SEQUENCE STRATIGRAPHY IN MIXED CLASTIC-CARBONATE STRATA, UPPER PENNSYLVANIAN, EAST-CENTRAL ILLINOIS

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SEQUENCE STRATIGRAPHY IN MIXED CLASTIC-CARBONATE STRATA, UPPER PENNSYLVANIAN, EAST-CENTRAL ILLINOIS

edited by C. Pius Weibel

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APPLICATION OF CYCLOTHEMIC-BASED SEQUENCE STRATIGRAPHY TO
UPPER PENNSYLVANIAN STRATA, EAST-CENTRAL ILLINOIS

C. Pius Weibel

Introduction

Sequence stratigraphy is one of the popular "new" areas in the study of sedimentary rocks, judged by the recent number of papers and abstracts that included the topic in their titles. Sequence stratigraphy, however, is not "new" to the Illinois Basin, as correctly pointed out by Sloss (1988). In 1932, Wanless and Weller described and differentiated genetically related units, bounded by unconformities, which they defined as cyclothsms. From the late 1920's to the middle 1940's cyclothsms were widely used for mapping of Pennsylvanian strata in the Illinois Basin, although some of the maps were not published until the 1950's. Cyclothsms also were widely used in stratigraphic studies from the late 1920's to the 1960's. In 1960, cyclothsms were dropped as a stratigraphic unit by the Illinois State Geological Survey (Kosanke and others, 1960). After the death of Wanless in 1970, the stratigraphic use of cyclothsms almost ceased in the basin. Seven years later, Mitchum and others (1977), in a seminal memoir that initiated a "rebirth" of sequence stratigraphy, defined a confromable succession of genetically related strata, bounded by unconformities, as a sequence. This seemingly paradoxical chain of events invites this question: Why was the application of sequence stratigraphy being phased out in the Illinois Basin while it was rapidly evolving elsewhere?

This field conference will attempt to answer this question by outcrop examination of cyclothsms on the field trip and in the following discussion. The intent is to: (1) review the rise and decline in usage of the cyclothem of Wanless and Weller (1932); (2) examine the application of cyclothsms to the strata in the field trip area; (3) show the relationship of cyclothsms to the hierarchy of sequence stratigraphy; (4) propose an allostratigraphic classification system for these strata based on the cyclothem; and (5) indicate merits and limitations to application of sequence stratigraphy to these Pennsylvanian strata.

The Missourian and Virgilian rocks in east-central Illinois constitute an outlier of intermediate lithology, paleontologic character, depositional environment, and paleogeographic position between nearly wholly terrestrial Appalachian Basin strata and largely marine midcontinent rocks. Although older Pennsylvanian strata in the Illinois Basin have been extensively studied, this interval has been largely neglected, primarily because of poor exposures and absence of economically important strata. The field trip region (Figure 1) has little topographic relief and is covered by Pleistocene deposits. Most exposures are stream cut banks; quarries are relatively uncommon. We will examine strata ranging from the earliest Missourian Cramer Limestone Member-equivalent up to the upper Virgilian Greenup Limestone Member (Figure 2). These rocks are assigned to the uppermost Modesto, Bond and Mattoon Formations of the McLeansboro Group (Kosanke and others, 1960).
Figure 1. Map of field trip area, showing stops (1 to 6) and alternate stop 6 (6A).
Figure 2. Composite lithostratigraphic column, showing marine units, coals and sandstones. Unnamed units are either local in extent or have not been correlated with named units on the flanks of the Illinois Basin.
The Wanless and Weller cyclothem

Cyclic successions in Middle Pennsylvanian strata near Peoria, Illinois, were first recognized and described by Udden (1912). Udden interpreted each of the subdivisions to have formed in four successive depositional stages (Figure 3): (1) "accumulation of vegetation;" (2) "deposition of calcareous material;" (3) "sand importation;" and (4) "aggradation to sea level and soil making" (Ibid., p. 47). The boundary between Udden's subdivisions, which is between the underclay and coal, was genetically defined because recognition was based on interpretative depositional criteria.

Wanless (1929) recognized subdivisions similar to Udden's in the Alexis Quadrangle in western Illinois. He subdivided the Pottsville and Carbondale Formations (of the time) into cyclic successions, and referred to them as numbered "suites." Wanless (1929, 1931) and Weller (1930, 1931) described these successions but placed the boundary at the base of the basal sandstone. A year later, Wanless and Weller (1932) defined a cyclothem as a "series of beds deposited during a single sedimentary cycle of the type that prevailed during the Pennsylvanian period." The cyclothem is a terrestrial-marine succession, and is based on the eight units described by Weller (1930):

Marine strata:
- Shale with siderite nodules
- Marine limestone
- Calcareous shale
- Black, fissile shale

Terrestrial strata:
- Coal
- Underclay, may include nonmarine limestone nodules/bed
- Arenaceous shale
- Sandstone, with unconformable base

The unconformable base of the sandstone was selected as the boundary between cyclothems because Weller (1930, 1931) considered its formation to be the result of diastrophism. At that time, formations were treated as time units as well as rock units. Surfaces which marked "periods of instability" or diastrophism (usually unconformities) were best utilized for boundaries. Thus, cyclothems are genetically defined units because boundary selection was based on the interpretation of a diastrophic event. Weller (1930) had previously proposed that such a series of beds be given formational status, a proposal formally accepted by Willman and Payne (1942). For about the next 30 years, cyclothems were the fundamental lithostratigraphic unit for Middle and Upper Pennsylvanian strata in the Illinois Basin. Although only a few bedrock geologic maps of Middle and Upper Pennsylvanian strata were published between 1930 and 1960, most utilized the cyclothem as a mapping unit (Newton and Weller, 1937; Willman and Payne, 1942; Ball, 1952; Wanless, 1957).

Wanless (1956) introduced a stratigraphic classification of the entire Illinois Pennsylvanian based on cyclothems (Figure 4). This classification, however, was rejected by Kosanke and others (1960)
Figure 3. Stratigraphic column of Udden (1912), showing subdivision cycles at base of coal; note depiction of unconformably lower contact of sandstones.
McLeansboro group
- Millersville cyclothem
- Witt cyclothem
- Flat Creek cyclothem
- Bunje cyclothem
- Sorento cyclothem
- Shoal Creek cyclothem
- Macoupin cyclothem
- Carlinville cyclothem
- Trivoli cyclothem (No. 8 coal)
- Gimlet cyclothem
- Sparland cyclothem (No. 7 coal)
- Cutler cyclothem
- Bankston cyclothem

Carbondale group
- Jamestown cyclothem
- Brereton cyclothem (No. 6 coal)
- Briar Hill cyclothem
- St. David cyclothem (No. 5 coal)
- Summum cyclothem (No. 4 coal)
- Liverpool cyclothem (No. 2 coal)
- Abingdon cyclothem

Tradewater group
- Greenbush cyclothem
- Wiley cyclothem
- Seaborne cyclothem
- DeLong cyclothem
- Brush cyclothem
- Hermon cyclothem
- Seville cyclothem (No. 1 coal)
- Pope Creek cyclothem
- Tarter cyclothem
- Babylon cyclothem

Caseyville group
- DeKoven cyclothem (DeKoven coal)
- Colbert cyclothem (Davis coal)
- Stonefort cyclothem
- Macedonia cyclothem
- Delwood cyclothem
- Grindstaff cyclothem
- Pounds cyclothem
- Battery Rock cyclothem
- Lusk cyclothem

Figure 4. Cyclothems recognized by Wanless (1962).

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Figure 5. Comparison of the cyclothem-based classification (see Figure 4) on the left with the key-bed based classification of Kosanke and others (1960) on the right (modified from Wanless, 1962). Each of the groups on the left side was comprised of cyclothems. The limestone, coal and sandstone units on the right side are formation-boundary key beds.
because of difficulty in mapping the basal sandstone and variations in the cyclothem succession. They replaced cyclothemic formations with much thicker, key bed-bounded formations, such as the Mattoon Formation (Figure 5). A separate, but informal, cyclical classification was retained, ostensibly because it was considered "useful in geologic interpretation" (Ibid., p. 9). In reality, however, use of cyclothsms, for either lithostratigraphic classification or geologic interpretation, was terminated by the Illinois State Geological Survey.

The modified cyclothem in the field trip area

Although Worthen (1875) first investigated the geology of east-central Illinois, Newton and Weller (1937) proposed the first stratigraphic column for the area, using cyclothsms as the fundamental lithostratigraphic (and mapping) unit. Subsequent studies, using diverse data, resulted in at least 15 different proposed stratigraphic successions (Figure 6). Weibel (1986, 1988) determined the proper stratigraphic order of the Virgilian strata (equivalent to the upper half of Mattoon Formation). The stratigraphic order was rectified by adopting a modified version of the Wanless and Weller (1932) cyclothem and by mapping these cyclothsms as lithostratigraphic units. Weibel (1988) modified the cyclothem by placing the base at either the top of the coal or at the base of the lowest marine unit, resulting in a marine→terrestrial succession (Figure 7). The modified cyclothem is a genetic stratigraphic succession like Udden’s (1912) subdivisions and Wanless and Weller’s (1932) original cyclothem, but differs in being bounded by the surface recording the first marine sediments deposited in the overall marine→terrestrial succession. This greatly simplifies recognition of cyclothem boundaries because the terrestrial-to-marine transition is in a relatively thin portion of the succession and characteristically is marked by abrupt lithologic change. From this point on, "cyclothem" in the text refers to this modified cyclothem except where referenced to Wanless and Weller (1932).

Is a cyclothem a lithostratigraphic unit?

The North American Stratigraphic Code considers cyclothsms to be an informal lithostratigraphic unit that is clearly differentiated from the standard lithostratigraphic units of group, formation, and member (Article 22j, North American Commission on Stratigraphic Nomenclature [NACSN], 1983). The placement of cyclothsms in the same category as lithostratigraphic units, however, is not entirely appropriate. Because cyclothsms are genetic sequences, the lithic units at an individual cyclothem boundary may be variable, particularly strata underlying the boundary, instead of the single lithic change at the boundary required of lithostratigraphic units. The lithic change at the boundaries of cyclothsms is dependent upon the environments of deposition, which could differ laterally from one place to another. For example, the base of the Shumway cyclothem in the western part of its outcrop area is the "Lake Sara limestone," a fossiliferous, marine limestone. In the eastern part of its outcrop area, the
Figure 6. Compilation of perceived stratigraphic successions of Mattoon Formation limestone members. Not all of the limestones listed are examined on this field trip. Abbreviations: Bogota (Bogla), Bonpas (Bonpa, Bon), Calhoun (Ca), Effingham (Ef), Greenup (Gp), “Lake Sare” (LS), LaSalle (LaSal, L), Livingston (Lvst, L), Millersville (Mlrs, M), “Middlesworth” (Mid), Newton (Newtn, Ne), “Parkersburg” (Pk), “Reisner” (Reisr), Omega (Om), “Shamrock” (Shmrck), Shumway (Shmwy, Sh), “Steel Bridge” (StBdg, SB), Woodbury (Wdbry). The “Shamrock” Limestone (Needham, 1931) has priority over “Reisner” (Kosanke and others, 1960).
Figure 7. Comparison of the boundaries of the Wanless and Weller cyclothem with those of the modified cyclothem. The stratigraphic column is a hypothetical succession; the upper coal is succeeded by a nonmarine shale.
"Teutopolis shale", a black, fissile shale, is the base of the Shumway because the "Lake Sara" is absent, presumably because of non-deposition. Such a variation in lithic change at the boundary is not endorsed by the Code. The Code recommends proposal of a new or different unit where a significant lateral change in lithology occurs (Article 23a, NACSN, 1983). Utilizing lithic boundaries that change from place to place violates the intent of the Code, which is to maintain consistent and standard unit definition and use.

Allostratigraphy

If cyclothems are not lithostratigraphic units, then what are they? A cyclothem is better classified as an allostratigraphic unit than as a lithostratigraphic unit. The Code defines an allostratigraphic unit as "a mappable stratiform body of sedimentary rock that is defined and identified on the basis of its bounding discontinuities." The Code does not define discontinuities, but it does include geomorphic surfaces and upper boundaries of paleosols as examples. According to the glossary of geology (Bates and Jackson, 1980), a stratigraphic discontinuity is "any interruption in sedimentation, whatever its cause or length, usually a manifestation of nondeposition and accompanying erosion; an unconformity."

Cyclothems contain several surfaces separating lithic units which are interpreted to be stratigraphic discontinuities. Bedding plane surfaces within lithic units may (and many do) represent a stratigraphic discontinuity but are considered insignificant for this study. Boundaries designated for Pennsylvanian lithostratigraphic units in the Illinois Basin have included the tops and bottoms of coals and limestones and bases of underclays and sandstones. Not all of these boundaries, however, are stratigraphic discontinuities and therefore not all are eligible for bounding allostratigraphic units. Four boundaries are generally characterized as stratigraphic discontinuities in the cyclothem: top of coal, coal-underclay boundary, base of sandstone unit, and base of marine strata (Figure 8).

Top of coal

Strata overlying coal beds in the Illinois Basin range from marine to nonmarine and are lithologically

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Figure 8. Hypothetical cyclothem showing stratigraphic discontinuities.
variable. The strata above coal beds in the Illinois Basin are dominantly marine (Weller, 1930); nonmarine strata overlying coals generally are associated with sandstone channels (Treworgy and Jacobson, 1985). The contact between coal beds and overlying marine strata will be discussed later.

Most detailed studies of coal bed contacts have occurred in coal mines. Damberger (1973), in his study of "white-tops" of the Herrin Coal Member (Carbondale Formation) in northwestern Illinois suggested that the top of the coal in some areas was subjected to erosion before burial. Edwards and others (1979), in a mine in Jefferson County, Illinois, described the contact of the Energy Shale Member with the underlying coal as abrupt, although coaly layers and lenses may be present in the basal portion of the shale. Some studies have indicated that this contact may be conformable. According to Bauer and DeMaris (1982), the Energy Shale Member conformably overlies the Herrin Coal. The shale generally "slightly" interfingers with the underlying coal at the Old Ben Mine No. 24. However, Bauer and DeMaris concluded that floods from the nearby Walshville channel may have occasionally flooded the coal swamp. The upper contact of the coal bed often is the record of a large flooding event which disrupted and terminated peat deposition and deposited clastic sediments, and therefore is a stratigraphic discontinuity.

Paleoecologic studies of spores, coal balls, plant impressions in both coal beds and overlying nonmarine strata provide data indicating a disruption in sedimentation. These studies show that the plant community and ecology of the flora of the overlying strata significantly differed from that of the coal (DiMichele and others, 1985). Phillips and Peppers (1984) determined that pronounced changes in type and abundance of lycopod-dominated forests in the Herrin Coal occurred at lithologic changes from mineral-rich or clastic rich bands. From this they inferred changes in water level, flooding, forest fires, and changes in nutrient supply as ecologic factors causing the change in plant community. Because of the water-holding capacity of coal swamp substrate, only the severest environmental changes (particularly changes in moisture) caused major floristic changes (Phillips and others, 1985). Thus the floristic change in fossil flora from coal bed to overlying strata also is indicative of a disruption and changes in depositional environment, i.e., a stratigraphic discontinuity. This is supported by the DiMichele and DeMaris (1987) conclusion that a *Lepidodendron* forest rooted at the top of the Herrin Coal represented a changes from coal-swamp condition to a clastic dominated swamp, accompanied by physical disturbance.

In summation, the contact at the top of coal beds is a surface that records a disruption in sedimentation. It may not represent a stratigraphic discontinuity everywhere on all coal beds, but the surface marks a major change in depositional environments, including significant changes in fossil flora.
Underclay-coal contact

Early ideas suggested that underclays were fossil soils upon which the coal-forming plants grew (for a summary, see Rimmer and Eberl, 1982). Weller (1930, 1931) and Wanless (1931) noted that local unconformities occur below "certain persistent coals," indicating the absence of a direct relationship between coal and underclay. The current hypothesis is that the underclay formed prior to peat accumulation (Huddle and Patterson, 1961, Rimmer and Eberl, 1982; Hughes and others, 1987), although the relationship between underclays and coals is not yet completely understood. Underclays probably are paleosols (Robinson and Wright, 1987), but they were soils for contemporaneous plants and not for the coal-swamp plants, except for perhaps near the upper contact with the coal (Hughes and others, 1987). Alteration of the underclay, however, may have occurred before, during, and after peat deposition (Rimmer and Eberl, 1982).

The paleosol hypothesis for underclay formation and the absence of a contemporaneous relationship between underclays and coals indicate that contact separating the two lithic units is a stratigraphic discontinuity. Weller (1931), as well as Udden (1912), considered this contact to be one of the two important breaks in the sedimentary succession of the cyclothem (the other being the unconformity below the basal sandstone). He further recognized that the time represented by the underclay, including primary deposition and subsequent pedogenic alteration, could represent the longest hiatus in the succession and may be most appropriate as a cyclothem boundary. Weller (1931), however, considered diastrophic events (major uplifting and/or subsidence) to be the primary basis for subdivision of strata (and geologic time). Pedogenesis was considered to be characteristic of cratonic stability, and therefore the underclay-coal boundary was thought by Weller to be inappropriate as a formational boundary.

Base of sandstone unit

Worthen (1873) recognized an unconformity at the base of a sandstone above the Springfield Coal Member near Peoria. These unconformities are indicated by the sandstone cutting down into and truncating bedding of underlying strata, having a sharp contact, and containing basal conglomerates. Savage (1927) also recognized these stratigraphic discontinuities and proposed their use, instead of coal beds, as boundaries for the Pottsville, Carbondale, and McLeansboro Formations. Weller (1931) considered the basal unconformity of sandstones to be so widespread that he made the generalized assertion that "nearly all" sandstones rested unconformably upon the underlying beds. Weller (1930, 1931) considered this contact an important unconformity suitable for a formational boundary. He considered this unconformity a result of diastrophism and therefore to be the preferred choice for the cyclothem boundary. Wanless and Weller (1932) consequently defined the cyclothem using the basal unconformity below the sandstone as the base of the cyclothemes.
Base of marine strata

Marine layers have long been recognized as wide-spread key beds in the Middle and Upper Pennsylvanian of the Illinois Basin (Wanless, 1939). Marine beds include fossiliferous limestones, generally sparsely to moderately fossiliferous, fissile, black shales, and fossiliferous, calcareous, gray shales. Weller (1930) considered the boundary marking the base of the marine strata to be one of two surfaces caused by diastrophism (the other being the unconformity below the basal sandstone). Although Weller thought that transgression of seas over coal-swamps probably was a more significant diastrophic event than that represented by the basal sandstone unconformity, he rejected this surface because marine beds do not succeed all coals.

Strata above coal beds in the Illinois Basin are dominantly marine (Weller, 1930). The sharp contact between marine strata and the underlying strata indicates an abrupt change in depositional environments. The top of the underlying stratum locally is argillaceous or calcareous, depending upon the lithology of the overlying marine stratum, or, it contains interbedded laminae of the same lithology as the overlying stratum. The base of the marine interval has been described as an erosional surface. Bauer and DeMaris (1982) documented a local erosional surface on the top of the Herrin Coal in the Old Ben Mine No. 24 in Franklin County, Illinois. The erosion occurred after deposition of the nonmarine, gray, Energy Shale Member and before deposition of the marine, black, fissile Anna Shale. If the lowermost marine stratum is a black, fissile shale, it often contains a thin, fossiliferous, transgressive breccia (equivalent to a ravinement) in the Illinois Basin. Such ravinements have been described by Zangerl and Richardson (1963), Palmer and others (1979), Weibel (1988), and Weibel and others (1989). Transgressive breccias are less widespread in calcareous strata, but Scheiing and Langenheim (1985) described abraded fragments of marine fossils in the basal marine stratum, a calcareous gray shale, of the Shumway cyclothem (Stop 2). A few Pennsylvanian black shales in the basin are nonmarine. Treworgy and Treworgy (1983) explained a sparsely fossiliferous, black shale between the Herrin and Danville Coal Members of the Carbondale Formation in east-central Illinois as a fresh- or brackish-water deposit. Weibel (1988) suggested that the "Graveyard Hill" shale is a shallow, possibly brackish-water deposit. These shales, however, are laterally restricted and lack definitive marine fossils.

Of the four above stratigraphic discontinuities, the underclay-coal contact and the upper boundary of the coal are rejected as boundaries because their occurrence is dependent upon the presence of a coal bed within the cyclothem, and not all cyclothems contain coal. The two boundaries potentially suitable as an allostratigraphic boundary are thus the base of the marine strata and the base of the sandstone unit. These two boundaries are the same two that Weller (1930) considered suitable for the cyclothem boundary. It is ironic that the choice of the base of the sandstone as the cyclothem boundary by Wanless and Weller (1932) was not the best choice. In my opinion, the base of the marine
strata is the preferred cyclothemic boundary, despite being considered and rejected by Weller (1930). The reasons for this conclusion follow.

Wanless (1962) noted that the basal sandstone boundary was an irregular boundary and was difficult to differentiate in the absence of channel sandstones. The irregularity is partially caused by the channel sandstones occurring at different stratigraphic positions within the cyclothem. The unconformities at the base of the sandstones, therefore, probably are not contemporaneous and in some places, multiple unconformities occur because of stacked sandstone bodies. The unconformity below the basal sandstone probably is discontinuous. Kosanke and others (1960) estimated that less than 20 percent of the area between cycloths included the unconformity below the basal sandstone (Compare with the Weller's (1931) statement about the extent of the unconformity). If the basal sandstone is an infilling of fluvial/deltaic channels that have been eroded in underlying strata, the intervening areas were characterized by gradual, uninterrupted deposition. This resulted in a gradational boundary between the sandstone and the underlying unit, usually a shale. Some areas may have been characterized by short-lived interruptions of sedimentation or by formation of thin paleosols. Paleosols in this part of the cyclothem are recognizable in outcrop and in cores, but such exposures are uncommon, and cores of Upper Pennsylvanian strata are few in the basin. All of these criteria indicate that this stratigraphic discontinuity is generally difficult to recognize regionally and is not suitable for the boundary as an allostratigraphic unit.

Weibel (1988) recognized that marine units lack the thickness irregularities that are characteristic of the basal sandstone unit. Marine units and the coal, which is often stratigraphically adjacent to marine units, are readily recognizable both at the surface and on most geophysical logs. In addition, basal sandstones in the Upper Pennsylvanian strata of east-central Illinois typically do not crop out and may be laterally restricted. Marine units crop out often and are more laterally continuous than sandstone units. The base of the marine strata, therefore, is a more suitable allostratigraphic boundary than the base of the sandstone unit. An allostratigraphic cyclothem defined by this boundary is analogous to similar genetically related units, the depositional sequence of Vail and others (1977) and sequence stratigraphy stratal units defined by Van Wagoner and others (1990).

**Sequence stratigraphy**

Widespread use of sequence stratigraphy, with the exception of the systematic boundaries, has come about only in the last decade, although the concept of utilizing unconformity-bounded intervals of strata was used in the late eighteenth century (see review by Sloss, 1988). This recent appreciation was stimulated by seismic stratigraphy. After several decades of study by major petroleum companies, seismic stratigraphy was largely introduced, with considerable impact, to the public with the publication of American Association of Petroleum Geologists Memoir 26 (Payton, 1977). Although the relationship
between subsurface stratigraphy and seismograms has been understood for some time, the evolution to the concept of seismic stratigraphy paralleled technological advances in data acquisition and processing of seismic reflections. Seismic stratigraphy is based on the analysis of depositional sequences (relatively conformable successions of genetically related, unconformable-bounded strata) and the relationship of these sequences to adjacent sequences (Mitchum, 1977). Although development of seismic stratigraphy is one of the major advances in modern stratigraphy, the concepts initially were used in regional studies with primarily geophysical data. Sequence stratigraphy developed from the integration of seismic stratigraphy, well logs, and studies of cores, sample cuttings, and outcrops. This approach, using a hierarchical framework of stratigraphic units that encompasses laminae to the cratonic sequences of Sloss (1950, 1963), is becoming widely accepted. The apparently rapid acceptance of this hierarchical framework is probably due in part to its deeply rooted historical basis in the unconformity-bounded unit (e.g., the unconformity-bounded Paleozoic systems of Ulrich, 1911) and its overall applicability by practitioners of stratigraphy. Most stratigraphers in non-petroleum industries previously were excluded from seismic stratigraphic applications because most seismic data are confidential. Acceptance of the Sloss cratonic sequences may have been delayed by the absence of a defined hierarchy of stratigraphic units, although Sloss (1963) considered sequences to be of higher rank than supergroups.

Sequence stratigraphy is defined by Van Wagoner and others (1990) as "the study of genetically related facies within a framework of chronostratigraphically significant surfaces." The sequence, a direct descendent of the depositional sequence, is considered to be the fundamental unit of sequence stratigraphy and consists of a relatively conformable, genetically related succession of strata bounded by unconformities or their correlative conformities (Mitchum, 1977). The hierarchy of units in sequence stratigraphy, from smallest to largest, consists of lamina, laminaset, bed, bedset, parasequence, parasequence set, and sequence. Of these units, the parasequence is most similar to the cyclothem.

Van Wagoner and others (1990) defined a parasequence as "a relatively conformable succession of genetically related beds or bedsets bounded by marine-flooding surfaces and their correlative surfaces." Parasequences characteristically range from about 10 to 200 feet thick, extend laterally from over 10 to over 10,000 square miles, and were interpreted to be deposited in a time interval ranging from about 100 to over 50,000 years. A cyclothem (modified) is very similar to these units (Ibid.), particularly in thickness and lateral extent. The length of time interpreted for deposition of cyclothems is a subject of debate (Heckel, 1986, 1991a; Klein, 1990, 1991; Langenheim, 1991), but it does not invalidate this correlation of a parasequence with a modified cyclothem. The parasequence-equivalent cyclothem, thus, is the basic unit for the application of sequence stratigraphy to the Upper Pennsylvanian strata of east-central Illinois. Use of the cyclothem as the basic unit for sequence stratigraphy does not parallel Van Wagoner and others (1990), who advocated the sequence as the
fundamental unit. Use of the cyclothem as the basic unit is warranted because cyclothem boundaries are most readily identifiable from data available for this study. The data consist of studies of outcrops that rarely expose more than one entire cyclothem, very few continuous cores through the studied interval, and numerous geophysical logs. Seismic data have not been used.

Cyclothemic units

Cyclothems are composed of a variable number of lithologic units, separated by conformable or unconformable surfaces that have significance in the application of sequence stratigraphy. Each of these lithologic units generally comprise a "bedset," which is equivalent to the traditional bed. Depositional environments are inferred from study of bedsets (beds), and important events in the depositional history of the cyclothem are inferred from the intervening surfaces. Although the cyclothem is used as the basic unit for this study instead of the sequence, terminology and concepts of sequence stratigraphy are applicable to the cyclothem succession.

Each cyclothem contains a marine-flooding surface, a surface upon which the initial marine sediments are deposited. Van Wagoner and others (1988) described this surface as one that separates younger from older strata and across which an abrupt increase in water depth occurred. Marine-flooding surfaces in Upper Pennsylvanian strata in east-central Illinois are planar and have a subtle topographic relief that is probably less than ten feet. These surfaces are similar to those described by Van Wagoner and others (1988) but contrast with marine-flooding surfaces documented by Wanless (1952) in western Illinois where Middle Pennsylvanian marine strata flooded paleo-channels or paleo-valleys. Johnson (1972) and Krausse and others (1979) inferred topographic relief based on the mapping of nonmarine and marine strata over the Middle Pennsylvanian Herrin Coal.

The transgressive marine bed is characteristically thin and consists of a single lithologic bed. It is composed of a thin limestone bed, a carbonate ravinement, or a black shale ravinement. Transgressive limestones, such as within the Newton and Shumway cyclothems, generally are massive, bioturbated grain-supported biocalcarenites. Transgressive limestones are less laterally persistent than either the condensed "core" shales or regressive limestones. The "Lake Sara" limestone of the Shumway cyclothem seems to be restricted to the basinward western (and perhaps southwestern) part of the field area.

A "core" shale consists of a black, fissile, marine shale which was deposited at the time of maximum transgression (Heckel, 1977). The fossil content of these shales in the study area characteristically is sparse to moderate and lacks diversity, excepting basal, transgressive lag deposits. This bed is the most consistently widespread of cyclothem units and is a key lithostratigraphic unit for local and regional correlations.
"Core" shale beds have the character of condensed sections. Loutit and others (1988) defined condensed sections as thin marine units that consist of pelagic to hemipelagic sediments deposited at a low sedimentation rate. The sedimentation rate of "core" shales is a subject of controversy; Zangerl and Richardson (1963) concluded that the Mecca Quarry Shale Member (Carbondale Formation) was deposited in less than 10 years, whereas Heckel (1977), studying "core" shales in the midcontinent, advocated deposition over a much longer period of time, probably in the thousands of years. Coveny and others (1991) suggested that some Pennsylvanian "core" shales were deposited rapidly near shore, such as the Mecca Quarry, while others were deposited slowly offshore. Zangerl and Richardson's (1963) conclusion, however, is based on the erroneous assumption that deposition and compaction of organic muds occurred simultaneously. Differences in paleontologic and lithologic content suggest individual "core" shales were deposited in a continuum from relatively deep to relatively shallow water depths.

In addition to its usefulness as a key lithostratigraphic unit, condensed beds often contain microfossils that provide a biostratigraphic framework to integrate with the lithostratigraphy. Conodonts from these "core" shales, along with associated macrofossils from the shale or adjacent marine strata, have proven to be very useful for erecting a biostratigraphic framework for Middle and Upper Pennsylvanian strata (Heckel, 1986; Boardman and Heckel, 1989; Heckel and others, 1991).

The highstand marine bed is deposited when the marine transgression has reached its point of maximum transgression. This bed often is the "core" shale. In cyclothems that do not contain a "core" shale, this beds usually is a marine limestone. In a few cyclothems, the highstand marine bed is a calcareous shale.

The regressive marine beds is characteristically a shoaling-upward succession. It compositionally ranges from limestone to a calcareous shale, including interbedded limestone and shale. It generally is thicker and more widespread than the transgressive marine bed.

Exposure surfaces have been recognized in the midcontinent on top of regressive limestones (Goebel and others, 1989; Heckel, 1983; Schutter and Heckel, 1985; Watney, 1980). In the Illinois Basin, only a few exposure surfaces have been recognized (Weibel, 1988); however, it is likely that most previous studies overlooked or did not understand the significance of exposure surfaces. Exposure surfaces on carbonates are recognized by the occurrence of the dissolution and cementation features of early meteoric diagenesis. Exposure surfaces on clastic rocks generally contain paleosol features and are discussed below.

The prograding terrestrial beds comprise most of the strata above the marine beds up to the base of the underclay. These beds lithologically consist of shale, siltstone and sandstone and generally are the thickest portion of cyclothems. These beds were deposited in response to falling sea level during regressions.
Erosional surfaces occur within strata deposited during times of marine regression, progradation of terrestrial beds, and during initial marine transgression. Erosional surfaces at the bases of incised paleo-valleys or paleo-channels are the most obvious. Erosional surfaces of small hiatuses are probably relatively abundant throughout the prograding terrestrial beds, but are harder to recognize and are in the interval which is generally poorly exposed.

The lowstand terrestrial bed(s) is/are deposited when the marine regression has reached its maximum. It is difficult to determine exactly which beds were deposited during the lowstand without knowing the rate of progradation. A higher subsidence rate will result in faster progradation; lowstand will occur during deposition of beds in the upper portion of the prograding terrestrial beds. Underclay paleosols and coal beds will indicate lowstand conditions. Slower subsidence will result in slower progradation; lowstand may occur during deposition of beds in the lower portion of the prograding terrestrial beds. In Upper Pennsylvanian strata, it appears that the former is more prevalent, indicated by the gradational transition from beds of marine origin to beds of terrestrial origin. The latter, however, occurs at Stop 4, where progradation lagged behind regression and an exposure surface formed at the top of the Greenup Limestone.

Paleosols, like exposure surfaces, indicate extensive subaerial weathering and separate older beds from younger beds. They commonly occur in underclay deposits. Not all underclays, however, are paleosols (Hughes and others, 1987), i.e., compare underclays at Stop 2 and Stop 6. Paleosols probably are present within the prograding terrestrial beds but have not been identified because of poor exposures. These paleosols would be less extensive and represent shorter periods of exposure and weathering than underclay paleosols because of faster sedimentation rates during the progradation associated with the regression.

**Proposed allostratigraphic classification**

Erection of an allostratigraphic classification system based on the cyclothem, and separated from the lithostratigraphic classification system, is herein recommended. An allostratigraphic classification has advantages that the lithostratigraphic classification lacks. Dual, parallel classifications (Figure 9) thus offer the advantages of both systems.

Cyclothems constitute basic geologic mapping units that are both convenient and usable (Willman and Payne, 1942; Ball, 1952; Wanless, 1957; Weibel, 1988). Middle and Upper Pennsylvanian formations in the Illinois Basin are thick, provide little control for detailed stratigraphic and structural control, and are useful primarily only in small-scale maps. Cyclothems are genetic units and thus constitute a natural framework for classification. The lithostratigraphic formations are based on arbitrary key beds, whereas cyclothems are recognized by the discontinuity between the marine and nonmarine strata, which may be more wide spread than the key beds. In fact, individual key beds
Figure 9. The composite lithostratigraphic column of Figure 2, with the parallel, cyclothem-based allostratigraphic column. The allostratigraphic classification contains more mapping units that are suitable for stratigraphic and structural control, than does the lithostratigraphic classification. See text for additional discussion. G. = Greenup cyclothem, W. = Woodbury cyclothem.
bounding the formations are absent locally, resulting in thick, undifferentiated intervals. Most cyclothems are laterally continuous and are useful for local and regional correlations. Recognition of cyclothems is essential for basin analysis; i.e., for determining rates of subsidence and tectonic uplift and volumes of sediment accumulated. The necessary precise biostratigraphic control for basin analysis is being developed for the Illinois Basin (Peppers, 1988; Heckel and others, 1991) and is based on a cyclothemic framework (see paper by Heckel and Weibel, this guidebook). Basin analysis derived from use of the larger, key-bed bounded lithostratigraphic formations probably would be generalized and of little use, particularly since multiple-bed members are not recognized within the cyclical portions of the Pennsylvanian column. Cyclothems also provide a more convenient framework for sedimentological studies than the lithostratigraphic formations.

Kosanke and others (1960) listed several objections to the use of cyclothems as a lithostratigraphic unit. The use of the cyclothem as a distinct allostratigraphic unit nullifies most of their objections. The difficulties of mapping the base of the sandstone on the surface and in the subsurface, and the desire to map "economic" units are resolved by use of the modified cyclothem, instead of the Wanless and Weller cyclothem. Marine units consistently crop out more widely than the basal sandstone; coal, limestone, and black shale generally are readily recognized in cores and cuttings and on the more common geophysical logs; and the "economic" units of limestone, underclay, and coal are either at the boundary or very close to it.

Kosanke and others (1960) recommended that a uniform classification system be used for the entire Pennsylvanian. Such a recommendation is superfluous because a classification system should reflect changes in the geology, rather than forcing an arbitrary uniform system onto the rock column. The allostratigraphic classification should only be used where allostratigraphic units are recognized, whereas a lithostratigraphic classification should be applicable to the entire stratigraphic column. In the Illinois Basin, such allostratigraphic units occur in Middle and Upper Pennsylvanian strata. Finally, the objection to the supposed lack of lithologic differences between cyclothems by Kosanke and others (1960) is negated by the use of allostratigraphically defined units.

The allostratigraphic classification is based upon the cyclothem, a marine-terrestrial succession. In two situations, however, the marine units may be absent, rendering it difficult to differentiate cyclothems. Downcutting by a channel during the maximum regression (lowstand) can have eroded marine strata deposited during the early stages of deposition of that cyclothem. In some cases, the strata of the underlying cyclothem also may be eroded. The other situation occurs in strata landward of the marine strata pinchout. Both situations are most likely to occur on the basin flanks. In the former situation, cyclothems can be correlated by careful tracing of both individual beds and stratigraphic discontinuities. In the latter situation, the cyclothem with the marine strata can be
correlated by tracing of the bed and can be aided by biostratigraphy. Beyond the pinchout, the cyclothem may not be differentiated.

The use of parallel stratigraphic classifications is not without a precedent. Inclusion of an allostratigraphic classification system in the Code (NACSN, 1983) indicates that parallel systems are acceptable (Articles 58-60). The Code further specifies that division of a rock column into cyclothems must be distinct from division into groups, formations, and members (Article 22j). Parallel use of lithostratigraphic units with magnetostratigraphic, biostratigraphic, or pedostratigraphic units is evident by a cursory literature review. Hydrostratigraphic units have been proposed and have been used (Seaber, 1988).

Recognition of the cyclothem as an allostratigraphic unit contests the inclusion of the cyclothem under the lithostratigraphic section of the Code (NACSN, 1983). The cyclothem is an allostratigraphic unit and should be included in the allostratigraphic section. According to the Code (Article 59), the hierarchy of allostratigraphic units is, in decreasing rank order, allogroup, alloformation, and allomember. The alloformation is the fundamental allostratigraphic unit; this implies that a cyclothem is equivalent to an alloformation. The Code, however, defined an allostratigraphic unit as a mappable body (Article 58, NACSN, 1983), and not all cyclothems are mappable. Weibel (1988) suggested that Virgilian cyclothems in the Illinois Basin can be mapped using both single cyclothems and groups of cyclothems as mapping units. This approach differs significantly from Wanless's (1956) suggestion that every cyclothem be considered a single mappable formal lithostratigraphic unit. Use of the term cyclothem is thus preferred because it avoids the problem of an alloformation consisting of both single and multiple cyclothems, the cyclothem has a deeply-rooted history, the cyclothem has precedence over the definition of alloformations, and its use will avoid the likely confusion of using both formation and alloformation. Preference of an older, more established unit name over the name sanctioned by a Stratigraphic Commission also is not without a precedent. The (cratonic) sequences of Sloss (1950, 1963) are referred to as "synthems", according to the International Subcommission on Stratigraphic Classification (See Sloss, 1988).

A composite stratigraphic column for Missourian and Virgilian strata in east-central Illinois is shown in Figure 9. It includes both the lithostratigraphic and allostratigraphic classifications. Coals, black shales, limestones, and a few sandstones are shown on the stratigraphic column. Named units indicate a reliable correlation with outcrops, generally type sections, of the units. Units that are depicted as lens on the graphic column are laterally restricted; however, this does not mean that all the other units are present everywhere in the study area. For example, several cyclothems (M3, M4 and Omega) are not present in a core drilled near Charleston. In this area, the stratigraphic interval of these cyclothems is occupied by chiefly sandstone. Apparently, an influx of sandstone prevented deposition
of the marine and finer clastic portions of these cyclothems, or the marine portions of these cyclothems never reached this area.

Revisions by Weibel (1988) in the Virgilian stratigraphic succession are included but space prevents complete substantiation; thus all newly named or newly applied lithostratigraphic units (members or beds) are informal and bracketed by quotations. The non-numerically named cyclothems were modified or proposed by Weibel (1988) or Weibel and others (1989). The Virgilian allostratigraphic column is based on detailed outcrop examination supported by relatively recently available subsurface data. Unlike previous studies, Virgilian exposures throughout the region were examined. In most cases, correlations combined methods that resulted in a well-substantiated stratigraphic succession. Despite few outcrops, local correlation is possible, because the marine portion of each cyclothem is typically a distinct lithologic sequence of black, fissile shale and/or limestone. Lateral facies changes occur in limestone, but are generally recognizable. The black, fissile shales are distinctive in relative thicknesses and in the presence/absence of large calcareous concretions. Several cyclothems contain distinct marine fossil assemblages. Regional structural trends and physical tracing of cyclothems also were used in determining stratigraphic succession. Subsurface correlations are based on stratigraphic succession, thicknesses of the black shales and the intervals between them, and correlation with outcrops.

The allostratigraphic column for the Missourian Series is based mostly on a recent detailed, subsurface study of cores and geophysical logs (Weibel, 1991). Not all of the cyclothems in this study were traced to their respective type localities, and none of the type localities have been personally examined. Many of the units shown, therefore, are unnamed. The Missourian cyclothems consequently are designated by a letter-number combination. The letter refers to the lithostratigraphic formation in which the cyclothem is within (B = Bond, M = Mattoon, and BM = Bond & Mattoon undifferentiated), and the number refers to position in sequence starting from or near the base of the formation. Cyclothems below cyclothem B1 at Stop 5 have only very recently been under examination; these cyclothems are unnamed for this study and will be referred to by their respective correlative limestones (in quotations).

Limitations of parasequence sets and sequences

The problem of fitting the cyclothem into the hierarchy of allostratigraphic units is a lesser problem than recognizing stratal units larger than the parasequence-equivalent cyclothem. Recognition of parasequence sets and sequences is dependent upon the differentiation of the different types of boundaries. The boundaries of sequences, parasequence sets, and parasequences are all stratigraphic discontinuities. The differences between these boundaries are relative and are dependent upon recognition of their respective stratal units. They are, in addition, difficult to assess without regional
study. Mitchum and others (1977) defined a sequence boundary as an unconformity (presumably significant). A parasequence set boundary is bounded by "major" marine-flooding surfaces, and a parasequence boundary by marine-flooding surfaces. All three boundaries may consist of correlative conformities, respectively.

Parasequence boundaries are relatively easy to identify in the Pennsylvanian strata in the field trip area because of ease in recognizing marine strata overlying nonmarine strata (including estuarine deposits) at the cyclothem boundary. Differentiation between a parasequence set boundary and a parasequence boundary is difficult because of the subjective identification of "major" marine-flooding surfaces. The question of identifying a parasequence set and its boundaries may only be answered by detailed regional sequence stratigraphic study of the numerous Pennsylvanian cyclothems. Until those studies are undertaken, parasequence set boundaries can be only conjectured.

A similar problem exists with the identification of sequence boundaries. Van Wagoner and others (1988) recognized two types of sequence boundaries, Type 1 and Type 2. Type 1 sequence boundaries are characterized by concurrent subaerial exposure and erosion caused by stream rejuvenation, basinward shift in facies, downward shift in coastal onlap, and onlap of overlying strata. Type 1 boundaries are interpreted to have formed when eustatic fall of sea level exceeds basin subsidence (Ibid.). This basinward facies shift often results in a sequence boundary with nonmarine/shallow water marine strata above and deeper water marine strata below. Type 1 sequence boundaries, therefore should occur at the basal unconformity of the sandstone unit, which Wanless and Weller (1932) recognized at the cyclothem boundary. The boundary, however, can only be recognized as a Type 1 sequence boundary when the unconformity is widespread and the associated regression is regional. Such regression would result in formation of extensive paleosols. Several paleosols have been studied in the midcontinent that may be associated with sequence boundaries (Watney, 1980; Prather, 1985; Schutter and Heckel, 1985; Goebel and others, 1989; Joeckel, 1989). Equivalent boundaries, however, have not been identified in the Illinois Basin.

A Type 2 sequence boundary forms when eustatic fall of sea level is less than or equal to basin subsidence (Van Wagoner and others, 1988). In this situation, the depositional-shoreline break is characterized by the absence of a relative sea level change. Type 2 boundaries have not been recognized in the study area. Brown (1989), in his sequence stratigraphy study of the Virgilian and Wolfcampian Series in north-central Texas, recognized mostly Type 1 sequences and only a few Type 2 sequences.

Upper Pennsylvanian strata in east-central Illinois were deposited in platform/continental shelf environments. Laterally equivalent continental slope and basin deposits are not preserved in the basin. The Middle Pennsylvanian in the basin also consists of platform/shelf deposits. Absence of continental slope and basin deposits is the most important reason why sequence boundaries are not readily
recognizable in Upper Pennsylvanian rock in east-central Illinois. Watney and others (1991) noted that platform/continental shelf environments have limited accommodation space for sedimentary deposition. They also concluded that the platform/shelf strata preserve the best record for sea level highstands and basin strata preserve the best record for lowstands. It is possible that a regional study and the addition of seismic data to the data base could rectify recognition of this boundary. The sequence stratigraphy concepts of Van Wagoner and others (1988; 1990) are thus best applied to studies of rock intervals that include platform, continental slope and basin deposits.

Interbasinal and global correlations

Sequence stratigraphic concepts have also been applied to interbasinal and global correlations of cyclic late Paleozoic strata. Wanless (1939) first attempted, with significant success, correlation of cyclothems from the Illinois Basin to the Appalachian Basin and from the midcontinent to the Illinois Basin (Wanless and Wright, 1978). Ross and Ross (1985, 1987, 1988) have presented charts showing correlations between globally-correlated faunal zones and transgressive-regressive depositional sequences. These sequences are equivalent to several cyclothems/parasequences and thus are roughly equivalent to parasequence sets. They have described more than 50 transgressive-regressive depositional sequences within cyclic Carboniferous and lower Permian strata worldwide. Boundaries of these depositional sequences are based on correlation of biostratigraphic zones and are not correlated to lithostratigraphic unconformities. The relationship between depositional sequences and zone boundaries is based on the presumption that whenever a faunal turnover occurred, it was caused by a widespread regression followed by a subsequent transgression. Consequently, their depositional sequence boundaries reflect faunal changes which may or may not be related to a transgressive-regressive event. Thus, their charts are flawed in that the stratigraphic discontinuities shown are not necessarily the most widespread and significant, and that other, widespread and more significant discontinuities are not shown, especially discontinuities unmarked by a recognizable faunal change.

Heckel (1986; Boardman and Heckel, 1989) has correlated transgressive-regressive "cycles of deposition" (equivalent to a cyclothem/parasequence) from the midcontinent to north-central Texas. These correlations are also supported by biostratigraphic data (although largely unpublished). In this case, however, the data were applied to the rock column, whereas Ross and Ross (ibid.) applied the rock column to the biostratigraphic zones. Heckel (ibid.) informally classified transgressive cycles as major, intermediate, and minor. Boundaries between these cycles may be analogous to parasequence, parasequence set, and/or sequence boundaries.
Conclusions

An allostratigraphic classification, based on a modified cyclothem and equivalent to a parasequence, is herein proposed for Upper Pennsylvanian strata in east-central Illinois. Formal recognition of allostratigraphic units is not included in this report. Such recognition awaits publication in a more widely distributed publication. Use of cycloths in a classification independent from a lithostratigraphic classification is accepted by the Illinois State Geological Survey (Kosanke and others, 1960) and by the Code (Article 22j, NACSN, 1983). A cyclothem-based allostratigraphic classification is warranted because it permits correlation with similar lithostratigraphic units (boundary at base of marine stratum) in Iowa (Ravn and others, 1984) and Missouri (Howe, 1953; Searight and Howe, 1961). Lithostratigraphic units in Kansas are not cyclothem based, but the boundaries are largely based on widespread limestone units (Jewett and others, 1968), which are often correlative with the lower portion of cycloths.
ROAD LOG

Road log begins and ends at the Effingham Holiday Inn.

0.0 Exit parking lot of Holiday Inn. Turn left onto frontage road. Proceed to stop light.

0.1 Intersection of frontage road and Fayette Ave. Turn right (west) toward Interstate 57/70.

0.3 Cross over Interstate 57/70.

0.05 Turn right onto entrance ramp to Interstate 57/70.

0.95 Cross over U.S. Rte. 40 and Conrail Railroad.

1.0 Veer right onto Interstate 70. Begin descent down from Illinoian till plain onto Little Wabash floodplain.

1.05 Cross Little Wabash River.

0.6 Begin ascent from floodplain up to Illinoian till plain. Most of the field trip route will be on Illinoian till plain or dissected Illinoian till plain. Between the Mattoon Field and Fox Ridge State Park, the route will be on Wisconsinian till plain. Just south of these two localities, the route will travel over Wisconsinian outwash over Illinoian till plain.

2.1 Cross Lily Creek.

3.75 Cross Second Creek.

0.85 Cross Coon Creek.

1.8 Exit right at exit 82 to Altamont.

0.3 Stop. Turn left (south).

0.9 Big Creek.

3.2 Intersection, turn left (east) onto 500N.

1.7 Cross abandoned railroad bed; pass through "town" of Gilmore.

0.3 Turn south (right) at 500E, 500N.

0.55 Cross abandoned railroad bed.

0.25 Cross Fulfer Creek. Park on south side of bridge. Walk east (0.1 mile) along creek towards railroad trestle to outcrop on north side of creek. STOP 1 (Figure 10).

---- Turn around and retrace route back to Altamont.

6.8 I-70 overpass, continue north into Altamont.
0.8 Intersection of U.S. Rte. 40 and Illinois Rte. 128. Continue straight (north) on Illinois Rte. 128 through Altamont.

0.5 Cross Conrail Railroad.

4.4 Cross Moccasin Creek. Two miles to the west (left) of here is the Louden Field, one of the largest in the basin. Exxon recently announced that the oil field is for sale.

1.4 Stop sign at 1600N, 300E. Continue north on 300E.

1.8 Stop sign. Turn left (west), correction line jog.

0.1 Turn right (north) onto 300E.

0.7 Cross Wolf Creek under Union Pacific Railroad.

0.3 Stop sign. Turn right (east) onto IL-33.

0.05 Cross Union Pacific Railroad.

0.4 Cross Wolf Creek.

2.3 Cross Morris Creek.

1.5 Road bears left, proceed straight on 1900N.

0.75 Drive through north edge of Shumway, past church.

2.05 Stop sign at "Y" junction with IL-32, turn right (south).

0.05 Cross Shool Creek.

0.45 Turn left (east) at 1000E, 1850N.

0.5 Turn left (north) at 1050E, 1850N.

0.3 Private residence. Park and walk north (0.25 mi) on abandoned road to exposures along Shoal Creek just west of condemned bridge. STOP 2 (Figure 11).

------ Retrace route back to IL-32.

0.8 Turn left (south) onto Illinois Rte. 32.

1.1 Stop sign. Turn left (southeast) at junction of Illinois Rte. 32/33.

2.55 Cross Little Wabash River.

0.5 Leave woods, enter fast-food Nirvana in Effingham.

0.3 Stop. Frontage road and Illinois Rte. 32/33. Proceed straight and cross over Interstate 57/70.

0.3 Stoplight. Turn left (east) onto Interstate 57/70.

1.8 Cross over U.S. Rte. 45 and Illinois Central Railroad.

---

Figure 11. Location map of Stop 2. Arrow 1 points to outcrop at Stop 2. Arrow 2 indicates additional exposures of the same stratigraphic interval. Contour interval is 3 meters. Scale same as Figure 10.
1.1 Veer left onto Interstate 57 north. The oil field just northeast of Interstate 57/70 intersection is the Teutopolis Field, which has at least one oil well operating.

3.5 Cross East Branch.

1.65 Enter Shelby County.

3.55 Enter Cumberland County.

7.5 Cross Bush Creek. Oil wells to right (east) are in the Mattoon South Field, a small oil field just south of and on the same structure as the much larger Mattoon Field.

0.7 Enter Coles County.

1.05 Southern end of Mattoon Field to right (east).

1.2 Begin ascent up Wisconsin terminal moraine.

1.0 Cross axis of Mattoon Anticline.

0.9 Cross U.S. Rte. 45. The discovery well for the Mattoon Field is just southeast of this intersection, probably within the entrance ramp area.

2.9 Cross little-used railroad.

1.4 Cross Kickapoo Creek.

0.8 Exit right at exit 190A onto Illinois Rte. 16 east.

0.9 Stoplight. Proceed straight (east) towards Charleston.

5.3 Cross Norfolk Southern Railroad.

0.1 Cross Riley Creek.

0.5 Enter Charleston. Proceed straight (east) on Illinois Rte. 16 through the town.

1.1 Eastern Illinois University is to the right (south).

0.8 Stoplight. Intersection of Illinois Rte. 16/130. Proceed ahead (east-northeast) on Illinois Rte. 16.

3.15 Turn left (north) onto quarry access road just before Embarras River bridge. Enter Charleston Stone Company quarry to STOP 3 (Figure 12).

Figure 12. Location map of Stop 3. The quarry is in the W1/4, section 5 and in section 32. Contour interval is 3 meters. Scale same as Figure 10.
Retrace route back to intersection of Illinois Rte. 16/130.
3.15 Turn right (south) onto Illinois Rte. 130.
2.4 Cross Embarras River.
4.3 Turn right (west) into Fox Ridge State Park. Follow lead vehicle to LUNCH STOP. After lunch, return to park entrance.
--- Turn right (south) onto Illinois Rte. 130 and begin descent down Wisconsinian terminal moraine.
1.9 Enter Cumberland County.
2.0 Turn right (west).
0.95 On the left (south) is the main entrance to the Charleston Sand and Gravel Co. quarry. Deposits of Wisconsinian outwash are the source for the materials produced.
0.25 Cross Clear Creek.
0.6 Road turns sharply to left (south).
0.15 Turn right (west).
0.05 Park just east of Ryans Bridge. Walk along lane on east bank of Embarras River to STOP 4 (Figure 13).
--- Return to Illinois Rte. 130.
2.0 Turn right (south). For the next 4 miles, the route crosses topography incised below the Illinoian till plain adjacent to the Embarras River.
2.8 Cross Hurricane Creek.
2.3 Cross Lost Creek.
0.8 Cross Bell Branch.
0.6 Cross over Interstate 70.
0.1 Turn left (east) onto entrance ramp to Interstate 70. Scattered outcrops of the Greenup Limestone Member are in the area. As we drove south from Charleston, we were obliquely moving off the axis of the LaSalle Anticlinal Belt into the Fairfield Basin. After turning east, we are now moving back up on to the western flank of the structure.
5.45 Cross Range Creek.
3.05 To the north (left), oil wells in the Siggins Field are in view. About 1.5 miles north of here is the Siggins "oil mine," an unusual method of attempting to extract oil.

The Siggins Field is an old oil field; the discovery well was drilled in 1906. Production is almost entirely from Lower Pennsylvanian sandstones. Three Star Drilling and Producing Corp. constructed an 8 ft by 8 ft shaft down to 426 ft depth. At about 350 ft depth, a 24 ft
diameter room was excavated and 33 upward tilted wells, totaling approximately 34,870 ft in length, were drilled into the "first Siggins" sandstone. The well lengths varied from 300 to 2,000 ft. Each near-horizontal well has a valve and leads into a central collection pipe. Production is a combination of gravity draining and waterflooding. The mine is producing about 25 BOPD.

This operation is one of two oil mines in the basin. The other mine, now reportedly dormant, is in the Colmar-Plymouth Field in McDonough County, western Illinois.

0.45 Enter Clark County.
1.25 Exit right at exit 129 to Illinois Rte. 49 to Casey.
0.35 Stop. Turn right (south).
0.85 Stop. Intersection of U.S. Rte. 40/Illinois Rte. 49. Continue ahead (south) through Casey on Illinois Rte. 49.
0.65 Stoplight. Proceed straight (south). Cross Old National Road.
0.05 Cross Conrail Railroad.
0.7 Leave Casey.
1.85 Turn left (east) at 100E, 800N.
3.0 Turn right (south) at 800N, 400E.
0.95 Park along road near barn to left (north).
STOP 5 (Figure 14).

Proceed on foot to outcrops along this east-flowing tributary to the North Fork of the Embarras River.

Figure 14. Location map of Stop 5. Arrows 1 and 2 point to outcrops at Stop 5A and 5B, respectively. Arrows 3 and 4 point outcrops at Stop 5C. Arrows 5 and 6 point to exposures of younger cyclothems, not examined on this field trip. Contour interval of the upper two-thirds of the map is 3 meters; lower one-third is 1.5 meters. Scale same as Figure 10.

The wells in this area are in the Johnson North Field. This oil field is one of several aligned along a north-south axis, indicating probable structural control of the reservoirs. The area is a virtual museum of 50+ year old oil field equipment. At the end of the road is a tipped-over, wooden tank barrel.

Return to Greenup via Interstate 70.
18.8 Exit right at exit 119 onto Illinois Rte. 130. [Or, use optional route at end of log.]
0.3 Stop. Turn left (south).
0.5  Stop. Intersection of Illinois Rte. 121/130. Cross Old National Road. Proceed straight. Downtown Greenup to the right has several stores that still have false fronts and sidewalks covered by second floor patios.

0.2  Stop. Intersection of U.S. Rte. 40/Illinois Rte. 130. Continue on (south).

0.4  Cross over Conrail Railroad.

2.7  Village of Liberty Hill.

1.25  Cross Range Creek.

0.05  Drive through Hidalgo North Field.

0.95  Enter Jasper County.

1.15  Hidalgo road. Enter Hidalgo Field.

3.55  Rose Hill road.

0.55  Enter Rose Hill-Hidalgo South Field.

2.9  Falmouth road.

3.0  Junction with Illinois Rte. 33. Proceed ahead (straight). The largely abandoned Jasper North Field is within the timbered area just east of the highway. To the right on the Embarras River floodplain are several elevated pump houses for wells which supply municipal water for Newton.

1.05  Cross Embarras River. Enter Newton.

0.25  Turn right (west) onto Marion St.

0.5  Turn right (north) onto 3rd Ave. Drive down to south bank of Embarras River.

0.1  Park at bottom of hill. Proceed on foot eastward along south bank of Embarras River to STOP 6 (Figure 15).

-----  Return to Marion St.

0.1  Turn right (west) onto Marion St.

0.25  Stop. Turn left (south) onto Van Buren St.

0.15  Stoplight. Turn right (west) onto Illinois Rte. 33.

5.85  Village of Lis.

3.3  Enter Wheeler.

0.25  Cross Big Muddy Creek.

2.55  Enter Effingham County.

0.65  Enter Dieterich.

0.35  Cross Dieterich Creek.

2.05  Cross Bishop Creek.

Figure 15. Location map of Stop 6. Arrow points to exposure along the south bank of the Embarras River. Contour interval is 1.5 meters. Scale same as Figure 10.
2.05 Cross Little Salt Creek.
2.05 Cross Teutopolis-Elliotstown road.
0.7 Drive through Teutopolis South Field.
2.4 Cross Salt Creek.
0.1 Enter Effingham. Follow on Illinois Rte. 33.
0.8 Cross Conrail Railroad.
0.5 Turn left (west) onto Fayette Avenue (and U.S. Rte. 40). Stay on Fayette Avenue.
0.45 Pass under the Illinois Central Railroad.
0.55 Stoplight at intersection of Fayette Avenue and Henrietta St. (intersection of U.S. Rte. 40, Illinois Rte. 32 & Illinois Rte. 33). Proceed straight ahead (west).
0.3 Turn right (north) at traffic signal onto frontage road.
0.1 Holiday Inn. Disembark.

OPTIONAL ROUTE: Greenup to Effingham.
18.8 Pass Exit 119. Continue straight ahead on Interstate 70.
1.0 Cross Embarras River.
0.35 Cross over Illinois Rte. 121.
0.4 Cross abandoned railroad.
4.85 Cross Cottonwood Creek.
1.85 Cross Muddy Creek. About 1 to 1.5 miles south (left) of here is the exposure of the Woodbury cyclothem.
5.95 Enter Effingham County.
0.35 Exit right at exit 105 (Montrose).
0.35 Stop. Turn right (north).
0.1 Enter Cumberland Co.
0.25 Park along road. Optional STOP 6 (Figure 16). Walk west to southwest facing cutbank on drainage paralleling the road.
------ Turn around and proceed south.
0.25 Enter Effingham County.
0.1 Turn right onto entrance ramp to Interstate 70 west.
2.0 Montrose Field to the left (south).

Figure 16. Location map of optional Stop 6. Arrow points to exposure in drainage on west side of road. Contour interval of the east half of the map is 3 meters; west half is 1.5 meters. Scale same as Figure 10.
2.55  Cross Second Salt Creek.
1.3   Pass exit to Interstate 57. Continue straight.
0.85  Merge with Interstate 57.
0.85  Cross over U.S. Rte. 45 and Illinois Central Railroad.
0.65  Billboard paradise.
1.9   Exit right at exit 159.
0.35  Stop. Turn left (east) onto Fayette Avenue.
0.5   Turn left (north) at traffic signal onto frontage road.
0.1   Holiday Inn. Disembark.

END OF LOG.
FIELD TRIP STOPS
C. P. Weibel, R. L. Langenheim, and J. F. Stratton

STOP 1: Weibel: Upper cyclothem M4 and lower Omega cyclothem.

Location: South cut bank, Fulfer Creek, just west of railroad trestle, 600 ft FWL, 1400 ft FSL, Section 12, T. 6 N., R. 4 E., Edgewood 7.5’ Quadrangle, Effingham County.

The Omega cyclothem (Figure 17), as originally defined by Wanless (1956), contained only one named unit, the Omega Limestone Member; neither upper nor lower boundaries were specified. The lack of specified boundaries probably was not an oversight, but rather was the consequence of the inability to identify or map the basal sandstone and/or its basal unconformity in the area. This situation is one of the problems that Kosanke and others (1960) cited when they rejected formal recognition of cyclothems as lithostratigraphic units. The Omega cyclothem was modified by Weibel and others (1989) to include strata from the base of the Omega Limestone Member up to the base of the Shumway cyclothem. The cyclothem is further modified herein, to include the marine, gray to dark gray shale that locally occurs between the Omega Limestone Member and the underlying coal. The practical use of having marine strata at the base of a cyclothem was demonstrated in part on an older geological map of Illinois (Weller and others, 1945) on which the Omega Limestone was mapped. No other strata have been mapped on the surface in this area.

Strata below the Omega cyclothem are in the upper portion of cyclothem M4 (Weibel, 1991).

Downstream from here, a coal, probably equivalent to the Calhoun Coal Member, occurs at the top of cyclothem M4 (Figure 18). With the recognition of a cyclothem as an allostratigraphic unit, the lower boundary of the Omega cyclothem varies from being at the base of the Omega Limestone or at the base of a thin, fossiliferous, dark gray fissile shale, which underlies the limestone about 0.75 miles downstream from this locality (Figure 18).

The sandstone in the stream bed may be equivalent to the basal sandstone in the Wanless and Weller cyclothem. The nature of the lower contact is unknown, and one can only speculate whether it is or is not the infill of an entrenched valley that formed during regression. The overlying fining-upward facies is a record of the basinward progradation of coastal plain-deltaic sediments, which are capped by a probable paleosol at this site. It is not possible to determine whether this progradation occurred simultaneously with the marine regression, or if most of the progradation occurred during maximum lowstand. Identification and mapping of entrenched valleys and subaerial exposures in cyclothem M4 could resolve this issue.

The timing of the formation of the paleosol at the top of cyclothem M4 is also difficult to determine, but the paleosol probably occurred during maximum lowstand. The succeeding coal-swamp formed either during maximum lowstand when subsidence maintained a high water table for the coal swamp to flourish, or during the early flooding phase, when the transgression maintained the water
Figure 17. Stratigraphic column of the upper part of cyclothem M4 and the lower part of the Omega cyclothem at Stop 1. Column headers: formation (F), member or bed (M), Wanless and Weller cyclothem (W), and modified cyclothem (C).
table. Eventually the transgression flooded the entire shelf, locally depositing a transgressive lag (a ravinement), which is a dark gray, fossiliferous shale above the coal at the downstream exposure.

The variation in the stratigraphic position of the base of the Omega cyclothem, which is the marine flooding surface, either indicates the occurrence of a subtle, pre-limestone-deposition geomorphic surface, or the occurrence of local facies just above the flooding surface. The calcarenitic nodules at the base of the limestone at this site suggest that this marine flooding surface is locally an erosional surface. The highstand facies of this cyclothem is the phylloid algal bank of the Omega Limestone. The progradation of deltaic sediments apparently was slower than the regression of marine water, allowing an exposure surface? to form on the top of the limestone. Prograding sediments subsequently buried this surface.

The Omega Limestone is unstudied petrographically but macroscopically appears to be mostly phylloid algal limestone with abundant well-preserved, pelmatozoan fragments, fusulinids, and numerous brachiopods. Unpublished ISGS field notes described a gray to brown shale with siderite nodules overlying the limestone in this area, although I have not yet found such an exposure.

The Omega Limestone marks the base of the Virgilian Series in the Illinois Basin. Until recently, placement of this boundary was debatable. Weller and others (1942) correlated the Omega with the Lansing Group (uppermost Missourian). They correlated Illinois Virgilian limestones to only group level in Kansas because of the general endemism of Virgilian fusulinids in the Illinois Basin and poorly understood field relationships. Cooper (1946), using ostracodes, correlated the Omega with the Deer

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Figure 18. Stratigraphic column of the upper part of cyclothem M4 and the lower part of the Omega cyclothem, located in Fulfer Creek, just north of an abandoned quarry, 1200 ft FEL, 800 ft FSL, same section as Stop 1. This excellent Omega Limestone exposure was used as a ford for a quarry access road and not excavated. Erosion has removed most of the sideritic cap on the limestone and revealed less altered surfaces. Brachiopods, fusulinids, and grazing trails are common but difficult to extract. The underlying coal (probable Calhoun equivalent) is separated from the limestone by a thin dark-gray bituminous shale.
Creek Limestone of Kansas (upper Shawnee Group, middle Virgilian). Hopkins and Simon (1975) placed the boundary "a few feet below the coal that occurs just below the Shumway Limestone Member" (Stop 2). This placement inexplicitly was based on its position on the Geologic Map of Illinois (Willman and others, 1967). Wanless (1975) correlated the Omega with the Oread Limestone (lower Shawnee Group), resulting in placement of the boundary significantly below the Omega Limestone. The range overlap of the fusulinids and correlation based on lithological and genetic sequences led Weibel (1988) to correlate the Omega with the Haskell Limestone Member, Lawrence Formation (Douglas Group) of Kansas. Boardman, Mapes, and Work (1989) recommended and Boardman, Barrick, and Heckel (1989) proposed movement of the Virgilian up to the base of the Haskell based on study of conodonts and ammonoids. Conodonts extracted from calcarenite nodules at the base of the Omega Limestone indicate equivalence with the Haskell-Little Pawnee interval (Heckel and others, 1991; see paper by Heckel and Weibel).

The Omega lithology appears very similar to that of the younger Greenup Limestone Member (STOP 4), and therefore probably caused Grogan and Lamar (1940) and Weller and others (1942) to correlate the two units, the latter tentatively. Cooper (1946), however, asserted that no ostracode species were common to both the Greenup and Omega Limestones and tentatively correlated the Omega with the Bonpas Limestone Member in Richland County. Dunbar and Henbest (1942) collected Triticites venustus and T. ohioensis from the Omega just west of the road, and poorly preserved T. venustus from the Bonpas; this suggests equivalence. Palynological study of the coal underlying the Omega (Figure 18) and the Calhoun Coal Member, which underlies the Bonpas Limestone, indicates probable, but not conclusive, equivalence (R. Peppers, personal communication).

The Omega and Bonpas Limestones have not been physically correlated in the subsurface. On the west side of the basin, the Omega has been mapped northward just beyond the Wisconsinian terminal moraine. Southward, it has been mapped beyond its type locality, the village of Omega. It has not been mapped in the southern portion of the basin, but it was quarried just north of Fairfield, Wayne County. In this area, outcrops are even more scarce. The Bonpas Limestone crops out just southeast of Olney, Richland County, but it has not been reported either on the surface or in the subsurface farther north. In the Charleston core, a thick interval dominated by sandstone occupies the stratigraphic position of the cyclothems M3 and M4, and the Omega cyclothem. Wanless probably would have referred to this interval as a clastic wedge, but its extent has not been mapped. Such clastic wedges may represent stacked lower and upper shoreface deposits on a fluvial or wave-dominated shoreline where deposition rate equals accommodation rate, or they may represent delta front deposits in a fluvial-dominated shoreline where deposition rate is greater than accommodation rate.

The Omega Limestone is curiously more mappable on the surface than in the subsurface, although no one has recently attempted to trace it or the Bonpas into the subsurface from their outcrop
areas. Both, however, crop out similarly close to the Shumway cyclothem, suggesting equivalence. This does not mean, however, that the apparent discontinuity of these limestones rules out the possibility of the cyclothem being physically traced in the subsurface. These limestones undergo a facies change between this area and the outcrop area of the Bonpas Limestone in Richland County. The Bonpas is a bioclastic limestone occurring in lens-shaped beds in comparison to the relatively more laterally continuous outcrops of the phylloid algal-dominated Omega Limestone. The Bonpas also is not associated with an underlying dark gray fissile shale. Thus, only an equivalent flooding unit, consisting of marine strata of any lithology, at the base of the Omega cyclothem, above the underlying terrestrial deposits of cyclothem M4, is required for subsurface correlation.

STOP 2: Langenheim and Weibel: Upper Omega cyclothem and lower Shumway cyclothem.
Location: North-facing cut bank on Shoal Creek, just west of derelict steel truss bridge on abandoned township road, 50 ft FEL, 150 ft FSL, SW/4, Section 26, T. 9 N., R. 5 E., Effingham North 7.5' Quadrangle, Effingham County.

The Shumway cyclothem was first referred to by Weller and Newton (1938), who named it for the small hamlet of Shumway. Weller and Bell (1941) described a sequence of eight units, most of which are exposed at this locality. Like most of the Upper Pennsylvanian cyclothems in Illinois, the nomenclatural origin of the Shumway is complex. Both Weller and Newton (1938) and Weller and Bell (1941) considered the Shumway cyclothem to be a unit "roughly" equivalent to a formation, without individually naming beds or members of the cyclothem. At that time, such units often were referred to (either formally or informally) by using the cyclothem name along with the lithology of the unit. Subsequent workers, such as Weller and others (1942), thus referred to the limestones of the cyclothem as the "upper" and "lower" Shumway limestones, respectively. When Kosanke and others (1960) rejected the cyclothem, they were not able to refer to the many individual lithologic units using the cyclothem "surname." They consequently renamed some units, while rejecting the names of others. In most of the upper Pennsylvanian cyclothems, the cyclothem name was restricted to the respective marine limestone. Some of the results were less than illuminating. In the case of the Shumway cyclothem, only the upper marine limestone was named. In the case of the Gila cyclothem (abandoned by Weibel, 1988; Weibel and others, 1989), the name unfortunately was applied to a brackish-water limestone less than 5 cm thick; the cyclothem does not contain a laterally extensive marine limestone.

Scheihing and Langenheim (1985), who extensively studied this outcrop (Figure 19) and others on the western side of the basin, described the following 12 beds.
Bed description

Shumway cyclothem

12 Sandstone, up to 12 m, medium- to fine-grained. Base channelled as much as 4 m into underlying unit, top covered, base an abrupt contact.

11 Claystone and shale, 25 cm to 4.7 m, gray, slightly silty, non-calcareous, siderite concretions.

10 Shumway Limestone Member: Limestone, 29 to 33 cm, dark gray to medium-gray, uppermost 8 cm grain-supported calcarenite, micrite and argillaceous matrix; slabby to thin-bedded; lower 16 cm mud-supported micrite; single massive bed. Bed is abundantly fossiliferous with brachiopod and echinoderm debris dominant.

Figure 19. Stratigraphic column of the upper part of Omega cyclothem and the lower part of the Shumway cyclothem at Stop 2. LSL = "Lake Sara" limestone. SLM = Shumway Limestone Member. Column headers: formation (F), member or bed (M), Wanless and Weller cyclothem (W), and modified cyclothem (C).
40

Shumway Limestone Member: Shale, 0 to 24 cm, gray; calcareous; fossiliferous; brachiopods, pectinoids, oxidized plant debris; locally black.

“Teutopolis” shale, shale, 86 cm to 1.4 m, black; fissile; basal 37 cm (approx.) blocky to poorly fissile, with abundant shell fragments; base abruptly gradational.

“Lake Sara” limestone, limestone, 6 to 30 cm, dark- to medium-gray; uppermost 3 to 4 cm grain supported fossil hash in silty, calcareous to carbonaceous matter; middle portion massive, bioturbated limestone with well-preserved, unabraded shells; basal 3 cm abundantly argillaceous, with carbonaceous debris and coaly material; fossils abundant.

Shale, 5 to 7 cm, gray to black, calcareous, abundant fusain and vitrain fragments, sand-sized fossil debris.

Omega cyclothem

Watson Coal Bed, 1 to 11 cm, coal, vitrain dominated, thin fusain laminae; limestone lenses as much as 1.5 cm thick containing diverse fossil fragments, carbonaceous debris and silt sized quartz grains.

Claystone (underclay), up to 2 m, medium to light gray; non-calcareous, Stigmaria sp. rootlets.

Limestone (underclay limestone), very fine-grained, green-gray, fecal pellets, corroded ostracodes and bivalves, birds-eye texture.

Shale, dark gray to variegated, abundant oxidized plant debris.

Siltstone and sandstone, laminated, burrowed both vertically and horizontally.

Beds 1 through 11 comprise the Shumway cyclothem as perceived by Wanless and Weller. Cyclothem modification (Weibel, 1988; Weibel and others, 1989) has resulted in beds 1 through 5 being assigned to the Omega cyclothem and the remainder to the Shumway cyclothem.

The upper Omega cyclothem is no longer very well exposed at this locality. The beds were deposited during the later stages of the progradation of coastal plain-deltaic sediments that began after regression of the marine water that deposited the underlying Omega Limestone. Scheihing and Langenheim (1985) interpreted the depositional environments for beds 1 to 4 as occurring in channels and associated floodplains of an alluvial-deltaic plain environment. Bed 3 was interpreted to represent a lacustrine deposit. Bed 4, an underclay paleosol, is separated from the overlying coal bed by a stratigraphic discontinuity. The thin coal suggests a relatively short life for the peat swamp. Occurrence of limestone lenses containing abraded marine fossils within the coal indicates that the coal probably formed just prior to the subsequent transgression, which initiated deposition of the Shumway cyclothem. Scheihing and Langenheim (1985) considered these limestone lenses to possibly be deposited by storm-washed sediments into local depressions in the peat swamp. It is also possible that
these lenses represent rip-up clasts (an early stage ravinement?) as the marine waters flooded the peat swamp.

The marine flooding surface, a stratigraphic discontinuity, is marked by deposition of an abundantly calcareous and carbonaceous shale which contains abraded, diverse marine fossils (the ravinement proper). As the transgression continued, calcareous mud was deposited in water deep enough for deposition of the "Lake Sara" bed which contains a diverse fauna of fusulinids, corals and brachiopods. The fossils are abraded and transported in the lower part of the bed, but are unabraded and well-preserved in the upper part.

As the transgression deepened, anaerobic conditions developed and the black, fissile "Teutopolis" shale was deposited. This shale is characteristic of black, fissile marine shales of the Virgilian in the Illinois Basin. It contains a restricted fossil assemblage; productoid and inarticulate brachiopods are abundant at the base but decrease in number upward. In the middle portion of the bed, the fossils are predominately nektonic, consisting of fish scales and conodonts. The upper portion is essentially devoid of fossils. As aerobic conditions returned, black shale deposition was replaced by gray shale, containing sparse brachiopods and pectinoids. The overlying Shumway Limestone Member records shoaling and regression; it consists of a mud-supported calcilutite grading upward into an argillaceous, grain-supported calcarenite. The limestone textures and the abundant, diverse, fragmented, marine fossils indicate deposition in a shallow water, open marine environment. As regression ensued, prograding coastal plain-deltaic sediments overwhelmed the Shumway Limestone. The uppermost bed (12) is not well exposed, but was interpreted by Scheihing and Langenheim (1985) to be deposited in a fluvial channel.

The Watson Coal Bed (formerly referred to as the "Shumway Coal") here is only a few cm below the "Lake Sara" limestone, but according to R. Peppers (personal communication, in Scheihing, 1978), it biostratigraphically correlates with the Watson Coal at its type locality about 14 miles to the south. The Watson Coal at that site, however, is about 2 m below the "Lake Sara" limestone, indicating either that the coals are not quite contemporaneous, or that post-peat swamp, pre-marine inundation, depositional events are locally variable.

The "Lake Sara" limestone is restricted to western outcrops of the Shumway cyclothem, being reported between Watson and Mason along the Little Wabash River in south-central Effingham County (Scheihing and Langenheim, 1985), as well as in wells logged in northwestern Effingham County (Weibel, 1988). This limestone has also been referred to as the "lower Shumway Limestone" (Weller and others, 1942).

The "Teutopolis" shale, the most widespread member of the Shumway cyclothem, has been recognized in many coal exploratory wells in the region (Weibel, 1988). The "Ingraham" shale of the overlying Bogota cyclothem (not seen on this field trip) is also widely recognized in the subsurface.
Because these shales are readily recognized on gamma ray logs while adjacent limestones are not, these shales delineate the lower boundaries of the Shumway and Bogota cyclothems in the subsurface where wells with gamma ray logs are present. Fortunately, gamma ray logs are available for most of the study area.

The Shumway Limestone Member, formerly restricted to bed 10 of the section at this locality (Kosanke and others, 1960; Scheihing and Langenheim, 1985), has been expanded to include the gray calcareous shale of bed 9 (Weibel, 1988; Weibel and others, 1989). Given the substantial lateral irregularity of the shale and limestone, it is more convenient to separate the "Teutopolis" shale and Shumway Limestone Member on the basis of gray versus black shale. In this way, all rocks in the basal part of the Shumway cyclothem may be consistently assigned to defined and named rock units. The Shumway Limestone Member averages 32 cm thick where present, is reduced to a layer of nodules in the southern half of the outcrop area, and is absent in wells logged in the northern half of the field trip area. It apparently is at its maximum thickness at this locality.

Scheihing and Langenheim (1978a, 1978b, 1980) described 43 invertebrate taxa from their beds 6 to 10, which comprise the marine portion of the sequence. Their work, coupled with that of Dunbar and Henbest (1942), who described Triticites pauper and T. turgidus, Cooper (1946), who described the ostracode fauna, Tucker (1976a), who described the nautiloids, and Tucker and Paukstis (1977), who described a conulariid, make the Shumway fauna by far the most thoroughly described and illustrated normal marine fauna from the Illinois Basin. If Tucker's (1976b) faunal list and Scheihing and Langenheim's (1985) list of undescribed taxa are taken into account, the Shumway fauna at this stop includes well over 100 invertebrate species:

<table>
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<th>Taxon</th>
<th>Bed:</th>
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<th>9</th>
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<tr>
<td>Triticites pauper Dunbar and Condra</td>
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<td>T. turgidus Dunbar and Condra</td>
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<tr>
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<tr>
<td>(?) Trigonoglossa cf. T. nebrascensis</td>
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<tr>
<td>Enteletes hemiplicatus (Hall)</td>
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Rhipidomella carbonaria (Swallow) x T
Derbyoides nebrascensis Dunbar and Condra x T
Derbyia (?) crassa (Meek and Hayden) x x x S,T
Lissochonetes geinitzianus (Waagen) x S,T
Quadrochonetes geronticus Dunbar x S
and Condra
Neochonetes cf. N. granulifer (Owen) x S,T
Hystriculina texana Muir Wood and Cooper x x S
Kozlowskia splendens (Norwood and Pratten) x T
Retaria lasallensis (McChesney) x S,T
Echinaria sp. x T
Pulchratia symmetrica (McChesney) x S
Juresania symmetrica (McChesney) x T
J. nebrascensis Dunbar and Condra x x S
Antiquatonia cf. A. portlockiana (Norwood and Pratten)
Reticulatia huecoensis (King) x T
(?) Linoproductus sp. x S
Cancrinella boonensis (Swallow) x S
Cancrinella sp. x S
Wellerella tetrahedra Dunbar and Condra x S
W. osagensis (Swallow) x T
Hustedia mormoni (Marcou) x T
Cleiothyridina atrypoides (Girty) x T
Composita argentea (Shumard) x S
C. subtilita (Hall) x S,T
Crurithyris planoconvexa (Shumard) x x x S
Neospirifer dunbari dunbari R. H. King x S
N. dunbari gibbosus Dunbar and Condra x T
N. triplicatus (Hall) x T
Punctospirifer kentuckyensis (Shumard) x T
GASTROPODA
Euphemites carbonarius (Meek) x x S,T T
(?) Glabrocinctulum grayvillense x T
(Worthern and Pratten)
G. sp. x S
Pharkidonatus percarinatus (Conrad) x T
Straparollus (Amphiscaea) subrugosus x S
(Meek and Worthen)
S. subquadратus Meek and Worthen x T
Trepospira depressa (Cox) x T
Wortenia tabulata (Conrad) x T
Bellerophon stevensianus (McChesney) x T
Shansiella sp. x T
S. broadheadi (?) (White) x S
Leptopsis sp. x T
Ianthinopsis paludaеformis (?) (Hall) x S,T
I. primogenius (Conrad) x T
(?) I. sp. x S
Meekospira sp. x T
Stephanocyga sp. x T
CEPHALOPODA
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<td>Pseudorthoceras knoxense (McChesney)</td>
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<td>x</td>
<td>S</td>
<td></td>
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</tr>
<tr>
<td>Mooreoceras normale (?) Miller, Dunbar and Condra</td>
<td>x</td>
<td></td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. sp.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Brachycycloceras dilatum (Meek and Worthen)</td>
<td>x</td>
<td></td>
<td>T</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>B. normale Miller, Dunbar and Condra</td>
<td>x</td>
<td></td>
<td>T</td>
<td></td>
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<tr>
<td>Tainoceras monilifer Miller, Dunbar and Condra</td>
<td>x</td>
<td></td>
<td>T</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>T. sexilineatum Tucker</td>
<td>x</td>
<td></td>
<td>S,T</td>
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<tr>
<td>Cooperoceras sp.</td>
<td>x</td>
<td></td>
<td>T</td>
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<tr>
<td>Metacoceras copei Tucker</td>
<td>x</td>
<td></td>
<td>T</td>
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<tr>
<td>M. mcheshneyi Murphy</td>
<td>x</td>
<td></td>
<td>T</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Domatoceras mattoonensis Tucker</td>
<td>x</td>
<td></td>
<td>T</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stearoceras involutum Tucker</td>
<td>x</td>
<td></td>
<td>T</td>
<td></td>
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</tr>
<tr>
<td>Solenochilus shumwayense Tucker</td>
<td>x</td>
<td></td>
<td>T</td>
<td></td>
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<tr>
<td>Lioceras lilatum (Girty)</td>
<td>x</td>
<td></td>
<td>T</td>
<td></td>
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<tr>
<td>Ephippioceras moinei Tucker</td>
<td>x</td>
<td></td>
<td>T</td>
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<td></td>
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<tr>
<td>Gonioloboceras sp.</td>
<td>x</td>
<td></td>
<td>T</td>
<td></td>
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<tr>
<td>Eoasinite sp.</td>
<td>x</td>
<td></td>
<td>T</td>
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**BIVALVIA**

<table>
<thead>
<tr>
<th>Taxon</th>
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<tbody>
<tr>
<td>Nuculans</td>
<td>x</td>
<td>S</td>
</tr>
<tr>
<td>(?) Lithophaga subelliptica Sayre</td>
<td>x</td>
<td>S</td>
</tr>
<tr>
<td>Volscinella subelliptica Newell</td>
<td>x</td>
<td>S</td>
</tr>
<tr>
<td>(?) Promytilus annosus var. annosus Newell</td>
<td>x</td>
<td>S</td>
</tr>
<tr>
<td>Streblocnida sp.</td>
<td>x</td>
<td>S</td>
</tr>
<tr>
<td>Euchondria levicula Newell</td>
<td>x</td>
<td>S</td>
</tr>
<tr>
<td>Pectinsis</td>
<td>x</td>
<td>S</td>
</tr>
<tr>
<td>Pernopecten attenuatus (?) (Herrick)</td>
<td>x</td>
<td>S</td>
</tr>
<tr>
<td>P. ohioensis Newell</td>
<td>x</td>
<td>S,T</td>
</tr>
<tr>
<td>Lima retifer Shumard</td>
<td>x</td>
<td>S</td>
</tr>
<tr>
<td>Astartella concentrica (Conrad)</td>
<td>x</td>
<td>S</td>
</tr>
<tr>
<td>A. compacta Girty</td>
<td>x</td>
<td>S</td>
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<tr>
<td>Wilkingia costatum (Meek and Worthen)</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Palaeolis taffiana (Girty)</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Nuculopsis girtyi Schenck</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Placunopsis carbonaria Meek and Worthen</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Monopteria longa (Geinitz)</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Edmondia ovata Meek and Worthen</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Palaeolima retifer (Shumard)</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>P. equistriata (Boebe)</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Fasciulacncha knighti Newell</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Phastia bellistriatus (Stevens)</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Paralleloodon sangamonensis (Worthen)</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>P. obsoletus (Meek)</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Schizodus sp.</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Solenomya subelliptica (Meek)</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Acanthopecten carboniferus (Stevens)</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Pteronites sp.</td>
<td>x</td>
<td>T</td>
</tr>
<tr>
<td>Modiolomorpha sp.</td>
<td>x</td>
<td>T</td>
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</tbody>
</table>

**SCAPHOPODA**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Presence</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Prodentatium sp.</td>
<td>x</td>
<td>T</td>
</tr>
</tbody>
</table>
**PELMATOZOANS**

Columnals  

**ECHINOIDEA**  
(?) Archaeocidaris sp.  

**OSTRACODA**  
Unidentified ostracodes  

**TRILOBITA**  
Ditomopyge scitula (Meek and Worthen)  
Ameura sp.  

**ANNELIDA**  
Serpulopsis sp.  

**VERTEBRATA**  
Fish scales  
Listrocanthus sp. (spines)  

This list has been compiled from lists by Scheihing and Langenheim (1985) and Tucker (1976a, b) without altering their systematic conclusions. Specimens listed by Scheihing and Langenheim are labeled "S"; those from Tucker are labeled "T"). All of Tucker’s specimens are from the lower part of the Shumway Limestone (bed 10). Those from Scheihing and Langenheim’s list are diversely collected from beds 6 through 10 of the Shumway type locality. Most of the Scheihing and Langenheim taxa and the cephalopods and conulariid of Tucker have been systematically described and illustrated. The bulk of Tucker’s taxa are taken from unsupported species lists. Critical comparison of the collections doubtless would reveal substantial duplication.

Correlation of the Shumway marine sequence with the Kansas section has ranged from uppermost Missourian through middle Virgilian (for a review, see Weibel and others, 1989). Neither fusulinid (Weller and others, 1942) nor ostracode (Cooper, 1946) studies were definitive. Scheihing and Langenheim (1980) and Langenheim and Scheihing (1983), after analyzing joint occurrences of brachiopods at Shumway and in the Kansas section, as well as considering other paleontologic data, concluded that the Shumway best correlates with the Oread Limestone. They (Scheihing and Langenheim, 1978b) also quoted Wanless (personal communication, 1962) as correlating the Shumway black shale ("Teutopolis" shale) with the Heebner Shale Member of the Oread Limestone. Weibel (1988) utilized several lithostratigraphic criteria and also correlated the Shumway cyclothem with the Oread. Recent conodont study (see paper by Heckel and Weibel) has confirmed these correlations.

**STOP 3: Stratton and Weibel: Cyclothem BM1 (Millersville-Livingston Limestone Member).**

Location: Charleston Stone Company Quarry. Approximately 3.5 miles east of Charleston, just north of Illinois Rte. 16, along both sides of the Embarras River. The quarry is mostly within the W¼, Section 5, T. 12 N., R. 10 E., and in Section 32, T. 13 N., R. 10 E., but the strata will probably be examined in the SW¼, NW¼, Section 5, T. 12 N., R. 10 E., Ashmore 7.5’ Quadrangle, Coles County.
The Livingston-Millersville Limestone Member is the key bed marking the top of the Bond Formation and is the thickest Pennsylvanian carbonate unit in the Illinois Basin. Exposures of the Livingston Limestone in Coles County are about 6.5 m thick, but Clegg (1959) reported the limestone to be 15 m or more westward in the Coles County subsurface. Dunbar and Henbest (1942) recognized the fusulinid *Triticites ohioensis* in both the Livingston Limestone and the Millersville Limestone Members; *T. ohioensis* is present in the limestone at this quarry. There is some question as to the proper naming of the limestone at this quarry. West of the LaSalle anticlinal belt, the limestone is referred to the Millersville Limestone, whereas east of the structure, the limestone is referred to Livingston Limestone (Kosanke and others, 1960). The Charleston Stone Quarry, however, is located within the LaSalle Anticlinal Belt. For this stop description, Livingston Limestone will be used because of its use by local geologists.

Neither the Livingston nor the Millersville cyclothems have been precisely defined nor widely used. The Livingston cyclothem was originally named by Ball (1943) for strata in northeastern Macoupin County that he correlated with the Livingston Limestone Member, first described by Worthen (1875) in Clark County. These strata later were correlated correctly with the Shoal Creek cyclothem (Ball, 1952), although Weller and others (1942) correctly used the name. The Millersville cyclothem has only been introduced in a list of cyclothems by Wanless (1956). Weibel (1991) referred to the interval in a core from Wayne County that includes the stratigraphic position of the Livingston-Millersville Limestone Member as cyclothem BM1. This interval, at that locality, is over 80 feet thick and consists of a basal thin marine unit (black shale bed and overlying calcareous mudstone bed), a relatively thick succession of sandstone, siltstone and shale beds, and the uppermost beds of two pairs of underclay-coal beds separated by a thin clastic interval. Weibel (1991) informally referred to the cyclothem because of difficulty in recognizing the Millersville-Livingston Limestone Member in Wayne County. Ongoing study of conodonts from the marine unit in this core should resolve uncertainties in the correlation.

The Livingston Limestone Member, and perhaps an exposure of the underlying black fissile shale, will be the only beds examined at this stop. The black fissile shale overlies the coal of the underlying cyclothem; the coal is approximately 15 cm thick in a pit at the northwest corner of the quarry property. Giffin (1978) examined the black fissile shale bed at several nearby locations and described a "dwarf" fauna of conodonts, bryozoans, "dwarf" crinoids, ostracodes, and fish denticles. It also crops out at in the northwest corner of the quarry property.

The Livingston Limestone consists of a lower limestone bed, a middle shale, and an upper limestone bed (Figure 20). Giffin (1978) recognized two major facies within the Livingston Limestone, a shelf mud facies, consisting of the middle shale, and an algal bank facies, found in both the lower and upper limestone beds.
The lower bed of the Livingston is a medium bedded, light gray calcisiltite which grades into a biocalcarenite. Shale partings with limestone nodules are common near the top of the lower unit. Vugs, stylolites, and sparry calcite stringers are common. Fossils include brachiopods, bryozoans, and crinoid columnals. Giffin (1978) recognized a phylloid algal bank facies with associated calcarenitic beds of fragmented, abraded Osagia-coated skeletal grains. The coarsening upward succession suggests that the bed is a regressive limestone.

The middle shale consists of thin beds of massive greenish-gray, silty, calcareous clay. Generally, the unit ranges from 50 to 90 cm thick and is abundantly fossiliferous. Thin fossiliferous limestone beds occur in the uppermost 35 cm of the shale. This shale contains the majority of the diverse normal-marine fauna of the Livingston Limestone Member (see below). Giffin (1978) interpreted this bed as a shelf mud facies, consisting of a heterogeneous mixture of terrigenous and carbonate lithologies. Horne (1965) mapped this bed and interpreted it as prodeltaic muds from a clastic wedge that thickened to the east and southeast. Bioturbation is extensive in the upper portion of the shale facies. This unit yields the most diverse, abundant and best preserved marine faunas in the Illinois Basin. Slow deposition of the shaly facies is suggested by the large number of suspension feeders in the fauna. The reason for the excellent preservation of the community is unknown; perhaps a storm-related event resulted in a rapid burial.

The upper bed of the Livingston comprises one meter of massive, mottled calcarenite grading into 75 cm of light gray to greenish gray nodular calcisiltite. Vugs and spar-filled stringers are common throughout the upper unit. Fossils include crinoid columnals, brachiopods, and bryozoans. Giffin (1978) also interpreted a phylloid algal bank origin for this bed, a common explanation for the Late...
Pennsylvanian limestones in the Midcontinent region (Welch, 1977). Giffin (1978) further recognized four subfacies within the algal bank facies based on abundance of fossil allochems, micritic matrix, replacement by dolomite, insoluble residues, and field characteristics. Both the upper and lower limestones of the Livingston Limestone at the quarry represent Giffin’s (1978) algal mud subfacies. He characterized this subfacies as a massive bedded calcilutite or calcisiltite with sparry calcite stringers parallel to bedding.

The absence of an obvious stratigraphic discontinuity between the limestone beds at the quarry is surprising because (1) near the Illinois-Indiana border, an interval consisting of underclay, coal, and black, fissile shale between the limestone beds has been reported, and (2) study of conodonts from the shales underlying the lower and upper Millersville limestones in the Charleston core (see paper by Heckel and Weibel) indicates two transgressive-regressive sequences. Additional biostratigraphic and lithostratigraphic studies are needed to resolve this complexity.

*Composita* is the most common taxon comprising the fauna of the Livingston Limestone. An analysis of the fauna indicates that it is representative of an abundant, diverse normal marine fauna. Preservation of taxa is excellent and the presence of immature and juvenile forms suggests little surface abrasion or extensive post-mortem transportation. Large fenestella fronds, articulated crinoids, and intact brachiopod spines indicate an absence of strong wave action. Most of the taxa are suspension feeders, indicating little turbulence, but are close enough to shore for current action to supply nutrients to the benthic community (Peters, 1985).

The following list contains the majority of taxa that have been identified from the Livingston Limestone at the Charleston Stone Quarry.

**PROTISTA:**
- *Triticites ohioensis*

**PORIFERA:**
- *Reniera*
- *Hexactinellida*
- *Geodites*

**COELENTERATA:**
- *Lophophyllidium proliferum*

**BRACHIOPODA:**
- *Orbiculoidea missouriensis*
- *Dervbia crassa*
- *Chonetinella flemingi*
- *Kozlowskia splendens*
- *Reticulatia huecoensis*
- *Hustedia mormoni*
- *Neospirifer dunbari*
- *Punctospirifer kentuckensis*
- *Crurithyris planoconvexa*
- *Composita subtilita*
- *Composita ovata*
Mesolobus mesolubus
Antiquatonia
Linoprodactus
Juresania
Spirifer
Neospirifer triplicatus
Neospirifer cameratus
Solemya

BRYOZOA:
Fistuliporid
Tabulipora
Rhomboopora lepidodendroides
Polypora
Septopora
Fenestella

BIVALVIA:
Acanthopecten carboniferus

GASTROPODA:
Glabrocinquium grayvillense
Platyceras

CEPHALOPODA:
several unidentified species

TRILOBITA:
Ameura
Ditomopyge

CRINOIDEA:
Apographiocrinus typicalis
Erisocrinus typus
Euonychocrinus simplex
Elbatocrinus elegans
Stellarocrinus virgilensis
Pollusocrinus avanti
Terpnocrinus ocoyaenis
Clathrocrinus clinatus
Endelocrinus tumidus spinulosus
Microcaracrinus conjugulus

CONULARIIDAE:
two unidentified species

VERTEBRATA:
Petalodus
Ctenoptychius
Fissodus
Deltodus
Helodus
Orodus
Azzigodus
Cladodus

The quarry has long been a favorite area for fossil collectors, both amateur and professional. Several theses and publications have been generated from studies at the quarry (Gilliam, 1973; Gilliam and Schram, 1975; Giffin, 1978; Peters, 1985; Stratton and Horowitz, 1986; Meyerholtz and Stratton,
1987; Stratton and Horowitz, 1987; and Peters and Lane, 1990). The Department of Geology and Geography at Eastern Illinois University maintains a comprehensive fossil collection for study by interested professionals. The material is available for loan.

STOP 4: Weibel: Lower Greenup cyclothem.

Location: East bank along Embarras River, 0.2 mile north of Ryan Bridge, 1500 ft FWL, north edge, Section 2, T. 10 N., R. 9 E., Toledo 7.5' Quadrangle, Cumberland County.

Newton and Weller (1937) named the Greenup cyclothem for exposures near the village of Greenup, east-central Cumberland County. As originally defined, the cyclothem consisted of an ascending sequence of sandstone/sandy shale, fossiliferous limestone (Greenup Limestone Member), and calcareous sandstone/"poorly bedded" shale. Weibel (1988) and Weibel and others (1989) redefined the cyclothem to include strata from the base of the Greenup Limestone Member up to the base of the "Graveyard Hill" shale of the Toledo cyclothem. Approximately 2.5 m of gray shale separate the limestone from this shale. The "Graveyard Hill" shale, however, may be a restricted marine or a brackish water deposit and therefore may not be the record of the flooding surface. Additional study of this shale and associated strata may result in the revision of these cyclothems.

The Greenup Limestone Member is recognized only in Cumberland County. The bed is a gray, moderately fossiliferous, phylloid algal limestone. Fusulinids dominate the upper and lower parts with brachiopods, corals, and gastropods in the middle. The limestone nodules within shale at the very base of the Greenup petrographically are an Osagia-encrusted, pelecypod, pelmatozoan, grain-supported biocalcarenite. The nodules mark the flooding surface of marine waters transgressing over coastal plain sediments. The mixture of clastic sediments and abraded marine fossils indicate some erosion of the pre-existing shale occurred, resulting in a stratigraphic discontinuity. The succeeding massive portion consists of a complex association of three microfacies: (1) a clastic microfacies grading from biocalcisiltite with scattered bioclasts, into matrix-supported biocalcarenite, and into grain-supported biocalcarenite; (2) a compacted, phylloid algal, bioaccumulated limestone; and (3) a phylloid algal, biococonstructed limestone. The top of the unit is intraclastic, pisolithic, neomorphosed limestone, with features diagnostic of a paleosol, and a definitive stratigraphic discontinuity.

This exposure of the Greenup cyclothem (Figure 21) demonstrates that the presence of coal is not essential for recognition of a cyclothem. Weller (1930), revealing a bias toward cyclothsems containing a coal, had rejected the transgressive flooding surface as the (Wanless and Weller) cyclothem boundary because "marine beds do not succeed all of the coal in most areas." Use of a cyclothem consisting of a marine-terrestrial succession nullifies Weller's restrictive reasoning. Coal beds, however, are useful in subsurface studies where the overlying marine strata are not recognizable, unless core or cuttings samples are available. Unrecognizable marine strata are thin limestones and calcareous shales,
which are not detectable on standard self-potential and resistivity logs, and black, fissile shales, which commonly overlie coals in the Illinois Basin but are identifiable only on gamma-ray logs.

Dunbar and Henbest (1942) described Triticites mediocris, T. mediocris var. angustus, and T. callosus from the Greenup Limestone, but did not collect at this locality. Other fossils in the limestone include: Lophophylidium sp., Phricodithyris? sp., Crurithryis planoconvexa, Astartella sp., Punctospirifer kentuckensis, Trachydomia sp., Derbyia sp., Ditomopyge? sp., Natocoptis? sp., Hustedia mormoni, Wellera osagensis, Platyceras (Orthonychia)? sp., fistuliporoid bryozoa, calcareous algae, and pelmatozoa.

Location: Exposures in an eastward draining tributary to the North Fork of the Embarras River in the SW¼, Section 2, and the SE¼, Section 3, T. 9 N., R. 14 W., Casey 7.5' Quadrangle, Clark County.

The outcrops in this tributary offer a rare opportunity to view several cyclothems in a single traverse, including exposures of the basal sandstone of the Wanless and Weller cyclothem. Newton and Weller (1937) first described seven (Wanless and Weller) cyclothems in this tributary and in a parallel tributary about 1 mile to the south. The following is a reproduction of their description of the section (p. 10-11, Newton and Weller, 1937).

<table>
<thead>
<tr>
<th>Thickness</th>
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<th>Inches</th>
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<tbody>
<tr>
<td>LaSalle cyclothem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandstone, thin-bedded, basal member of this cyclothem</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Macoupin cyclothem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shale, brownish-gray, very slightly silty, laminated, closely jointed, small ironstone concretions</td>
<td></td>
<td>10-15</td>
</tr>
<tr>
<td>Limestone, nodular in part with abundant shell fragments, especially Ambocoelia</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Shale, medium dark gray, very fossiliferous with Ambocoelia, Phanerotrema gravillensis, and Chonetes</td>
<td></td>
<td>2 6</td>
</tr>
<tr>
<td>Shale, black, thinly laminated, rather brittle, with a few fossils</td>
<td></td>
<td>2 9-10</td>
</tr>
<tr>
<td>Coal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layer Description</td>
<td>Depth (ft)</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------</td>
<td>------------</td>
<td></td>
</tr>
<tr>
<td>Underclay, medium dark gray to olive gray, with some calcareous nodules in</td>
<td>7-9</td>
<td></td>
</tr>
<tr>
<td>lower 18 inches.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shale, yellowish-brown to bluish-gray, nonsilty to slightly sandy.</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Coaly streak, not persistent.</td>
<td>2/3</td>
<td></td>
</tr>
<tr>
<td>Underclay, medium gray, sandy.</td>
<td>6-18</td>
<td></td>
</tr>
<tr>
<td>Shale, gray, sandy, soft.</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Sandstone, shaly and thin-bedded, and sandy shale.</td>
<td>10±</td>
<td></td>
</tr>
</tbody>
</table>

**Flannigan cyclothem**

<table>
<thead>
<tr>
<th>Layer Description</th>
<th>Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shale, gray, soft, silty to slightly sandy, with large flattened ironstone</td>
<td>20±</td>
</tr>
<tr>
<td>concretions in lower part.</td>
<td></td>
</tr>
<tr>
<td>Coal.</td>
<td>1</td>
</tr>
<tr>
<td>Underclay, olive green to greenish-gray, with some slickenside surfaces and</td>
<td>6</td>
</tr>
<tr>
<td>calcareous nodules.</td>
<td></td>
</tr>
<tr>
<td>Limestone, impure, nodular, &quot;fresh-water&quot; type.</td>
<td>1</td>
</tr>
<tr>
<td>Shale, light bluish-gray, very sandy with irregular bedding.</td>
<td>6</td>
</tr>
<tr>
<td>Sandstone, fine grained, micaceous, and sandy shale, grading into under-</td>
<td>4-5</td>
</tr>
<tr>
<td>lying shale.</td>
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</table>

**Shoal Creek cyclothem**

<table>
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<th>Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shale, greenish-gray to medium-gray weathering a rusty brown color, lower 6</td>
<td>15</td>
</tr>
<tr>
<td>feet containing medium to large calcareous ironstone nodules.</td>
<td></td>
</tr>
<tr>
<td>Limestone, weathering a rusty brown color, massive, dense to crystalline,</td>
<td>2 1/2-3</td>
</tr>
<tr>
<td>conglomeratic in upper 1 foot, very fossiliferous with crinoid stems in abundance</td>
<td></td>
</tr>
<tr>
<td>(fig. 3).</td>
<td></td>
</tr>
<tr>
<td>Shale, greenish-gray, fossiliferous with black pebbles at base.</td>
<td>4-8</td>
</tr>
<tr>
<td>Shale, black, with gray clay streaks, hard, somewhat slaty, fossiliferous,</td>
<td>4</td>
</tr>
<tr>
<td>with gypsum crystals.</td>
<td></td>
</tr>
<tr>
<td>Coal, rather shaly.</td>
<td>1</td>
</tr>
<tr>
<td>Underclay, gray to greenish-gray with slickensides in upper part and secondary</td>
<td>4-7 1/2</td>
</tr>
<tr>
<td>calcite crystals in lower part.</td>
<td></td>
</tr>
<tr>
<td>Limestone, very impure, nodular &quot;fresh-water&quot; type.</td>
<td>1</td>
</tr>
<tr>
<td>Sandstone, buff to medium gray, fine grained and micaceous, with some sandy</td>
<td>4-5</td>
</tr>
<tr>
<td>shale.</td>
<td></td>
</tr>
<tr>
<td>Shale, drab to greenish-gray, very sandy.</td>
<td>15</td>
</tr>
<tr>
<td>Sandstone, thin-bedded to shaly.</td>
<td>10</td>
</tr>
</tbody>
</table>

**Collinsville cyclothem**

<table>
<thead>
<tr>
<th>Layer Description</th>
<th>Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, weathering reddish brown, crystalline, sandy in places, with</td>
<td>1</td>
</tr>
<tr>
<td>irregular upper surface, fossiliferous with Composita and productids most</td>
<td>10</td>
</tr>
<tr>
<td>abundant.</td>
<td></td>
</tr>
<tr>
<td>Shale, greenish-gray to drab.</td>
<td>2</td>
</tr>
<tr>
<td>Sandstone, thin-bedded.</td>
<td>6</td>
</tr>
<tr>
<td>Shale, sandy, light bluish-gray, with concretions.</td>
<td>20-25</td>
</tr>
<tr>
<td>Sandstone, thin-bedded to shaly, with much carbonaceous material.</td>
<td>8</td>
</tr>
</tbody>
</table>

**Tivoli cyclothem**

<table>
<thead>
<tr>
<th>Layer Description</th>
<th>Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, impure, nodular, very fossiliferous, with Ambocelia.</td>
<td>1</td>
</tr>
<tr>
<td>Shale, black, slaty, fossiliferous with Composita, Ambocelia, etc.</td>
<td>1</td>
</tr>
<tr>
<td>Shale, black, slaty to flaky with Rhombopora and crinoid stems.</td>
<td>1</td>
</tr>
<tr>
<td>Coal.</td>
<td>8-10</td>
</tr>
<tr>
<td>Underclay.</td>
<td>2±</td>
</tr>
<tr>
<td>Shale, gray, sandy.</td>
<td>4</td>
</tr>
<tr>
<td>Sandstone, hard, calcareous, thin-bedded, shaly, and sandy shale.</td>
<td>15-20</td>
</tr>
</tbody>
</table>

**Gimlet cyclothem**

<table>
<thead>
<tr>
<th>Layer Description</th>
<th>Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shale, gray, silty, with spheroidal weathering and flat ironstones.</td>
<td>30</td>
</tr>
</tbody>
</table>
The field trip will visit exposures of what Newton and Weller (1937) referred to as the Gimlet, Trivoli, and Shoal Creek cyclothems. Outcrops of the two cyclothems above the Shoal Creek have been examined but are too far upstream to visit on this trip. Exposures of the highest cyclothem, the LaSalle, have not been found in this ravine, but probably refer to the Livingston Limestone quarried in section 28, T.10 N., R. 14 W., about 4½ miles from here. Exposures of the marine unit of the Collinsville cyclothem have not been found in this ravine, but study of Newton and Weller’s field notes indicates that it may be exposed in the ravine to the south.

STOP 5A: North-facing cutbank, 1700 ft FWL, 500 ft FNL, SW/4, Section 2, T. 9 N., R. 14 W.

The marine unit in this exposure, consisting of a thin dark gray to black shale bed between two nodular limestone/calcareous shale beds, was not recognized by Newton and Weller (1937). It is possible that the lower portion of this outcrop (Figure 22) was not exposed when Newton and Weller examined this ravine over 50 years ago. Their description of the unit within their Gimlet cyclothem fits the upper part of this exposure. This marine unit has been biostratigraphically correlated, using conodonts recovered from the dark gray to black shale, with the Cramer Limestone Member, and adjacent marine strata, of the Modesto Formation (see paper by Heckel and Weibel). The Cramer Limestone is the upper limestone of a limestone-black shale-limestone interval exposed in Peoria County, western Illinois. This marine unit is part of the Trivoli cyclothem (Wanless, 1957), indicating a miscorrelation by Newton and Weller (1937). The marine unit within the Gimlet is the older Lonsdale-West Franklin marine unit and underlies the Trivoli. The Trivoli cyclothem has not been revised because it has not been examined at its type locality. In addition, revision would result in the Trivoli Sandstone Member being excluded from (below) a revised Trivoli cyclothem; this probably would require a new cyclothem name.

Stratigraphic discontinuities at the boundaries between these beds are not obvious, but such a discontinuity is interpreted to be present between the marine unit and the underlying dark gray mudstone. This boundary is represented by a flooding surface and a progradational fining-upward facies. This boundary is interpreted to be a parasequence boundary that separates the marine unit from the underlying dark gray mudstone.

Figure 22. Stratigraphic column of the cyclothemic interval containing the "Cramer" marine unit of the Modesto Formation at Stop 5A. Column headers: formation (F), member or bed (M), Wanless and Weller cyclothem (W), and modified cyclothem (C).
is the marine flooding surface, marking transgression over deltaic and prodeltaic muds. The relatively small thickness of this marine unit and the absence of any evidence of erosion of this unit indicates that the distal edge of the sediments deposited by the transgressing marine waters may not be that far to the east from this site. The high stand position of this transgression probably occurred within the dark gray to black shale. This inundation was relatively short-lived as coastal plain-deltaic sediments rapidly prograded over the upper limestone/calcareous shale, which records the regression.

This marine-flooding surface is not very distinctive lithologically and it may not be readily identifiable using subsurface data. Practical mapping may result in these two allostratigraphic units being undifferentiated in this area. Such a situation would be repeated with other cyclothems at the distal edges of the marine units where subsequent prograding coastal plain-deltaic sediments have preserved and not eroded the marine strata.

STOP 5B: North-facing cutbank, 700 ft FEL, 950 ft FNL, SW/4, Section 3, T. 9 N., R. 14 W.

This outcrop (Figure 23) is the best exposure of the unconformity at the base of the Wanless and Weller cyclothem in the study area. Newton and Weller (1937) presumably designated this sandstone as the basal unit of the Collinsville cyclothem and the underlying marine unit, coal and underlying strata within the Trivoli cyclothem. The discussion at Stop 5A indicates that this correlation is incorrect. This marine unit has been biostratigraphically correlated, using conodonts recovered from the black fissile shale, with a black fissile shale that underlies the Macoupin Limestone Member of the Modesto Formation (see paper by Heckel and Weibel). The Macoupin Limestone is not present here but Newton and Weller's description indicates that it probably is present in the ravine to the south. This marine unit is part of the Macoupin cyclothem (Ball, 1952) exposed in Macoupin County, west-southwestern Illinois. The Collinsville cyclothem of Newton and Weller (1937) has never been described elsewhere; the Collinsville
Limestone (name apparently abandoned) has been reported in western Illinois (Wanless, 1939) and may be equivalent to the Piasa Limestone Member of the Modesto Formation or a slightly younger limestone.

This exposure of the sandstone cutting down into the marine unit is an appropriate setting for a discussion of sequence boundaries. The boundary between cyclothems (equivalent to parasequences) is the marine flooding surface. A marine flooding surface is either a parasequence boundary, or a sequence set boundary, or both. The difference between a parasequence boundary and a parasequence set boundary has not been well defined. Van Wagoner and others (1990) described the boundaries as marine-flooding surfaces and its correlative surfaces versus major marine flooding surfaces and its correlative surfaces, respectively. They also stated that parasequence set boundaries separate distinctive parasequence-stacking patterns. These stacking patterns, i.e., progradational, retrogradational, and aggradational, cannot be readily recognized from isolated outcrops. Thickness trends of parasequences suggest that if parasequence-stacking patterns eventually are recognized, they will be either progradational or aggradational.

Recognition of a sequence boundary from isolated outcrops or cores also is difficult. A sequence boundary is an unconformity and its correlative conformity; it has chronostratigraphic significance (Ibid.). Regional study is required to identify a sequence boundary because it can range from a chronostratigraphically significant unconformity to a conformable surface. At this site, an unconformity is present, but its chronostratigraphic significance may not be determined until it has been laterally traced. Van Wagoner and others (1990) recognized four criteria for the unconformable part of a sequence boundary (type-1):

1. Evidence of erosional truncation or a laterally correlative subaerial exposure surface (paleosol).
2. Occurrence of coastal onlap or onlapping of overlying strata onto the margins of incised valleys.
3. Evidence of a downward shift in coastal onlap.
4. Regional evidence of one or more of the above.

It is obvious that a major fall in relative sea level is required to form a sequence boundary. One of the consequences of such a fall in sea level is the formation of incised valleys as fluvial channels eroded down into the underlying strata during the regression. The sandstone body exposed here is a portion of an incised valley/channel, which formed during the regression that deposited the underlying black fissile shale. Incised valley/channel formation is contemporaneous with the prograding coastal plain-deltaic sediments during sea level fall. Maximum valley/channel depth occurs when sea level has reached a lowstand. Complete infilling of these valleys/channels is initiated by a relative rise in sea level and sediment is no longer bypassed. Transgression is responsible for both the infilling channels and deposition of marine strata on the intervening areas between channels. Channel infills thus can record
a marine flooding event. The evidence for this event, however, often is not recognized and is not
differentiated from other channel infilling process, e.g. channel migration and avulsion.

STOP 5C: South-facing cutbank, 1350 ft FWL, 800 ft FNL, SW/4, Section 3 and north-facing
cutbank, 1200 ft FWL, 900 ft FNL, Section 3, T. 9 N., R. 14 W.

Newton and Weller (1937) referred to the stratigraphic interval exposed in these two cutbanks
(Figure 24) as the Shoal Creek cyclothem. The upper portion of this interval is the basal portion of a
modified cyclothem designated cyclothem B1 by Weibel (1991). The lower portion, beneath the marine
unit, is the upper part of an unidentified/unnamed cyclothem. The marine unit of cyclothem B1 has

![Diagram](image-url)

**Figure 24.** Stratigraphic column of the upper part of an unnamed cyclothem and the
lower part of the cyclothem BM1 at Stop 5C. CLM = Carthage Limestone Member.
Column headers: formation (F), member or bed (M), Wanless and Weller cyclothem (W),
and modified cyclothem (C).
been biostratigraphically correlated using conodonts recovered from the black fissile shale (see paper by Heckel and Weibel). The conodonts indicate correlation with a black fissile shale that underlies the Carthage Limestone Member of the Bond Formation at the type locality of the Shoal Creek Limestone (now preempted in favor of Carthage Limestone).

The sandstone bed in the lower part of the exposed interval is probably an infilled channel, but is probably not part of the incised valley represented by the sandstone bed at Stop 5B. The sandstone may be part of an unexposed, modified "Collinsville" cyclothem. Additional work in this area is required to determine the stratigraphic relationships of the interval between Stops 5B and 5C. Newton and Weller (1937) described an underclay and a thin coal beneath the marine unit of cyclothem B1. These beds are no longer not well exposed, but record soil formation on a coastal-deltaic plain succeeded by a peat-swamp. The marine-flooding surface is the top of the peat swamp. The overlying marine unit record the transgressive, highstand, and regressive events of the cyclothem. The Carthage Limestone has not been petrographically examined, but macroscopic study indicates that it is a coarsening-upward limestone, suggesting deposition during regression.


Location: South bank of Embarras River, in Newton, just north of cemetery, 850 ft FEL, 100 ft FNL, Section 1, T. 6 N., R. 9 E., Newton 7.5' Quadrangle, Jasper County.

Newton and Weller (1937) named the Newton cyclothem for strata cropping out in the vicinity of Newton, although they surprisingly did not refer to or describe this exposure (Figure 25). As originally defined, the cyclothem consisted of an ascending sequence of shale, "fresh-water" limestone, underclay, dark gray shale, "middle" limestone, black shale, and gray shale containing siderite concretions. Except for the "fresh-water" limestone and the underclay, these units are recognized here. The cyclothem designation, however, has been modified. The lower 1.5 to 2.5 m of strata at this exposure comprise the top of the modified Bogota cyclothem (Weibel, 1988; Weibel and others, 1989). Depending upon the river level, most of this strata is gray shale with interbeds of siltstone and very fine-grained sandstone. The top of the cyclothem is a dark gray, slightly calcareous mudstone containing myalinid pelecypods. The Newton cyclothem was modified to include strata from the base of the "Shamrock" Limestone Member up to the base of the "Dieterich" shale of the Mint Creek cyclothem (Ibid.). Only the lower part of the modified Newton cyclothem is exposed here; the upper part will not be examined on this field trip.

Needham (1931) defined the "Shamrock" Limestone Member as a gray, fossiliferous limestone cropping out near the village of Shamrock in southwestern Jasper County. Newton and Weller (1937), without citing Needham, designated an equivalent unit cropping out near Newton, as the "middle" limestone of the Newton cyclothem. Kosanke and others (1960) formally demoted the Newton
cyclothem and elevated only the limestone bed as a member of the Mattoon Formation. At the same time, the name "Newton" was abandoned because of preoccupation and replaced by the name "Reisner," after a school located near the type locality. Needham (1931), however, with his introduction of the name "Shamrock," has priority over both Newton and Weller (1937) and Kosanke and others (1960).

The upper portion of the Bogota cyclothem at this site is a record of coastal plain-deltaic sediments, which prograded basinward during the regression of the marine waters which had deposited the underlying Bogota Limestone Member of the Mattoon Formation (not examined on this trip). The upper boundary of the cyclothem is the marine-flooding surface at the base of the marine unit of the overlying Newton cyclothem. This marine-flooding surface is not on the top of a coal bed, which is commonplace in the basin, but is on top of coastal plain-deltaic deposits. Evidence of erosion of this surface by the transgressing marine waters has not been found; it is possible that the surface is also a paleotopographic surface.

The basal bed of the Newton cyclothem, the "Shamrock" Limestone, at this site and others, is texturally homogenous, lacking upward or downward grading. Pervasive bioturbation may have destroyed any primary depositional textures. Petrographically, the "Shamrock" is a is bioturbated, mud-supported biocalcarenite with an argilaceous, neomorphosed matrix. Brachiopod, encrusting foraminifer, and pelecypod bioclasts are abundant. Gastropod, pelmatozoan, and ostracode bioclasts are common; trilobites and Tuberitina are rare. Most bioclasts are encrusted by Osapia. The limestone locally is grain-supported. The contact between the "Shamrock" and the overlying "Wetweather" shale generally is gradational, but the transition occurs within a relatively thin interval. At this site, the contact is abrupt.

---

**Figure 25.** Stratigraphic column of the upper part of the Bogota cyclothem and the lower part of the Newton cyclothem at Stop 6. SLM = "Shamrock" Limestone Member. Column headers: formation (F), member or bed (M), Wanless and Weller cyclothem (W), and modified cyclothem (C).
The black, fissile "Wetweather" shale is generally less than 1 m thick and characterized by a pelecypod- and brachiopod-dominated, fossiliferous base and by the absence of large calcareous concretions. The middle and upper portions are sparsely fossiliferous with poorly-preserved pelecypods, coalified plant fragments, and fish fragments. After these sediments were deposited in an anaerobic environment, aerobic conditions simultaneously returned with the regression of the marine waters and progradation of coastal plain-deltaic sediments. These sediments, exposed in the upper part of this outcrop, have scattered, poorly preserved marine fossils (brachiopods and pelecypods), suggesting deposition in either prodeltaic or mud-dominated coastal marine environments.

The "Wetweather" shale differs from other Virgilian black shales in the basin in that it is relatively laterally restricted. The shale is recorded only on a few coal exploration well logs in northwestern Cumberland County and in the south-central part of the study area. The younger "Dieterich" shale, in comparison, is widespread, being recorded in most coal exploratory wells within its outcrop area.


Location: Drainage just west of county road, about 0.3 miles north of Montrose, 300 ft FEL, 900 ft FSL, Section 35, T. 9 N., R. 7 E., Teutopolis 7.5’ Quadrangle, Cumberland County.

This outcrop is similar to Stop 6, except that the interval exposed is not as thick.
CURRENT STATUS OF CONODONT-BASED BIOSTRATIGRAPHIC CORRELATION OF
UPPER PENNSYLVANIAN SUCCESSION BETWEEN ILLINOIS AND MIDCONTINENT

Philip H. Heckel and C. Pius Weibel

Introduction

Accurate correlation of Pennsylvanian strata among cratonic basins will provide a framework for (1) determining the lateral extent of marine incursions and resulting sedimentary environments and (2) determining relative rates of subsidence in different areas, which can lead to detecting and differentiating local versus regional tectonic effects and to determining rates of change in the evolution of depositional basins. The uppermost Middle and Upper Pennsylvanian succession in the Midcontinent outcrop belt (Iowa to Oklahoma) is characterized by a series of marine transgressive-regressive "stratigraphic sequences" bounded by terrestrial to deltaic deposits and paleosols, of which the sequences including widespread marine incursions have been recognized as cyclothems; these cyclothems have been reasonably shown to have resulted from glacial-eustatic rise and fall of sea level (e.g., Heckel, 1986, 1990). Detailed biostratigraphic correlation of individual cyclothems based on conodonts, ammonoids, and fusulinids has been established between the Midcontinent and north-central Texas (Boardman and Heckel, 1989). Ongoing work is establishing a similar conodont-based framework of correlation between the Midcontinent, the Illinois Basin, and north-central Texas (Heckel and others, 1991).

Early work on correlation of the Illinois Basin succession with other regions (Wanless, 1939; Weller and others, 1942; Cooper, 1946) emphasized Middle Pennsylvanian strata because the economic importance of the coals had led to a better understanding of the stratigraphy and paleontology within that part of the basin. In contrast, understanding of the succession of named units in the Upper Pennsylvanian evolved more slowly and was still uncertain within the state above the Shoal Creek (Carthage) Limestone Member of the Bond Formation as recently as Hopkins and Simon (1975). The succession above the Shumway Limestone Member of the Mattoon Formation has only more recently become definitely established (Weibel, 1988; Weibel and others, 1989).

Detailed collection of the succession of black to dark gray, commonly phosphatic, marine shales from the long core (Figure 26, middle) drilled to investigate the gas content of coal beds near Charleston, Illinois (Popp and others, 1979), has provided a vertical succession of distinct marine units containing abundant offshore conodont faunas for the east-central part of the Illinois Basin. Although detailed taxonomic analysis of the faunas is not yet complete, certain distinctive characteristics of the

Figure 26. Correlation of major marine units in upper three quarters of the Charleston core with the cyclic succession along the Midcontinent outcrop belt (slightly modified from Boardman and Heckel, 1989), and with outcrops in type areas of named marine units in Illinois, based on abundant conodont faunas (large-tailed oval symbols) in black to gray, often phosphatic shales. Solid lines indicate definite correlations, whereas dashed lines indicate compatible correlations (usually with sparse faunas—indicated by small symbols) and possible alternative correlations. The Shoal Creek marine unit includes the Carthage Limestone Member. The current Missourian-Virgilian boundary in Kansas is shown as a dashed line; the proposed revised boundary is shown as a solid line.
faunas, in conjunction with their vertical succession, allow correlation of these marine units with the classic cyclothem sequence along the Midcontinent outcrop belt (Figure 26, left), where the conodont faunas of similar shales have provided much of the basis for the Midcontinent—Texas correlation (Boardman and Heckel, 1989). In addition, preliminary study of the conodont faunas recovered from collections of similar shales in outcrop localities in Illinois, including several type localities of named marine units (Figure 26, right), has initiated the process of confirming (or revising) the vertical succession of named stratigraphic units in the uppermost Middle and Upper Pennsylvanian strata in the Illinois Basin.

The following is a summary of the distinctive aspects of the conodont faunas from marine units in the uppermost Middle and Upper Pennsylvanian portion of the Charleston core. The marine units are discussed in ascending stratigraphic order, and probable correlatives in Illinois and the Midcontinent are indicated. The taxonomic concepts of Barrick and Boardman (1989) are followed herein. Measurements of intervals in the Charleston core (ISGS County No. 22795, Core No. C12418) are based on footages marked on the core boxes. Popp and others (1979) correlated some of the coals and limestones in the core, presumably on the basis of relative stratigraphic position from key beds. In most cases, only the limestones of the marine portion of Pennsylvanian cyclothems have been named in Illinois. In cyclothems where the marine portions contain additional lithologies, the name of the marine limestone is applied herein to the entire marine unit. Cyclothem names of Kosanke and others (1960), are used in cases where other names are not currently available.

Lonsdale-West Franklin marine unit

The limestone from ~854 to 861 feet in the Charleston core was correlated by Popp and others (1979) with the West Franklin Limestone Member of the Modesto Formation. This limestone contains a thin gray shale at 859.1 to 860.3 feet, which yielded an abundant distinctive conodont fauna that is essentially identical with that described from a similar shale by J. W. Swade (unpublished data, University of Iowa) in the Lonsdale Limestone Member of the Modesto Formation from a locality between Galesburg and Peoria in western Illinois. This same fauna also was described by Swade (1985) from a shale below the Cooper Creek Limestone Member of the "Lost Branch" Formation of Iowa, and was utilized by Heckel (1991b) in correcting longstanding miscorrelations at the top of the Marmaton Group along the Midcontinent outcrop belt. This has resulted in the formal establishment of the Lost Branch as a new formation at the top of the Marmaton Group, which is at the top of the Desmoinesian Stage (and Middle Pennsylvanian Series) in the Midcontinent. This fauna contains the highest occurrences of the genus Neognathodus, Idiognathodus sp. 6 of Swade 1985, and Gondolella magna, and the only occurrence of platformless Gondolella (cf. G. denuda) in the Marmaton Group. Because faunas in marine horizons above the Lost Branch Formation and its correlatives are distinctly
different from those in the Lost Branch, and because palynofloras in coals above the Lost Branch and its correlatives are distinctly different from those in coals below the Lost Branch and its equivalents (Peppers, 1984), the Desmoinesian-Missourian Stage (hence Middle-Upper Pennsylvanian Series) boundary is currently recognized at the top of the Lost Branch Formation in the Midcontinent (Heckel, 1991b). This boundary in the Charleston core is between the top of the West Franklin Limestone and the base of a blocky mudstone that contains features characteristic of subaerial exposure.

Cramer marine unit

The next higher marine unit in the Charleston core consists of gray fossiliferous to black fissile shale from ~842.5 to 846.4 feet. This unit, which overlies the Chapel (No. 8) Coal Member and includes the position of the Cramer Limestone Member of the Modesto Formation, named from Peoria County in western Illinois, was not correlated by Popp and others (1979). The shales from 843.4 to 846.4 feet in the core contain an abundant conodont fauna that includes nodose forms of *Idiognathodus* such as *I. clavatulus*, as well as *I. lobatus*, which resembles Desmoinesian *I. delicatus*, but is recognized as distinct by Barrick and Boardman (1989). This fauna allows correlation of the Cramer marine unit with the Mound City Shale Member of the Hertha Limestone in the Midcontinent, which contains the same species; it also generally confirms the correlation of the Cramer Limestone (which typically overlies the dark shales in its type area) with the Sniabar Limestone Member of the Hertha, as suggested by Hopkins and Simon (1975). This fauna was also recovered from the dark gray to black shale in the lowest exposed marine unit at the Martinsville Dome transect (Stop 5) on this field trip. The absence of marine units between the Cramer unit and the underlying West Franklin Limestone below the paleosol in the Charleston core indicate that no marine equivalent to either the South Mound Shale Member of the Seminole Formation or the Exline Limestone of the Midcontinent are present in this part of Illinois.

Macoupin marine unit

The next higher marine unit in the Charleston core consists of black shale from 774.5 to 776.3 feet overlain by sandstone and limestone correlated with the Macoupin Limestone Member of the Modesto Formation (Popp and others, 1979). This black shale contains an abundant conodont fauna that includes the first appearance of *Streptognathodus cancellosus* and the only occurrence of *Gondolella denuda* in the Missourian part of the succession. This same fauna was recovered from black shale that underlies the type Macoupin Limestone near Carlinville, Illinois (see Schutter, 1983, p. 846), which confirms the correlation of the Macoupin horizon in the Charleston core. All critical elements of this fauna are found in the Hushpuckney Shale Member of the Swope Limestone, the next marine formation above the Hertha in the Midcontinent, indicating correlation of the Macoupin marine unit with
the Swope cyclothem. Our initial correlation of the marine unit above the Cramer in the Martinsville Dome transect (Stop 5) with the Macoupin on the basis of stratigraphic position is now confirmed by the recent recovery of *S. cancellosus* and *G. denuda* from the slaty black fissile shale.

Shoal Creek marine unit

The next higher marine unit in the Charleston core consists of black shale from 735.6 to 737.8 feet directly overlain by about 8 feet of limestone correlated with the Shoal Creek (Carthage) Limestone Member of the Bond Formation by Popp and others (1979). The black shale contains an abundant conodont fauna that is characterized by the first appearance of *Streptognathodus confragus*, and of a group of smooth surfaced *Idiognathodus* that includes *I. magnificus* and dominates the nodose forms that are common in older strata. These critical forms are present in a sample collected by R. J. Jacobson and C. B. Trask and processed by Schutter (1983, p. 838) from black shale below the Shoal Creek Limestone in its type area along Shoal Creek near Jamestown in Clinton County, Illinois, thus confirming the correlation of the Shoal Creek (Carthage) Limestone in the Charleston core. Although the Shoal Creek Limestone is now referred to as Carthage Limestone, the name Shoal Creek is retained for the entire marine unit within that cyclothem. This fauna is found also in the Stark Shale Member of the Dennis Limestone of the Midcontinent, the next major cyclothem above the Swope, which indicates correlation of the Shoal Creek marine unit with the Dennis cyclothem and confirms the correlation of the Shoal Creek (Carthage) Limestone with the lower part of the Winterset Limestone (the upper member of the Dennis) mentioned by Hopkins and Simon (1975). This fauna was also recovered from dark shale below the Shoal Creek (Carthage) Limestone in the Martinsville Dome transect (Stop 5) on this field trip.

"Fithian" marine unit

The next higher major marine unit in the Charleston core extends from 654.6 to 661.9 feet and consists of about 5 feet of gray to dark gray fossiliferous shale, with a black laminated layer, and overlain and underlain by layers of shaly limestone; this interval was not correlated by Popp and others (1979). The dark gray shale sample from 659.2 to 660.1 feet contains an abundant distinctive conodont fauna that includes a conspicuously large-lobed morphotype of *I. magnificus*, and the first appearance (in this core) of the more deeply troughed species of *Streptognathodus*, *S. elegantulus* and *S. gracilis*. The same fauna has been recovered from black shale in the Fithian cyclothem in its type area along Salt Fork (see Schutter, 1983, p. 893) in Vermilion County, Illinois; hence this name is used provisionally for this marine zone. The same fauna also characterizes the Quivira Shale Member of the Dewey Limestone (as revised by Heckel, ms. in review) of the Midcontinent, thus establishing correlation of the Fithian marine unit with the Dewey cyclothem. The Dewey is separated from the
Dennis by the Cherryvale Shale, which includes a marine cycle of intermediate lateral extent, where *S. elegantulus* and *S. gracilis* first appear in the Midcontinent. This lesser cycle may be represented between 698 and 705 feet in the Charleston core by sparsely fossiliferous marginal marine shales from which no conodonts were recovered.

**Lower Millersville marine unit**

The next higher marine unit in the Charleston core is the Millersville Limestone Member of the Bond Formation and associated shale, which consists of two limestones (often informally referred to as lower and upper Millersville) separated by 11 feet of dark gray shale. Both the lower and upper limestones of the Millersville will be seen at Stop 3. The lower Millersville Limestone (from 553 to 560 feet in the core) overlies 2 feet of black shale (560 to 562 feet) that contains an abundant conodont fauna. This fauna is characterized by most of the same forms of *Idiognathodus* as in the Fithian unit (except for the large-lobed morphotype of *I. magnificus*), and by several morphotypes of *Streptognathodus* including *S. elegantulus*, *S. gracilis*, and more dominantly in this unit, *S. excelsus*. This fauna also occurs in the Muncie Creek Shale Member of the Lola Limestone in the Midcontinent, which indicates correlation of the lower Millersville marine unit with the Lola cyclothem, the next major cyclothem above the Dewey Limestone in the Midcontinent. A similar fauna was recovered from black shale beneath the Livingston Limestone Member of the Bond Formation in the Fairmount Quarry in Vermilion County, which re-affirms the long-standing correlation of the Millersville Limestone with the Livingston Limestone of easternmost Illinois. More significantly, this fauna is identified in collections made by Schutter (1983, p. 934) from the gray and black shale below the LaSalle Limestone Member of the Bond Formation at Bailey Creek in the large quarries near Oglesby in LaSalle County, Illinois. This confirms the earlier correlation of the LaSalle Limestone with the Millersville-Livingston Limestone by Newton and Weller (1937) and subsequently many others.

**Upper Millersville marine unit**

This unit consists of the 11-foot dark gray shale (from ~542 to 553 feet) and the overlying 14-foot limestone (~528 to 542 feet) that respectively form the middle and top of the Millersville Limestone in the Charleston core. Most of the shale lacks macrofossils and contains very few conodonts and thus probably represents rapid detrital influx. A sample from a fossiliferous zone at the top (542.6 to 543.2 feet), however, contains a small fauna that is dominated by *Streptognathodus elegantulus* and *S. gracilis* and includes *Idioprioniodus*, a genus that is present in all conodont-rich shales below and generally occurs almost entirely in more offshore shales. This fauna is compatible with that found in the Quindaro Shale Member of the Wyandotte Limestone of the Midcontinent, which is a marine cycle of intermediate lateral extent that lies above the Lola Limestone with no evidence of
subaerial exposure in much of Kansas and is separated from it by prodeltaic shale in the Kansas City region. This confirms (in part) the correlation by Hopkins and Simon (1975) of the Millersville Limestone (but only the upper part) with the Argentine Limestone of Missouri, the member of the Wyandotte that overlies the Quindaro Shale in that region.

"Little Vermilion" marine unit

The next higher major marine unit in the Charleston core is in the Mattoon Formation and consists of nearly 1 foot (482.9 to 483.8 feet) of black phosphatic to dark gray shale with shell layers, overlain by 0.5 foot of limestone and succeeded by decreasingly fossiliferous gray shale; this unit was not correlated by Popp and others (1979). The shales sampled from 482.9 to 483.6 feet contain an abundant conodont fauna dominated by *Idiognathodus simulator* and *Streptognathodus firmis*, both first appearances, and also includes the highest occurrence of abundant broad-platformed species of *Gondolella* in the core. An abundant conodont fauna that includes *I. simulator* (recorded as *S. simulator*), probable *S. firmis* (recorded as *S. oppletus*) and broad-platformed *Gondolella* was reported by Merrill and Martin (1976, p. 267-268) in limestone and shale of the Little Vermilion Limestone Member of the Mattoon Formation in its type area in LaSalle County. At this locality it is the next marine unit above the LaSalle Limestone. Because at least the basal LaSalle is now firmly correlated with the lower Millersville Limestone (which lies not far below the marine unit at the 483-foot depth in the Charleston core), the name "Little Vermilion" is provisionally applied to this marine unit in the Charleston core, pending study of conodonts from outcrops of both the Little Vermilion Limestone and of other marine units just above the Millersville-Livingston Limestone in central and southern Illinois. The first appearances of *I. simulator* and *S. firmis* in combination with the highest abundant occurrence of broad-platformed *Gondolella* in the Midcontinent are in the Eudora Shale Member of the Stanton Limestone, indicating correlation of the "Little Vermilion" marine unit with the Stanton cyclothem. The marginal marine black shales that contain sparse *Adetognathus* conodont faunas and overlie coals at 503 feet and 516 feet between this unit and the Millersville Limestone in the Charleston core may be equivalent to the Plattsburg Limestone of the Midcontinent, which lies between the Stanton and Wyandotte cycles there.

Omega marine unit

The Omega marine unit is absent in the Charleston core, probably because the core interval from just above the "Little Vermilion" marine unit (477 feet) to the base of the Shumway marine unit (303.2 feet; see below) is mainly sandstone and siltstone, much of which may be fillings of channels that cut out the Omega unit in this interval. The outcrop of the Omega Limestone Member of the Mattoon Formation that is visited on this field trip (Stop 1) is about 20 miles north of its type section and lies
stratigraphically between the Millersville and Shumway Limestones. Samples of fossiliferous shale and calcarenite from just below the main ledge of Omega Limestone at Stop 1 yielded a moderately abundant conodont fauna that is dominated by *Streptognathodus alekseevi* and includes *S. zethus* as well as *S. firmis*. This fauna allows correlation of the Omega marine unit with the Haskell-Cass cyclothem of the Midcontinent, in which *S. zethus* first appears. This first appearance in a marine unit that is widespread in the Midcontinent and correlated into Texas (Boardman and Heckel, 1989) and Illinois (herein) led to the proposal by Boardman and others (1989) that the Missourian-Virgilian boundary be redefined at the base of the Haskell Limestone. This definition would place the boundary at the base of the Omega marine unit in Illinois, which lies at the top of the underclay and coal horizon at Stop 1 on this trip.

**Shumway marine unit**

The marine unit extending upward from 303.2 feet to some distance above 295 feet in the Charleston core includes a limestone (~300 to 302 feet) that Popp and others (1979) tentatively correlated with Shumway Limestone Member of the Mattoon Formation. A cross section by Weibel (1988) supports this tentative correlation. Black to dark gray shale samples from 295.0 to 299.5 feet contain an abundant conodont fauna dominated by *Idiognathodus simulator* (its highest occurrence in the core) with some *Streptognathodus alekseevi* and the highest occurrence of the genus *Idioprioniodus* in the core. This fauna was also recovered from black shale collected from the type section of the Shumway Limestone (Stop 2), thus confirming the identification of the Shumway marine unit in the Charleston core. The highest occurrences of *I. simulator* and *Idioprioniodus* in the Midcontinent are in the Heebner Shale Member of the Oread Limestone, thus confirming the correlation of the Shumway unit with the Oread cyclothem proposed by Scheihing and Langenheim (1980) and Weibel (1988).

**Bogota marine unit**

About 100 feet above the Shumway unit in the Charleston core is a marine unit extending from 199.2 to 202.7 feet and consisting of two thin limestones separated by gray fossiliferous shale, which was not correlated by Popp and others (1979). The gray shale from 201.0 to 202.6 feet contains an extremely abundant conodont fauna dominated by *Streptognathodus alekseevi* and *S. ruzhencevi* and including the highest *Idiognathodus tersus* and small-platformed *Gondolella* in the core. Two critical elements of this fauna (*I. tersus* and *S. ruzhencevi*) were recovered from two samples of dark gray to black shale collected from the marine unit that includes the Bogota Limestone Member at two different localities (Stops 10 and 11 of Weibel and others, 1989) each about two miles from the Bogota type section, thus identifying this marine unit in the core as the Bogota. All elements of this fauna are found in the Queen Hill Shale Member of the Lecompton Limestone of the Midcontinent (which also contains
the highest \textit{I. tersus} in that region, based partly on data of von Bitter, 1972), thus confirming the
correlation of the Bogota marine unit with the Lecompton cyclothem suggested by Weibel (1988).

Newton marine unit

A little over 30 feet above the Bogota unit in the Charleston core is a thin marine limestone
(from 167.5 to 168.1 feet) overlain by about 1 foot of black shale (166.5 to 167.5 feet), neither of
which were correlated by Popp and others (1979). The black shale contains an abundant conodont
fauna dominated by \textit{Streptognathodus alekseevi} with \textit{S. ruzhencevi}, but lacks \textit{Idioprioniodus} and
\textit{Gondolella}. This same fauna was recovered in similar abundance from black shale above a similar thin
limestone cropping out along the Embarras River in Newton, Illinois (Stop 6) about 4 miles from the
original type section of the Newton cyclothem (Newton and Weller, 1937), thus allowing identification
of this interval in the Charleston core as the Newton marine unit, as suggested by Weibel (1988). This
fauna is also found in the Larsh-Burroak Shale Member of the Deer Creek Limestone in the
Midcontinent, the next major cyclothem above the Lecompton in that region. This is compatible with
the correlation of the Newton with the Deer Creek cyclothem suggested by Weibel (1988). However,
considering the preliminary stage of understanding of conodont faunas above the Queen Hill Shale in
the Midcontinent, possible correlation of the Newton with the Avoca Limestone, a cycle of intermediate
scale between the Lecompton and Deer Creek, cannot be ruled out at this time.

Greenup marine unit

The highest Pennsylvanian unit in the Charleston core is a 7-foot-thick limestone (from 92 to
98.7 feet) about 70 feet above the Newton marine unit. This limestone is the thickest limestone above
the Millersville in the core and is lithostratigraphically correlated with the Greenup Limestone Member
of the Mattoon Formation (Weibel, 1988), visited at Stop 4, which is just 6 miles north of its type
section near the town of Greenup and 10 miles south of the site of the Charleston core. The base of
the Greenup Limestone in the core (from 98.0 to 98.7 feet) contains a conodont fauna of low-moderate
abundance that contains \textit{Streptognathodus alekseevi}, \textit{S. ruzhencevi} and small specimens of \textit{S. firmis}.
This fauna has a generalized mid-Virgilian aspect that is essentially compatible with that of most post-
Queen Hill faunas of the Midcontinent. Considering the position of the Greenup above the Newton unit
in the core and separated from the Newton by another marine horizon (at 148 to 149 feet) with a
similar fauna of low-moderate abundance, the Greenup may correlate either with the Hartford Limestone
Member of the Topeka Formation, a cycle of intermediate scale between the Deer Creek and Topeka
cyclothems in the Midcontinent or with the higher major cyclothem in the Topeka Limestone there.
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