2 41.175	5 42.470	11 44.185	12 45.455	12 47.128	8
38.395	3 40.050	8 41.178	12 42.502	8 44.203	5 45.495	5 47.130	15
38.413	8 40.060	2 41.198	5 42.504	11 44.212	12 45.548	10 47.148	3
38.450	2 40.063	3 41.252	8 42.528	8 44.233	5 45.550	15 47.153	2
38.503	8 40.065	2 41.258	2 42.529	2 44.270	11 45.570	10 47.158	8
38.532	2 40.067	3 41.280	8 42.540	8 44.298	5 45.580	15 47.170	2
38.533	5 40.075	2 41.282	11 42.542	11 44.302	12 45.590	10 47.187	8
38.565	2 40.095	8 41.345	8 42.578	8 44.345	5 45.605	2 47.238	5
38.572	9 40.105	2 41.347	11 42.600	3 44.350	12 45.648	10 47.278	9
38.648	2 40.123	8 41.360	8 42.605	12 44.370	5 45.650	15 47.293	2
38.650	5 40.140	5 41.380	5 42.620	5 44.413	9 45.735	10 47.305	10
38.700	2 40.145	12 41.395	12 42.628	12 44.448	5 45.736	2 47.340	5
38.702	5 40.165	5 41.412	5 42.640	5 44.452	11 45.757	10 47.370	2
38.713	2 40.171	12 41.421	12 42.643	12 44.495	5 45.758	15 47.415	8
38.721	8 40.178	5 41.430	5 42.697	5 44.502	15 45.780	10 47.445	2
38.835	2 40.182	12 41.438	12 42.712	8 44.532	5 45.785	2 47.447	15
38.845	3 40.197	5 41.450	5 42.780	2 44.540	9 45.835	10 47.475	8
38.898	2 40.203	12 41.460	12 42.852	4 44.580	5 45.890	11 47.535	5
38.912	3 40.227	5 41.500	5 42.938	2 44.595	8 46.020	8 47.570	8
38.935	2 40.252	8 41.510	8 42.990	3 44.610	5 46.022	15 47.625	2
38.950	3 40.265	5 41.560	11 43.020	5 44.613	12 46.026	2 47.635	8
38.965	8 40.270	12 41.595	8 43.090	2 44.630	5 46.035	11 47.648	2
38.989	2 40.280	5 41.605	2 43.112	5 44.633	12 46.058	2 47.665	8
39.005	8 40.285	12 41.658	8 43.140	8 44.645	5 46.061	5 47.666	2
39.050	2 40.305	5 41.661	11 43.152	4 44.650	12 46.130	2 47.685	8
39.070	3 40.315	12 41.700	8 43.170	2 44.665	5 46.150	9 47.768	2
39.080	9 40.330	5 41.702	11 43.190	9 44.670	12 46.160	5 47.783	8
39.110	3 40.352	4 41.732	8 43.214	2 44.698	2 46.165	12 47.805	2
39.135	8 40.375	5 41.734	2 43.240	8 44.715	8 46.172	5 47.810	8
39.210	2 40.382	12 41.745	8 43.250	4 44.718	5 46.180	12 47.850	5
39.220	3 40.428	5 41.764	5 43.251	2 44.723	12 46.190	5 47.863	8
39.262	2 40.435	12 41.771	12 43.267	4 44.733	5 46.195	12 47.880	5
39.270	9 40.450	5 41.780	2 43.343	2 44.735	12 46.208	5 47.890	8
39.310	2 40.475	9 41.790	9 43.350	12 44.750	5 46.212	12 47.908	5
39.380	8 40.485	5 41.800	2 43.365	2 44.752	11 46.225	2 47.918	8
39.381	2 40.487	12 41.812	5 43.372	12 44.780	5 46.230	12 47.919	2
39.429	8 40.510	5 41.823	2 43.415	2 44.808	11 46.265	5 47.928	8
39.440	3 40.520	12 41.829	4 43.420	12 44.809	2 46.270	12 47.975	5
39.450	12 40.550	5 41.880	2 43.515	5 44.828	11 46.288	5 48.065	8
39.470	3 40.555	12 41.888	4 43.525	4 44.832	2 46.310	8 48.122	8
39.502	8 40.578	5 41.920	2 43.569	2 44.840	15 46.360	5 48.235	5
39.505	2 40.620	8 41.995	10 43.573	4 44.880	5 46.375	8 48.275	8
39.550	8 40.630	5 42.062	2 43.580	2 44.882	15 46.420	5 48.285	5
39.551	2 40.635	12 42.078	10 43.588	3 44.965	10 46.450	7 48.290	8
39.565	8 40.660	5 42.080	11 43.605	2 44.970	11 46.452	15 48.300	5
39.582	1 40.740	8 42.095	8 43.615	3 45.012	10 46.480	2 48.310	8
39.590	8 40.742	2 42.096	2 43.650	2 45.015	2 46.512	4 48.340	5
39.650	1 40.768	8 42.148	10 43.662	3 45.052	10 46.575	5 48.348	8
39.655	8 40.769	2 42.150	11 43.695	2 45.060	2 46.580	12 48.388	5
39.670	1 40.795	8 42.170	10 43.705	4 45.112	10 46.618	5 48.510	8
39.726	4 40.815	15 42.182	5 43.725	2 45.114	15 46.625	12 48.580	11
39.740	2 40.835	8 42.190	12 43.738	4 45.143	10 46.698	5 48.595	2
39.750	9 40.852	8 42.198	5 43.835	2 45.145	15 46.723	8 48.620	11
39.768	2 40.854	15 42.215	11 43.850	4 45.170	10 46.725	2 48.640	15
39.775	9 40.869	3 42.248	5 43.900	2 45.218	11 46.750	4 48.672	8
39.800	2 40.890	15 42.298	8 43.915	3 45.248	5 46.752	2 48.674	15
39.852	8 40.925	2 42.302	11 43.938	2 45.275	5 46.772	8 48.690	2
39.860	15 40.958	8 42.325	8 43.955	3 45.280	12 46.821	2 48.692	4
39.880	8 40.990	5 42.327	2 43.996	2 45.348	5 46.856	10 48.699	2
39.900	5 41.002	8 42.345	8 44.002	15 45.355	12 46.885	2 48.702	4
39.945	9 41.012	5 42.346	2 44.042	2 45.392	5 46.915	5 48.712	2
39.960	5 41.014	15 42.402	8 44.055	8 45.402	12 46.978	4 48.722	4

NSQ (continued)

48.730	2	50.015	12	51.772	2	52.982	5	54.425	4
48.735	9	50.035	2	51.810	8	52.995	8	54.438	2
48.747	2	50.052	8	51.812	5	53.035	5	54.440	4
48.751	4	50.098	5	51.818	12	53.042	12	54.460	2
48.760	2	50.105	15	51.825	5	53.082	2	54.490	3
48.763	4	50.220	5	51.830	12	53.101	8	54.535	8
48.778	2	50.245	10	51.835	5	53.135	2	54.603	2
48.783	9	50.250	15	51.841	12	53.137	4	54.628	8
48.792	2	50.338	10	51.870	5	53.150	2	54.660	5
48.798	9	50.341	15	51.875	12	53.153	4	54.682	8
48.805	2	50.372	5	51.940	5	53.195	2	54.718	2
48.813	9	50.378	8	51.945	12	53.196	8	54.800	10
48.830	2	50.398	5	51.965	5	53.210	3		
48.833	4	50.402	9	51.970	12	53.255	2		
48.838	2	50.448	5	52.015	5	53.260	12		
48.841	4	50.518	8	52.025	12	53.270	2		
48.845	2	50.528	2	52.080	5	53.281	9		
48.847	4	50.530	8	52.100	9	53.370	2		
48.860	2	50.538	2	52.180	5	53.439	8		
48.898	9	50.541	8	52.190	8	53.480	2		
48.905	2	50.548	2	52.192	2	53.485	9		
48.923	9	50.608	8	52.220	8	53.505	2		
48.925	3	50.665	5	52.240	5	53.512	9		
48.962	9	50.750	8	52.252	11	53.582	2		
48.968	2	50.760	5	52.275	5	53.590	10		
48.971	8	50.768	8	52.278	12	53.623	2		
48.988	2	50.778	5	52.312	5	53.624	5		
48.991	8	50.781	12	52.315	12	53.725	2		
49.001	2	50.825	5	52.335	5	53.727	5		
49.078	11	50.868	2	52.348	11	53.730	2		
49.079	2	50.880	11	52.415	5	53.763	7		
49.182	11	50.910	2	52.420	12	53.785	2		
49.225	2	50.920	9	52.440	5	53.830	5		
49.315	4	50.940	2	52.450	12	53.900	8		
49.380	5	50.950	9	52.475	5	53.945	2		
49.385	8	50.960	2	52.500	8	53.947	5		
49.415	5	50.972	9	52.510	2	54.005	2		
49.420	12	51.000	2	52.550	8	54.010	5		
49.475	5	51.005	12	52.553	15	54.040	2		
49.482	12	51.020	2	52.558	2	54.042	5		
49.508	5	51.022	12	52.562	4	54.055	2		
49.518	12	51.030	2	52.571	2	54.057	5		
49.528	5	51.038	12	52.574	4	54.071	2		
49.532	12	51.050	2	52.603	2	54.072	5		
49.548	5	51.073	5	52.608	4	54.089	2		
49.554	12	51.165	2	52.633	2	54.095	8		
49.582	5	51.172	12	52.645	3	54.122	2		
49.588	12	51.200	2	52.653	2	54.128	9		
49.628	5	51.210	12	52.727	5	54.140	2		
49.740	10	51.218	2	52.748	2	54.148	3		
49.758	5	51.221	12	52.760	4	54.165	2		
49.762	12	51.235	2	52.762	2	54.190	3		
49.785	5	51.238	12	52.785	8	54.262	2		
49.790	12	51.425	2	52.787	2	54.335	3		
49.821	5	51.430	12	52.802	8	54.350	2		
49.828	12	51.592	2	52.803	2	54.353	4		
49.848	5	51.620	7	52.831	8	54.362	2		
49.855	12	51.660	2	52.848	5	54.367	4		
49.870	5	51.663	12	52.855	12	54.375	2		
49.918	11	51.670	2	52.875	5	54.377	4		
49.933	2	51.698	8	52.885	12	54.385	2		
49.940	12	51.718	2	52.898	5	54.387	4		
49.975	2	51.720	9	52.912	7	54.405	2		
49.990	8	51.740	2	52.951	5	54.407	4		
50.010	2	51.743	12	52.965	12	54.423	2		

APPENDIX 4: FAUNAL DATA

Two faunal data sets are presented below: The first set consists of 150 samples taken from all the study outcrops that was used in the analyses of Figs. 4-9 through 4-14. The second data set consists of those 77 samples used to determine detailed faunal patterns within 4 m of section at the Rice and Gage Streets outcrop, which is illustrated in Fig. 4-6. For each data set the following headings are used: LOC = outcrop locality (See Fig. 4-2), LEV = stratigraphic level (m) from which the sample was taken, and # = Sample number. Other headings represent various faunal elements, as explained below:

RAFINE	*Rafinesquina*
HEBERT	*Hebertella*
PLECTO	*Plectorthis*
PLATYS	*Platystrophia*
DALMAN	Dalmanellids, probably all *Heterorthina fairmountensis*
ZYGOSP	*Zygospira*
LINGUL	Lingulids and Lingulid-like inarticulate fragments
INARTI	Other inarticulates, encrusting types, mostly *Petrocrania*
PETROC	*Petrocrania*
CARITO	*Caritodens demissa*
AMBONY	*Ambonychia*
MODIOL	*Modiolopsis* and similar bivalves
NUCULO	Nuculoid bivalves, other small bivalves
CYCLON	*Cyclonema*
GASTRO	High-spired gastropods
CEPHAL	Cephalopods--mostly actinoceroids
FLEXIC	*Flexicalymene meeki*
ISOTEL	*Isotelus*
CERAUR	*Ceraurus*
ACIDAS	Odontopleurids, possibly *Acidaspis*
ENCRUS	Encrusting trepostome bryozoans, smooth
HEXAGO	Encrusting trepostome bryozoans, monticules
ESCHAR	*Escharapora*
CRYPTO	Cryptostomes, bilaminate
CYCLOS	Cyclostome bryozoans, arachnoid encrusting forms
CINCIN	Crinoid columnals Cf. *Cincinnaticrinus*
PYCNOC	Crinoid columnals Cf. *Pycnocrinus*
SCOLEC	Scolecodonts
TRYPAN	"Trypanites" simple borings
CORNUL	*Cornulites*

LARGER-SCALE FAUNAL DATA SET, PERCENT TRANSFORMED

LOC	LEV	#	RAFINE	HEBERT	PLECTO	PLATYS	DALMAN	ZYGOSP	LINGUL	INARTI	CARITO	AMBONY	MODIOL
CHS	2.30	1	14.0351	10.5263	0.0000	0.0000	0.0000	3.5088	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	3.85	2	5.3540	1.1898	0.0000	0.0000	0.0000	0.5949	1.7847	0.0000	0.0000	0.0000	0.0000
CHS	4.07	3	35.1171	0.0000	6.6890	1.6722	0.0000	0.0000	0.0000	0.0000	0.0000	3.3445	0.0000
CHS	4.50	4	18.5185	2.8490	0.0000	0.0000	0.0000	22.0798	0.7123	0.0000	0.0000	0.0000	0.0000
CHS	4.90	5	44.6097	1.8587	0.0000	7.4349	0.0000	16.7286	0.0000	0.0000	0.0000	0.0000	1.8587
CHS	5.35	6	9.1842	3.2415	18.9087	5.9427	0.0000	2.7012	0.0000	0.5402	1.6207	2.7012	0.0000
CHS	6.20	7	11.1524	0.0000	0.0000	1.4870	0.0000	57.9926	0.0000	0.0000	0.0000	0.0000	0.7435
CHS	6.90	8	18.6125	4.2301	0.0000	10.9983	0.0000	47.3773	0.0000	0.0000	0.0000	0.0000	0.8460
CHS	7.43	9	0.0000	0.0000	0.0000	0.0000	0.0000	50.2541	1.9763	0.0000	0.0000	0.5647	0.8470
CHS	8.19	10	12.6761	7.7465	0.0000	0.7042	0.0000	40.8451	0.0000	0.0000	0.0000	0.7042	0.0000
CHS	8.70	11	9.9110	1.3439	0.0000	0.5039	0.1680	20.1579	0.0000	0.0000	0.1680	0.0000	0.0000
CHS	9.67	12	2.5641	0.0000	0.0000	0.0000	0.0000	74.3590	2.5641	0.0000	2.5641	5.1282	0.0000
CHS	10.05	13	16.9811	0.0000	0.0000	0.9434	0.0000	57.5472	0.9434	0.0000	1.8868	2.8302	0.9434
CHS	10.40	14	13.0890	2.6178	0.0000	2.6178	0.0000	41.0122	0.0000	0.0000	0.0000	1.3089	2.1815
CHS	10.87	15	12.6792	4.9614	0.0000	11.0254	0.0000	23.7045	0.0000	1.1025	1.1025	0.5513	0.0000
CHS	11.54	16	36.8272	2.8329	0.0000	18.4136	0.0000	7.0822	0.0000	1.4164	0.0000	0.0000	0.0000
CHS	12.05	17	0.2135	0.0000	0.0000	0.9609	0.0000	2.9895	0.0000	0.0000	0.1068	0.1068	0.0000
CHS	12.61	18	0.8518	0.0000	0.0000	5.1107	0.0000	8.5179	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	13.20	19	11.1167	0.0000	0.0000	3.0318	0.0000	12.1273	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	13.89	20	23.7335	0.0000	0.0000	3.1949	0.0000	22.8206	0.0000	0.4564	0.0000	0.0000	0.0000
CHS	14.55	21	12.3486	0.0000	0.0000	1.1874	0.0000	50.8193	0.0000	0.2375	0.0000	0.2375	0.4749
CHS	15.00	22	21.4133	0.0000	0.0000	2.1413	0.0000	1.0707	0.0000	0.0000	1.6060	0.5353	0.0000
CHS	15.45	23	44.4659	0.4833	0.0000	13.5331	0.0000	13.5331	0.0000	0.0000	0.0000	2.9000	0.0000
CHS	15.70	24	12.7758	0.0000	1.1614	47.6190	0.0000	4.6458	0.0000	0.0000	0.0000	1.1614	0.0000
CHS	16.25	25	1.9763	0.3953	0.0000	0.1976	0.0000	1.5810	0.0000	0.0000	0.1976	0.0000	0.0000
MAF	2.91	26	16.6945	0.8347	0.0000	15.8598	0.0000	16.6945	0.0000	0.0000	0.0000	0.0000	0.0000
MAF	3.43	27	25.1748	0.0000	4.1958	9.7902	0.0000	15.3846	0.0000	0.0000	0.0000	1.3986	0.0000
MAF	4.00	28	2.6596	0.0000	24.1578	0.8865	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MAF	4.37	29	2.5773	0.0000	25.7732	0.0000	0.0000	0.0000	5.1546	0.0000	0.0000	2.5773	5.1546
MAF	5.10	30	15.9151	0.7958	0.0000	1.5915	0.0000	55.4377	0.0000	0.0000	0.0000	0.5305	0.0000
MAF	5.40	31	2.1067	4.2135	0.0000	0.7022	0.0000	48.4551	0.7022	0.0000	0.7022	11.2360	2.1067
MAF	6.20	32	14.5051	0.0000	0.0000	0.8532	0.0000	47.7816	1.7065	0.8532	0.0000	0.0000	0.0000
MAF	6.40	33	21.1572	1.2953	0.0000	0.0000	0.0000	62.8238	0.0000	0.0000	0.2159	0.0000	0.0000
MAF	7.00	34	33.7525	1.6545	0.3309	1.6545	1.9854	32.7598	0.0000	0.0000	0.3309	0.0000	0.3309
MAF	7.88	35	8.1967	0.0000	0.0000	0.0000	0.0000	60.1093	25.9563	0.0000	0.0000	0.0000	0.0000
MAF	8.40	36	31.8292	1.6116	0.0000	0.4029	0.0000	49.1539	1.2087	0.4029	0.8058	3.2232	0.4029
MAF	8.80	37	19.2878	0.0000	0.0000	0.7418	0.0000	61.5727	1.4837	0.0000	0.0000	1.4837	1.4837
MAF	9.15	38	9.8325	0.0000	0.0000	1.4567	0.0000	54.6249	0.0000	0.0000	0.0000	1.8208	0.3642
MAF	9.70	39	34.5413	0.0000	0.0000	19.2525	0.0000	30.5776	0.0000	0.0000	0.0000	0.0000	0.5663
MAF	10.15	40	12.1951	1.7422	0.0000	6.9686	0.0000	24.3902	0.0000	0.0000	1.7422	0.0000	0.0000
MAF	10.60	41	32.0000	0.0000	0.0000	16.0000	0.0000	24.0000	0.0000	0.0000	4.0000	16.0000	8.0000
MAF	11.35	42	28.2152	0.0000	0.0000	4.5932	0.0000	24.9344	0.0000	0.0000	0.6562	3.2808	0.0000
MAF	12.12	43	16.5493	0.0000	0.0000	0.3521	0.0000	53.5211	0.0000	0.0000	0.0000	0.0000	0.3521
MAF	12.52	44	33.7972	1.9881	0.0000	0.0000	0.0000	41.7495	3.9761	0.0000	0.0000	1.9881	0.0000
MAF	13.05	45	45.4545	0.0000	0.0000	2.2727	0.0000	20.4545	0.7576	0.0000	0.0000	0.7576	1.5152
MAF	13.32	46	19.1083	0.0000	0.0000	1.1240	0.0000	33.7205	0.0000	0.0000	0.0000	0.0000	0.3747
MAF	13.85	47	31.8627	0.0000	0.0000	8.5784	0.0000	17.1569	0.0000	0.0000	0.0000	7.3529	0.0000
MAF	14.20	48	29.5567	0.0000	0.0000	3.2841	0.0000	19.7044	0.8210	0.0000	0.8210	0.0000	0.8210
MTN	5.05	49	2.7996	0.0000	1.1198	0.0000	0.0000	0.0000	17.9171	0.0000	0.0000	3.3595	2.7996
MTN	5.65	50	13.4288	0.8953	11.6383	7.1620	0.0000	2.6858	0.8953	0.0000	0.0000	0.0000	0.0000
MTN	6.00	51	7.8616	0.0000	69.9686	3.9308	0.0000	0.0000	3.9308	0.7862	0.0000	1.5723	0.0000
MTN	6.65	52	11.9617	0.0000	27.5120	0.0000	0.0000	1.1962	11.9617	1.1962	0.0000	1.1962	0.0000
MTN	6.86	53	10.2686	0.0000	24.4866	0.0000	0.0000	1.5798	0.0000	0.0000	0.0000	4.7393	0.7899
MTN	7.40	54	31.8602	0.5139	0.0000	3.5971	0.0000	42.1377	0.0000	0.5139	1.0277	0.5139	0.5139
MTN	7.64	55	45.3125	1.5625	0.0000	3.1250	0.0000	23.4375	0.0000	0.0000	0.0000	7.8125	1.5625
MTN	8.70	56	7.7220	0.0000	0.0000	0.0000	0.0000	46.3320	1.9305	0.0000	0.0000	4.5045	3.8610
MTN	9.16	57	44.3593	1.6429	0.0000	0.5476	3.2859	35.0493	0.5476	0.0000	0.0000	0.5476	0.0000
MTN	9.37	58	28.1280	0.0000	0.0000	0.0000	8.2444	46.0718	0.0000	0.0000	0.0000	0.4850	0.9699
MTN	10.05	59	54.3478	0.0000	0.0000	0.9881	6.9170	29.6443	0.0000	0.0000	0.0000	0.4941	0.4941
MTN	11.04	60	36.0231	0.0000	0.0000	0.0000	0.0000	23.4150	31.3401	0.0000	0.3602	0.3602	1.0807
MTN	11.25	61	66.6667	0.0000	0.0000	0.0000	0.0000	17.2549	6.6667	0.0000	0.3922	1.1765	0.0000
MTN	12.15	62	17.8777	0.0000	0.0000	0.0000	0.0000	48.4429	2.8835	0.0000	0.0000	4.0369	1.1534
MTN	12.80	63	13.8889	0.5556	0.0000	0.5556	0.0000	31.6667	0.5556	0.0000	0.5556	1.6667	0.5556
MTN	13.10	64	20.6751	1.2658	0.0000	0.4219	0.0000	54.8523	0.0000	0.0000	0.0000	0.8439	0.8439
MTN	13.36	65	33.5170	0.4591	0.0000	4.1322	0.0000	34.4353	1.8365	0.0000	0.4591	0.0000	0.4591

LARGER-SCALE FAUNAL DATA SET, PERCENT TRANSFORMED (continued)

LOC	LEV	#	RAFINE	HEBERT	PLECTO	PLATYS	DALMAN	ZYGOSP	LINGUL	INARTI	CARITO	AMBONY	MODIOL
MTN	13.50	66	33.0813	1.8904	0.0000	11.3422	0.0000	32.1361	0.0000	0.0000	0.0000	0.9452	0.0000
MTN	14.00	67	8.5714	0.0000	0.0000	1.4286	0.0000	52.8571	0.0000	0.0000	5.7143	2.8571	0.0000
MTN	14.65	68	42.2111	0.0000	0.0000	1.5075	0.0000	26.1307	0.0000	0.0000	0.0000	1.0050	0.5025
MTN	14.96	69	37.8270	0.0000	0.0000	0.8048	0.0000	47.8873	0.0000	0.0000	0.0000	0.0000	0.0000
MTN	15.40	70	22.5179	0.0000	0.0000	5.1177	0.0000	18.4237	0.0000	0.0000	0.0000	0.0000	0.0000
MTN	15.80	71	7.6046	0.0000	0.0000	8.5551	0.0000	8.5551	0.0000	0.0000	0.4753	0.9506	0.4753
MTN	16.22	72	7.8802	0.2251	0.0000	0.6754	0.0000	57.6382	0.0000	0.4503	0.0000	0.1126	0.0000
MTN	16.85	73	31.5931	0.0000	0.0000	1.1558	0.0000	46.0412	0.0000	0.0000	0.0000	0.1926	0.0000
MTN	17.10	74	35.6866	0.0000	0.0000	0.0000	0.0000	20.1707	0.0000	0.0000	0.0000	8.5337	1.5516
MTN	17.48	75	66.6667	0.0000	0.0000	0.0000	0.0000	10.7527	0.0000	0.0000	0.0000	0.0000	0.0000
WYN	3.00	76	15.7303	0.0000	2.2472	4.4944	0.0000	0.0000	0.0000	0.0000	2.2472	4.4944	0.0000
WYN	3.50	77	33.5329	7.1856	0.0000	3.5928	0.0000	9.5808	0.0000	0.0000	0.0000	0.0000	0.0000
WYN	4.05	78	21.2102	1.2477	9.9813	5.6145	0.0000	14.9719	0.0000	0.6238	0.0000	0.6238	0.0000
WYN	4.35	79	8.1967	0.0000	22.6986	1.8916	0.0000	5.0441	0.6305	0.0000	1.2610	0.6305	0.0000
WYN	5.05	80	6.8125	2.8684	47.6873	2.1513	0.0000	6.8125	2.1513	1.7928	0.0000	1.4342	0.3586
WYN	5.50	81	22.8802	0.0000	1.3459	0.0000	0.0000	14.8048	2.6918	1.3459	0.0000	0.0000	0.0000
WYN	5.96	82	38.9785	2.6882	0.0000	7.6165	0.0000	37.1864	0.0000	0.0000	0.4480	0.0000	0.0000
WYN	6.57	83	11.6202	0.0000	0.3320	0.0000	0.0000	52.1248	0.9960	0.0000	0.3320	3.3201	2.9880
WYN	7.20	84	38.8889	3.3333	0.0000	0.0000	0.0000	36.6667	0.0000	0.0000	0.0000	2.2222	1.6667
WYN	7.61	85	10.6707	0.5081	0.5081	0.0000	0.0000	65.5488	0.0000	0.0000	0.0000	0.0000	6.6057
WYN	7.95	86	18.0568	2.1496	0.0000	6.0189	0.0000	44.7120	0.0000	0.0000	0.0000	0.4299	1.2898
WYN	8.55	87	28.9412	2.5882	0.4706	2.8235	0.0000	39.0588	0.0000	0.0000	0.0000	0.9412	1.1765
WYN	9.13	88	3.2852	0.0000	0.0000	0.0000	0.0000	72.2733	0.0000	0.0000	1.9711	0.0000	0.0000
WYN	9.60	89	17.3475	3.6374	0.0000	6.7152	0.0000	18.1869	0.0000	0.0000	0.5596	0.2798	0.0000
WYN	9.90	90	19.9288	2.8470	0.3559	14.5907	0.0000	25.2669	0.0000	6.7616	0.7117	0.7117	0.0000
WYN	10.30	91	1.6393	5.3279	0.0000	27.4590	0.0000	29.9180	0.0000	0.0000	0.0000	1.2295	0.0000
WYN	11.00	92	50.6098	0.6098	0.0000	15.2439	0.0000	13.4146	0.0000	2.4390	0.0000	0.6098	0.0000
WYN	11.20	93	31.5789	1.5038	0.0000	5.2632	0.0000	18.7970	0.0000	9.0226	0.0000	1.5038	1.5038
SIP	0.45	94	2.3328	0.0000	0.0000	0.0000	0.0000	0.7776	1.5552	3.1104	0.0000	0.0000	0.0000
SIP	0.85	95	8.3102	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.7701	0.0000
SIP	1.55	96	10.1099	0.0000	7.0330	1.3187	0.0000	1.3187	1.3187	0.0000	0.0000	0.0000	0.0000
SIP	1.75	97	5.0590	0.0000	16.8634	0.0000	0.0000	3.3727	5.0590	0.0000	0.0000	0.0000	1.6863
SIP	2.45	98	2.9347	0.0000	17.6082	0.7337	0.0000	0.0000	0.0000	0.7337	0.0000	2.9347	0.0000
SIP	2.85	99	21.2985	1.3741	0.0000	1.7176	0.0000	48.4370	1.0306	4.1223	0.0000	0.0000	0.0000
SIP	3.20	100	31.0799	0.6806	0.0000	1.1343	0.0000	58.0762	0.0000	0.0000	0.0000	0.0000	0.0000
SIP	3.75	101	0.0000	0.0000	0.0000	0.0000	0.0000	37.5375	1.5015	1.5015	0.0000	18.0180	4.5045
SIP	4.10	102	0.0000	0.0000	0.0000	0.0000	0.0000	45.9427	4.1766	0.0000	0.0000	6.5632	1.7900
SIP	4.57	103	15.3218	0.0000	0.0000	0.0000	0.0000	62.3085	0.5107	0.0000	0.0000	0.5107	0.5107
SIP	4.90	104	10.6686	0.5334	0.0000	0.0000	0.0000	73.6131	0.0000	0.0000	0.0000	0.5334	0.1778
SIP	5.19	105	64.0693	2.1645	0.0000	6.9264	4.3290	4.7619	0.0000	0.0000	0.4329	0.0000	0.0000
SIP	5.50	106	55.5556	0.0000	0.0000	0.0000	0.8230	29.2181	6.1728	0.0000	0.0000	0.8230	0.0000
SIP	5.95	107	31.4770	0.0000	0.0000	0.0000	0.0000	24.8184	26.0291	0.0000	0.0000	12.7119	1.2107
SIP	6.45	108	17.5676	0.0000	0.0000	0.0000	0.6757	43.2432	11.4865	0.0000	1.3514	3.3784	4.7297
SIP	7.10	109	0.0000	0.0000	0.0000	0.0000	0.0000	14.2857	2.8571	0.0000	0.0000	61.4286	2.8571
SIP	8.00	110	32.3529	0.0000	0.0000	0.0000	0.3268	33.0065	0.0000	0.3268	0.3268	7.5163	0.3268
SIP	8.65	111	32.7675	0.1974	0.0000	0.1974	1.7765	51.1251	0.5922	0.0000	0.1974	0.1974	0.5922
SIP	9.05	112	57.5049	0.0000	0.0000	0.0000	0.0000	23.3918	0.0000	0.0000	0.0000	0.9747	2.9240
SIP	9.39	113	9.7888	0.0000	0.0000	0.2576	0.0000	81.6589	0.2576	0.0000	0.5152	0.2576	0.0000
SIP	9.70	114	31.2500	0.0000	0.0000	0.0000	0.0000	36.6587	0.0000	0.0000	1.2019	0.0000	5.4087
SIP	10.20	115	69.3878	0.0000	0.0000	0.0000	0.0000	17.3469	0.5102	0.0000	0.0000	1.0204	0.0000
SIP	10.53	116	61.5213	1.1186	0.0000	5.5928	0.0000	13.4228	0.0000	0.0000	0.0000	0.0000	0.0000
SIP	10.70	117	15.9091	0.0000	0.0000	5.6818	0.0000	75.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SIP	10.95	118	12.8388	0.0000	0.0000	8.5592	0.0000	59.9144	0.0000	0.0000	0.0000	2.1398	0.0000
SIP	11.70	119	19.8753	0.0000	0.0000	0.7794	0.0000	14.8090	0.0000	0.0000	0.3897	0.0000	0.0000
SIP	12.05	120	13.1551	0.0000	0.0000	0.8352	0.0000	46.3562	2.2969	0.0000	0.2088	0.2088	0.0000
SIP	12.45	121	5.2226	0.0000	0.0000	1.4922	0.0000	31.8329	0.0000	0.0000	0.0000	1.7409	0.0000
SIP	12.90	122	59.0753	0.0000	0.0000	0.0000	0.0000	35.9589	0.0000	0.8562	0.0000	1.7123	0.0000
LBG	17.80	123	23.0934	0.0000	2.6853	0.0000	0.0000	1.6112	9.6670	2.1482	0.0000	0.5371	0.5371
LBG	18.60	124	16.8729	0.0000	1.1249	2.2497	0.0000	3.3746	1.1249	0.0000	0.0000	0.0000	0.0000
LBG	19.00	125	27.3038	2.2753	3.4130	4.5506	0.0000	12.5142	0.0000	1.1377	0.0000	0.0000	0.0000
LBG	19.65	126	5.9636	0.0000	32.9567	1.5694	0.0000	5.9636	6.9052	0.3139	0.0000	6.2775	0.0000
LBG	20.22	127	15.7171	0.0000	33.7263	0.6549	0.0000	3.6018	2.9470	2.2921	0.0000	0.6549	0.0000
LBG	20.68	128	11.7589	0.0000	37.2366	0.0000	0.0000	24.9878	0.9799	2.9397	0.0000	2.9397	0.4900
LBG	21.10	129	13.9721	0.0000	0.0000	0.0000	0.0000	51.8962	1.9960	1.9960	0.0000	0.0000	0.0000
LBG	21.40	130	11.3169	9.2593	0.0000	8.2305	0.0000	54.5268	0.0000	0.0000	0.0000	1.0288	0.0000

LARGER-SCALE FAUNAL DATA SET, PERCENT TRANSFORMED (continued)

LOC	LEV	#	RAFINE	HEBERT	PLECTO	PLATYS	DALMAN	ZYGOSP	LINGUL	INARTI	CARITO	AMBONY	MODIOL
LBG	21.75	131	32.4528	4.1509	0.0000	1.5094	0.0000	48.6792	0.0000	0.0000	0.3774	0.0000	0.0000
LBG	22.35	132	28.9100	2.8436	0.0000	0.0000	0.0000	33.1754	2.3697	0.0000	0.0000	1.4218	7.1090
LBG	22.55	133	4.7569	1.5856	0.0000	1.5856	0.0000	77.1670	0.0000	0.0000	0.0000	0.0000	0.5285
LBG	22.81	134	18.4295	0.0000	0.0000	0.0000	0.0000	72.1154	2.4038	0.4006	0.8013	0.8013	2.8045
LBG	23.32	135	0.9337	0.0000	0.0000	0.0000	0.0000	68.6274	3.2680	0.0000	0.4669	0.0000	12.6050
LBG	23.95	136	36.8852	3.6430	0.0000	0.9107	0.0000	46.9035	0.0000	0.0000	0.0000	0.0000	0.0000
LBG	24.35	137	22.2458	2.1186	0.0000	0.0000	0.0000	42.3729	3.1780	0.0000	0.0000	1.0593	3.1780
LBG	24.45	138	23.8866	2.8340	0.0000	0.4049	0.0000	63.9676	0.0000	0.0000	0.4049	0.0000	0.4049
LBG	25.05	139	34.5423	11.5141	0.0000	18.9983	0.0000	16.1197	0.5757	0.0000	0.5757	0.0000	2.3028
LBG	25.52	140	8.3955	12.1269	0.0000	29.8507	0.0000	13.9925	0.0000	2.7985	4.6642	0.9328	0.9328
LBG	25.82	141	17.0940	1.8315	0.0000	7.3260	0.0000	43.3455	0.0000	4.2735	0.0000	0.0000	1.2210
LBG	26.43	142	8.5000	1.5000	0.0000	11.5000	0.0000	7.0000	0.0000	0.5000	0.0000	2.0000	1.0000
LBG	26.95	143	2.6061	0.0000	3.7230	4.0953	0.0000	40.2085	0.0000	0.0000	0.3723	0.0000	0.0000
LBG	27.50	144	6.0790	0.0000	0.0000	5.5724	0.0000	22.2898	0.0000	0.5066	0.0000	0.0000	0.0000
LBG	28.00	145	0.0000	0.0000	0.0000	7.1315	0.0000	3.1696	1.5848	0.0000	0.0000	2.3772	0.0000
LBG	28.50	146	17.1617	0.0000	0.0000	11.2211	0.0000	9.9010	0.0000	0.6601	0.6601	1.9802	0.6601
LBG	28.85	147	15.5699	0.2938	0.0000	19.3890	0.0000	49.3537	0.2938	0.0000	0.0000	0.2938	0.0000
LBG	29.60	148	38.2490	0.8500	0.0000	5.5249	0.0000	34.4241	0.0000	0.4250	0.0000	0.4250	0.0000
LBG	30.05	149	38.6493	0.4068	0.0000	1.6273	0.0000	21.1554	0.0000	1.6273	0.8137	0.0000	0.0000
LBG	30.35	150	44.2478	0.0000	0.0000	23.5988	0.0000	0.0000	0.0000	0.0000	0.0000	2.9499	2.9499

LARGER-SCALE FAUNAL DATA SET, PERCENT TRANSFORMED (continued)

LOC	LEV	#	NUCULO	CYCLON	GASTRO	CEPHAL	FLEXIC	ISOTEL	CERAUR	ACIDAS	ENCRUS	HEXAGO	ESCHAR
CHS	2.3	1	0.0000	0.0000	0.0000	0.0000	0.0000	21.4035	0.0000	0.0000	0.0000	0.0000	42.1053
CHS	3.85	2	0.0000	1.1898	0.0000	0.0000	10.4700	14.3367	0.0000	0.8328	1.7847	0.0000	10.7079
CHS	4.07	3	18.3946	0.0000	0.0000	0.0000	2.3411	12.0401	3.6789	0.0000	0.0000	0.0000	6.6890
CHS	4.5	4	0.0000	0.0000	0.0000	0.0000	0.2849	0.2849	0.0000	0.0000	2.1368	0.0000	42.0228
CHS	4.9	5	0.0000	0.0000	0.0000	0.0000	0.0000	0.3717	0.0000	0.0000	0.0000	0.0000	24.1636
CHS	5.35	6	0.0000	0.0000	0.0000	0.0000	4.5381	2.6472	0.6483	0.5402	11.8855	0.0000	14.5867
CHS	6.2	7	0.0000	0.0000	0.0000	0.0000	1.3383	0.6691	0.0000	0.0000	0.0000	0.0000	16.3569
CHS	6.9	8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	7.43	9	0.0000	0.0000	36.1378	0.0000	4.5172	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.19	10	0.0000	0.0000	0.0000	0.0000	0.9859	0.0000	0.0000	0.0000	2.1127	1.4085	0.0000
CHS	8.7	11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0168	0.0000	0.0000	0.0000
CHS	9.67	12	0.0000	0.0000	12.8205	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.05	13	1.8868	0.0000	6.6038	0.0000	2.8302	0.0000	0.0000	0.0000	0.9434	0.0000	0.0000
CHS	10.4	14	0.4363	0.0000	0.8726	0.0000	1.5707	0.0000	0.0000	0.4363	0.0000	0.0000	0.0000
CHS	10.87	15	0.0000	0.0000	1.1025	0.0000	4.4101	0.0000	0.0000	0.5513	2.7563	0.0000	0.0000
CHS	11.54	16	0.0000	0.0000	0.0000	0.0000	5.0992	0.0000	0.0000	0.0000	9.9150	0.0000	0.0000
CHS	12.05	17	0.0000	0.0000	0.0000	0.0000	0.0641	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	12.61	18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	13.2	19	0.0000	0.0000	0.0000	0.0000	0.5053	2.1728	0.0000	1.0106	1.5159	0.0000	0.0000
CHS	13.89	20	0.0000	0.0000	0.0000	0.0000	1.1867	1.7800	0.0000	0.0000	0.0000	15.0616	0.0000
CHS	14.55	21	0.0000	0.0000	0.0000	0.0000	0.0475	0.3087	0.0000	0.0000	4.9869	0.0000	0.0000
CHS	15	22	0.0000	0.0000	0.0000	0.0000	0.0000	0.2141	0.0000	0.0000	35.8672	0.0000	0.0000
CHS	15.45	23	0.0000	0.4833	0.0000	0.0000	0.0000	1.7883	0.0000	0.0000	8.2165	0.4833	0.0000
CHS	15.7	24	0.0000	1.1614	1.1614	1.1614	1.3937	1.0453	0.0000	1.1614	4.6458	0.0000	0.0000
CHS	16.25	25	0.0000	0.3953	0.0000	0.0000	0.7510	0.8696	0.0000	0.0000	0.3953	0.0000	0.0000
MAF	2.91	26	0.0000	0.0000	0.0000	0.0000	0.1669	0.0000	0.0000	0.0000	10.0167	0.0000	11.6861
MAF	3.43	27	0.0000	0.0000	0.0000	0.0000	4.7552	2.0979	0.0000	0.0000	0.0000	0.0000	12.5874
MAF	4	28	0.0000	0.0000	0.0000	0.0000	9.2642	4.2110	0.0000	1.1082	2.4379	0.0000	24.6011
MAF	4.37	29	0.0000	0.0000	0.0000	0.0000	29.8969	3.0928	0.0000	0.0000	0.0000	0.0000	0.0000
MAF	5.1	30	0.0000	0.0000	0.0000	0.0000	0.2653	0.0000	0.0000	0.2653	1.0610	0.0000	0.0000
MAF	5.4	31	0.7022	0.0000	5.6180	1.4045	1.6854	0.0000	0.0000	0.0000	7.0225	0.0000	0.0000
MAF	6.2	32	0.0000	0.0000	0.8532	0.0000	1.8771	0.0000	0.0000	0.0000	0.8532	0.0000	0.0000
MAF	6.4	33	0.0000	0.0000	0.0000	0.0000	0.9499	0.0000	0.0000	0.2159	2.1589	0.2159	0.0000
MAF	7	34	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.9854	0.0000	0.0000
MAF	7.88	35	1.3661	0.0000	1.3661	0.0000	0.2732	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MAF	8.4	36	1.2087	0.0000	2.8203	0.8058	0.0806	0.0000	0.0000	0.0000	2.8203	0.0000	0.0000
MAF	8.8	37	0.7418	0.0000	2.2255	0.0000	1.3353	0.0000	0.0000	0.0000	2.2255	0.0000	0.0000
MAF	9.15	38	0.0000	0.0000	20.3933	0.0000	1.3110	0.0000	0.0000	0.0000	1.8208	0.0000	0.0000
MAF	9.7	39	0.0000	0.0000	0.0000	0.0000	1.4723	0.0000	0.0000	0.5663	6.2288	0.0000	0.0000
MAF	10.15	40	3.4843	0.0000	8.7108	0.0000	14.9826	0.0000	0.0000	5.5749	3.4843	0.0000	0.0000
MAF	10.6	41	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MAF	11.35	42	0.0000	0.0000	2.6247	0.0000	0.6562	0.0000	0.0000	0.0000	3.2808	0.0000	0.0000
MAF	12.12	43	0.0000	0.0000	0.0000	0.0000	0.8451	0.6338	0.0000	0.0000	0.0000	15.8451	0.0000
MAF	12.52	44	0.0000	1.9881	0.0000	0.0000	0.0000	1.9881	0.0000	0.1988	5.9642	0.0000	0.0000
MAF	13.05	45	0.0000	0.0000	0.0000	0.0000	0.0000	0.7576	0.0000	0.0000	8.3333	0.0000	0.0000
MAF	13.32	46	0.0000	0.0000	0.0000	0.0000	0.0000	0.1873	0.0000	0.3747	18.3589	8.2428	0.0000
MAF	13.85	47	0.0000	0.0000	0.0000	0.0000	0.0000	0.7353	0.0000	0.0000	15.9314	0.0000	0.0000
MAF	14.2	48	0.0000	0.0000	0.0000	0.0000	0.0000	0.9031	0.0000	0.0821	27.0936	0.0000	0.0000
MTN	5.05	49	20.1568	1.1198	0.5599	0.0000	6.6069	7.0549	0.0000	0.0000	3.9194	0.0000	0.0000
MTN	5.65	50	0.0000	0.0000	0.0000	0.0000	0.0000	0.6267	0.0000	0.0000	0.0000	0.0000	51.9248
MTN	6	51	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	3.9308	0.0000	6.2893
MTN	6.65	52	0.0000	0.0000	0.0000	0.0000	5.2632	3.1100	1.9139	0.0000	1.1962	0.0000	26.3158
MTN	6.86	53	0.0000	0.0000	0.0000	0.0000	2.2117	6.7930	2.6856	0.0000	0.7899	0.0000	3.1596
MTN	7.4	54	0.0000	0.0000	1.0277	0.0000	0.0000	0.0000	0.0000	0.5139	0.0000	0.0000	0.0000
MTN	7.64	55	0.0000	0.0000	3.1250	0.0000	3.1250	0.0000	0.0000	0.0000	1.5625	0.0000	9.3750
MTN	8.7	56	0.0000	0.0000	10.2960	0.0000	1.0296	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MTN	9.16	57	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.1906	0.0000	0.0000
MTN	9.37	58	0.0000	0.0000	0.0000	0.0000	0.0970	0.0970	0.0000	0.4850	1.4549	0.0000	0.0000
MTN	10.05	59	0.0000	0.0000	0.0000	0.0000	0.0988	0.0000	0.0000	0.0000	0.9881	0.0000	0.0000
MTN	11.04	60	1.0807	0.0000	0.0000	0.0000	0.2161	0.0000	0.0000	0.0000	2.5216	0.0000	0.0000
MTN	11.25	61	2.7451	0.0000	0.3922	0.0000	0.0000	0.0000	0.0000	0.0000	1.5686	0.0000	0.0000
MTN	12.15	62	1.7301	0.0000	14.9942	0.5767	0.8074	0.0000	0.0000	0.0000	5.1903	0.0000	0.0000
MTN	12.8	63	1.1111	0.0000	33.3333	0.0000	0.0000	0.0000	0.0000	1.1111	0.5556	0.0000	0.0000
MTN	13.1	64	0.0000	0.0000	2.5316	0.0000	1.4346	0.2532	0.0000	0.8439	0.0000	0.0000	0.0000
MTN	13.36	65	0.4591	0.0000	1.3774	0.0000	0.5510	0.0000	0.0000	3.0303	0.9183	0.0000	0.0000

LARGER-SCALE FAUNAL DATA SET, PERCENT TRANSFORMED (continued)

LOC	LEV	#	NUCULO	CYCLON	GASTRO	CEPHAL	FLEXIC	ISOTEL	CERAUR	ACIDAS	ENCRUS	HEXAGO	ESCHAR
MTN	13.5	66	0.0000	0.0000	1.8904	0.0000	4.5369	0.0000	0.0000	0.0000	0.9452	0.0000	0.0000
MTN	14	67	4.2857	0.0000	20.0000	0.0000	1.4286	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MTN	14.65	68	0.0000	0.0000	0.5025	0.0000	0.0000	0.0000	0.0000	0.5025	1.0050	0.0000	0.0000
MTN	14.96	69	0.0000	0.0000	0.0000	0.0000	0.1610	0.0402	0.0000	0.0000	2.4145	0.0000	0.0000
MTN	15.4	70	0.0000	0.0000	0.0000	0.0000	0.0000	2.5589	0.0000	2.0471	17.4002	0.0000	0.0000
MTN	15.8	71	0.0000	0.0000	0.0000	0.0000	3.8973	6.9867	0.0000	0.5228	9.0304	0.9506	0.0000
MTN	16.22	72	0.0000	1.0132	0.0000	0.0000	0.8556	1.8125	0.0000	0.5178	3.0395	0.1126	0.0000
MTN	16.85	73	0.0000	0.0000	0.0000	0.1926	0.2697	0.7128	0.0000	0.0000	10.9805	4.4307	0.0000
MTN	17.1	74	0.0000	0.0000	0.0000	0.0000	0.0000	2.5601	0.0000	0.0000	7.7580	0.0000	0.0000
MTN	17.48	75	0.0000	0.0000	0.0000	0.0000	0.0000	0.2151	0.0000	0.0000	15.0538	0.0000	0.0000
WYN	3	76	0.0000	0.0000	0.0000	0.0000	3.1461	4.2697	0.8989	0.0000	15.7303	0.0000	33.7079
WYN	3.5	77	0.0000	0.0000	0.0000	0.0000	0.2395	0.1198	0.0000	0.0000	8.3832	0.0000	15.5689
WYN	4.05	78	0.0000	0.0000	0.0000	0.0000	0.1248	1.0605	0.0000	0.0000	3.7430	0.0000	38.6775
WYN	4.35	79	0.0000	0.0000	0.0000	0.0000	6.6835	0.5044	1.2610	1.2610	3.1526	0.0000	27.1122
WYN	5.05	80	0.0000	0.0000	0.3586	0.0000	5.1631	2.4740	2.7250	0.7171	5.0197	0.7171	5.0197
WYN	5.5	81	0.0000	0.0000	0.0000	0.0000	0.2692	3.0956	0.2692	0.0000	10.7672	0.0000	20.1884
WYN	5.96	82	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.7921	0.0000	0.0000
WYN	6.57	83	0.9960	0.0000	2.9880	0.0000	1.1288	0.3320	0.0000	0.0000	5.3121	0.0000	0.0000
WYN	7.2	84	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5556	0.0000	0.0000
WYN	7.61	85	0.0000	0.0000	15.7520	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WYN	7.95	86	0.0000	0.0000	2.1496	0.0000	0.5159	0.0000	0.0000	0.0000	3.4394	0.0000	0.0000
WYN	8.55	87	0.0000	0.0000	0.0000	0.4706	1.2706	0.0000	0.0000	0.2353	2.1176	0.0000	0.0000
WYN	9.13	88	13.7976	0.0000	5.9133	0.0000	2.7595	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WYN	9.6	89	0.0000	0.0000	1.3990	0.0000	0.8954	0.0000	0.0000	0.0000	0.8394	0.0000	0.0000
WYN	9.9	90	0.0000	0.0000	0.7117	0.0000	1.6370	0.0000	0.0000	1.4235	3.5587	0.0000	0.0000
WYN	10.3	91	0.0000	0.0000	1.6393	0.0000	0.4098	0.0000	0.0000	0.8197	2.4590	0.4098	0.0000
WYN	11	92	0.0000	0.0000	1.8293	0.0000	0.0000	0.0000	0.0000	0.0000	6.0976	0.6098	0.0000
WYN	11.2	93	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	8.2707	0.0000	0.0000
SIP	0.45	94	0.0000	0.7776	1.5552	0.0000	2.4883	2.6439	0.7776	0.0000	2.3328	0.0000	6.9984
SIP	0.85	95	0.0000	0.0000	0.0000	0.0000	5.5402	1.3850	0.0000	0.0000	5.5402	0.0000	2.7701
SIP	1.55	96	0.0000	0.0000	0.0000	0.0000	2.9011	1.6264	0.4396	0.0000	0.0000	0.0000	9.2308
SIP	1.75	97	0.0000	0.0000	1.6863	0.0000	9.4435	8.2631	0.0000	0.0000	1.6863	0.0000	0.0000
SIP	2.45	98	0.0000	0.0000	0.7337	0.0000	4.5488	1.2472	0.1467	0.0000	0.7337	0.0000	5.8694
SIP	2.85	99	0.0000	0.0000	0.0000	0.0000	1.3741	0.9962	0.1374	0.0000	4.1223	0.0000	4.1223
SIP	3.2	100	0.0000	0.0000	0.0000	0.0000	0.0454	0.0000	0.0000	0.0000	0.9074	0.0000	0.0000
SIP	3.75	101	0.0000	0.0000	0.0000	0.0000	0.6006	0.0000	0.0000	0.0000	7.5075	0.0000	0.0000
SIP	4.1	102	0.5967	0.0000	5.9666	0.0000	4.1766	0.0000	0.0000	0.0000	0.5967	0.0000	0.0000
SIP	4.57	103	0.0000	0.0000	0.0000	0.0000	1.0215	0.0000	0.0000	0.0000	0.5107	0.0000	0.0000
SIP	4.9	104	0.0000	0.0000	0.0000	0.0000	0.2134	0.0000	0.0000	0.1778	1.0669	0.0000	0.0000
SIP	5.19	105	0.0000	0.0000	0.0000	0.0000	0.0866	0.0000	0.0000	0.4329	2.1645	0.0000	0.0000
SIP	5.5	106	0.0000	0.0000	0.0000	0.0000	0.0823	0.0000	0.0000	0.0000	3.2922	0.0000	0.0000
SIP	5.95	107	0.6053	0.0000	2.4213	0.0000	0.1211	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SIP	6.45	108	2.0270	0.0000	7.4324	2.0270	2.7027	0.0000	0.0000	0.0000	2.0270	0.0000	0.0000
SIP	7.1	109	0.7143	0.0000	7.8571	2.1429	0.0000	0.0000	0.0000	0.0000	0.7143	0.0000	0.0000
SIP	8	110	0.3268	0.0000	9.1503	0.0000	0.2614	0.4575	0.0000	0.6536	5.2288	0.0000	0.0000
SIP	8.65	111	0.0000	0.0000	0.0000	0.0000	0.1184	0.0000	0.0000	0.0000	3.1583	0.0000	0.0000
SIP	9.05	112	0.0000	0.0000	0.9747	0.0000	0.1949	0.0000	0.0000	1.9493	0.9747	0.0000	0.0000
SIP	9.39	113	0.0000	0.0000	2.8336	0.0000	1.5971	0.0000	0.0000	0.0000	0.5152	0.0000	0.0000
SIP	9.7	114	0.0000	0.0000	13.2212	0.0000	0.2404	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SIP	10.2	115	0.0000	0.0000	0.5102	0.0000	0.0000	0.0000	0.0000	0.0000	1.5306	0.0000	0.0000
SIP	10.53	116	0.0000	0.0000	1.1186	0.0000	0.0000	0.0000	0.0000	0.0000	2.2371	0.0000	0.0000
SIP	10.7	117	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.1364	0.0000	0.0000	0.0000
SIP	10.95	118	0.0000	0.0000	0.0000	0.0000	0.0000	0.1427	0.0000	0.0000	1.4265	0.0000	0.0000
SIP	11.7	119	0.0000	0.0000	0.0000	0.0000	0.0000	1.2471	0.0000	0.0000	1.1691	0.0000	0.0000
SIP	12.05	120	0.6264	0.0000	0.0000	0.0000	1.6705	1.3155	0.0000	0.2088	1.0441	0.0000	0.0000
SIP	12.45	121	0.0000	0.0000	0.2487	0.0000	0.0995	0.1243	0.0000	0.4974	0.4974	0.0000	0.0000
SIP	12.9	122	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LBG	17.8	123	0.0000	2.1482	0.0000	0.0000	3.8668	6.9817	4.1890	1.6112	5.9076	0.0000	5.9076
LBG	18.6	124	0.0000	0.0000	0.0000	0.0000	0.0000	0.3375	0.0000	0.0000	1.1249	0.0000	40.4949
LBG	19	125	0.0000	0.0000	0.0000	0.0000	0.2275	0.3413	0.0000	0.0000	11.3766	0.0000	27.3038
LBG	19.65	126	0.0000	0.0000	0.0000	0.0000	0.4394	1.4438	4.3942	0.6905	3.7665	0.0000	13.8104
LBG	20.22	127	7.8585	0.0000	0.0000	0.0000	3.2744	1.6372	4.7151	0.0000	7.2037	0.0000	6.8762
LBG	20.68	128	0.0000	0.0000	0.0000	0.0000	3.5277	1.3229	6.4674	0.0000	5.3895	0.0000	0.0000
LBG	21.1	129	0.0000	0.0000	0.0000	0.0000	0.0000	0.9980	0.0000	0.0000	5.9880	0.0000	9.9800

LARGER-SCALE FAUNAL DATA SET, PERCENT TRANSFORMED (continued)

LOC	LEV	#	NUCULO	CYCLON	GASTRO	CEPHAL	FLEXIC	ISOTEL	CERAUR	ACIDAS	ENCRUS	HEXAGO	ESCHAR
LBG	21.4	130	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	3.0864	0.0000	0.0000
LBG	21.75	131	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	3.0189	1.8868	0.0000
LBG	22.35	132	0.0000	0.0000	0.4739	0.0000	3.6967	0.0000	0.0000	0.0000	13.2701	0.4739	0.0000
LBG	22.55	133	0.0000	0.0000	0.0000	0.0000	0.9514	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LBG	22.81	134	0.0000	0.0000	0.0000	0.0000	0.6410	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LBG	23.32	135	0.4669	0.0000	0.0000	0.4669	2.1475	0.0000	0.0000	0.0000	1.4006	0.4669	0.0000
LBG	23.95	136	0.0000	0.0000	0.0000	0.0000	0.1821	0.0000	0.0000	0.0000	3.6430	0.0000	0.0000
LBG	24.35	137	0.0000	0.0000	15.8898	0.0000	4.4492	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LBG	24.45	138	0.0000	0.0000	0.0000	0.0000	0.4049	0.0000	0.0000	0.0000	1.2146	0.0000	0.0000
LBG	25.05	139	0.0000	0.0000	0.0000	0.0000	0.8060	0.1727	0.0000	0.0000	2.3028	0.0000	0.0000
LBG	25.52	140	0.0000	0.0000	0.0000	0.0000	2.0522	0.0000	0.0000	1.8657	5.5970	0.0000	0.0000
LBG	25.82	141	0.0000	0.0000	4.2735	0.0000	8.3028	0.0000	0.0000	2.5641	2.4420	0.0000	0.0000
LBG	26.43	142	0.0000	0.0000	0.0000	0.0000	0.5000	0.0000	0.0000	0.0000	8.5000	0.0000	0.0000
LBG	26.95	143	0.0000	1.1169	0.0000	0.0000	0.6701	3.1273	0.0000	0.7446	1.1169	0.0000	0.0000
LBG	27.5	144	0.0000	0.0000	0.0000	0.0000	0.1013	1.7224	0.0000	1.5198	4.0527	0.0000	0.0000
LBG	28	145	0.0000	1.5848	0.0000	0.0000	0.0000	0.3170	0.0000	0.0000	0.7924	0.0000	0.0000
LBG	28.5	146	0.0000	0.0000	0.0000	0.0000	0.1320	0.8581	0.0000	0.7921	10.5611	0.0000	0.0000
LBG	28.85	147	0.0000	0.5875	0.0000	0.0000	0.0588	1.4101	0.0000	0.0000	4.1128	0.5875	0.0000
LBG	29.6	148	0.0000	0.0000	0.0000	0.0000	0.0000	0.3825	0.0000	0.0000	5.9499	0.0000	0.0000
LBG	30.05	149	0.0000	0.0000	0.0000	0.0000	0.0814	0.2441	0.0000	0.0000	6.5094	2.0342	0.0000
LBG	30.35	150	0.0000	0.0000	0.0000	0.0000	0.0000	3.2448	0.0000	0.0000	5.8997	0.0000	0.0000

LARGER-SCALE FAUNAL DATA SET, PERCENT TRANSFORMED (continued)

LOC	LEV	#	CRYPTO	CYCLOS	CINCIN	PYCNOC	SCOLEC	TRYPAN	CORNUL
CHS	2.3	1	0.0000	0.0000	0.7018	7.7193	0.0000	0.0000	0.0000
CHS	3.85	2	11.8977	0.0000	4.4021	35.4551	0.0000	0.0000	0.0000
CHS	4.07	3	1.6722	0.0000	1.3378	7.0234	0.0000	0.0000	0.0000
CHS	4.5	4	1.4245	0.0000	3.1339	6.5527	0.0000	0.0000	0.0000
CHS	4.9	5	0.0000	0.0000	0.3717	2.6022	0.0000	0.0000	0.0000
CHS	5.35	6	2.7012	0.0000	6.0508	2.3771	1.0805	8.1037	0.0000
CHS	6.2	7	0.7435	0.0000	1.6357	7.8810	0.0000	0.0000	0.0000
CHS	6.9	8	14.3824	0.0000	0.1692	0.0000	3.3841	0.0000	0.0000
CHS	7.43	9	0.0000	0.0000	0.0565	0.0000	0.5647	1.9763	3.1056
CHS	8.19	10	29.5775	0.0000	1.1268	0.0000	0.0000	0.7042	1.4085
CHS	8.7	11	66.0171	0.0000	1.3775	0.0000	0.3360	0.0000	0.0000
CHS	9.67	12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.05	13	1.8868	1.8868	0.0000	0.0000	0.9434	0.9434	0.0000
CHS	10.4	14	30.9773	0.0000	0.2618	0.0000	0.8726	1.3089	0.4363
CHS	10.87	15	33.0761	1.1025	0.2205	0.0000	1.6538	0.0000	0.0000
CHS	11.54	16	16.9972	1.4164	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	12.05	17	90.4335	0.1068	0.0000	0.0000	0.1068	4.1640	0.7474
CHS	12.61	18	46.8484	0.0000	0.0000	0.3407	0.0000	38.3305	0.0000
CHS	13.2	19	66.1951	0.5053	1.6170	0.2021	0.0000	0.0000	0.0000
CHS	13.89	20	14.6052	0.0000	0.0000	3.9251	1.3692	11.8667	0.0000
CHS	14.55	21	26.3595	2.1373	0.0000	0.8549	0.0000	0.0000	0.0000
CHS	15	22	19.2719	1.6060	0.0000	14.6681	0.5353	1.0707	0.0000
CHS	15.45	23	5.3166	0.9667	0.0000	5.8966	0.4833	0.0000	1.4500
CHS	15.7	24	13.9373	0.0000	0.0000	6.9686	0.0000	0.0000	0.0000
CHS	16.25	25	91.8972	0.0000	0.0000	0.5534	0.0000	0.0000	0.7905
MAF	2.91	26	4.1736	0.0000	11.6861	10.5175	1.6694	0.0000	0.0000
MAF	3.43	27	19.5804	0.0000	0.0000	0.8392	1.3986	2.7972	0.0000
MAF	4	28	24.6011	0.0000	0.7979	4.8316	0.0000	0.2216	0.2216
MAF	4.37	29	10.3093	0.0000	1.0309	6.7010	7.7320	0.0000	0.0000
MAF	5.1	30	19.3634	0.0000	0.0000	0.0000	0.0000	4.7745	0.0000
MAF	5.4	31	9.8315	0.0000	0.0000	0.0000	0.7022	1.4045	1.4045
MAF	6.2	32	29.8635	0.0000	0.8532	0.0000	0.0000	0.0000	0.0000
MAF	6.4	33	7.1244	0.0000	0.6045	0.0000	0.2159	2.3748	0.6477
MAF	7	34	21.5089	0.0000	0.0662	0.0000	0.0000	3.6400	0.0000
MAF	7.88	35	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.7322
MAF	8.4	36	0.4029	0.0000	0.0000	0.0000	0.0000	0.8058	2.0145
MAF	8.8	37	0.0000	2.2255	0.0000	0.0000	0.0000	5.1929	0.0000
MAF	9.15	38	7.2833	0.0000	0.0000	0.0000	0.7283	0.0000	0.3642
MAF	9.7	39	4.5300	0.5663	0.0000	0.0000	1.1325	0.0000	0.5663
MAF	10.15	40	13.9373	1.7422	1.0453	0.0000	0.0000	0.0000	0.0000
MAF	10.6	41	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MAF	11.35	42	17.0604	0.0000	0.2625	0.0000	0.0000	13.7795	0.6562
MAF	12.12	43	7.3944	2.8169	0.0000	1.6901	0.0000	0.0000	0.0000
MAF	12.52	44	1.9881	0.0000	0.0000	0.3976	3.9761	0.0000	0.0000
MAF	13.05	45	17.4242	0.7576	0.0000	0.7576	0.7576	0.0000	0.0000
MAF	13.32	46	7.8681	5.2454	0.0749	3.8217	0.0000	1.4987	0.0000
MAF	13.85	47	3.6765	0.0000	0.0000	2.4510	1.2255	9.8039	1.2255
MAF	14.2	48	4.9261	0.8210	0.0000	2.1346	0.8210	8.2102	0.0000
MTN	5.05	49	1.6797	0.0000	26.4278	3.9194	0.5599	0.0000	0.0000
MTN	5.65	50	8.9526	0.0000	0.8953	0.8953	0.0000	0.0000	0.0000
MTN	6	51	1.5723	0.0000	0.1572	0.0000	0.0000	0.0000	0.0000
MTN	6.65	52	0.0000	0.0000	3.3493	3.8278	0.0000	0.0000	0.0000
MTN	6.86	53	30.8057	0.7899	6.3191	4.5814	0.0000	0.0000	0.0000
MTN	7.4	54	10.7914	0.0000	0.1028	0.2055	0.5139	6.1665	0.0000
MTN	7.64	55	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MTN	8.7	56	19.3050	0.0000	4.3758	0.0000	0.6435	0.0000	0.0000
MTN	9.16	57	6.0241	0.5476	1.4239	0.0000	0.0000	3.8335	0.0000
MTN	9.37	58	3.8797	0.9699	8.6324	0.0000	0.0000	0.4850	0.0000
MTN	10.05	59	3.4585	0.0000	1.5810	0.0000	0.0000	0.4941	0.4941
MTN	11.04	60	0.3602	0.3602	0.0000	0.0000	0.0000	0.0000	2.8818
MTN	11.25	61	0.0000	0.0000	0.0000	0.0000	0.0000	1.1765	1.9608
MTN	12.15	62	1.7301	0.0000	0.0000	0.0000	0.0000	0.0000	0.5767
MTN	12.8	63	13.8889	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MTN	13.1	64	15.1899	0.4219	0.0000	0.0000	0.0000	0.0000	0.4219
MTN	13.36	65	16.0698	0.0000	0.0000	0.0000	0.4591	1.8365	0.0000

LARGER-SCALE FAUNAL DATA SET, PERCENT TRANSFORMED (continued)

LOC	LEV	#	CRYPTO	CYCLOS	CINCIN	PYCNOC	SCOLEC	TRYPAN	CORNUL
MTN	13.5	66	10.3970	0.0000	0.0000	0.0000	0.0000	2.8355	0.0000
MTN	14	67	2.8571	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MTN	14.65	68	26.1307	0.0000	0.5025	0.0000	0.0000	0.0000	0.0000
MTN	14.96	69	10.0604	0.0000	0.0000	0.0000	0.0000	0.8048	0.0000
MTN	15.4	70	27.6356	0.0000	0.2047	0.0000	0.0000	4.0942	0.0000
MTN	15.8	71	42.3004	0.9506	0.0951	7.2243	0.0000	0.9506	0.4753
MTN	16.22	72	3.8275	1.1257	0.0000	6.0790	0.0000	9.1185	5.5162
MTN	16.85	73	2.8896	0.0000	0.0000	0.0000	0.0000	1.5411	0.0000
MTN	17.1	74	8.5337	0.0000	0.1552	1.0861	0.0000	13.9643	0.0000
MTN	17.48	75	6.4516	0.0000	0.0000	0.8602	0.0000	0.0000	0.0000
WYN	3	76	2.2472	0.0000	4.4944	6.2921	0.0000	0.0000	0.0000
WYN	3.5	77	1.1976	0.0000	2.8743	3.3533	0.0000	14.3713	0.0000
WYN	4.05	78	0.0000	0.0000	0.3743	1.7467	0.0000	0.0000	0.0000
WYN	4.35	79	3.7831	0.0000	1.3871	9.4578	0.0000	5.0441	0.0000
WYN	5.05	80	2.1513	0.0000	0.2151	3.0118	0.0000	0.3586	0.0000
WYN	5.5	81	1.3459	0.0000	3.7685	17.2275	0.0000	0.0000	0.0000
WYN	5.96	82	8.0645	0.0000	0.0000	0.0896	0.0000	3.1362	0.0000
WYN	6.57	83	14.2762	0.0000	0.5976	0.0000	0.3320	1.6600	0.6640
WYN	7.2	84	1.1111	0.0000	0.0000	0.0000	0.0000	15.5556	0.0000
WYN	7.61	85	0.0000	0.0000	0.4065	0.0000	0.0000	0.0000	0.0000
WYN	7.95	86	6.0189	0.0000	1.0318	0.0000	0.0000	14.1874	0.0000
WYN	8.55	87	16.4706	0.7059	0.0941	0.0471	0.0000	2.1176	0.4706
WYN	9.13	88	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WYN	9.6	89	9.7929	0.0000	0.3358	0.0000	0.0000	40.0112	0.0000
WYN	9.9	90	10.6762	1.0676	0.1423	0.0000	0.0000	9.6085	0.0000
WYN	10.3	91	4.0984	0.8197	0.0000	0.0000	0.0000	21.3115	2.4590
WYN	11	92	4.8780	0.6098	0.0000	0.0000	0.0000	1.2195	1.8293
WYN	11.2	93	16.5414	0.7519	0.0000	0.0000	0.0000	4.5113	0.7519
SIP	0.45	94	56.7652	0.0000	10.2644	7.6205	0.0000	0.0000	0.0000
SIP	0.85	95	0.0000	0.0000	70.3601	3.3241	0.0000	0.0000	0.0000
SIP	1.55	96	62.4176	0.0000	1.1429	1.1429	0.0000	0.0000	0.0000
SIP	1.75	97	32.0405	0.0000	9.7808	3.3727	1.6863	0.0000	0.0000
SIP	2.45	98	50.6236	0.0000	8.5106	1.9076	0.0000	0.0000	0.7337
SIP	2.85	99	7.2140	0.0000	0.1374	3.2291	0.0000	0.0000	0.6870
SIP	3.2	100	7.2595	0.0000	0.1361	0.0000	0.4537	0.0000	0.2269
SIP	3.75	101	10.5105	0.0000	16.8168	0.0000	1.5015	0.0000	0.0000
SIP	4.1	102	20.8831	0.0000	0.3580	0.0000	1.1933	0.0000	7.7566
SIP	4.57	103	11.7467	0.0000	0.9193	0.0000	0.0000	1.5322	5.1073
SIP	4.9	104	11.2020	0.0000	0.0356	0.0000	0.3556	0.8890	0.5334
SIP	5.19	105	7.3593	0.0000	6.8398	0.0000	0.4329	0.0000	0.0000
SIP	5.5	106	0.4115	0.0000	0.3292	0.0000	0.0000	0.4115	2.8807
SIP	5.95	107	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6053
SIP	6.45	108	0.0000	0.0000	0.0000	0.0000	0.6757	0.6757	0.0000
SIP	7.1	109	0.7143	0.0000	0.0000	0.0000	0.0000	0.0000	6.4286
SIP	8	110	4.5752	0.3268	0.1961	0.0654	0.6536	3.9216	0.0000
SIP	8.65	111	0.0000	0.0000	0.0000	0.0000	0.0000	7.3036	1.7765
SIP	9.05	112	5.8480	0.0000	0.3899	0.0000	0.0000	3.8986	0.9747
SIP	9.39	113	0.7728	0.0000	0.0000	0.0000	0.0000	0.5152	1.0304
SIP	9.7	114	12.0192	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SIP	10.2	115	7.1429	0.0000	0.0000	0.0000	0.0000	2.5510	0.0000
SIP	10.53	116	2.2371	0.0000	0.4474	0.0000	0.0000	12.3043	0.0000
SIP	10.7	117	1.1364	0.0000	0.0000	0.0000	1.1364	0.0000	0.0000
SIP	10.95	118	0.0000	0.0000	0.0000	0.0000	0.0000	14.9786	0.0000
SIP	11.7	119	59.6259	0.0000	1.0912	1.0133	0.0000	0.0000	0.0000
SIP	12.05	120	29.4425	0.4176	0.0418	1.1276	0.6264	0.2088	0.2088
SIP	12.45	121	49.2415	0.4974	0.0000	8.0080	0.0000	0.4974	0.0000
SIP	12.9	122	0.0000	0.0000	0.1712	2.2260	0.0000	0.0000	0.0000
LBG	17.8	123	3.7594	0.0000	6.4447	18.3673	0.0000	0.0000	0.5371
LBG	18.6	124	13.4983	0.0000	13.9483	5.8493	0.0000	0.0000	0.0000
LBG	19	125	6.8259	0.0000	2.2753	0.4551	0.0000	0.0000	0.0000
LBG	19.65	126	13.1827	0.0000	0.7533	1.5694	0.0000	0.0000	0.0000
LBG	20.22	127	6.2213	0.0000	0.2620	2.0301	0.0000	0.0000	0.3274
LBG	20.68	128	0.0000	0.0000	0.1960	1.7638	0.0000	0.0000	0.0000
LBG	21.1	129	3.9920	0.0000	1.1976	7.9840	0.0000	0.0000	0.0000
LBG	21.4	130	10.2881	0.0000	2.0576	0.2058	0.0000	0.0000	0.0000

LARGER-SCALE FAUNAL DATA SET, PERCENT TRANSFORMED (continued)

LOC	LEV	#	CRYPTO	CYCLOS	CINCIN	PYCNOC	SCOLEC	TRYPAN	CORNUL
LBG	21.75	131	3.7736	0.0000	0.0000	0.0000	0.0000	3.7736	0.3774
LBG	22.35	132	5.2133	0.0000	0.0948	0.0000	0.0000	0.0000	0.9479
LBG	22.55	133	3.6998	0.0000	9.7252	0.0000	0.0000	0.0000	0.0000
LBG	22.81	134	0.4006	0.0000	0.0000	0.0000	0.0000	0.0000	1.2019
LBG	23.32	135	1.8674	0.9337	0.2801	0.0000	0.9337	0.0000	5.1354
LBG	23.95	136	6.8306	0.0000	0.5464	0.0000	0.0000	0.4554	0.0000
LBG	24.35	137	5.2966	0.0000	0.2119	0.0000	0.0000	0.0000	0.0000
LBG	24.45	138	4.0486	0.0000	0.0000	0.0000	0.0000	2.4291	0.0000
LBG	25.05	139	4.0299	0.0000	0.0000	0.0000	0.0000	8.0599	0.0000
LBG	25.52	140	12.1269	0.0000	0.0000	0.0000	0.9328	3.7313	0.0000
LBG	25.82	141	6.1050	0.0000	0.0000	0.0000	0.6105	0.6105	0.0000
LBG	26.43	142	54.5000	0.0000	0.0000	0.0000	0.5000	4.0000	0.0000
LBG	26.95	143	33.8794	0.3723	0.1489	1.8615	0.0000	5.5845	0.3723
LBG	27.5	144	57.2442	0.0000	0.8105	0.1013	0.0000	0.0000	0.0000
LBG	28	145	7.9239	0.0000	0.1585	21.8700	5.5468	47.5436	0.0000
LBG	28.5	146	11.2211	0.6601	0.1320	20.8581	0.0000	12.5413	0.0000
LBG	28.85	147	1.4689	0.0000	0.0000	0.7051	1.4689	3.8190	0.5875
LBG	29.6	148	9.7748	0.0000	0.0000	2.2949	0.0000	1.7000	0.0000
LBG	30.05	149	11.3914	0.0000	0.0000	10.5777	0.0000	1.6273	3.2547
LBG	30.35	150	8.8496	0.0000	0.0000	8.2596	0.0000	0.0000	0.0000

HIGHER-RESOLUTION FAUNAL DATA SET, PERCENT TRANSFORMED

LOC	LEV	#	RAFINE	HEBERT	PLATYS	DALMAN	ZYGOSP	LINGUL	PETROC	CARITO	AMBONY	MODIOL	NUCULO
CHS	6.80	1	30.4348	2.1739	8.6957	0.0000	58.6957	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	7.00	2	11.0803	5.5402	12.4654	0.0000	40.1662	0.0000	0.0000	0.0000	0.0000	1.3850	0.0000
CHS	7.05	3	27.1186	1.6949	1.6949	0.0000	40.6780	0.0000	0.0000	0.0000	6.7797	0.0000	0.0000
CHS	7.07	4	13.5593	0.8475	0.0000	0.0000	74.5763	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	7.14	5	30.2691	1.1211	1.1211	0.0000	45.9641	0.0000	0.0000	0.0000	0.0000	0.5605	0.0000
CHS	7.32	6	5.1020	0.2430	0.0000	0.0000	87.7065	0.0000	0.0000	0.0000	0.0000	0.7289	0.0000
CHS	7.38	7	8.0745	0.0000	0.0000	0.0000	74.5342	0.0000	0.0000	0.6211	2.4845	1.8634	0.0000
CHS	7.40	8	0.0000	0.0000	0.0000	0.0000	30.6011	0.5464	0.0000	0.0000	1.0929	1.6393	0.0000
CHS	7.44	9	0.0000	0.0000	0.0000	0.0000	71.2617	3.5047	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	7.49	10	29.5405	2.1882	0.0000	0.0000	36.1050	1.0941	0.0000	0.0000	1.0941	0.0000	0.0000
CHS	7.82	11	3.9683	0.3968	0.0000	0.0000	88.0952	0.7937	0.0000	0.0000	0.3968	0.0000	0.0000
CHS	7.83	12	11.7371	0.0000	0.0000	0.0000	67.2926	0.0000	0.0000	0.0000	0.0000	0.7825	0.0000
CHS	7.90	13	16.0039	0.9699	0.0000	0.0000	76.1397	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.00	14	0.0000	0.0000	0.0000	0.0000	95.8904	3.4247	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.05	15	8.5366	0.0000	0.0000	0.0000	89.0244	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.11	16	0.0000	0.0000	0.0000	0.0000	94.9153	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.18	17	4.4776	10.4478	0.0000	0.0000	34.3284	0.0000	0.0000	0.0000	1.4925	0.0000	0.0000
CHS	8.28	18	20.0000	5.3333	1.3333	0.0000	46.6667	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.28	19	28.3288	1.5454	0.8950	0.0000	56.7518	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.31	20	10.4712	0.0000	0.0000	0.0000	83.7696	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.36	21	7.1429	0.0000	0.0000	0.0000	88.5714	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.38	22	42.1053	2.6316	0.0000	0.0000	46.0526	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.42	23	31.0160	0.5348	1.6043	0.0000	60.9626	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.44	24	47.8779	1.5768	0.5256	0.0000	21.5412	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.49	25	45.1527	2.5531	8.3719	0.0000	21.0599	0.0000	0.0000	0.0000	1.0916	0.0000	0.0000
CHS	8.53	26	47.7876	1.7699	6.1947	0.0000	21.2389	0.0000	0.0000	0.0000	0.8850	0.0000	0.0000
CHS	8.55	27	22.5352	1.8779	0.4695	0.0000	56.3380	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.59	28	47.4453	4.8662	3.6496	0.0000	32.8467	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.60	29	51.9481	6.4935	6.4935	0.0000	25.9740	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.62	30	47.5793	0.8347	1.6694	0.0000	10.0167	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.65	31	40.5394	4.1424	1.2150	0.0000	20.4650	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.68	32	7.8394	0.9407	0.9407	0.0000	13.1703	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.73	33	12.3010	1.8090	0.0000	0.3618	28.2200	0.0000	0.0000	0.3618	0.0000	0.0000	0.0000
CHS	8.74	34	41.4048	3.0920	1.8359	0.0000	34.1028	0.0000	0.0000	0.0000	0.3381	0.0000	0.0000
CHS	8.81	35	78.0220	4.3956	1.0989	0.0000	8.7912	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.83	36	85.0877	2.6316	1.7544	0.0000	7.0175	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.85	37	49.7820	5.8651	3.9063	0.9738	19.9751	0.0000	0.0000	0.9738	0.0000	0.4888	0.0000
CHS	8.87	38	38.9140	5.4299	2.7149	0.0000	26.6968	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.91	39	29.8063	0.7452	0.7452	0.7452	37.2578	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.95	40	20.4167	0.8333	1.2500	0.0000	73.3333	0.0000	0.0000	0.0000	0.4167	0.0000	0.0000
CHS	8.99	41	49.3373	3.6819	3.6819	1.4728	25.0368	0.0000	0.0000	0.0000	0.0000	0.7364	0.0000
CHS	9.02	42	3.6765	0.0000	0.7353	0.0000	27.9412	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	9.20	43	1.0395	0.0000	0.0000	0.0000	95.6341	2.0790	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	9.35	44	5.8824	0.0000	0.0000	0.0000	29.4118	58.8235	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	9.38	45	21.4286	0.0000	0.0000	0.0000	53.5714	17.8571	0.0000	0.0000	3.5714	0.0000	0.0000
CHS	9.40	46	4.8232	0.0000	0.0000	0.0000	36.9775	40.1929	0.0000	0.0000	1.6077	0.0000	0.0000
CHS	9.64	47	2.5641	0.0000	0.0000	0.0000	74.3590	2.5641	0.0000	2.5641	5.1282	0.0000	0.0000
CHS	9.95	48	23.3918	0.5848	0.0000	0.0000	61.9883	11.6959	0.0000	0.0000	1.1696	1.1696	0.0000
CHS	10.02	49	20.0000	0.0000	0.0000	0.0000	44.0000	4.0000	0.0000	4.0000	12.0000	4.0000	8.0000
CHS	10.08	50	16.0494	0.0000	1.2346	0.0000	61.7284	0.0000	0.0000	1.2346	0.0000	0.0000	0.0000
CHS	10.17	51	29.1829	0.6485	0.6485	0.0000	44.0986	0.0000	0.0000	0.6485	1.9455	1.2970	0.0000
CHS	10.22	52	0.8696	0.0000	0.0000	0.0000	66.0870	3.4783	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.29	53	1.4286	1.4286	0.0000	0.0000	88.5714	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.30	54	24.3605	0.0000	0.6090	0.0000	66.9915	0.0000	1.8270	0.0000	0.0000	0.0000	0.0000
CHS	10.35	55	30.8057	0.0000	2.3697	0.0000	56.8720	0.0000	0.0000	2.3697	0.0000	0.0000	0.0000
CHS	10.36	56	6.4935	0.0000	0.0000	0.0000	62.7706	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.38	57	20.8791	3.2967	3.2967	0.0000	51.6484	0.0000	0.0000	0.0000	2.1978	1.0989	0.0000
CHS	10.44	58	7.9595	2.1708	2.1708	0.0000	34.0087	0.0000	0.0000	0.0000	0.7236	2.8944	0.7236
CHS	10.45	59	9.9751	0.0000	1.2469	0.0000	24.9377	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.49	60	2.3148	0.0000	0.2315	0.0000	34.7222	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.58	61	0.0000	0.0000	0.0000	0.0000	62.5000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.62	62	16.3793	6.0345	1.7241	0.0000	39.6552	0.0000	0.8621	0.0000	1.7241	2.5862	0.0000
CHS	10.67	63	12.4740	7.2765	4.1580	0.0000	32.2245	0.0000	0.0000	1.0395	0.0000	1.0395	0.0000
CHS	10.71	64	14.4455	1.0062	5.3650	0.0000	34.6390	0.0000	0.0000	0.0000	0.5031	0.2516	0.0000
CHS	10.75	65	24.8898	0.7098	3.9480	0.0000	42.5100	0.0000	0.7098	0.0000	0.0000	0.0000	0.0000

HIGHER-RESOLUTION FAUNAL DATA SET, PERCENT TRANSFORMED (continued)

LOC	LEV	#	RAFINE	HEBERT	PLATYS	DALMAN	ZYGOSP	LINGUL	PETROC	CARITO	AMBONY	MODIOL	NUCULO
CHS	10.78	66	44.7598	1.0917	3.2751	0.0000	17.4672	0.0000	3.2751	0.0000	0.0000	0.0000	0.0000
CHS	10.81	67	23.0978	4.7554	7.4728	0.0000	25.8152	0.0000	0.0000	0.0000	0.0000	1.3587	0.0000
CHS	10.86	68	10.2941	10.2941	10.2941	0.0000	30.8824	0.0000	1.4706	0.0000	0.0000	0.0000	0.0000
CHS	10.88	69	14.2349	1.7794	11.5658	0.0000	19.5730	0.0000	0.0000	1.7794	0.8897	0.0000	0.0000
CHS	10.89	70	10.2962	2.0524	4.2836	0.0000	34.2442	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.90	71	2.0458	2.7716	4.2579	0.0000	51.4675	0.0000	0.0000	0.0000	0.1836	0.1836	0.0000
CHS	10.91	72	23.1561	4.2882	19.7256	0.0000	11.1492	0.0000	0.0000	0.0000	0.8576	0.0000	0.0000
CHS	10.95	73	8.5158	4.8662	20.6813	0.0000	30.4136	0.0000	1.2165	0.0000	0.0000	0.0000	0.0000
CHS	10.99	74	18.1661	2.5952	23.3564	0.0000	15.5709	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	11.01	75	10.8303	3.6101	17.1480	0.0000	24.3682	0.0000	0.9025	0.0000	0.0000	0.0000	0.0000
CHS	11.05	76	15.2984	4.1257	6.5901	0.0000	49.8407	0.0000	0.4015	0.0000	0.0000	0.0000	0.0000
CHS	11.18	77	5.2632	0.0000	2.6316	0.0000	47.3684	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

HIGHER-RESOLUTION FAUNAL DATA SET, PERCENT TRANSFORMED (continued)

LOC	LEV	#	GASTRO	FLEXIC	ACIDAS	ENCRUS	CRYPTO	CYCLOS	CINCIN	PYCNOC	SCOLEC	TRYPAN	CORNUL
CHS	6.80	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	7.00	2	0.0000	0.0000	0.0000	0.0000	23.5457	0.0000	0.2770	0.0000	5.5402	0.0000	0.0000
CHS	7.05	3	0.0000	0.0000	0.0000	3.3898	6.7797	0.0000	0.0000	0.0000	0.0000	11.8644	0.0000
CHS	7.07	4	0.0000	0.0000	0.0000	0.0000	9.3220	0.0000	0.0000	0.0000	0.0000	1.6949	0.0000
CHS	7.14	5	0.0000	0.7848	0.0000	0.0000	19.6188	0.0000	0.0000	0.0000	0.5605	0.0000	0.0000
CHS	7.32	6	0.0000	1.7493	0.0000	0.2430	4.1302	0.0000	0.0972	0.0000	0.0000	0.0000	0.0000
CHS	7.38	7	8.0745	0.0000	0.0000	2.4845	1.2422	0.0000	0.0000	0.0000	0.0000	0.0000	0.6211
CHS	7.40	8	49.7268	6.9945	0.0000	0.0000	0.0000	0.0000	0.1093	0.0000	0.5464	3.8251	4.9180
CHS	7.44	9	21.6121	1.8692	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5841	0.0000	1.1682
CHS	7.49	10	0.0000	0.4376	0.0000	0.0000	29.5405	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	7.82	11	0.0000	0.0000	0.0000	0.3968	5.9524	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	7.83	12	0.0000	2.9734	0.0000	0.7825	16.4319	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	7.90	13	0.0000	0.0970	0.0000	6.3046	0.0000	0.0000	0.0000	0.0000	0.0000	0.4850	0.0000
CHS	8.00	14	0.0000	0.6849	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.05	15	0.0000	1.2195	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.2195	0.0000	0.0000
CHS	8.11	16	0.0000	5.0847	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.18	17	0.0000	2.0896	0.0000	0.0000	44.7761	0.0000	2.3881	0.0000	0.0000	0.0000	0.0000
CHS	8.28	18	0.0000	0.0000	0.0000	6.6667	16.0000	0.0000	0.0000	0.0000	0.0000	1.3333	2.6667
CHS	8.28	19	0.0000	0.0000	0.0000	7.3602	3.6967	0.0000	1.4220	0.0000	0.0000	0.0000	0.0000
CHS	8.31	20	0.0000	0.0000	0.0000	0.0000	5.2356	0.0000	0.0000	0.5236	0.0000	0.0000	0.0000
CHS	8.36	21	0.0000	0.0000	0.0000	4.2857	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.38	22	0.0000	0.0000	0.0000	2.6316	5.2632	0.0000	0.0000	0.0000	0.0000	1.3158	0.0000
CHS	8.42	23	0.0000	0.0000	0.0000	3.7433	1.0695	0.0000	0.0000	0.0000	0.0000	1.0695	0.0000
CHS	8.44	24	0.0000	0.0000	0.0000	17.6724	6.8761	0.0000	0.2292	0.0000	0.0000	3.7008	0.0000
CHS	8.49	25	0.0000	0.1452	0.0000	9.8381	7.9882	0.7308	0.1452	0.0000	0.0000	2.9231	0.0000
CHS	8.53	26	0.0000	0.0000	0.0000	7.9646	8.8496	0.0000	0.0000	0.0000	0.0000	5.3097	0.0000
CHS	8.55	27	0.0000	0.0000	0.0000	1.8779	9.3897	0.0000	0.0000	0.0000	0.0000	7.5117	0.0000
CHS	8.59	28	0.0000	0.0000	0.0000	0.0000	10.9489	0.0000	0.2433	0.0000	0.0000	0.0000	0.0000
CHS	8.60	29	0.0000	0.0000	0.0000	2.1645	6.4935	0.0000	0.4329	0.0000	0.0000	0.0000	0.0000
CHS	8.62	30	0.8347	0.0000	0.0000	0.8347	35.8932	0.0000	0.6678	0.0000	0.0000	1.6694	0.0000
CHS	8.65	31	1.0495	0.0000	0.0000	5.5229	26.2372	0.0000	0.0000	0.0000	0.0000	0.8285	0.0000
CHS	8.68	32	0.0000	0.0000	0.0314	0.0000	75.5723	0.0000	1.5052	0.0000	0.0000	0.0000	0.0000
CHS	8.73	33	0.0000	0.0000	0.0000	0.0000	54.9928	0.0000	1.2301	0.0000	0.7236	0.0000	0.0000
CHS	8.74	34	0.0000	0.0000	0.0000	5.5557	11.1580	0.0000	0.0000	0.0000	0.0000	2.5127	0.0000
CHS	8.81	35	0.0000	0.0000	0.0000	2.1978	4.3956	0.0000	0.0000	0.0000	0.0000	1.0989	0.0000
CHS	8.83	36	0.0000	0.0000	0.0000	2.6316	0.0000	0.0000	0.0000	0.0000	0.0000	0.8772	0.0000
CHS	8.85	37	0.0000	0.0000	0.0000	4.3951	11.6850	0.0000	0.0000	0.0000	0.0000	1.9550	0.0000
CHS	8.87	38	0.0000	0.0000	0.0000	6.3348	19.9095	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.91	39	0.0000	0.0000	0.7452	3.7258	25.3353	0.0000	0.1490	0.0000	0.0000	0.7452	0.0000
CHS	8.95	40	0.4167	0.0000	0.4167	0.4167	2.5000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	8.99	41	0.0000	2.7982	1.4728	2.2091	8.1001	0.0000	0.0000	0.0000	0.0000	1.4728	0.0000
CHS	9.02	42	0.0000	0.0000	0.0000	0.7353	66.9118	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	9.20	43	0.0000	0.2079	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0395
CHS	9.35	44	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	5.8824	0.0000	0.0000
CHS	9.38	45	3.5714	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	9.40	46	12.8617	0.3215	0.0000	3.2154	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	9.64	47	12.8205	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	9.95	48	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.02	49	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	4.0000	0.0000	0.0000
CHS	10.08	50	8.6420	3.7037	0.0000	1.2346	2.4691	2.4691	0.0000	0.0000	0.0000	1.2346	0.0000
CHS	10.17	51	9.7276	0.0000	0.0000	6.4851	0.0000	1.9455	0.1297	0.0000	0.0000	0.6485	2.5940
CHS	10.22	52	5.2174	0.0000	0.0000	0.8696	23.4783	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.29	53	2.8571	0.0000	0.0000	0.0000	5.7143	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.30	54	0.0000	0.7308	0.0000	0.0000	5.4811	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.35	55	0.0000	0.4739	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	7.1090	0.0000
CHS	10.36	56	0.0000	0.0000	0.0000	0.0000	30.3030	0.0000	0.0000	0.4329	0.0000	0.0000	0.0000
CHS	10.38	57	0.0000	1.0989	0.0000	0.0000	10.9890	0.0000	0.0000	0.0000	2.1978	3.2967	0.0000
CHS	10.44	58	1.4472	1.8813	0.7236	0.0000	44.1389	0.0000	0.4342	0.0000	0.0000	0.0000	0.7236
CHS	10.45	59	0.0000	1.2469	0.0000	0.0000	62.3441	0.0000	0.2494	0.0000	0.0000	0.0000	0.0000
CHS	10.49	60	1.6204	0.0000	0.0000	2.7778	55.5556	0.0000	0.0000	0.0000	0.0000	2.7778	0.0000
CHS	10.58	61	16.1290	3.2258	6.0484	0.0000	12.0968	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.62	62	23.2759	1.7241	0.0000	3.4483	0.8621	0.8621	0.0000	0.0000	0.0000	0.8621	0.0000
CHS	10.67	63	24.9480	1.2474	0.0000	2.0790	13.5135	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.71	64	12.1815	2.0783	0.8660	14.8083	13.8556	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CHS	10.75	65	4.8805	2.7465	1.5310	11.6631	4.0826	2.3289	0.0000	0.0000	0.0000	0.0000	0.0000

HIGHER-RESOLUTION FAUNAL DATA SET, PERCENT TRANSFORMED (continued)

LOC	LEV	#	GASTRO	FLEXIC	ACIDAS	ENCRUS	CRYPTO	CYCLOS	CINCIN	PYCNOC	SCOLEC	TRYPAN	CORNUL
CHS	10.78	66	4.3668	1.3100	0.0000	9.8253	12.0087	0.0000	0.4367	0.0000	1.0917	1.0917	0.0000
CHS	10.81	67	2.0380	2.1739	0.6793	9.5109	19.0217	0.0000	0.0000	0.0000	0.0000	2.0380	2.0380
CHS	10.86	68	0.0000	4.4118	0.0000	0.0000	25.0000	2.9412	0.0000	0.0000	4.4118	0.0000	0.0000
CHS	10.88	69	1.7794	4.4484	0.8897	4.4484	38.2562	0.0000	0.3559	0.0000	0.0000	0.0000	0.0000
CHS	10.89	70	2.2312	2.2074	1.8395	3.5426	38.6301	0.0000	0.0000	0.0000	0.4599	0.2129	0.0000
CHS	10.90	71	1.2940	0.1119	0.0000	4.2579	11.7500	0.5595	0.0000	0.0000	0.0000	21.1165	0.0000
CHS	10.91	72	2.5729	2.9160	0.0000	6.8611	6.8611	0.0000	0.1715	0.0000	0.8576	20.5832	0.0000
CHS	10.95	73	20.6813	1.4599	1.2165	6.0827	3.6496	0.0000	0.0000	0.0000	1.2165	0.0000	0.0000
CHS	10.99	74	6.9204	0.5190	0.0000	1.7301	16.4360	0.0000	0.0000	0.0000	14.7059	0.0000	0.0000
CHS	11.01	75	8.1227	0.9025	0.9025	1.8051	30.6859	0.0000	0.7220	0.0000	0.0000	0.0000	0.0000
CHS	11.05	76	4.9287	0.9968	0.0000	0.8030	16.6136	0.0000	0.0000	0.0000	0.0000	0.4015	0.0000
CHS	11.18	77	0.0000	0.0000	0.0000	0.0000	7.8947	0.0000	2.6316	0.0000	0.0000	34.2105	0.0000