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David L. Meyer
University of Cincinnati

Paul E. Potter
University of Cincinnati

Jennifer L. Thies
University of Cincinnati

William I. Ausich
The Ohio State University

Stephen A. Leslie
The Ohio State University

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A DEEP-TO-SHALLOW TRANSITION IN THE FORT PAYNE FORMATION (LOWER MISSISSIPPIAN), KENTUCKY HIGHWAY 61, CUMBERLAND COUNTY, KENTUCKY

DAVID L. MEYER, PAUL E. POTTER, AND JENNIFER L. THIES
DEPARTMENT OF GEOLOGY,
UNIVERSITY OF CINCINNATI

WILLIAM I. AUSICH AND STEPHEN A. LESLIE
DEPARTMENT OF GEOLOGICAL SCIENCES,
OHIO STATE UNIVERSITY

Introduction

The Fort Payne Formation of the Cumberland Saddle region of south-central Kentucky and north-central Tennessee is part of a vast marine sedimentation system that extended over much of North America during the Early Mississippian Period; broadly similar facies reached from Georgia through Tennessee and Kentucky, into western Illinois and Missouri, and into New Mexico and the northern Rockies (Pryor and Sable, 1974). Throughout North America the Fort Payne and its equivalents overlie a black shale (in Kentucky called the Chattanooga Shale) and underlie thick carbonates (in Kentucky, the Warsaw Formation and younger middle Mississippian limestones).

Six miles south of Burkesville, Ky., on Kentucky Highway 61, a complete section of the Fort Payne, from the top of the Chattanooga Shale well into the overlying Warsaw Formation, is exposed in 11 outcrops (Figs. 1–3). The Fort Payne is approximately 270 feet thick in this section and is composed of basal wackestone mounds; distinctive, fossiliferous, green clay shales associated with the mounds; detrital crinoidal packstones; argillaceous dolosiltstones, the most common lithology in the Fort Payne; and a dark, organic-rich shale, which caps a persistent coarsening-upward packstone unit.

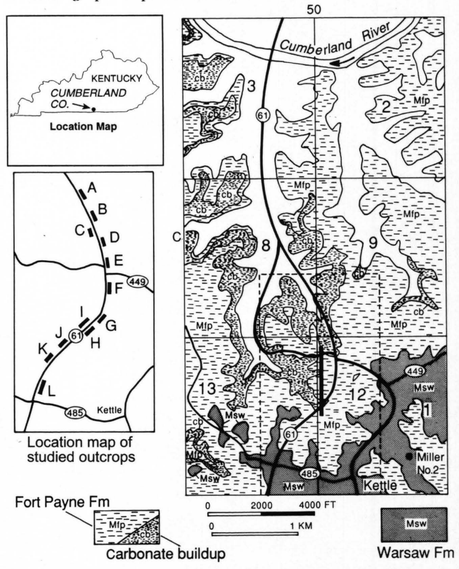


Figure 1. Location of study area and outcrops along Kentucky Highway 61, and simplified geology.

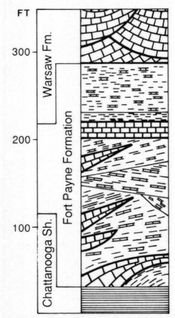
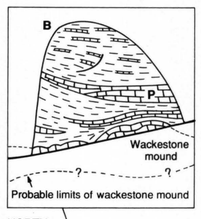


Figure 2. Stratigraphy of study area.

The 2-mile-long section crosses a gentle anticline at the north, between outcrops A and E. There appears to be a small fault or monoclinal fold at the southern end of outcrop H (Fig. 3). A wackestone mound west of the highway (outcrop I) has a very steep dip and may be part of this fault block.

These roadcuts were selected for study because they represent the best contiguous exposure of the interval from the deeper water Chattanooga Shale, through the transitional Fort Payne Formation, into rocks of the shallow-marine, crossbedded shelf represented by the Warsaw Formation. Notable features include wackestone mounds (Fig. 4) containing a coarse breccia, fossiliferous green shales associated with the mounds, steep depositional dips and wedging of beds, and listric bedding-plane faults. The Fort Payne's diverse fossil fauna of marine invertebrates includes crinoid calyxes, large echinoderm columnals and holdfasts, bryozoans, brachiopods, gastropods, and corals. The overlying Warsaw, which exhibits large-scale crossbedding and channeling, caps the sequence.

The mixed siliciclastic-carbonate deposit in this region displays many different lithologies and contains a wide range of sedimentary structures, including some spectacular slump sheets. The Fort Payne, with its diversity of depositional environments, possible equivalence with modern analogs, and relationships between organisms and sedimentation, clearly stands apart as one of the most challenging units for study east of the Mississippi River. It begs the question: was the Fort Payne deposited as a clinoform in deep water in front of the Borden Formation, its terrigenous equivalent to the east (Lewis and Potter, 1978; Ausich and Meyer, 1990; Meyer and Ausich, 1992; Meyer and others, 1995), or was it deposited on a shallow shelf or even a tidal flat (Chowns and Elkins, 1974; MacQuown and Perkins, 1982)?



A well-developed clinoform structure below the organic-rich shale in the upper part of the Fort Payne (Fig. 5) is defined by crinoidal packstone wedges that commonly thicken to the south or southwest in the direction of progradational basin filling (Klein, 1974). Depositional dips as steep as 13° are present in outcrops B, E, G, and H. Primary dip defined by packstone lenses is typical of the Fort Payne over much of south-central Kentucky. Some small, penecontemporaneous, listric faults terminate on bedding planes, and other faults are present.

Lithologies

Wackestone Mounds

On the Frogue 1:24,000-scale geologic quadrangle map, Lewis (1967) mapped the wackestone mounds and detrital crinoidal packstones of the Fort Payne as a single, separate unit, which he called "reef limestone."

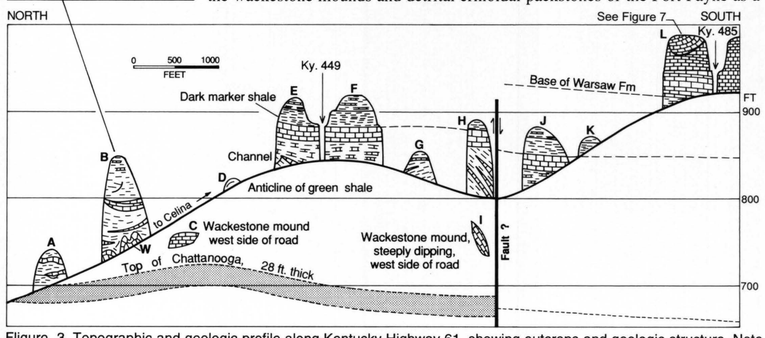


Figure 3. Topographic and geologic profile along Kentucky Highway 61, showing outcrops and geologic structure. Note possible fault at south end of outcrop H.

Wackestone mounds (outcrops A, B, and C) consist chiefly of massive wackestones and some micstones. Although they lack conspicuous bedding and shale partings, they nearly always contain coarse, rubble breccia zones and are commonly mottled with burrows (Fig. 4). Some stromatactis-like void fillings occur. In south-central Kentucky mound thicknesses range from a few feet to as much as 50 feet. Wackestone mounds always occur within a zone about 50 to 70 feet above the Chattanooga Shale and have yielded petroleum at shallow depths (Fig. 6). Drillers have referred to these limestones as the "Beaver Creek sands." Wackestone mounds have sharp contacts with the underlying green shales, which also occur above and lateral to the wackestone mounds. Wackestones are dominated faunally by both crinoids and fenestrate bryozoans.

Figure 4. Wackestone mound at outcrop B with breccia. Complete mound is on west side of road at outcrop C.

The detrital crinoidal packstones are more variable in thickness than the wackestone mounds. The packstone bodies can exceed 100 feet in thickness. Geometry varies from single-inclined, graded beds, to local sheets, to channel fills, and to large compound bodies with a pronounced clinoform structure. Sedimentary structures include graded bedding, crossbedding, and rare diamictites. Packstones may be interbedded with green shales, but are more commonly interbedded with argillaceous dolosiltstones. Typically, the packstones consist of coarse, disarticulated crinoid columnals mixed with bryozoan debris and brachiopod fragments in an argillaceous matrix. Packstones generally overlie the wackestone mounds and may extend to the top of the Fort Payne. All of these features are illustrated at outcrops B, E, F, G, and H (Fig. 3).

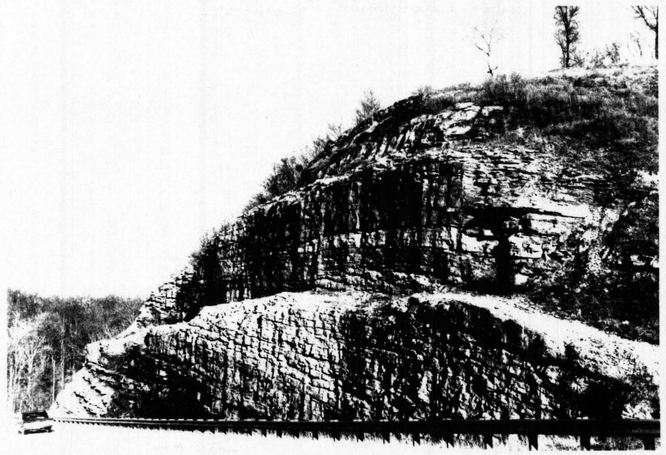


Figure 5. Steeply dipping lenses of interbedded green shale and packstone. A steeply dipping mound is also on the west side of the road.

Fossiliferous Green Shale

The green clay shale is moderately well laminated, contains little silt, is poorly indurated, and is commonly associated with the wackestone mounds either as mound-like cores or as beds flanking and overlying the wackestone mounds (outcrops A, B, and D). It is less commonly associated with packstones (outcrop H). Fossil abundance varies, from almost none to thin layers composed entirely of disarticulated crinoid debris. In addition to crinoids, the green shale includes blastoids, bryozoans, brachiopods, corals, gastropods, and trilobites.

Argillaceous Dolosiltstones

Dark bluish gray to olive gray in color, this impure, fine siltstone is the matrix of most of the Fort Payne, but locally it can form almost the entire Fort Payne sequence or only well-defined, thinner units (outcrops E, F, G, H, J, and K). This siltstone typically has continuous thin beds (0.75 to 1.25 inches thick), is abundantly burrowed, and is largely devoid of body fossils. The siltstone may grade into the green shale or into the packstones, and locally it may be very organic-rich, even resembling the Chattanooga in lithology. In the study section, there is a sharp contact between an overlying 11-foot-thick organic-rich siltstone and an underlying sheet-like crinoidal packstone, probably indicating a sudden deepening of the Fort Payne sea. This siltstone is a persistent marker bed in the upper half of the Fort Payne.

Chert and Dolomite

Isolated nodules and lenses of chert are present in the mounds and to a lesser degree in the packstones. Petrographically, chert, along with dolomite, occurs in virtually every thin section as replacements. Although not present in the study section, anhydrite nodules elsewhere in both the Fort Payne and Warsaw dissolve in outcrop and are converted to geodes by silicification (Chowns and Elkins, 1974).

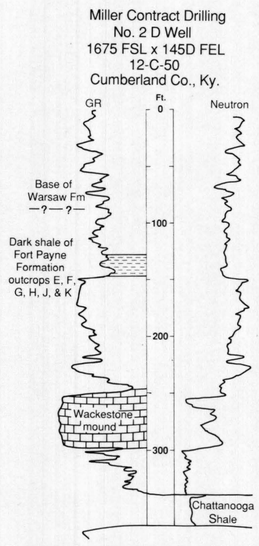


Figure 6. Gamma ray-neutron log of nearby well (see Fig. 1 for location of well). Note expression of wackestone mound and dark shale.

Warsaw Formation

The Fort Payne-Warsaw contact occurs in the lower few feet of outcrop L, where over 70 feet of Warsaw is exposed, most of which is a crossbedded, fine-grained packstone containing minor amounts of grainstones and wackestones. Crossbedding is profuse and becomes thicker higher in the outcrop. At the top of outcrop L is a large trough or channel over 300 feet wide and 23 feet deep (Fig. 7). The large-scale crossbedding on the marine shelf of the Warsaw shows persistent sand-wave migration to the southwest, the same orientation as the clinoforms of the Fort Payne.

This compact series of exposures along Kentucky Highway 61 records a regressive transition from the deep, anoxic Chattanooga and Early Mississippian basinal setting, through the clinoform infilling of the Fort Payne, to the shallow, crossbedded marine shelf of the Warsaw.

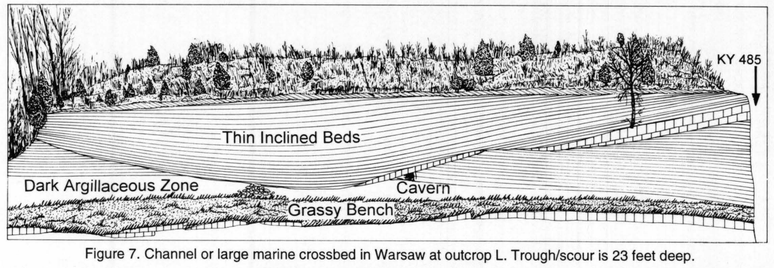


Figure 7. Channel or large marine crossbed in Warsaw at outcrop L. Trough/scour is 23 feet deep.

Paleontology and Age

Pelmatozoan echinoderms, including crinoids and blastoids, are abundant and diverse through the entire Fort Payne section. Although crinoid columnals are abundant, identifiable whole or partial calyxes are also commonly found. Twenty-three genera and 34 species of crinoids are known from the entire section. Monobathrid camerate crinoids are dominant, especially the genera *Actinocrinites, Agaricocrinus, Alloprosallocrinus, Eretmocrinus,* and *Macrocrinus.* Common inadunates are *Halysiocrinus, Synbathocrinus, Barycrinus,* and *Cyathocrinites.* Among the blastoids, *Deliablastus cumberlandensis* is common and *D. tribulosus, Hadroblastus breimeri, Perittoblastus liratus,* and *Xyeleblastus magnificus* are rare (Ausich and Meyer, 1988).

Cluster analysis of presence or absence of crinoid genera shows that the Kentucky Highway 61 crinoid assemblage bears a close similarity to assemblages from the Fort Payne at Whites Creek Springs in Tennessee, and to the Allens Creek Bank assemblage of the Edwardsville Formation of the Borden Group in Indiana (Thies, 1987). On this basis, the age of the Kentucky Highway 61 crinoid assemblage is late Osagean (equivalent to the Keokuk Limestone of the Mississippi River Valley section). *Alloprosallocrinus conicus,* a crinoid restricted to the late Osagean, is found as low as 123 feet above the base of the Kentucky Highway 61 section at outcrop B and as high as 256 feet at outcrop E, suggesting a late Osagean age for that entire interval.

Seven samples from an 11- to 13-inch-thick glauconitic shale with phosphatic nodules (Maury Shale equivalent) between the Chattanooga Shale and Fort Payne Formation at outcrop A were collected and analyzed for conodonts. Conodonts were obtained from all samples and all samples produced abundant conodonts with the exception of the lowermost sample. This analysis shows that the base of the Maury Shale equivalent has a lowermost Mississippian (Kinderhookian) age, because it contains an assemblage ranging from the lower *Siphonodella duplicata* to the *S. isosticha*-upper *S. crenulata* conodont zone (Fig. 8). This does not mean that the upper Chattanooga is Kinderhookian, however, because there may be a hiatus at the base of the Maury Shale equivalent; or, the fauna recovered from the base of the Maury Shale equivalent may contain redeposited conodonts. Faunal mixing in the upper half of the Maury Shale equivalent indicates redeposition of conodonts. In two samples, *Siphonodella* spp., which are restricted to the Kinderhookian (except for the Famennian species *S. praesulcata),* occur with *Gnathodus pseudosemiglabar,* a species that first appears in the middle *Scaliognathus anchoralis-Doliognathus latus* conodont zone (Osagean) (Lane and others, 1980). The occurrence of *G. pseudosemiglabar* below the base of the Fort Payne indicates that the base of the Fort Payne in this area is no older than the middle *S. anchoralis-D. latus* conodont zone (Fig. 8). The Maury Shale equivalent here represents starved-basin conditions extending from the middle(?) Kinderhookian to the middle Osagean.

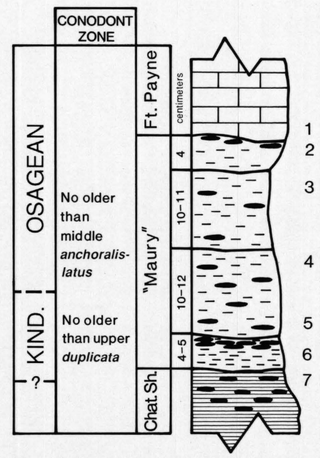


Figure 8. Detailed section of outcrop A showing location of conodont samples.

Brachiopods, bryozoans, gastropod mollusks, corals, and sponges are also common in the Fort Payne in these outcrops. Brachiopods include strophomenids, orthids, and spiriferids. Bryozoans include zoarial forms characteristic of Lower Mississippian faunas: delicate ramose (*Saffordotaxis incrassata*), bilaminate (*Cystodictya lineata*), fenestrate (*Fenestella* spp.), and encrusting forms. Platyceratid gastropods are common, although none were found attached to crinoids in what has been suggested as a commensal or coprophagous symbiosis. Both rugose and tabulate corals are common, especially the tabulate coral *Cladochonus crassus,* which is often encrusted on crinoid columns. Sponges occur as siliceous root tufts or in thin sections as spicules, but no entire specimens were found.

Crinoid Taphonomy

The abundance of crinoid calyxes increases upsection in the Fort Payne along Kentucky Highway 61, although specimens with arms or the stalk attached are very few. This mode of preservation suggests that most of the crinoids were not instantly buried at the living site, but underwent disarticulation and transportation before final burial. Monobathrid camerates with rigidly sutured calyxes, such as *Agaricocrinus, Alloprosallocrinus, Eretmocrinus,* and *Macrocrinus,* occur most frequently as intact calyxes, while most other crinoids with weaker plate sutures are preserved as partial calyxes or isolated plates. Crinoid holdfasts are only present in the upper part of the Kentucky Highway 61 section, and some are in growth position. These taphonomic features, as well as the faunal composition of the Fort Payne strata lying above the wackestone mounds, are similar to those in allochthonous sheet-like packstones in the Fort Payne along Lake Cumberland to the east (Meyer and others, 1989). These sheet-like packstones are interpreted as being debris flows deposited on the margins of crinoidal banks on a prograding basinal slope. Although the wackestone mound facies at the Kentucky Highway 61 section has not yielded many identifiable crinoids, available material indicates similarity to the autochthonous crinoidal wackestone mound facies also along Lake Cumberland. The upward-increasing abundance of calyxes suggests that higher strata of the Fort Payne were deposited nearer living crinoid populations.

Acknowledgments

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