1. Summary of Observations from a 40-Meter Cored Interval of the New Albany Shale in Well 1-3 Kavanaugh, Daviess County, Indiana

by
Remus Lazar and Juergen Schieber
Department of Geological Sciences, Indiana University,
Bloomington, Indiana 47405

An essentially continuous core of the New Albany Shale (~40 m thick) from well 1-3 Kavanaugh (Daviess County, Indiana, Fig. 1.1) was studied in detail (mm- to cm-scale) for variations in lithology, sedimentary structures, macrofossils, trace fossils, and organic carbon content. The five stratigraphic subdivisions of the New Albany Shale recognized by Lineback (1970) are all present in this core. In ascending order these are the Blocher, Selmier, Morgan Trail, Camp Run, and Clegg Creek Members (Fig. 1.1), described and illustrated below.

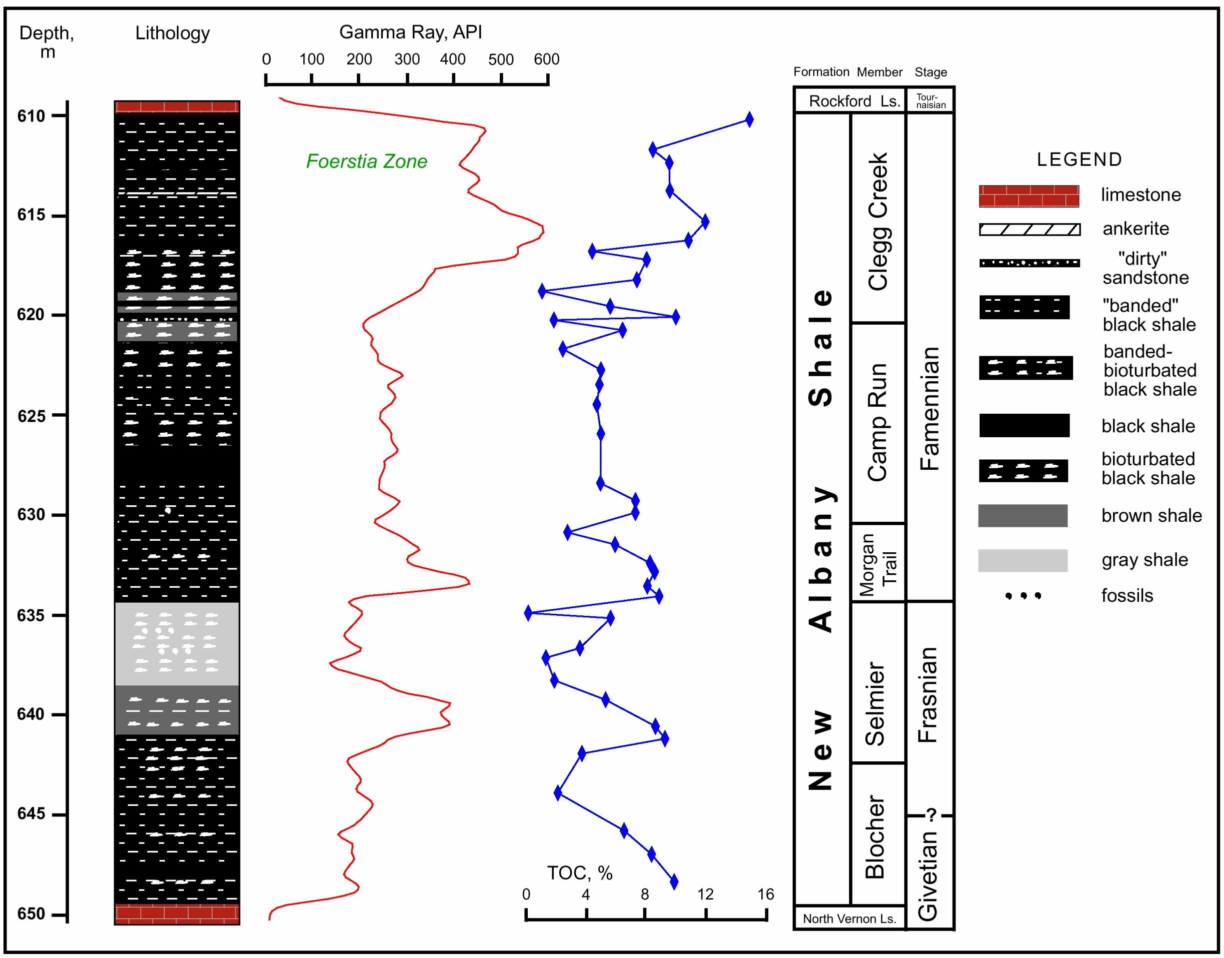

Figure 1.1: Lithology, gamma ray, total organic carbon (TOC), and stratigraphy of the New Albany Shale in well 1-3 Kavanaugh, Indiana.

Blocher Member:

648.72 m 649.44 m

Figure 1.2: Basal portion of the Blocher Member above the North Vernon Limestone (from well 1-3 Kavanaugh); red bar marks basal lag. The Blocher Shale consists primarily of banded black shale that is variably dolomitic, pyritic, and organic matter-rich (see also Fig. 1.1). Thin, brownish-black intervals with macroscopic bioturbation are also present (Fig. 1.1).

Within and at the base of the Blocher, cm-thick lag deposits consisting of a residue of coarser particles (carbonate clasts, fragments of silicified fossils, glauconite grains, quartz grains, broken and abraded fish bones, conodonts) mark laterally extensive erosion surfaces (Schieber, 1998a). For example, a 40 mm-thick basal lag (red bar, Fig. 1.2) with abundant crinoid fragments and carbonate clasts derived from the underlying North Vernon Limestone marks the unconformable basal contact of the Blocher Member. Lag deposits of variable thickness (1 mm to 2 cm) and composition (silty-sandy dolomitic, pyritic, conodont, bone fragment, and shell-bearing) occur higher up in the Blocher succession (Fig. 1.3). Their presence supports the concept of intermittent erosion within the Blocher due to intermittent lowering of sea level for thicker lags (with visible truncation of basal strata), and due to exceptionally strong but rare storms for thinner lags (Schieber, 1998a). Although these lags should eventually allow a sequence stratigraphic subdivision of the Blocher Member, onlap of the Blocher onto the Cincinnati Arch and irregular depth of erosion at the top of the Blocher makes lateral correlation of these lags tentative at best in the absence of biostratigraphical constraints (e.g., conodonts). Examination of additional cored intervals and alternative methods of lateral tracing, such as for example truncation of gamma ray log motives (Johri and Schieber, 1999; Schieber, 2000) may allow recognition of consistent subdivisions as our current research proceeds.

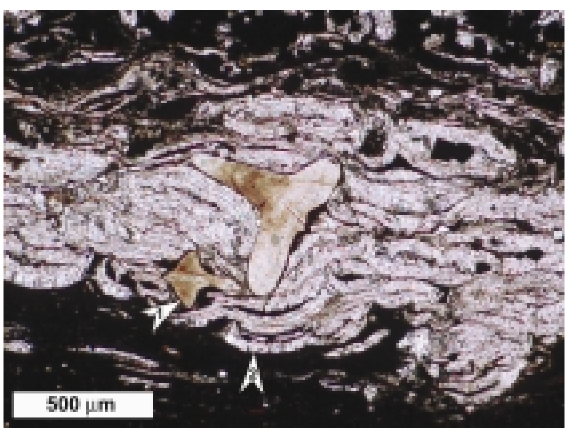

Figure 1.3: Photomicrograph of a conodont (arrow 1; transmitted light) and *Tentaculites* (arrow 2) lag at 0.9 m above the base of the Blocher. A thin lag like this is interpreted to be the product of relatively rare and strong storms (Schieber, 1998a).

The most common fossils observed in the Blocher are inarticulate brachiopods (*Lingula*, on bedding planes), pteropods (*Tentaculites*), and *Tasmanites*. *Tasmanites*, the cyst stage of fossil marine algae, is abundant in the black shale beds of the Blocher as well as in the entire New Albany Shale succession. The exact age of the Blocher is a moving target due to basal onlap and top erosion. Its base most likely gets older as we go westward into the Illinois Basin, and the top should overall get younger in a westward direction (more erosion near the Cincinnati Arch). For the southeastern Illinois Basin, available conodont studies suggest that the base of the Blocher should be no older than uppermost Givetian, and that it may range as high as Middle or even Upper Frasnian (Fig. 1.1) (Sandberg et al., 1994; Over, 2002). Conodonts from the basal lag in western Kentucky are Givetian in age (Ettensohn et al., 1988a), but because of the likelihood of reworking from underlying Middle Devonian carbonates, this does not allow us to define the onset of Blocher deposition.

Selmier Member:

A sharp increase in gamma-ray intensity marks the Blocher/Selmier boundary (Fig. 1.1). Composed of variably bioturbated, organic-rich brownish-black shale intervals that alternate with bioturbated and gray to dark-gray shale intervals, the Selmier Member differs distinctly from the Blocher Member (Figs. 1.1, 1.4). Centimeter to decimeter-thick intervals of black-gray shale cycles have long been interpreted to represent fluctuating anoxic to oxic conditions (e.g., Cluff, 1980; Calvert et al., 1996). Based on examination of comparable black-gray shale cycles within the Dowelltown Member of the Upper Devonian Chattanooga Shale in central Tennessee (Lobza, 1998) this phenomenon may ultimately be reflective of fluctuations in sea level. Settling experiments with clays and fine-grained organic matter (Schieber, 2003b) can also produce black-gray shale cycles, suggesting as an alternative mechanism, that they may also form when strong storms resuspend previously deposited sediment and give rise to post-storm settling segregation. Silty, sandy, pyritic, and shelly lags, as well as knife-sharp contacts at the base of a number of black shale beds are common throughout the Selmier and support the idea of a relatively shallow sea where mud deposition was affected by sea level fluctuations (Johnson et al., 1985), and storm events (Schieber, 1998a).

637.03 m 637.76 m

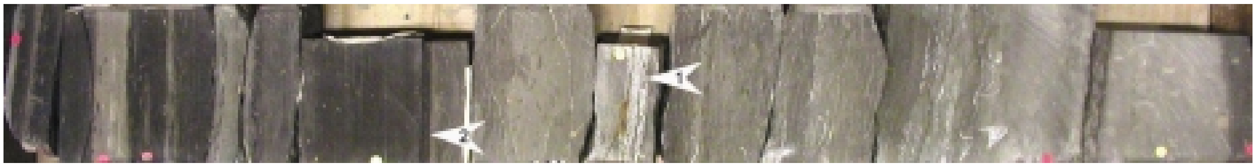

Figure 1.4: Black-gray shale cycles in the Selmier Member. Note the presence of a cm-thick shelly lag (arrow 1) and sharp-based black shale (arrow 2).

Gamma-ray intensity in the Selmier Member is highest in the basal third and considerably lower in the middle and upper portions of the member (Fig. 1.1). This upwards change in gamma-ray intensity corresponds to a change from massive black shale to gray bioturbated shales with interbedded black shales. The upper portion of the Selmier also contains large articulated (calcareous) brachiopods as well as lags composed of brachiopod shells (Fig. 1.4).

633.78 m Morgan Trail Selmier 634.54 m

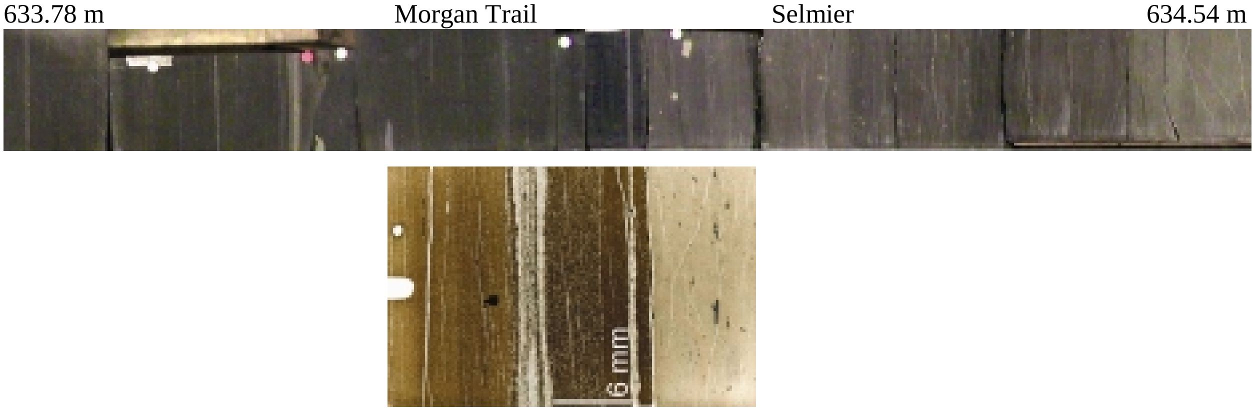

Figure 1.5: At the top of the Selmier occurs an abrupt change from gray bioturbated shale to massive banded black shale. The knife-sharp contact corresponds to a sharp increase in gamma-ray counts (Fig. 1.1) and marks the erosive contact between the Selmier and the overlying Morgan Trail Member. Based on conodont studies on comparable strata, the boundary between the Selmier and Morgan Trail Members coincides with the Frasnian-Famennian boundary (Fig. 1.1) (Sandberg et al., 1994; Over, 2002).

Morgan Trail Member:

The Morgan Trail Member consists mainly of banded black shales with numerous sub-mm- to mm-thick, pyritic and dolomitic-silty laminae (Fig. 1.5). Only a few brownish-black bioturbated shale intervals have been observed (Fig. 1.1). Conodonts indicate an Early Famennian age (Sandberg et al., 1994; Over, 2002). A characteristic feature of the Morgan Trail member are mm- to cm-thick beds of “dirty sandstone” that occur at a spacing of 5 cm to several dm. The latter consist largely of pyritic and chalcedonic infills (Fig. 1.6) of *Tasmanites* cysts within a matrix of clay, organic matter, silt grains, and conodonts and probably represent interludes of extreme sediment starvation and/or reworking (Schieber, 1998a).

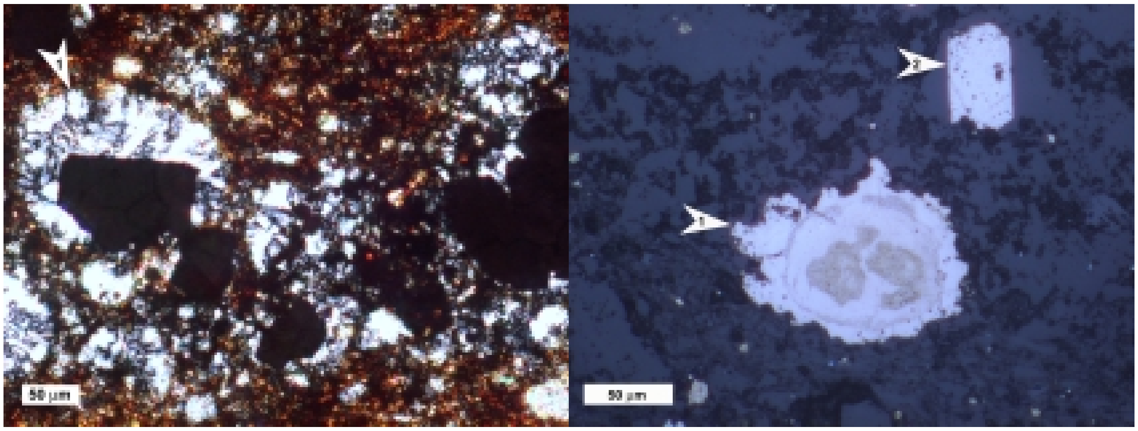

Figure 1.6: Photomicrographs of "dirty sandstone" with spherical to ellipsoidal quartz grains (chalcedony; arrow 1 at left; transmitted light), and pyrite (photo at right, arrows 1 and 2, reflected light), both representing infilled *Tasmanites* cysts. *Right:* Note pyrite replacement of circular "skin" of a *Tasmanites* cyst (preserved in pyrite grain marked with arrow 1), as well as euhedral pyrite overgrowth (arrow 2).

Tasmanites cysts produce a bright yellow fluorescence under UV light, and UV imaging of cored intervals shows distinctly *Tasmanites*-enriched intervals in the Morgan Trail Member. These enriched intervals may reflect winnowing of fines during lowering of sea level or sediment starvation during maximum flooding. The Morgan Trail contains conodonts of lower Famennian age (*triangularis* to middle *crepida* zone; Sandberg et al., 1994), and probably reflects the initial transgression of TR cycle IIe of Johnson et al. (1985). The *Tasmanites*-enriched interval shown in Figure 1.7 is from the Morgan Trail Member in well 1-3 Kavanaugh, coincides with a gamma-ray minimum, and probably reflects sediment starvation during maximum flooding. UV maxima also occur elsewhere in the New Albany succession and work is underway to use them for refined correlations and interpretation of sea level variations.

630.45 m 631.18 m

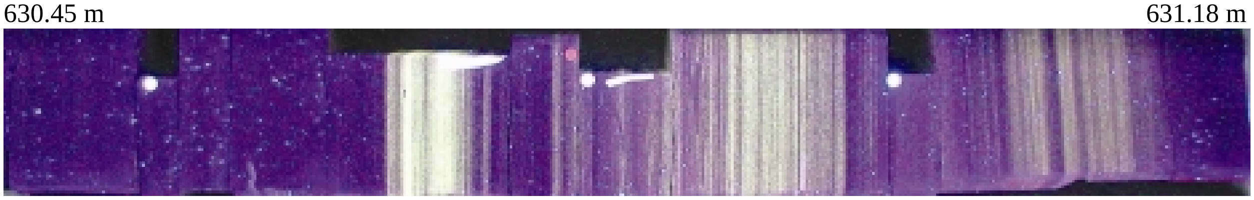

Figure 1.7: UV maxima (yellow) in the Morgan Trail Member. Probably marks maximum flooding for the Morgan Trail.

Camp Run Member:

In contrast to the Selmier, the Camp Run Member is generally composed of thicker beds of black to dark-brown shale (5-150 cm thick), separated by thinner beds (1-10 cm thick) of gray to dark-gray/brown bioturbated shale (see also Figs. 1.1, 1.8). Eastward from well 1-3 Kavanaugh (Daviess Co.), towards the shallower water near the Cincinnati Arch, the number and overall thickness of gray interbeds increases. Conodonts from Camp Run intervals elsewhere in Indiana yielded a Middle-Upper Famennian age (upper *crepida* through lower *marginifera* zone) for the Camp Run Member (Sandberg et al., 1994), corresponding to a regressive interval in the middle of TR cycle IIe of Johnson et al. (1985).

629.72 m 630.45 m

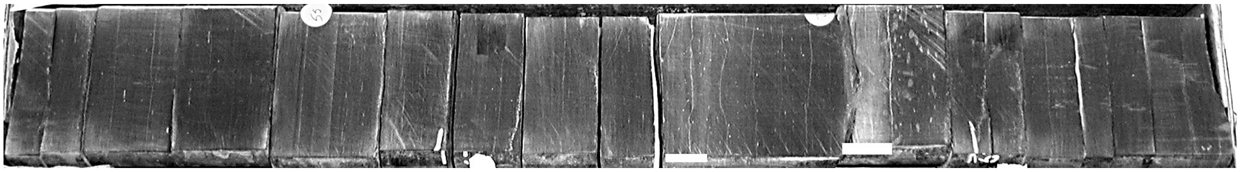

Figure 1.8: Core interval from Camp Run in well 1-3 Kavanaugh. Gray interbeds are marked with white bar at the bottom of the picture. Note burrows filled with gray shale in underlying black shale.

While in many exposures and cores the contact between Camp Run and overlying Clegg Creek Member is a sharp one and indicative of erosion prior to Clegg Creek deposition, in well 1-3 Kavanaugh the contact between the two members has a “transitional” character. An interval of about 1.5-m thickness is characterized by cm-thick sandy and pyritic lags, bioturbated gray and black shales, and by an abundance of reworked *Tasmanites* cysts (Fig. 1.9). This difference may be a reflection of water depth. It appears that on and near the Cincinnati Arch, pre-Clegg Creek erosion is the norm, whereas further away from the arch we see these “transitional” intervals. One could interpret the “transition” intervals as resedimented material that was eroded from arch locations during low-stand of sea level. The closest sequence-speak analog would be a low-stand wedge.

620.05 m Clegg Creek Camp Run 620.78m

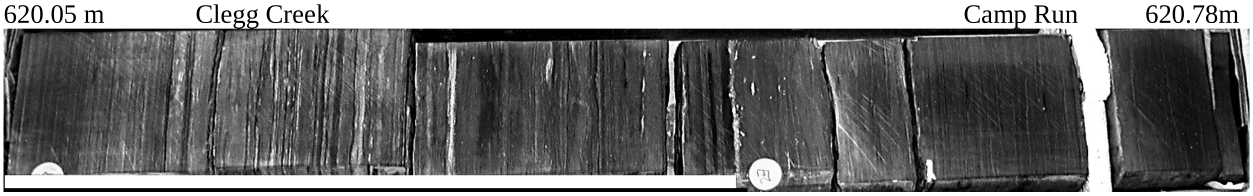

Figure 1.9: Cm-thick sandy and pyritic lags in the basal “transitional” interval of the Clegg Creek Member above the underlying Camp Run Member. The “transition” interval is marked with a white bar at the base of the photo. Our pick for the Clegg Creek base is the lag just to the left of the white circle. The base of the lag is probably erosive (see also Fig. 1.10 for details).

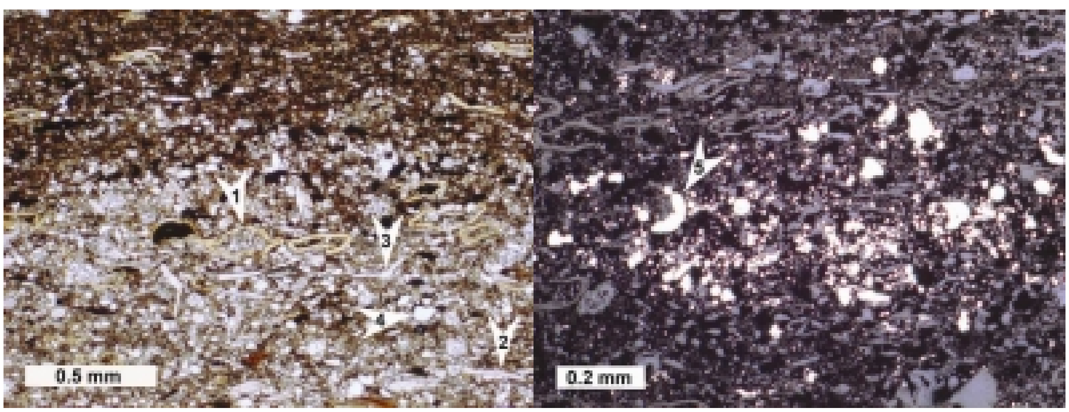

Figure 1.10: Photomicrographs of lag deposit at the boundary between the Camp Run and Clegg Creek Shales. *Left:* transmitted light shows an abundance of reworked *Tasmanites* cysts (arrow 1) and enrichment in coarser particles (*Lingula* shell fragments [arrow 2], conodonts [arrow 3], and rounded quartz grains [arrow 4]). *Right:* reflected light, shows enrichment in pyrite, bright spots. Arrow 5 marks a half-moon-shaped pyritic fill of a *Tasmanites* cyst (Schieber and Baird, 2001).

Clegg Creek Member:

609.90 m 610.64 m

Figure 1.11: Core photo of typical Clegg Creek black shale. It has a massive appearance with faint lamination and scattered sub-mm- to mm-thick silty laminae (quartzose and pyritic).

The Clegg Creek Member consists primarily of banded black shale with numerous sub-mm- to mm-thick silty laminae (quartzose and pyritic) (Fig. 1.11) and abundant disseminated fine crystalline pyrite. The Clegg Creek Shale also contains the highest concentrations of total organic carbon in the New Albany Shale succession (Fig. 1.1). Macroscopically bioturbated, brownish-black shale beds are present in the lower portion of the Clegg Creek. Conodonts from the eastern part of the Illinois Basin indicate that the base of the Clegg Creek is Upper Famennian (upper *marginifera* zone) in age (Sandberg et al., 1994). Judging from its distribution in the eastern U.S., as well as from the basal erosion surface that is observed in many places, the Clegg Creek represents a significant Famennian sea level rise. Given the biostratigraphic age of its base, the Clegg Creek probably coincides with the second transgressive pulse of TR cycle IIe of Johnson et al. (1985). The Clegg Creek Member is unconformably overlain by the Mississippian Rockford Limestone in well 1-3 Kavanaugh (Fig. 1.1).

The biostratigraphic marker *Foerstia* (*Protosalvinia*) (Schopf and Schwietering, 1970) was found in a 1.35-m-thick interval, approximately 7 to 8 m above the base of the Clegg Creek (Fig. 1.1). *Foerstia/Protosalvinia* occurrences coincide with highly pyrite enriched black shales, suggestive of very slow deposition, and probably mark a maximum flooding interval in the upper portion of the Clegg Creek Member. Although conodont data with regard to the age of the *Foerstia* Zone are not as tight as one would like them (Jeff Over, pers. commun., 2004), it seems to fall into the *trachytera* zone and thus may coincide with maximum flooding during the last transgressive pulse of TR cycle IIe (Johnson et al., 1985).

To summarize: Silty, sandy, pyritic, conodont, and shelly lags, as well as sharp-based black shale contacts, are common in the New Albany Shale and are typically indicators of laterally extensive erosion surfaces (Schieber, 1998a). Their recognition, added by the presence of marker beds (e.g., *Foerstia/Protosalvinia* Zone), UV maxima, and comparison of gamma-ray profile, shows that instead of representing a continuous depositional succession, the New Albany Shale consists of stacked shale packages bounded by erosion surfaces. We will identify the most significant of these surfaces during the field trip stops and make them the basis of relating stratigraphic units across the Cincinnati Arch between the Illinois and Appalachian Basins. Ultimately, what will emerge from this effort is a sequence stratigraphic framework for the Upper Devonian black shales of the eastern U.S.