



*National Association of State Boards of Geology*  
Council of Examiners Workshop

**Field Trip: April 15, 2012**

*Morning:*

**The Jeptha Knob Cryptoexplosive Structure  
Shelby County, Kentucky**

**William M. Andrews Jr.  
Mark F. Thompson**



*Afternoon:*

**Fossil Collecting at Grant Lake  
and Calloway Creek  
Limestone Outcrops**

**Frank R. Ettensohn  
Stephen F. Greb**

*Hosted by*

- **Kentucky Board of Registration for Professional Geologists**
- **Kentucky Geological Survey**

## DEDICATION

The Jephtha Knob portion of the field trip is dedicated to the memory of Calvin T. Schmidt, who through the years showed interest in the question of the origin of this structure and love of the Jephtha Knob area in his publication, "A History of Jephtha Knob," and allowed geologists access to his property so that they might pursue an answer.



Obituary from Davidson College:

Calvin Tafel Schmidt '49, of Shelbyville, Ky., died May 22, 2010, at his home. He was born Oct. 19, 1927, in Shelbyville. He was a lifelong resident of Shelbyville, the son of Frederick and Helen Tafel Schmidt. He was an alumnus of Davidson, where he was a member of Beta Theta Pi fraternity. He worked for 45 years at the Coca-Cola Bottling Co. of Shelbyville, 35 years as president. He cofounded Top Star Vending Co. and founded Stowaway, Shelby County's first mini-warehouse operation. Schmidt was a longtime leader in the Coca-Cola Bottlers Association and of the Soft Drink Association. He was a trustee of Burks Branch Baptist Church and a longtime member of the Juniper Hunting and Fishing Club and Shelbyville Rotary. He served his community through service on the boards of Shelbyville School System, United Way, Boy Scouts, Shelby County Community Theatre, and Jewish Hospital. He was instrumental in documenting the history of the Juniper Club, and the history of Jephtha's Knobs, and the Clayville area, where he had a farm. Schmidt was cofounder of a coffee club which met over many years in local restaurants. Woodworking was his lifelong hobby. He is survived by his wife, Yvonne, 98 Wedgewood Dr., Shelbyville KY 40065; his daughters, Linda DuBourg (Bill) and Carroll Senior (Dale); son Greg Batts (Paula); seven grandchildren; one great-grandchild. He was preceded in death by his first wife, Jean Moore Schmidt, and his brother, Craig R. Schmidt '43.

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**Morning Part: The Jephtha Knob Cryptoexplosive Structure,  
Shelby County, Kentucky**

**Afternoon Part: Fossil Collecting at Grant Lake and Calloway  
Creek Limestone Outcrops**

**Hosted by  
Kentucky Board of Registration for Professional Geologists  
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April 15, 2012**

## Acknowledgments

We would like to acknowledge the work of Gil Cumbee, Frank Ettensohn, Margaret Luther Smath, Terry D. Hounshell, Collie Rulo, Mark F. Thompson, William M. Andrews Jr., Frank R. Ettensohn, Stephen F. Greb, Patrick J. Gooding, Ray Daniel, Ryan Pinkston, and Richard A. Smath for their contributions in the preparation of this guidebook and Marsha Taylor-Meyer and family for setting up and preparing breakfast and lunch.

The Board of Registration for Professional Geologists and the Kentucky Geological Survey would like to thank the following sponsors for their generous contributions toward the ASBOG field trip:



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# The Jephtha Knob Cryptoexplosive Structure, Shelby County, Kentucky

William M. Andrews Jr. and Mark F. Thompson

This field trip is divided into two parts. First, we will examine the geology and geomorphology of a suspected impact structure. It will provide opportunities to discuss regional versus local geology, the effects of impacts on carbonate target rocks, and the geomorphic evolution of this structure.

A barbecue lunch will be provided by Rick's White Light Diner, Frankfort, Ky., "The Finest Dive in America" (just ask Guy Fieri, host of the Food Network's "Diners, Drive-ins, and Dives").

The afternoon portion will be a short drive to outcrops along Ky. 55, around the north side of Shelbyville. Here we can collect a number of fossil specimens.

## Roadlog Mileage

### Miles to Cumulative

0.0	0.0	Front of hotel.
0.1	0.1	Turn right on Corporate Campus Drive.
0.2	0.3	Turn right on Hurstbourne Green.
0.1	0.4	Turn right on Hurstbourne Parkway and proceed south on Hurstbourne Parkway.
1.6	2.0	Hurstbourne Parkway and Shelbyville Road (U.S. 60). Stay on Hurstbourne Parkway heading south.
1.7	3.7	Turn left onto entrance ramp to Interstate 64 East. Proceed on I-64 East.
2.2	5.9	Pass by Blankenbaker Parkway.
1.8	7.7	Pass by Gene Snyder Freeway.
12.7	20.4	Pass by exit 32 (Ky. 55).
3.6	24.0	Continue on I-64 East to exit 43 (Peytona/Waddy). Turn left on Ky. 395 (Peytona Beach Road).
2.1	26.1	Turn left on U.S. 60.
1.3	27.4	Turn left on Buzzard Roost Road.
1.4	28.8	Stop 1. After sharp right,

turn left into first driveway. Bus will back out, turn around, and head back to U.S. 60.

Turn left onto U.S. 60. Pass through Clay Village.

Turn left on Ky. 714.

Turn left into Knobs Farm, Britton Run (just before Knobs Farm, Britton Run, is mailbox 1790). **This is stop 1, Jephtha Knob.**

## Introduction

The following discussion is adapted from Thompson (2005) and is reproduced with the permission of the American Institute of Professional Geologists-Kentucky Section.

Many scientists today suspect that the Jephtha Knob structure (Fig. 1) is an impact structure. It is not listed with the more than 170 such places on Earth because many of the accepted criteria required to define impact structures have not been observed at Jephtha Knob. Ever since W.M. Linney mentioned Jephtha Knob in his 1887 geologic report (its first appearance in scientific literature), the interpretation of its origin has been a dynamic one, even to this day.

Jephtha Knob contains an eroded and buried remnant of a structure that is undergoing a second cycle of erosion. After deposition and lithification of the Middle and Late Ordovician shallow ma-

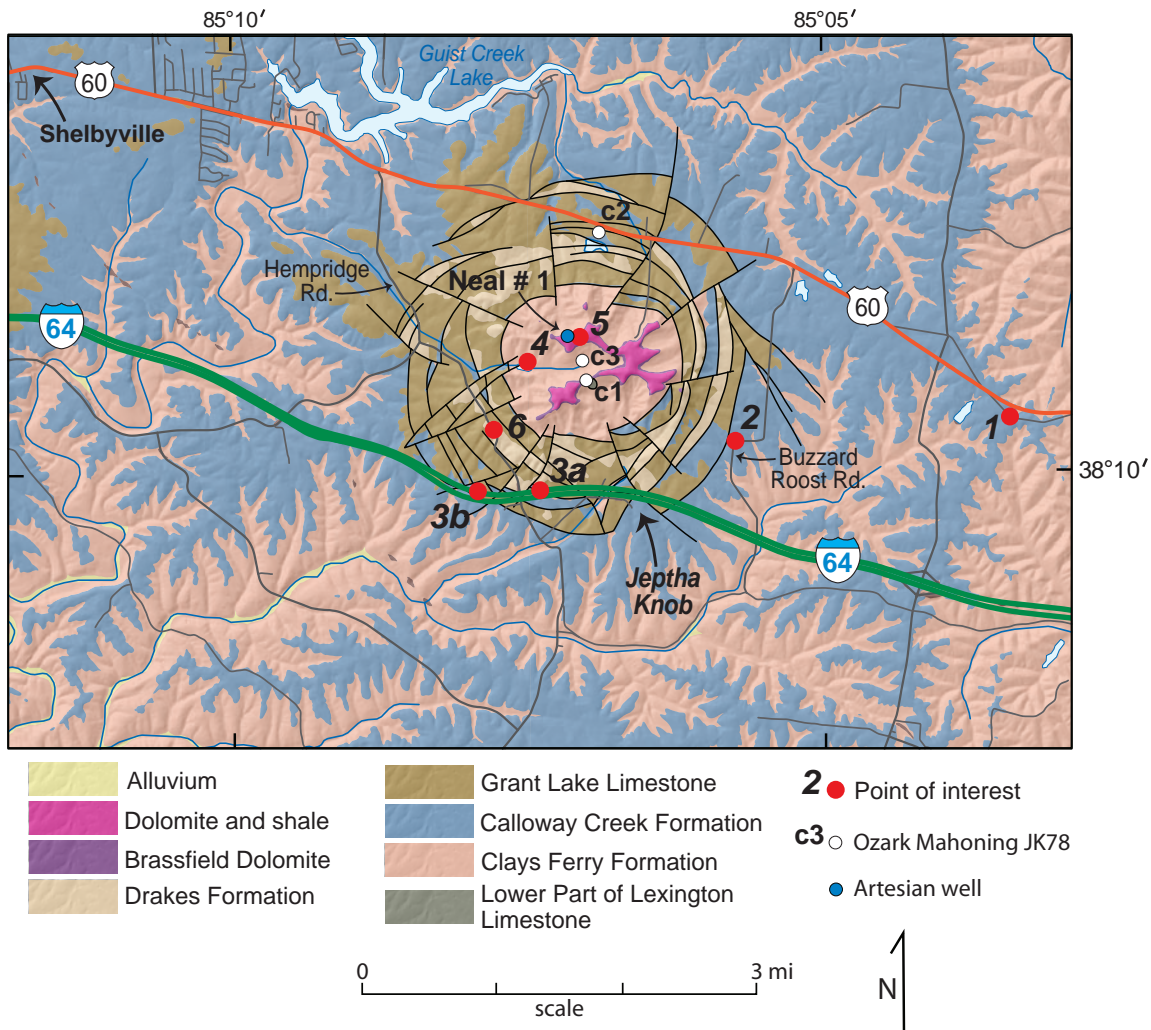


Figure 1. Geologic map of Jephtha Knob showing local roads and locations of points of interest. Adapted from Thompson (2005).

rine carbonates, the Jephtha Knob event occurred, forming a structure that was subjected to subaerial weathering process during Late Ordovician to Early Silurian time. A Silurian transgression resulted in carbonate deposition (Brassfield Formation), which buried the structure. Today, within the second cycle of erosion, much of the Jephtha Knob structure has been eroded down an additional 220 to 320 feet below the level of the Ordovician-Silurian contact (Fig. 2). As a result of erosion and a thick soil cover, only sparse rock crops out at Jephtha Knob.

The Jephtha Knob structure is a nearly circular (approximately 3 miles in diameter) area of uplifted, intensely faulted and folded, Middle to Late Ordovician, shallow marine carbonate rocks (Fig. 3).

Jephtha Knob is situated about 50 miles west of the axis of the Cincinnati Arch and nearly 50 miles north of the 38th Parallel Lineament of Heyl (1972) (Fig. 4). The photograph in Figure 2 (point of interest 1 on Figure 1) was taken from 3.25 miles east of the center of the structure. In the distant foreground, 2.5 miles away, is an outer arcuate belt of knobs (Figs. 2, 5). This eastern arcuate belt is approximately 1.7 miles long and trends north-south. Weathering processes on this complexly folded and faulted structure have characterized this outer arcuate belt of knobs with a pseudo-flatiron appearance. The occurrence of resistant rocks of the Drakes Formation in deeper, downdropped fault blocks relative to the other surrounding fault blocks caused the development of this arcuate knob belt.



Figure 2. Westward view of Jephtha Knob from 3 miles away. Horizontal line represents the approximate Ordovician-Silurian contact (world geodetic survey [WGS] 84 datum, N 38.17258716, W -85.05705901, elevation 910 feet).

There may once have been another arcuate belt of knobs approximately 0.25 mile to the east and possibly many others throughout Jephtha Knob's geomorphic history. An imaginary line drawn in a horizontal plane and placed just above this outer belt of knobs represents the approximate Ordovician-Silurian contact when viewed from this location (Fig. 2).

### Previous Scientific Investigations

The Jephtha Knob structure was first reported by William M. Linney (1887) of the Kentucky Geological Survey. Linney discovered localized faulting in the Jephtha Knob area and suggested that the structure was produced by localized subsidence and subsequent infilling of sediment. Walter H. Bucher (1925) produced the first geologic map of Jephtha Knob, based primarily on biostratigraphy, and suggested it had a cryptovolcanic origin. During the construction of Interstate 64 in eastern Shelby County, Willard Rouse Jillson (1962) discovered three previously unmapped faulted disturbances south of Jephtha Knob.

C. Ronald Seeger (1968) studied Jephtha Knob and performed geophysical work (gravity and magnetic surveys). His magnetic survey showed that a basement counterpart to the Jephtha Knob structure is unlikely because deformation essentially disappears 700 feet below the present surface of Jephtha Knob, leaving the crystalline basement rocks 5,500 feet below the present surface unaf-

ected. From this and many other findings, Seeger concluded an exogenetic origin for Jephtha Knob, hypervelocity impact from a bolide being the most likely mechanism. Seeger (1968) failed to provide confirming evidence of unquestionable criteria for his impact hypothesis, however.

Earle R. Cressman (1975a, b) mapped the Jephtha Knob structure on the basis of lithostratigraphy and produced the most detailed geologic maps of the structure in existence today. His maps show a cap rock, a central core of uplifted material, and a belt of faults and a belt of folds. The fault belt consists of radially propagating faults, several listric normal faults ringing the structure, and three reverse faults in contact with the central core of uplifted material (Cressman, 1981).

Seeger and others (1985) conducted an iridium survey in the vicinity of Jephtha Knob. They analyzed and compared samples collected from the highest breccia occurrences at Jephtha Knob, within the basal Brassfield Formation, along with other breccias found there. The basal Brassfield Formation breccias yielded anomalously high levels of iridium (0.094 to 0.122 ppb). Such small amounts of iridium may merely represent iridium that fell upon Earth during Ordovician-Silurian lacunae, only to be reworked and concentrated in lag deposits during Silurian transgression. Nevertheless, Seeger and others' (1985) survey may be worthy of further investigation by incorporating the Silurian rocks, which crop out approximately 19 miles

SYSTEM	SERIES	GROUP, FORMATION, MEMBER Heavy line to left of column marks units that crop out in structure		THICKNESS, IN FEET	DESCRIPTION
SILURIAN	Middle	Louisville Limestone Waldron Shale Laurel Dolomite Osgood Formation		75	Concealed by soil and chert residuum. Presence inferred from fossils identified in residuum (Foerste, 1931, p. 182) and from thickness of interval
	Lower	Brassfield Formation		18	Finely crystalline calcareous dolomite; contains abundant small vugs; angular fragments of very finely crystalline dolomite present in some beds; basal 3 to 6 ft. in several localities is calcarenite and calcirudite consisting largely of fragments reworked from Upper Ordovician formations
UNCONFORMITY					
ORDOVICIAN	Upper	Drakes Formation	Bardstown Member Rowland Member	25-50 50	Nodular-bedded fossiliferous limestone and shale Argillaceous, dolomitic limestone
		Grant Lake Limestone		140	Nodular-bedded fossiliferous limestone and shale
		Calloway Creek Limestone		60	Fossiliferous limestone and minor interbedded shale; 6-8 ft. thick calcarenite at top
		Clays Ferry Formation		300	Interbedded limestone and shale
	Middle	Lexington Limestone	Sulphur Well Member Perryville Limestone Member Tanglewood Limestone Member Grier Limestone Member Logana Member Curdsville Limestone Member	200	Fossiliferous limestone Calclutite Calcarenite Fossiliferous limestone Brachiopod coquina, calcisiltite, and shale; 24-56 ft. above base of formation. Calcarenite

Figure 3. Stratigraphic section at Jephtha Knob. Thickness and presence of members based on regional thickness and facies trends. From Cressman (1981).

west, into this survey. Detecting such low levels of iridium requires advanced techniques, instrumentation, and analytical experience, which only a handful of laboratories worldwide can provide (Montanari and Koberl, 2000; Koberl, personal communication, University of Vienna, 2005). Before his untimely death in 1980, Dr. Seeger was investigating the possibility that this structure is the central peak of a much larger complex crater (Seeger, 1968).

### Carbonate Impact Targets

The shock metamorphic effects on sedimentary targets, especially carbonates, are a relatively new frontier in impact geology. There are no definitive microscopic impact criteria for carbonate rocks at this time (Bevan M. French, personal communication, Smithsonian Institution, 2005). Much

of today's impact criteria are derived from studies performed on targets composed mostly of crystalline rocks (e.g., Sudbury, Ries, and Vredefort).

Gordon R. Osinski, J.G. Spray, Pascal Lee, and others are examining sedimentary targets with a fresh emphasis on carbonates. It has been widely held that sedimentary targets decompose during high temperatures as they release enormous quantities of H<sub>2</sub>O and CO<sub>2</sub> during impact, and therefore deduced that they contain approximately two orders of magnitude less melt rock than crystalline targets do. The work of these gentlemen is proving otherwise. In short, during abnormally high pressures that occur during impact, carbonate rocks do not behave as has been widely held. Carbonates may instead melt, break up as diverse breccias, and, in some cases, flow as a fluidized mass. These scientists have determined the clast-to-melt

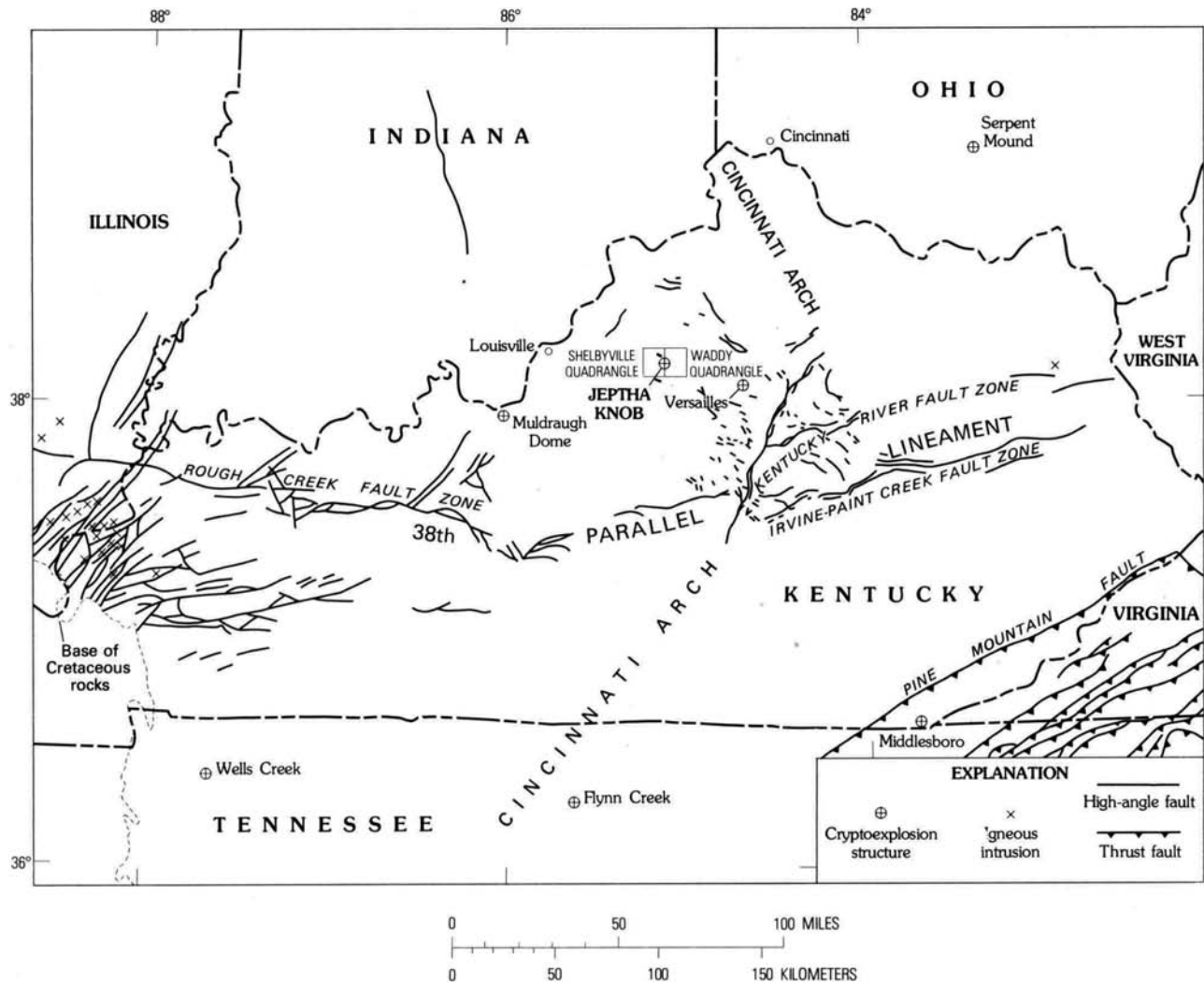


Figure 4. Map showing the structural features of Kentucky and parts of adjacent states. From Cressman (1981).

ratio of carbonates to be nearly equivalent to coherent impact melt sheets found in crystalline targets (Osinski and others, 2002a, b).

Conditions are not normal during impact events (Fig. 6). The rapid release of large amounts of energy in such events puts too much sudden stress on the target rocks for them to respond in the normal way. Typical impact velocities of tens of kilometers per second far exceed the velocities of sound in the target rocks (typically 3 to 5 miles/second). The resulting impact-produced shock waves travel through the target rocks at supersonic velocities, and they impose intense stresses on the rocks without giving them time to give way by normal deformation. In the shock-wave environment, transient pressures may exceed 500 gigapascals (GPa) at the impact point, and may be as high

as 10 to 50 GPa throughout large volumes of the surrounding target rock. Transient strain rates may reach seven to 12 orders of magnitude higher than those in ordinary geological processes. At the higher shock pressures ( $\geq 60$  GPa), shock-produced temperatures can exceed 2,000°C, and rapid, large-scale melting occurs immediately after the shock wave has passed (French, 1998).

## Points of Interest

**Point of Interest 2: Margin of the Fault and Fold Belts (WGS 84 datum, N 38.17009807, W 85.09581157, elevation 875 feet)**

This location occurs within the margin between this structure's proximal belt of faults and its distal belt of folds. The center of the Jephtha Knob

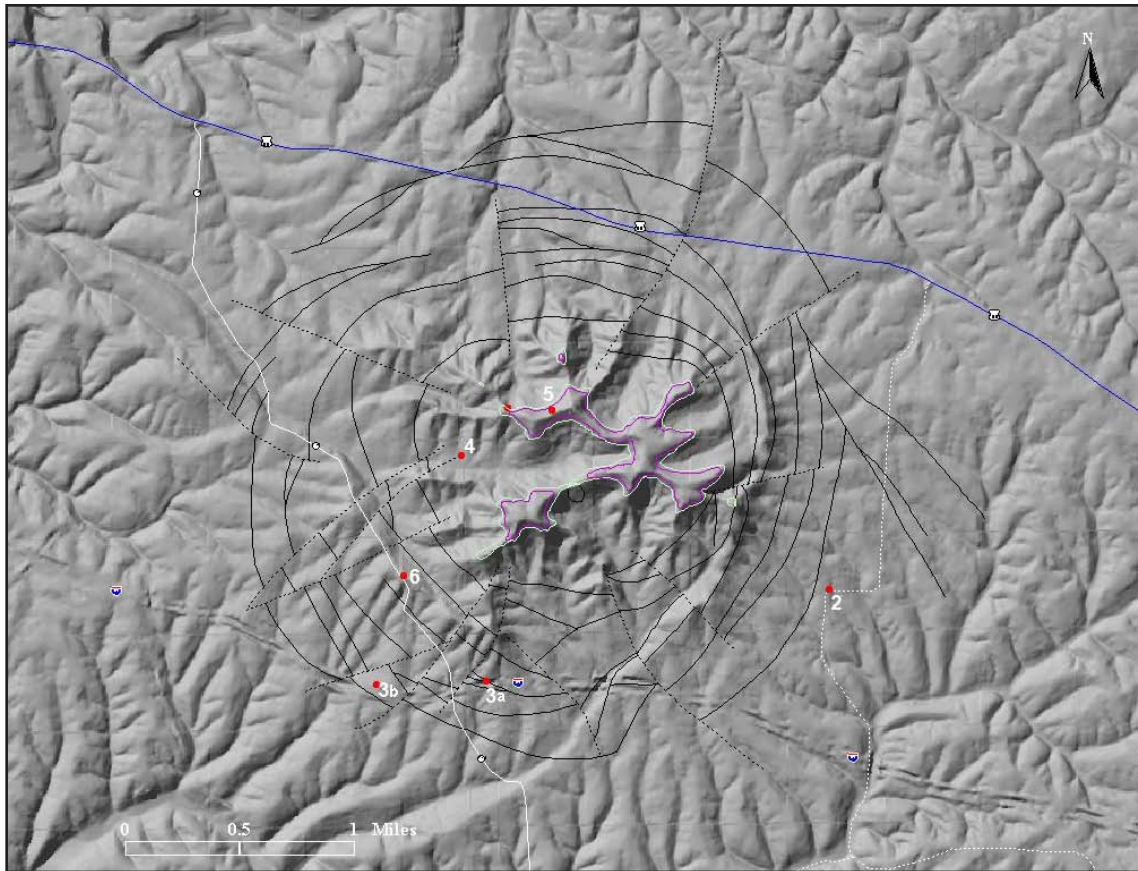


Figure 5. Hillshade digital elevation map displaying faults, Silurian cap rock contacts, local roads, and points of interest.

Characteristic	Regional Contact Metamorphism: Igneous Petrogenesis	Shock Metamorphism
Geological setting	Widespread horizontal and vertical regions of Earth crust, typically to depths of 10–50 km	Surface or near-surface regions of Earth's crust
Pressures	Typically < 1–3 GPa	100–400 GPa near impact point: 10–60 GPa in large volumes of surrounding rock
Temperatures	Generally $\leq 1,000^{\circ}\text{C}$	Up to $10,000^{\circ}\text{C}$ near impact point (vaporization): typically from $500^{\circ}$ to $3,000^{\circ}\text{C}$ in much of the surrounding rock
Strain rates	10,375 to 10.75	10.5 to 10.75
Time for completion of process	From $10^5$ to $10^7$ years	“Instantaneous”: Shock-wave passage through 10 cm distance, < $10^{-5}$ s; formation of large (100-km diameter) structure < 1 hour
Reaction times	Slow; minerals closely approach equilibrium	Rapid abundant quenching and preservation of metastable minerals and glasses

Figure 6. Shock metamorphism from impacts: distinction from other geological process (from French, 1998).

structure is 1.25 miles northwest of this location. This stop also affords a scenic view of the knobs as they appear to rise up out of the surrounding plain (Fig. 7). The lone knob in the distant foreground is 0.6 mile away and it is the tallest knob in the eastern outer belt of arcuate knobs, rising to 1,142 feet.

***Point of Interest 3a: Faults, Folds, and Injection Breccias(?) (WGS 84 datum, N 38.16473901, W 85.12339004, elevation 890 feet)***

*Note:* This stop is sure to produce much hand-waving, heated discussions, and flying sparks.

Late in the summer of 1961, when the “grade and drain” construction of I-64 in eastern Shelby County was nearly completed, Willard Rouse Jillson was driving the westbound lane during a reconnaissance tour and noted faulted disturbances at three points south of Jephtha Knob. None of Jillson’s observations were previously mapped by Bucher (1925).

Point of interest 3a is a visit to Jillson’s “Western Disturbance” (Fig. 8). Here we will observe mixed breccias injected into faults and bedding planes. Cressman (1981) noted that particular mixed breccias observed along Jephtha Knob faults

were not unlike the mixed breccias reported to occur at Sierra Madera in Texas (Wilshire and others, 1972); at both locations the breccias consist of fragments that have moved both upward and downward. The difference is that most of the mixed-breccia occurrences at Sierra Madera are not along faults, but are in the vicinity of the central uplift and form tabular sheets that cut the country rock at steep angles (Cressman, 1981). The Lockne impact structure in Sweden contains clastic injection (breccia) feeder dikes that cut through country rock and propagate sideways (Sturkell and Ormo, 1997).

In the summer of 2004, Mark F. Thompson observed breccias between at least three bedding planes at this location (Fig. 9). Further investigation (Fig. 10) revealed bedding in a frozen state breaking into clasts (cataclasis) and broken clasts in the process of being plucked from bedding planes and subsequently incorporated into the breccia matrix (cataclasite) (see polished section in Figure 11). He also noted that the rocks at this outcrop contain a wide range of amplitudes over a small cross section of area. These strata appear to have very rapidly been forced into a smaller compartment.

At this location in the summer of 2005, Mark F. Thompson observed what appears to be a feeder dike cutting through the limestone succession and



Figure 7. Scenic view from the northwest from the fault and fold margin. The knobs in the distant foreground appear to rise up from the surrounding plain.

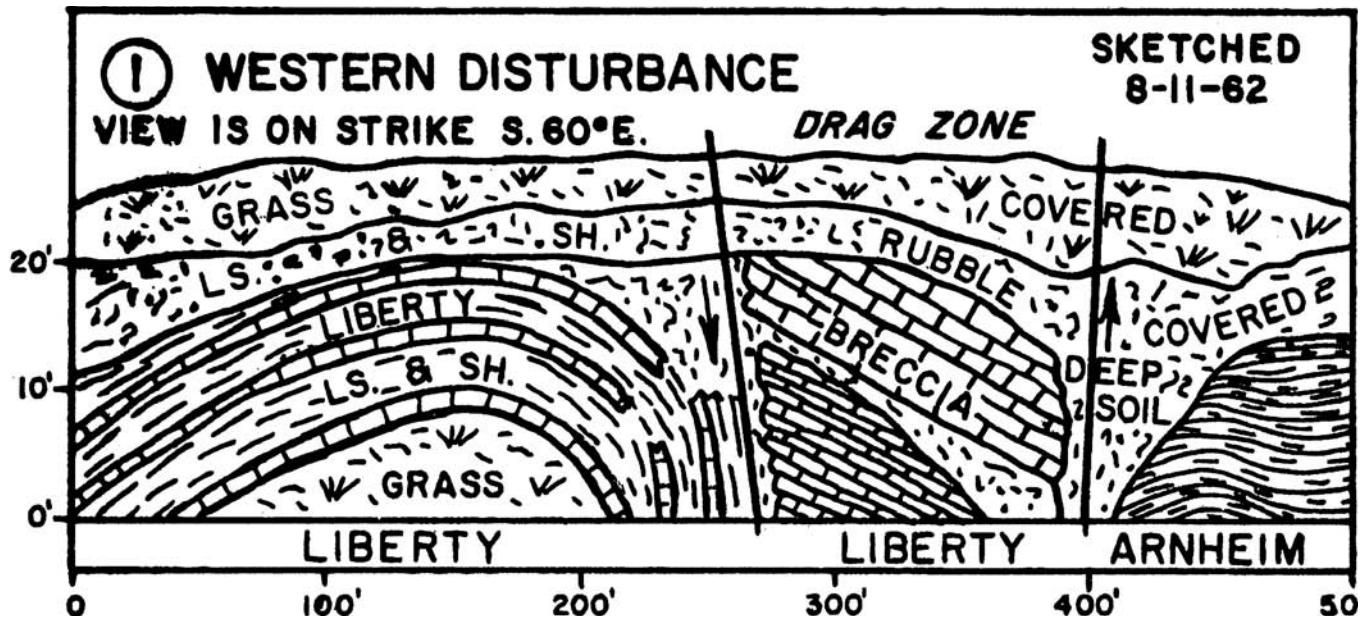


Figure 8. Sketch of deformed rocks of point of interest 3a. Tick marks are 10 feet vertical, 100 feet horizontal. This view covers from about 550 to 1,050 feet east of the Ky. 714 overpass on the north lane of I-64, in direction N60W. "Liberty" implies Drakes Formation; "Arnheim" implies Grant Lake Limestone. Rocks are more covered by soil and vegetation than implied in the sketch. A stratigraphic separation of over 500 feet is implied in the faulting shown here, but, as an indication of complexity, Cressman (1975b, 1981) mapped Calloway Creek Limestone south of these faults, and Clays Ferry is also involved. From Jillson (1962) and Seeger (1986).



Figure 9. Deformed rocks at point of interest 3a. The position of the rocks shown in Figure 10 is outlined. Notice the many ranges of amplitudes occurring here.



Figure 10. Cataclasite frozen during formation. Bedding is breaking into clasts (cataclasis), and broken clasts are in the process of being plucked from bedding planes and subsequently incorporated into the breccia matrix (cataclasite). A small-amplitude fold caps the cataclasite.

propagating sideways between bedding planes. Approximately 1,000 feet to the west is a very large sheet or irregular mass of breccias that may be walked upon.

Thompson cautiously interpreted the breccias and mixed breccias of the Jephtha Knob structure to have originated from impact-related clastic injections. The best model for this cursory field trip is that of the Ordovician Lockne impact structure in central Sweden (Fig. 12).

***Point of Interest 4 and Stop 1: The Knobs Farm—Resort Home (WGS 84 datum, N 38.17905664, W 85.12504228, elevation 930 feet)***

Stop 1, at the Knobs Farm (Fig. 13), is located 0.45 mile due west from the center of the structure and is approximately 0.2 mile inside the central uplift. This is private land, and permission must be

obtained from the landowner to enter. No exceptions!

***Point of Interest 5: A View from the Top and Ordovician-Silurian Contact (WGS 84 datum, N 38.18178177, W 85.11766621, elevation 1,165 feet)***

Point of interest 5 affords many spectacular views from the top of Jephtha Knob upon the Silurian cap rock (Fig. 14). After taking in the views, the Ordovician-Silurian contact can be examined (Fig. 15) and karren feature development upon the subparallel Brassfield dolostones can be looked at. Karren, from the German “wheel tracks,” are furrows that occur from solution by rain wash on carbonate rocks. Figure 16 is a polished slab of the Silurian Brassfield Formation present only in the Jephtha Knob area.

This location is 0.2 mile northwest of the center of the structure. Looking west-northwest from



Figure 11. Bedding in a frozen state breaking into clasts (cataclasis) and broken clasts in the process of being plucked from bedding planes and subsequently incorporated into the breccia matrix (cataclasite).

here, Kentucky's Knobs geophysical region can be viewed. This is the escarpment approximately 19 miles away on the distant horizon. The confluence of the Kentucky River with the Ohio River is approximately 35 miles due north in Carroll County, Ky. On a clear day it is possible to see clouds of steam rising from power plants along the Ohio River. Try to imagine a Pleistocene moment in which a 1-mile-thick ice sheet may have once glistened blue-green along the horizon to the north, or a herd of megafauna roaming and grazing the peneplain in the foreground. If you're into modern history, you might imagine buffalo migrations or Indians or pioneers traveling along the Midland Trail, which was succeeded by U.S. 60. More im-

portant, take a moment to experience the present moment and the deafening silence this location provides.

Why does this Jephtha Knob structure rise as a monadnock above the slightly rejuvenated peneplain of the Tertiary that we see before us? Why wasn't this structure eroded down to the approximately 900-foot elevation of the Lexington Peneplain? Is the cap rock protecting this structure? How could this occur when the cap rock once covered this entire region? Walter H. Bucher (1925) was the first to address this question, and subsequent observations have built upon his interpretation.

The reason Jephtha Knob survives as a residual hill on the Lexington Peneplain is most likely threefold. It is a combination of normal faulting, porous rock occurrences, and the presence of encompassing marginal synclines. The occurrences of the Drakes Formation in downdropped normal fault blocks have protected Jephtha Knob from earlier erosion. Present-day erosion is exposing these rocks in downdropped fault blocks. Their relatively porous and permeable nature with respect to other surficially exposed units has reduced surface runoff, however, and therefore inhibited Drakes Formation erosion. In other instances, the synclinal structures within the fault blocks that contain the Drakes Formation also inhibit surface runoff through capture and diversion away from stream channels. Therefore, all three of these conditions play a role in slowing erosion of the Jephtha Knob structure.

***Point of Interest 6: The Southwest Fault Belt and Arcuate Knob Belt (WGS 84 datum, N 38.17150354, W 85.12987562, elevation 990 feet)***

This point of interest is located in the middle of the southwestern fault belt and situated 0.9 mile southwest of the center of the Jephtha Knob structure. We're standing upon the spine of yet another arcuate knob belt. This southwestern belt of arcuate knobs is approximately 1.1 miles long and trends in a northwest-southeast direction. Like the eastern belt of arcuate knobs, this southwestern belt is also a product of differential erosion. In contrast to the eastern knob belt, the resistant Drakes Formation rocks here are in fault blocks that appear to be situ-

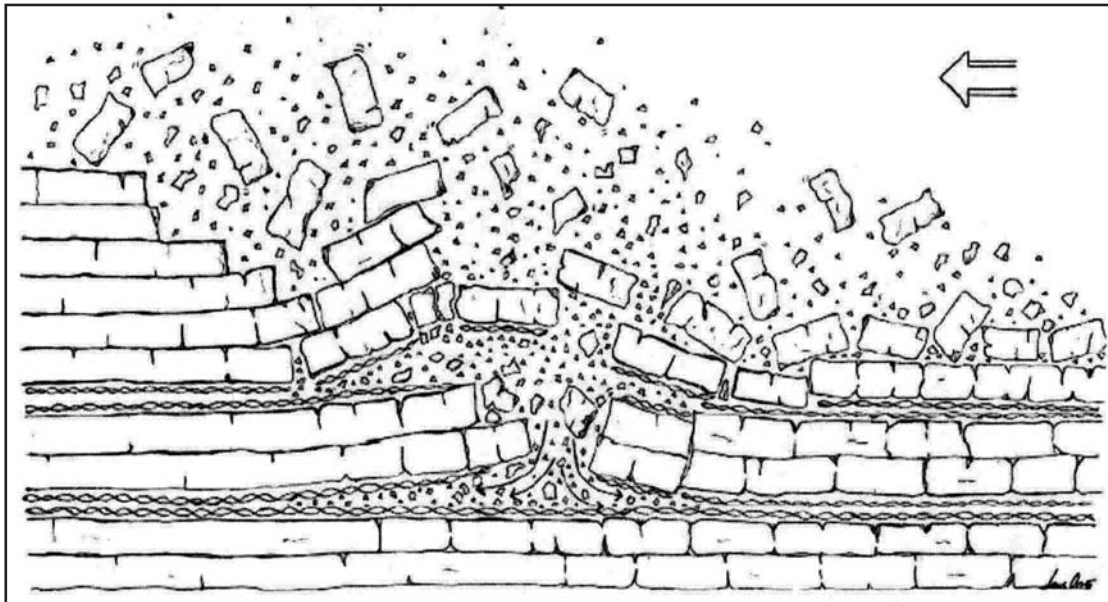


Figure 12. Drawing showing the rarefaction wave that follows the compression wave propagating through the sedimentary succession. The strata are separated along the bedding surfaces, especially along the weaker layers. Clastic material is sucked in between the separated beds (from Sturkell and Ormo, 1997).



Figure 13. Entrance to the Knobs Farm as it appeared on January 7, 2003. View is northeast. Britton Run is the valley in the foreground.



Figure 14. Scenic view looking northwest from the top of the Silurian cap rock.

ated at higher relative positions than many of the other surrounding fault blocks. Also noteworthy is that the rocks of the Drakes Formation at this location are tightly folded into an inwardly plunging syncline.

Erosive forces have been at work on the Jephtha Knob structure more excessively on its southwestern region than on its eastern region. This is because the structure is located in the headwaters of the westward-draining Salt River watershed. The southwestern section of Jephtha Knob is located in a more mature section of the Salt River drainage, whereas the eastern section is in the headwaters. Therefore, the eastern region is subject to slower erosive rates.

Looking 0.5 mile to the northeast, into the central uplift, you can see an approximately 90-foot-thick sequence of Silurian cap rock rising to an elevation of approximately 1,185 feet at its crest

(Fig. 17). The elevation of this location is 990 feet and it is near the contact between the Saluda and Bardstown Members of the Drakes Formation. Therefore, the strata within the fault block at this location have downdropped a minimum of 55 to 80 feet from their original stratigraphic position.

The view south is across the fault and fold belts (Fig. 18). I-64 is 0.5 mile due south, where it passes over some of the structure's southernmost faults. Beyond I-64 for approximately 0.5 more mile south is the fold belt that dampens into strata having structural dips consistent for this region, ranging from 16 to 22 feet per mile.

Appendix A contains core descriptions as well as some selected photographs of split and polished core sections to show some of the distorted bedding and possible breccia zones from the Ozark Mahoning JK78-1 core from the top of Jephtha Knob. Locations of cores are shown on Figure 1.



Figure 15. Silurian cap rock outcrop (Brassfield Formation) at the Ordovician-Silurian contact. This site is comparable to one that contains Seeger's (1985) iridium anomaly.

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Figure 16. Polished slab of the Silurian Brassfield Formation, which is slightly phosphatic and glauconitic, showing crinoid, bryozoan, and other fragments in a greenish-yellow dolomite.



Figure 17. Scenic view from the southwestern fault belt looking northeast into the central uplift and upon the overlying Silurian cap rock.

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Figure 18. Scenic view toward the southwest from the southwestern fault belt.



# Fossil Collecting at Grant Lake and Calloway Creek Limestone Outcrops

Frank R. Etensohn and Stephen F. Greb

## Roadlog Mileage

Miles to	Cumulative		2.0	6.9	
0.0	0.0	Exit out of Britton Run. Turn right onto Ky. 714.	1.8	8.7	Turn left onto Ky. 55/Freedom's Way.
1.6	1.6	Turn left onto U.S. 60.			Pull off onto shoulder and stop at outcrop of Calloway Creek and Grant Lake Limestone. <b>This is stop 2a</b> (Fig. 1).
3.3	4.9	Turn right onto Ky. 53/Business 55.			

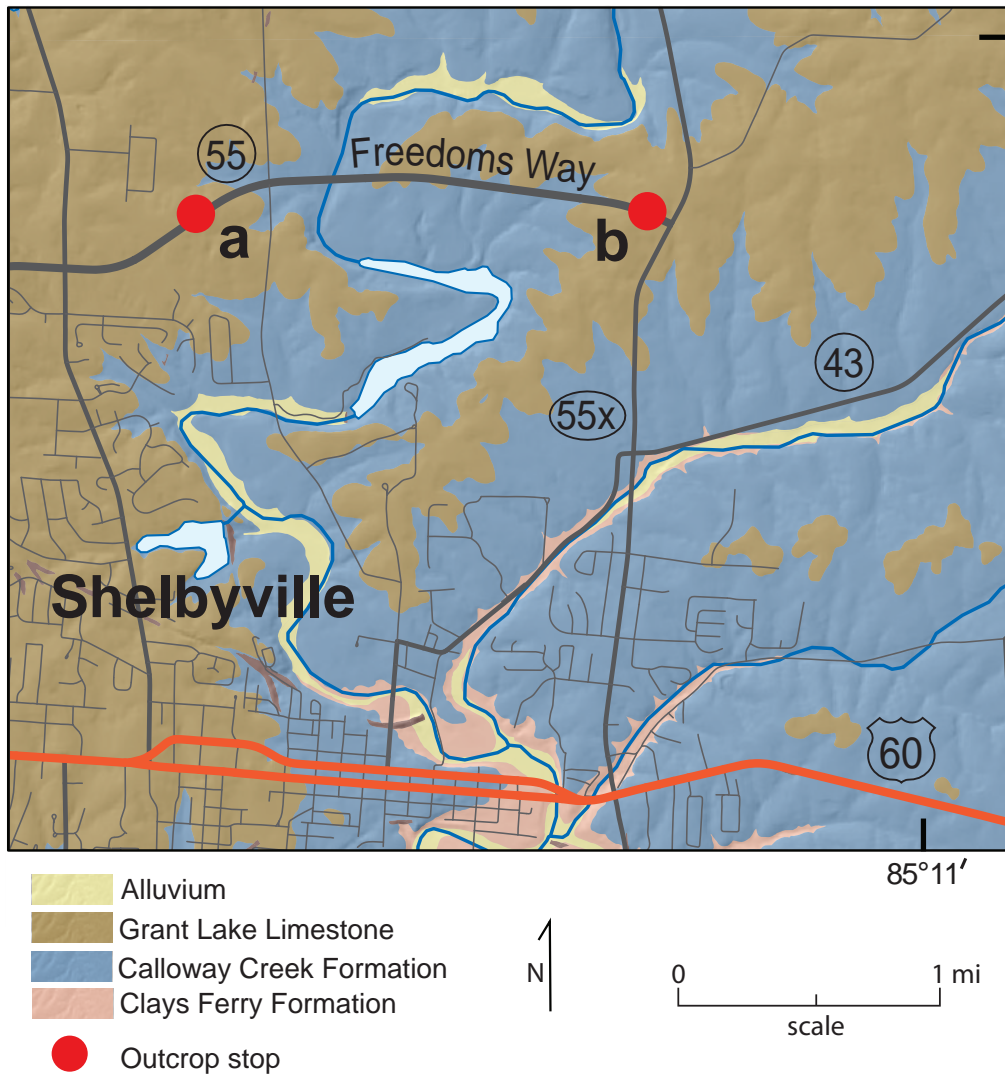


Figure 1. Location map showing stops 2a (WGS 84 datum, N 38.2441016, W 85.2311833) and 2b (WGS 84 datum, N 38.2411333, W 85.2013333).

## Introduction to Fossil-Hunting Localities

### Stratigraphy

The Upper Ordovician Calloway Creek and Grant Lake Limestones occupy the Maysvillian Stage of the Cincinnati Series (see, e.g., Cressman, 1975). The base of the Calloway Creek is the base of the Maysville, whereas the top of the Grant Lake Limestone is locally the top of the Maysville. The Grant Lake is equivalent to the McMillan Formation of older Kentucky literature, which was composed of the Bellevue, Corryville, and Mount Auburn Members. These names are widely used in paleontologic and paleoecologic investigations of the Cincinnati Series. Using the chronology of Ogg and others (2008), the Calloway Creek and Grant Lake Limestones are approximately 452 million years old.

Upper Ordovician strata in central Kentucky and the greater Cincinnati area have been divided into a series of third-order sequences (Pope and Read, 1997; McLaughlin and others, 2004). These sequences define broad sea-level trends, which can be correlated across much of North America. The same units can also be examined as part of a large regional regression that accompanied the waning stages of the Taconic tectophase of the Taconian Orogeny (Ettensohn, 1991, 2008).

### Upper Ordovician Paleogeography

The Upper Ordovician limestones and shales of central Kentucky were deposited on a very gently dipping ramp on the western margin of the Appalachian foreland basin. In addition, this area was a part of the continent Laurentia, which was situated in the subtropical, trade-wind belt, approximately 25° south latitude (Scotese, 2007) (Fig. 2). This position placed the region astride major storm pathways during Ordovician time (Marsaglia and Klein, 1983; Ettensohn and others, 1986).

### Depositional Environments

Rock units in the field area are inferred to have been deposited in a series of shallow marine depositional environments in an overall regressive (shallowing) sequence (Figs. 3–4). The deepest end member is represented by the Clays Ferry Formation; it consists of interbedded shales, fine-grained limestones, and siltstones, of which 50 percent is shale (Cressman, 1975). This unit has been interpreted to represent deep open-marine environments well below normal wave base (Cressman, 1973; Ettensohn, 1992). Although this unit is present in the Shelbyville area, it will not be visited on this trip.

The shallow end member is represented by the Rowland Member of the Drakes Formation (Figs. 3–4), which also crops out in the Shelbyville area but will not be seen on this trip. The Rowland Member is characterized by greenish gray, argillaceous, dolomitic limestones interbedded with silty, glauconitic mudstones (Cressman, 1975). Fossils are typically sparse, but accumulations of ostracods occur locally. Ripple marks and mud cracks cover many bedding surfaces. This unit has been interpreted to represent

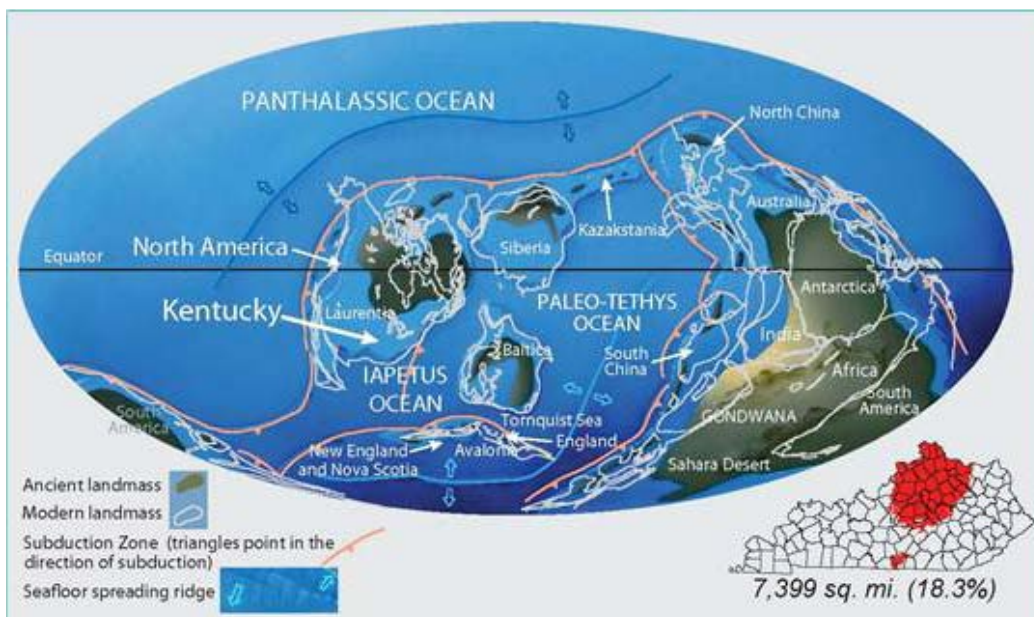


Figure 2. Paleogeographic reconstruction of Laurentia during Late Ordovician time (after Scotese, 2007) showing the location of the central Kentucky field trip area (red dot). Used with permission.

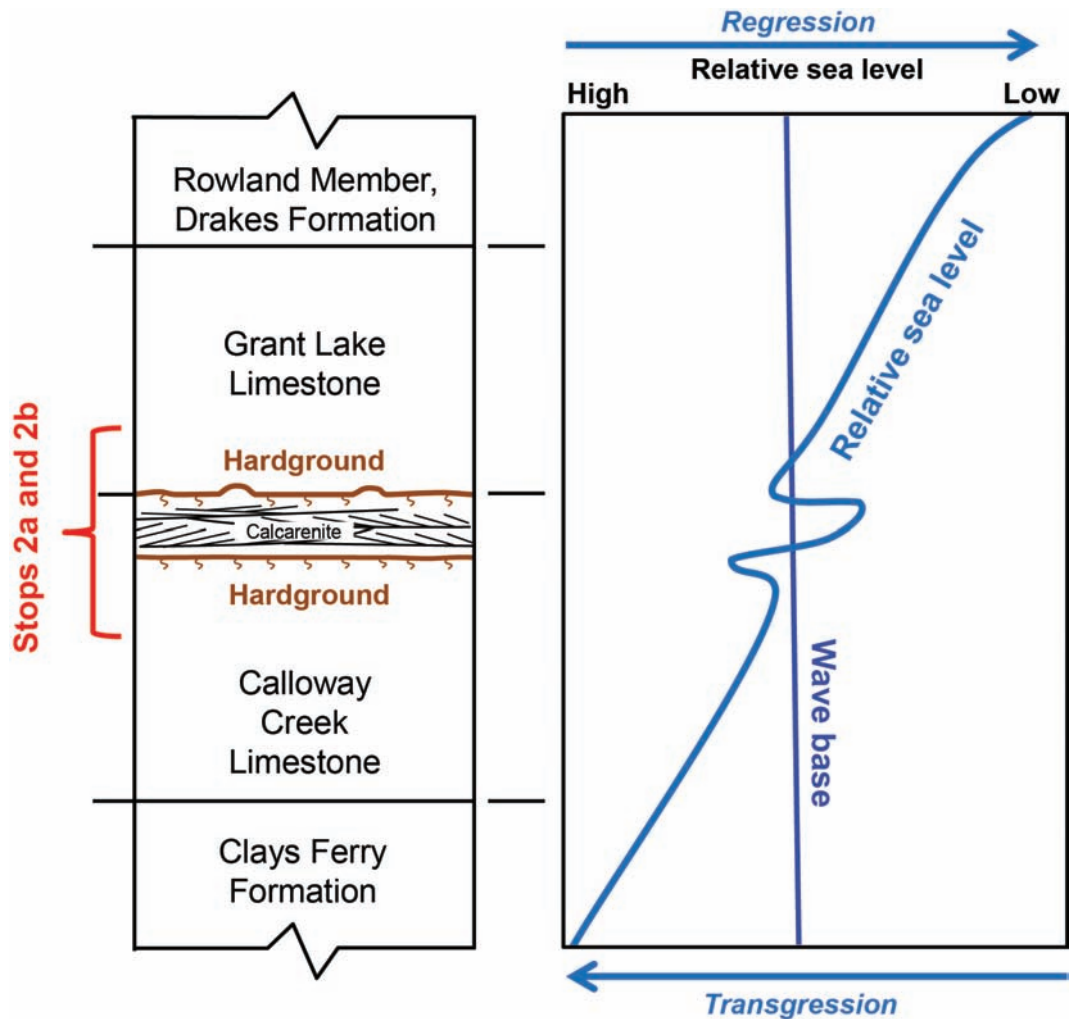


Figure 3. Relative sea-level curve and generalized stratigraphic column of Upper Ordovician strata in the Shelbyville area. Bracketed area to the left represents the part of the section viewed at the fossil-collecting stops.

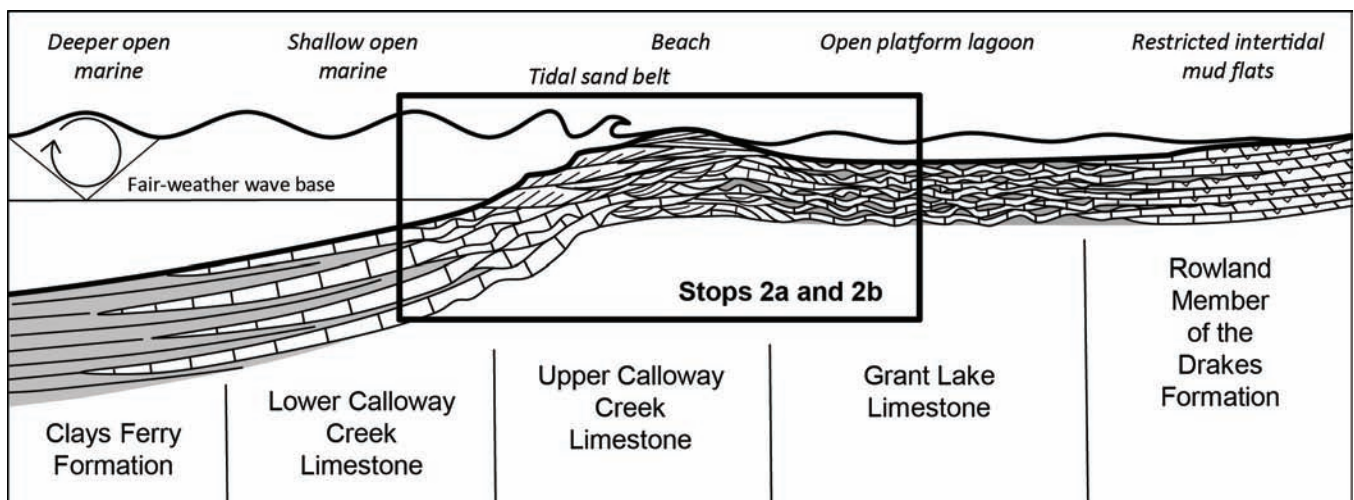


Figure 4. Schematic environmental continuum interpreted to represent the sequence of environments present in the Shelbyville area. The boxed-in area represents the part of the continuum represented in the fossil-collecting stops.

very shallow, quiet, intertidal mud flats (Weir and Peck, 1968).

Between these two end members, the Calloway Creek and Grant Lake Limestones represent the intervening shallow open-marine, tidal shoal,

and platform lagoonal environments (Fig. 4). These units are well exposed at stop 2.

### ***Calloway Creek Limestone***

The Calloway Creek Limestone is 60 feet thick in the Shelbyville area and is largely composed of interbedded fossiliferous calcarenites (80 percent) and interbedded calcareous shales (20 percent), although the upper 6 to 12 feet typically contains very coarse-grained, crossbedded calcarenites and calcirudites (Fig. 5). Fossils are dominated by large bryozoans and brachiopods, which are commonly fragmented (Cressman, 1975).

#### ***Lower Interval***

At stop 2a only the upper 18 feet of the Calloway Creek is exposed. The lower 6 feet of the unit contains thin, even-bedded, fossiliferous calcarenites and interbedded shales that are typical for the formation (Fig. 5). These beds represent storm deposition in a shallow, open-marine setting. Each thin bed of limestone probably represents a storm deposit that formed a firm substrate on which brachiopod and bryozoan communities could become established. Large robust, trepostome bryozoans are especially characteristic of Calloway Creek limestones (Cressman, 1975). The fragmented nature of many fossils shows the effects of storms on these bottom communities. Storm facies have been widely studied in Upper Ordovician strata

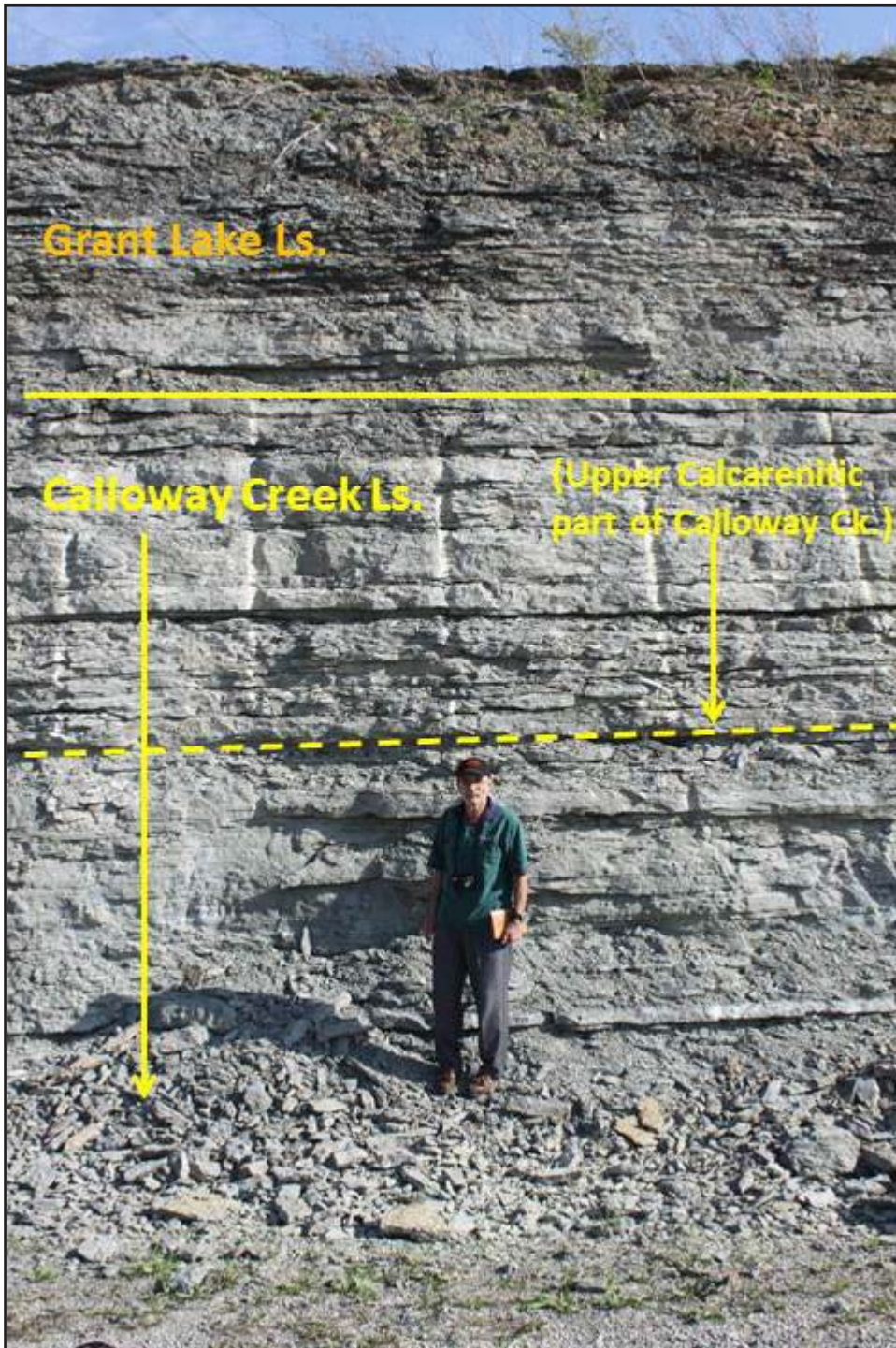


Figure 5. Parts of the stratigraphic section exposed on the south side of the highway at stop 2a.

of north-central Kentucky (see, e.g., Jennette and Pryor, 1993).

### **Upper Interval**

The lower Calloway Creek is separated from the upper 11 to 12 feet of the unit by a thin (1.5 inches), rust-stained hardground or discontinuity surface (Fig. 3). The hardground consists of pyrite oxidized to various iron oxides and phosphorite and represents a brief period of sediment starvation and sea-level rise at a parasequence boundary (Clepper and Etensohn, 2012). Overlying parts of the unit consist of light gray, bioclastic calcarenite and calcirudite with prominent crossbeds (Fig. 6), ripple bedding (Fig. 7), scours, and storm-lag horizons. Hummocky bedding is present below the crossbeds in the lower part of the upper interval. The prominent crossbeds at this stop appear to have foresets with opposing orientations, commonly referred to as herringbone crossbeds, but troughs in successive crossbeds are obliquely oriented rather than directly opposed. Large frag-

mented fossils and mudstone rip-up clasts are common throughout the interval (Fig. 8). Where the fossils have been dissolved and the mudstones weathered away, yellow calcite, orange-brown dolomite, and sphalerite have filled in the voids (Figs. 7–8), giving this part of the Calloway Creek Limestone an orange-brown-speckled appearance. Just beneath the hardground at the top of the formation, is a thin (6 to 8 inches), dark gray, fine- to medium-grained calcarenite that shows low-angle, unimodal crossbedding, dipping 2 to 9° south-southwest (Fig. 9).

The grain size and crossbedding in the upper Calloway Creek indicate deposition on a series of migrating sandbelt shoals above wave base (Fig. 4). Prominent crossbeds were probably deposited by tidal currents. Hummocky crossbedding in the lower part of the interval and amalgamated bedding suggests that storms also periodically reworked this sandbelt. Symmetrical ripples show the influence of fair-weather wave reworking. The low-angle bedding at the top of the interval repre-



Figure 6. Crossbeds from the upper calcarenitic part of the Calloway Creek Limestone (see Figs. 2–4) on the north side of the road at stop 2a.



Figure 7. Ripple bedding (center of the photograph) from the upper calcarenitic part of the Calloway Creek Limestone on the north side of the road at stop 2b. Brownish orange speckling on the exposure is a dolomitic infill cement.

sents a short interval of beach or lower-shoreface development on top of the shoals (Fig. 4). This beach facies, in turn, is abruptly overlain by another hardground or discontinuity surface marked by pyrite, iron and manganese oxides, and phosphorite (Figs. 3, 10). At both outcrops, the presence of large erosional remnants, as much as a foot thick, on the hardground (Fig. 11) suggests that a period of submarine erosion accompanied sediment starvation and flooding across this surface before deposition of the overlying Grant Lake Limestone (Fig. 3).

### Soft-Sediment Deformation

At the east end of the western outcrop, parts of the tidal sandbelt facies in the Calloway Creek have been deformed into penecontemporaneous, soft-sediment structures that have been called flow rolls, pseudonodules, or ball-and-pillow structures (Fig. 12). Structures like this can have many origins, but without further examination of additional exposures, the most likely origins are storm-related or seismic. Numerous studies have interpreted horizons of soft-sediment deformation (mostly ball-and-pillow structures) in the Upper Ordovician of central Kentucky, southeastern Indiana, and southern Ohio, as seismites, or beds formed from liquefaction induced by an earthquake (Kulp, 1995;

Pope and others, 1997; Ettensohn and others, 2002; Jewell and Ettensohn, 2004; McLaughlin and Brett, 2004). But not all soft-sediment deformation in the Upper Ordovician was related to earthquakes. Storms can also induce this kind of deformation through overpressuring by high-amplitude storm waves (Kraft and others, 1985; Okusa, 1985) or by the drag force of bottom storm currents (Lowe, 1976; Orange and Breen, 1992). At this stop, the overturning of crossbeds and the incomplete infilling of overlying scours by apparent storm-lag deposits in the same horizon as the ball-and-pillow structures (Fig. 12) suggest that storms were the likely origin for the deformation.

### Grant Lake Limestone

The Grant Lake Limestone is 150 feet thick in the field stop area (Cressman, 1975). At stops 2a and 2b only the basal 15 to 20 feet are exposed in these two cuts. The unit is composed of 70 to 90 percent medium- to coarse-grained, poorly sorted, argillaceous limestone with interbedded shale and mudstone (Weir and Peck, 1968; Cressman, 1975; Pojeta, 1975). The limestones are mainly irregularly bedded to nodular and are largely composed of rubbly jumbles of large fossil fragments and whole fossils surrounded by a limy, mud matrix (Fig. 13). Common fossils include the brachiopods



Figure 8. Linear voids in the outcrop reflect former rip-up clasts, some of which have been filled in with a brownish orange dolomite, calcite, and sphalerite.



Figure 9. Low-angle unimodal crossbeds at the top of the Calloway Creek Limestone that may represent a short-lived beach on the north side of the road at stop 2b.



Figure 10. Iron-stained hardground or discontinuity surface on top of the Calloway Creek Limestone on the north side of the road at stop 2b.



Figure 11. Example of an erosional remnant as much as 1 foot thick (above notebook), encased with the iron-stained hardground deposits, on top of the Calloway Creek Limestone on the north side of the road at stop 2b.



Figure 12. Penecontemporaneous, soft-sediment deformation of crossbeds that is commonly called flow rolls, pseudonodules, or ball-and-pillow structures, overlain by a large scour incompletely filled by apparent storm-lag deposits. From near the top of the Calloway Creek Limestone on the north side of the road at stop 2b.

*Vinlandostrophia ponderosa*, *V. laticosta*, *Rafinesquina alternata*, *Hebertella occidentalis*, various massive ramose and platy trepostome bryozoans, internal molds of burrowing modioliiform pelecypods, the pelycepod *Ambonychia flanaganensis*, crinoid debris, and internal gastropod molds. Table 1 is a list of known fossils from the Grant Lake Formation in Kentucky. Plates of common fossils are included in Appendix B.

The stratigraphic position of the unit, as well as its lithologic and faunal makeup, suggest that the Grant Lake was deposited in an extensive, open-marine, platform lagoon behind the tidal sandbelt of the Calloway Creek and the restricted, intertidal mudflats of the Rowland Member of the Drakes Formation (Fig. 4). The abundance of mud and fine-grained carbonate in the unit suggests that it was deposited in a generally quiet-water, platform environment protected behind the Calloway Creek sandbelt. However, the bottom of

the platform lagoon was clearly above wave base because it was continually ravaged and reworked by storm waves as is indicated by the jumbles of stacked brachiopod shells that characterize the unit (Fig. 14). Added to the disruption caused by storms was intense bioturbation by an abundant infauna of modioliiform pelecypods (Appendix B, Plate B2), which has given rise to the nodular appearance of limestone in shales throughout the unit (Appendix B, Plate B2). As the aragonite shells of these pelecypods easily dissolved, crude internal molds of these pelecypods are all that remain, but these molds are common throughout the unit.

## Paleoecology

Fossils are abundant in the Grant Lake Formation and many reveal information about the paleoecology of the unit. *Rafinesquina alternata* is a relatively flat strophomenid brachiopod (Appendix B, Plate B1). It is common in shalier inter-

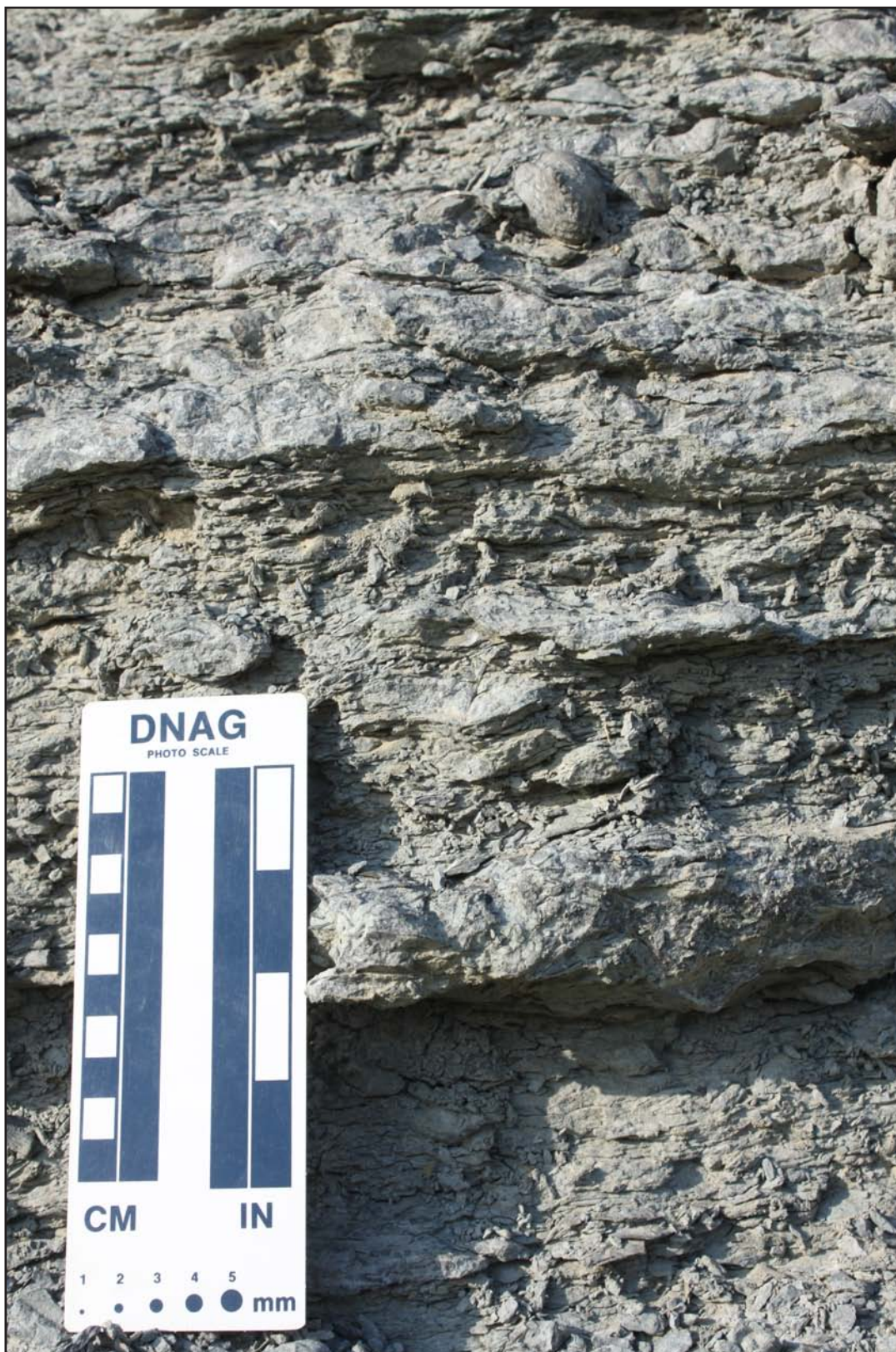


Figure 13. Typical Grant Lake Limestone lithology composed of irregularly bedded to nodular limestone and shale, showing rubbly jumbles of large fossil fragments and whole fossils surrounded by a limy mud matrix. From the north side of the road at stop 2a.

**Table 1.** Fossils reported from the Grant Lake Limestone in central Kentucky and the greater Cincinnati area. Updated from Weir and others (1984) and Kentucky Geological Survey paleontological database.

### Arthropods

#### Crustaceans/Ostracodes

- Bolbopisthia* sp.
  - aff. *B. reticulata* (Kirk)
- Ceratopsis* sp.
  - C. oculifera* (Hall)
- Cryptophyllus* sp.
- Ctenobolbina* sp.
  - aff. *C. cilata* (Evans)
- Kenodontochilina* sp.
  - aff. *K. subnodosa glabra* Berdan
- Laccoprimitia* sp.
- Leperditella* sp.
- Quasibollia*
  - Q. persulcata* (Ulrich)
- Saffordellina* sp.
  - S. striatella* Berdan
- Ulrichia* sp.
  - U. nodosa* (Ulrich) [previously *Warthinia nodosa* Ulrich]

#### Brachiopods

##### Orthids (small)

- Cincinnatiina* sp.
  - C. meeki* (Meek) [previously reported as a species of *Dalmanella*, *Onniella*, and *Reserella*]
- Dalmanella* sp.? [may refer to *C. meeki* above]
- Zygospira* sp.
  - Z. modesta* Hall

##### Orthids (large)

- Hebertella* sp.
  - H. occidentalis* (Hall)
- Vinlandostrophia* sp. (previously *Platystrophia*)
  - V. cypha* (James)
  - V. laticosta* (Meek)
  - V. ponderosa* (Foerste)

#### Bryozoans

##### Trepustome

- Amplexopora* sp.
  - A. ampla* Ulrich and Bassler
  - A. cingulata* Ulrich
  - A. filiasa* (d'Orbigny)
  - A. parva* Utgaard and Perry
  - A. welchi* James
- Atactoporella* sp.
  - A. mundula* (Ulrich)
  - A. ortonii* (Nicholson)
- Batostoma* sp.
  - B. implicatum* (Nicholson)
- Batostomella*
  - B. igracilis* (Nicholson)
- Calloporrella* sp.
- Cyphotrypa*? sp.
- Dekayia* sp.
  - cf. *D. appressa* Ulrich
  - D. aspera* Milne-Edwards and Haime
  - cf. *D. nicklesi* (Ulrich and Bassler)
  - D. pelliculata* Ulrich

##### Trilobites

- Flexicalymene* sp.
  - F. meeki* (Foerste)
- Isotelus* sp.
- Pterygometopus (Achatella)* sp.
  - P. (A.) cincinnatiensis* Meek
  - P. (A.) microps* (Green)

##### Inarticulate craniids

- Petrocrania* sp.
  - P. scabiosa* (Hall)

##### Strophomenids

- Eochonetes* sp.
- Rafinesquina* sp.
  - R. alternata* (Emmons)
- Strophomena* sp.

- Heterotrypa* sp.
  - H. frondosa* (d'Orbigny)
  - H. inflecta* (Ulrich)
  - H. paupera* (Ulrich)
  - H. solitaria* (Ulrich)
- Homotrypa* sp.
  - H. curvata* Ulrich
  - cf. *H. flabellaris spinifera* Bassler
  - cf. *H. pulchra* Bassler
  - cf. *H. spinea* Cummings and Galloway
- Mesotrypa*? sp.
- Monticulipora*? sp.
  - M. cincinnatiensis*? (James)
- Nicholsonella* sp.
  - N. vaupeli* (Ulrich)
- Parvohallopora* sp.
  - P. ramosa* (d'Orbigny)
  - P. subnodosa* (Ulrich)
- Peronopora* sp.
  - cf. *P. decipiens* (Rominger)
- Stigmatella* sp.

Table 1. Continued.

**Bryozoans (continued)**

## Other Bryozoans

*Bythopora* sp.  
*B. dendrina* (James)  
*Ceramoporella* sp.  
*Constellaria* sp.  
*C. florida* Ulrich  
*Corynotrypa* sp.  
*Crepipora?* sp.  
*Cuffeyella* sp.

*Escharopora* sp.  
*Graptodictya* sp.  
*Stictopora* sp.  
 cf. *S. lata* (Ulrich)  
*Trigonodictya?* sp.  
*Vinella* sp.  
*V. radialis* Ulrich

**Chordates**

## Conodonts

*Amphelognathus* sp.  
*A. grandis* Branson and Mehl  
*Cordylodus* sp.  
*Drepanodus* sp.  
*D. homocurvatus* Lindström  
*D. suberectus* Branson and Mehl  
*Drepanoistodus* sp.  
*D. suberectus* (Branson and Mehl)  
*Oulodus* sp.  
*O. casteri* Pulse and Sweet  
*O. oregonia* (Branson, Mehl, and Branson)  
*O. robustus* (Branson, Mehl, and Branson)  
*O. subundulatus* (Sweet and others)  
*O. ulrichi* (Stone and Furnish)

*Phragmodus* sp.  
*P. undatus* Branson and Mehl  
*Plectodina* sp.  
*P. tenuis* (Branson and Mehl)  
*Rhipidognathus* sp.  
*R. symmetricus* Branson, Mehl, and Branson

**Echinoderms**

## Crinoids

*Cincinnaticrinus* sp.  
*C. pentagonus* (Ulrich)  
*Dystactocrinus* sp.  
*D. constrictus* (Hall)  
*Ectenocrinus?* sp.

## Cyclocystoides

*Cyclocystoides* sp.

**Hemichordates**

## Graptolites

*Geniculograptus*  
*G. typicalis posterus* (Ruedemann)

## Edrioasteroids

*Carneyella* sp.  
*C. pilea* (Hall)  
*C. ulrichi* Bassler and Schideler  
*Curvitriordo* sp.  
*Isorophus* sp.  
*I. cincinnatiensis* (Roemer)  
*Streptaster* sp.  
*S. vorticellatus* (Hall)

**Molluscs**

## Bivalves (Pelecypods)

*Ambonychia* sp.  
*A. praecursa* (Ulrich)  
*Caritodens?* (*Pterinea*) sp.  
*C. demissa* (Conrad)  
*C. insueta* (Emmons)  
*Ctenodonta* sp.  
*C.?* *cingulata* Ulrich  
 aff. *C. iphigenia* Billings  
 aff. *C.?* *longa* (Ulrich)  
*C. pectunuculoides* (Hall)  
*Cuneamya* sp.  
*Cycloconcha* sp.  
*Cymatonota* sp.  
*Deceptrix*  
 cf. *D. filistriata* (Ulrich)

*Ischrodonta* sp.  
*Lyrodesma* sp.  
*L. inornatum* Ulrich  
*Modiolodon?* sp.  
*Modiolopsis* sp.  
*M. modiolaris* (Conrad)  
*Nuculites* (*Cleidophorus*) sp.  
*Pholadomorpha* sp.  
*Psiloconcha* sp.  
*Rhytimya* sp.  
*R. convexa* Ulrich  
*R. mickleboroughi* (Whitfield)  
*R. munda* (Miller and Faber)

Table 1. Continued.

**Molluscs (continued)**

## Cephalopods

orthocone unspecified [previously *Orthoceras* sp.]*Orthonybyoceras* sp. [previously *Treptoceras* sp.]

## Monoplacophores (snail-like)

*Cyrtolites* (*Cyrtolites*) sp.*C. ornatus* Conrad*Helcionopsis* sp.**Porifera**

## Sponges

*Pattersonia* sp.*P. difficilis* Miller*P. tuberosa* (Beecher)

## Gastropods

*Cyclonema* sp.*Loxoplocus* (?*Donaldiella*) sp.*Paupospira* sp.*Phragmolites* sp.*Sphenosphaera* sp.

## Stromatoporoids

*Stromatocerium* sp.

beds and is considered to have been a colonizer of muddy substrates. Like other strophomenid brachiopods, *Rafinesquina* has one valve that is concave and one that is convex. In life, it likely lived with the larger, convex valve down, "floating" as

it were in the mud (Leighton, 1998) (Fig. 15). Alexander (1975) noted that *R. alternata* shells show subtle changes in shape through the Cincinnati Series, corresponding to bedding and grain size. Furthermore, a wide range of attached or encrust-



Figure 14. Stacked brachiopod of *Rafinesquina alternata* shells such as these suggest transport by storms. From the Grant Lake Limestone on the north side of the road at stop 2a.

ing fossils are a common sight when looking at *Rafinesquina* shells in the Grant Lake Formation. When these brachiopods died, their shells were used as stable platforms of attachment for other organisms (Figs. 15–16). Attached fossils are termed epibionts or epizoans. Bryozoans, algae, brachiopods, molluscs, and *Cornulites* (tube worms?) have all been found attached to *Rafinesquina* and *Strophomena* shells in central Kentucky. Some *Rafinesquina* shells also exhibit small vertical holes, which have been interpreted as predatory boring and feeding by snails or other molluscs while the brachiopods were still alive (Bromley, 1981; Brett and Walker, 2002).

Two other abundant brachiopods in the Grant Lake are *Vinlandstrophia* and *Hebertella* (Appendix B, Plates B1–B2). Their shells are thicker and more robust than *Rafinesquina* shells. These shells could tolerate more agitated conditions than *Rafinesquina*. Nonetheless, the abundance of crushed *Vinlandstrophia* valves and unopened shells, filled like small geodes with sparry calcite cement (Fig. 17), indicate that many living brachiopods were rapidly buried during storms and not able to extricate themselves. Other *Vinlandstrophia* valves were broken and severely abraded, suggesting that they were transported for some distance in moving water and sediment.

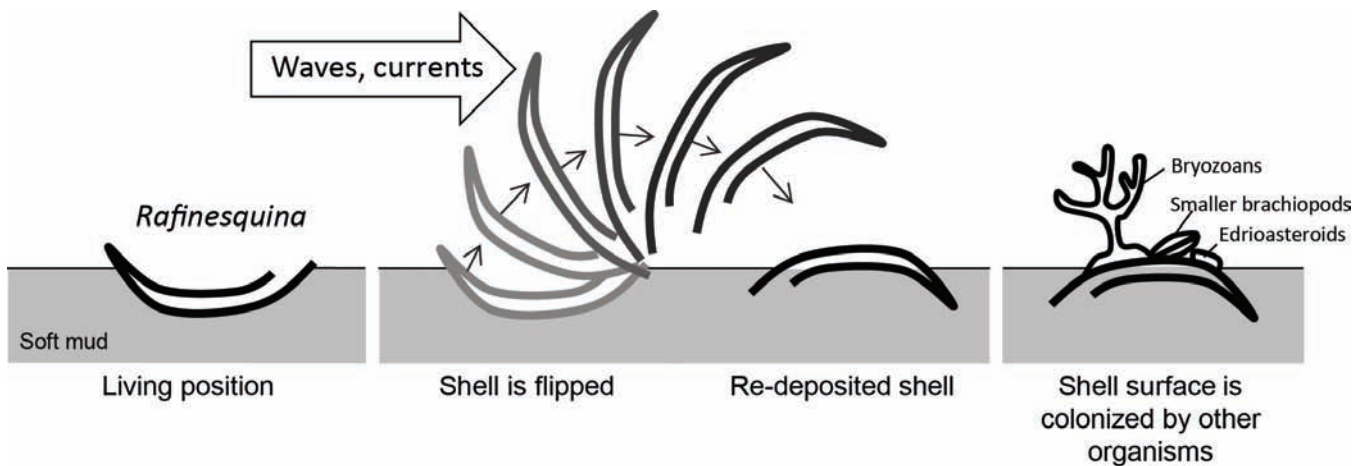


Figure 15. Interpretive diagram showing succession of substrate colonization in muddy, but storm-influenced, Grant Lake seas.

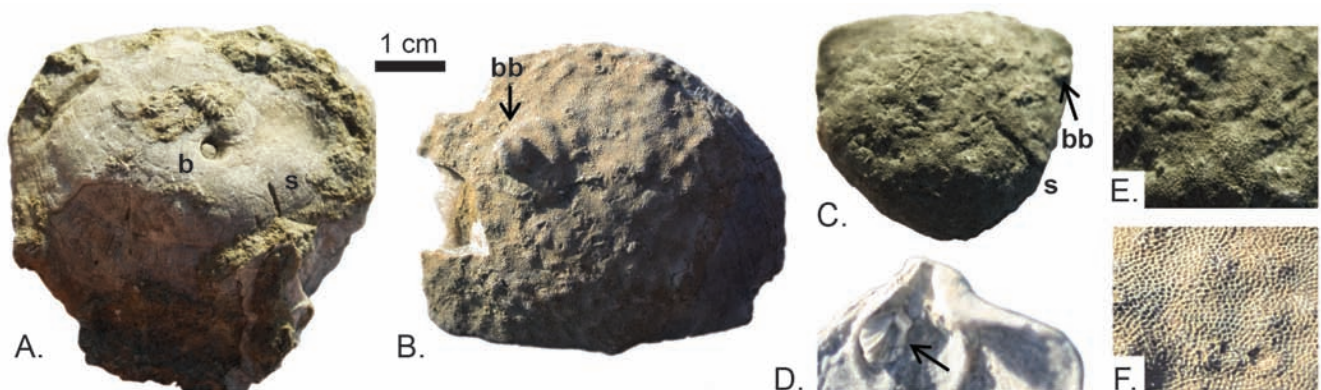


Figure 16. Examples of encrusting and attached epizoans on strophomenid shells in the Grant Lake Formation. (A) Borings (b) and straight grooves (s) also possibly representing borings on a *Rafinesquina* shell. (B) Base of a ramose bryozoan (bb) covered by encrusting bryozoans on a *Rafinesquina* shell. (C) Base of a branching bryozoan and different encrusting bryozoan on another *Rafinesquina* shell. (D) Small brachiopod (arrow), possibly *Zygospira*, on strophomenid valve. (E) Detail of encrusting bryozoan on (C). (F) Detail of encrusting bryozoan on (D).

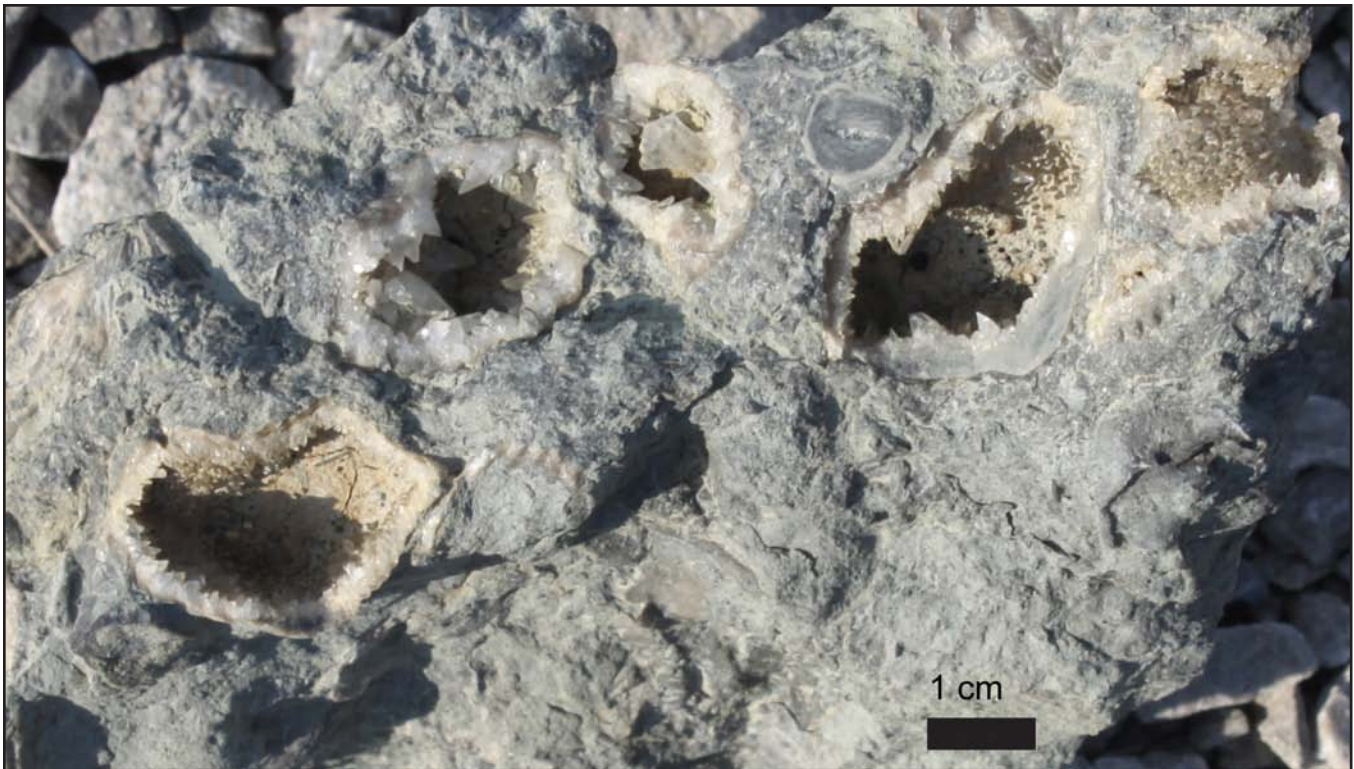


Figure 17. Geode-like infillings of sparry calcite cement from the brachiopod *Vinlandostrophia ponderosa*. This kind of preservation indicates that the brachiopods were buried alive so rapidly that the valves were not able to open afterward and permit sediment infilling. From the Grant Lake Limestone on the south side of the road at stop 2a.

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## **Appendix A**

Descriptions of the three cores drilled by the Ozark Mahoning Co. on Jephtha Knob. Ozark Mahoning was looking for lead and zinc-mineralization within Jephtha Knob.

Property Schmidt, Shelby County, KY Project Jephtha Knob Hole No. JK 7A-1  
 Sheet Number 1 Elevation 1105 (tz) Started April 6, 1978  
 Carter Coordinates 23-U-53 2250' PNL X 50' FEL Completed April 24, 1978  
 Dip Vertical Ultimate Depth 1945'

- 0-32 Overburden, no sample.
- 32-49 Breccia, principally fine and medium subangular fragments in a dolomitic argillaceous rock flour matrix, fragments all dolomitic, all rather porous and recrystallized, rather distinct dark gray throughout, hint of preferred orientation of long axis normal to core, few blebs of pyrite, all very soft, few very large fragments of porous drusy dolomite similar to material in deeper parts of hole.
- 49-50 Dolomite block, dips essentially parallel to core, very fine grained, somewhat mottled in appearance, possibly Wells Creek or Knox, unable to identify with certainty.
- 50-57 Dolomite, tan and light gray, finely crystalline, rather vuggy and porous, few fractures, .5' green shaley material at 56.  
 Note: Possible Tyrone
- 57-69 Mostly breccia as above, upper 4' mostly dark gray argillaceous dolomite breccia all rather vuggy and porous, little disseminated pyrite filling open spaces.  
 Note: Probably continuous breccia to this point, unbrecciated dolomites probably large blocks.
- 69-73 Dolomite, tan, very finely crystalline, well mottled by bluish gray streaks, dips probably steep, high variable, estimate about 45°.   
 Note: The unit above and those below strongly resemble Camp Nelson dolomite.
- 73-84 Dolomite, medium crystalline, very soft, very vuggy and porous, all rather pitted, partly friable, all brownish gray, dips at about 40°.
- 84-94 Dolomite, light gray and light tan, very finely crystalline, fairly well bedded, fairly abundant interlaminated argillaceous streaks, little brecciation in bottom, partly tan, more coarsely crystalline and vuggy, rather well laminated, dipping approximately 30 degrees.
- 94-101 Dolomite, light gray and light tan, very finely crystalline, well mottled, fairly well laminated, partly vuggy and porous, dips at approximately 40°.
- 101-113 Dolomite, gray, finely crystalline, very irregularly bedded, few patches and zones thoroughly recrystallized, vuggy and porous, bottom 1' shaley, bedding at all angles, highly disturbed.
- 113-129 Dolomite, tan, somewhat like the tan units above, all highly disturbed, very highly altered, dolomitized, parts very soft, vuggy and friable, bedding very irregular.
- 129-149 Dolomite, tan and light gray, mottled, mostly very dense and fine grained, partly recrystallized, bedding rather variable, average approximately 40°, somewhat more regular than units above, bottom fault contact dipping at about 45°.   
 Note: This is the bottom of the lithologies favoring Camp Nelson, lithologies below tend to favor Tyrone.
- 149-167 Dolomite, principally tan, fine and medium crystalline, partly vuggy and more coarsely crystalline, dips fairly regular at approximately 45°, 1' of fossil at bottom.  
 Note: This unit represents change in lithology, possibly beginning of Tyrone.
- 167-190 Dolomite, crystalline, tan and light tan, rather well bedded throughout, few fractures with slickensides, vuggy and porous, check nodule at 177 and 187, dips average approximately 50°.

- 190- Dolomite, mostly as above, little greenish gray argillaceous dolomite in middle, bottom 3" breccia, upper contact probable fault contact dipping at approximately 50°, little tan chert, one speck of sphalerite in fault gouge at bottom.
- Breccia, fairly coarse, tightly interlocked fragments of dark gray, argillaceous dolomite, partly calcareous, few chunks of limestone, few zones vuggy and very porous from recrystallization of dolomite, dips all highly irregular.
- Note: Texture resembles that of the tightly interlocked breccia in Platten limestone at Hicks Dome, calc vein at 199, fair pyrite veinlet 203.5. This breccia similar to breccia at top of hole.
- 219-231 Dolomite druse, extremely porous, crystalline dolomite with very abundant vugs lined with dolomite druse, all gray, all somewhat friable, very highly altered, few zones of argillaceous dolomite less well altered, unable to tell if this is breccia fragments bleached out or just vuggy dolomite.
- 231-245 Dolomitized breccia, all very vuggy and porous, very little limestone or calcite, calcite usually as blebs, probably fossils, breccia texture rather obscured by dolomitization, entire zone rather soft, spongy, consists of a loose dolomite crystals, all very porous and vuggy, all gray to dark gray and tan, rather massive pyrite at 236 surrounding small dolomite fragment.
- 245-254 Dolomite druse, very porous and vuggy, consists mostly of the loose aggregate of platy masses of dolomite crystals, very porous, very vuggy and spongy in appearance, few limey fragments in upper 2', entire zone probably represents recrystallized breccia, occasional small pyrite crystal on top of dolomite crystal.
- 254-295 Altered dolomitized breccia, consists of dolomitized fragments with bedding still evident and zones and patches of porous vuggy dolomite as described above, porous zones noticeably cellular, fragments randomly oriented, some are slightly calcareous but principally thoroughly dolomitized, fracture with possible minor fault between 284 and 286, bottom contact fairly distinct.
- Note: Would interpret zone above as a tightly interlocked breccia which has been rather thoroughly dolomitized and altered.
- 295-309 Dolomitized breccia, principally rather coarse, tightly interlocked fragments of various dolomitized limestones, rather abundant argillaceous material, all gray, partly vuggy, vugs lined with drusy calcite and drusy dolomite, grades rather quickly to below, all rather gray in color principally due to argillaceous material.
- 309-325 Brecciated limestone, principally highly disturbed coarse fragments, bedding at various angles, rather highly faulted in upper portion with strong slickensides, dipping approximately 30° (indicates strong horizontal component on movement), dark gray, very argillaceous limestone, bottom contact sharp, occasional patch of finer brecciation, vuggy, common vugs mostly lined with calcite, fairly massive, disseminated pyrite, sometimes associated particularly at 319.
- Note: Use of the term breccia may not be totally appropriate. In some of the above described units the degree of comminution is relatively minor but the units are very highly disturbed.
- 325-325.4 Injection breccia, consists of principally fine, subrounded limestone fragments in a calcareous, rock flour matrix, top contact rather sharp, dipping at approximately 30°, contains one fairly large fragment.
- 325.4-335 Breccia, limestone, similar to above, bottom portions somewhat more highly comminuted.
- 335-343 Rock flour breccia consists of fine, medium and fairly coarse subrounded fragments floating in a calcareous, rock flour matrix, matrix material constitutes approximately 50% of total, unable to identify fragments, appears to dip at approximately 60°, slickensides, argillaceous material at top and bottom, brecciated limestone as above from 329-341, bottom contact rather sharp.

- 347-366 Brecciated limestone, essentially as above, grades rather quickly to below, all somewhat dolomitic, few parts very dolomitic, few vugs principally with calcite druse.
- 366-393 Drusy dolomite, occasional fragment of dolomite with bedding evident, all at various angles, all rather thoroughly recrystallized, very little calcite in entire section, highly altered portions consist of aggregate of dolomite crystals, generally very vuggy with dolomite druse lining vugs, considered a recrystallized breccia.
- 393-397 Dolomite druse essentially as above, somewhat more relic bedding evident indicating rather consistent dips of approximately 25°, occasional trace of pyrite on dolomite druse and vugs, occasional dark speck in more coarsely crystalline material.
- 397-403 Brecciated, dolomitic limestone, all rather argillaceous, strong slickensides in argillaceous material at bottom.
- 403-445 Drusy dolomite, all vuggy, porous, highly recrystallized, few fragments and zones less drusy, still dolomitic, dips erratic, little bedding remaining, occasional faint trace of pyrite on dolomite druse, grades rather quickly to below.
- Note: Shape of some of the vugs in the very coarsely crystalline dolomite druse suggests possibilities of breccia with vugs representing molds of leached fragments.
- 445-471 Dolomite druse mixed with fine grained, dark gray dolomite or dolomitic limestone, somewhat calcareous, vuggy portions essentially as above, bedding very erratic, few zones with considerable very fine pyrite on dolomite crystals, grades to below, rather well fractured throughout, fairly numerous slickensides on argillaceous parting indicating movement at various angles.
- 471-489 Dolomitic limestone and dolomite druse, interbedded limestone fairly dolomitic, drusy material as above, dips highly variable, from 60°-300, few fractures, possibly somewhat faulted, little disseminated pyrite at 283.
- 489-513 Dolomite druse, very vuggy, medium and coarse crystalline, bedding largely obscured, bedding at various angles.
- Note: Fair amounts of very fine pyrite are discernable throughout in vuggy zones, pyrite crystals are generally on dolomite crystals.
- 513-551 Dolomitized, argillaceous limestone blocks interbedded with vuggy, drusy dolomite as above, limestone blocks rather argillaceous, bedding highly variable, probably represents jumbled block, few fractures coarse crystalline calcite in vugs and along fractures, little pyrite in drusy dolomite, particularly where more coarsely crystalline and vuggy, grades rather abruptly to below.
- 551-581 Principally drusy dolomite, few blocks of calcareous dolomitic limestone, all gray, drusy portions with traces of pyrite, scattered argillaceous material, bedding at all angles, probably jumbled blocks, fairly well fractured throughout.
- Note: Dolomitization seems to be less complete in this unit and probably a gradual tendency over the last 100' for slightly increasing amounts of calcite and calcareous material in each section.
- 581-619 Interbedded, argillaceous, dolomitic limestone and drusy dolomite as above, bedding somewhat more irregular, dipping at mostly about 45° where bedding is discernable, somewhat more calcite in vuggy material, limestone portions argillaceous, few zones with abundant calcite fossils, little pyrite scattered throughout, somewhat more calcareous than above.
- 619-654 Limestone, medium crystalline, gray and light tan, fossiliferous, abundant interlaminated argillaceous partings and streaks, few zones somewhat disturbed, particularly shaley portions, bedding rather consistent, estimate dip to average 25°, few portions appear brecciated due to slippage in shaley material, little interbedded, dark brownish gray argillaceous limestone.

- 654-697 Limestone, interbedded light gray crystalline limestone and a dark gray, dolomitic limestone, all rather fossiliferous, partly fractured, few vugs with calcite crystals, few calcite crystals along fracture planes, bedding fairly regular, probably averages about 40°, considered moderately disturbed.
- 697-734 Limestone, interbedded crystalline and argillaceous as above, somewhat more highly disturbed, few argillaceous zones appear somewhat brecciated, 3" calc (barite?) veinlet at 728, few zones fairly well fractured, this unit somewhat more disturbed than above, dips somewhat more irregular, estimate bedding averages 40°.
- 734-767 Limestone, principally dark brownish gray, very argillaceous, somewhat dolomitic, little interbedded crystalline limestone, all somewhat fossiliferous, dips variable, moderately disturbed, vuggy, dolomitic, drusy from 749-755, 758-762, small calc veinlet at 765.5 with possible clear, crystalline barite or gypsum, bottom contact sharp, probably fault contact dipping at approximately 45°.
- Tyrone Formation
- 767-779.5 Dolomite, pale greenish gray, somewhat silty in appearance with darker greenish gray, somewhat silty in appearance with darker greenish gray mottling.
- 779.5-781.5 Dolomite, tan, brownish gray, finely crystalline, dips at approximately 10°.
- 781.5-782 Pencil Cave?, greenish gray shaley material, nearly flat bedded, very altered in appearance.
- 782-795 Dolomite, tan, crystalline, partly vuggy, all generally rather dense, dark gray chert nodule at 784, approximately .5' of tan gray chalcedonic chert at 789, veinlet of massive bladed barite? at 787.5, massive bladed barite in vug at 788, bedding nearly flat, essentially less than 10°.
- 795-812 Dolomite, tan, crystalline, essentially as above, rather massive, few interbedded zones vuggy and drusy, little disseminated pyrite, one large zinc crystal at 810, bottom contact dipping at about 60°, probable fault contact dipping throughout approximately 10°, somewhat more disturbed at bottom 1'.
- 812-817.5 Limestone, crystalline, gray, all rather highly disturbed, partly vuggy with little calcite druse, little barite in vugs, very similar to limestone from 760-773.
- 817.5-819 Highly contorted, shaley material, probably disturbed Pencil Cave material as above.
- 819-829 Dolomite, tan, crystalline, partly vuggy, little fairly massive calcite filling vugs, bottom contact sharp, dipping at 45°, appears to be fault contact.
- 829-839 Fault zone, mixed, tan crystalline dolomite, greenish gray shaley material like Pencil Cave with some fractures filled with barite and calcite, bottom contact rather sharp, dipping at approximately 45°, top contact at approximately 70°.
- 839-855 Dolomite, tan, crystalline, several thin shaley sections, rather vuggy, highly disturbed throughout, dips probably average 45 degrees, little tan, brecciated chert at top identical to tan, brecciated chert at 777.
- 855-855.5 Pencil Cave material, unable to determine if this is in place or represents cave-in in the hole, suspect cave-in.
- 855.5-874 Dolomite, tan, medium crystalline, grades to below, rather steeply dipping throughout at approximately 45°, rather vuggy and porous throughout with dolomite druse.
- 874-898 Dolomite, tan, principally fine grained, crystalline, partly vuggy throughout, distinct bluish gray mottling throughout, zones with abundant interbedded shaley and fossiliferous, dips somewhat variable, principally at approximately 45°, bottom contact sharp, represents small fault contact, this zone possibly represents Oregon?.

- 89<sup>a</sup>-91<sup>c</sup> Dolomite, finely crystalline, gray, light gray and light tan, partly well dolomitized and drusy, few zones and patches very vuggy with calcite and dolomite druse, bottom contact rather sharp, all dipping at approximately 40°, appears some beds selectively dolomitized, little faulting as small displacements on fractures, bottom contact represents fault contact dipping at approximately 45°.
- 915-925 Dolomite, tan, finely crystalline, upper parts well laminated, bottom portions irregularly mottled, few stringers of more coarse tan dolomite, partly vuggy, dips rather consistent at about 40°.
- 925-933 Dolomite, essentially as above, upper portions with interlaminated argillaceous partings, slightly more vuggy with little pyrite in vugs on top of dolomite druse, dips at about 45°, dips somewhat more irregular in bottom portions.
- 933-950 Dolomite druse, mostly well crystallized, soft, porous, vuggy, few zones somewhat less vuggy and well laminated, dips approximately 45°, fairly irregular, vugs principally lined with dolomite and little later calcite.
- 950-977 Dolomite, principally tan, very finely crystalline, well streaked with dark bluish gray, few parts fairly well bedded, dipping at various angles from 75-40°, dips very irregular, .5' at 973 well replaced with rather massive disseminated pyrite, pyrite stringers, blebs of gypsum, numerous fractures with slickensides, little massive gypsum at 975.
- 977-991 Dolomite, essentially as above, all highly disturbed, fairly well fractured, fairly abundant vertical beds, dips highly variable.
- 991-1007 Dolomite, tan, very finely crystalline, partly drusy, drusy portions rather vuggy, vugs commonly filled with coarse crystalline gypsum, bedding highly variable, upper portions approximately 80°, average throughout 45°, very irregular.
- 1007-1024 Dolomite, sublithographic, dense, mottled, well laminated in part, bedding highly variable, few shaley zones, large 1" bleb of gypsum at bottom, bedding highly variable, average approximately 60°, small patch of drusy, vuggy material at 1012 with vugs filled with pyrite and little disseminated pyrite, fairly numerous fractures with polished surfaces.
- 1024-1043 Dolomite, very highly disturbed, fairly well recrystallized, partly drusy, unable to discern bedding because of fracturing and recrystallization assume near vertical, dip variable, partly vuggy with occasional vug filled with gypsum, show of crystalline sphalerite filling vug at 1031, sphalerite mostly coarse blackjack with little surrounding rubyjack.
- 1043-1072 Dolomite, very highly disturbed, dips erratic, some nearly parallel to core, all fairly well fractured, few zones fairly brecciated, abundant slickensides on fractures, few patches somewhat vuggy in upper portions, dips tend to become somewhat more regular but still steep in bottom 5'.
- 1072-1086 Dolomite, principally finely crystalline, brown and tan, well mottled and streaked along bedding planes, few zones rather disturbed, few zones somewhat vuggy, dips rather steep, vary from approximately 70°-45°, tending to flatten toward bottom, little gypsum in vugs and in veinlet at bottom, rather numerous fractures with polished argillaceous material indicating movement along fractures at various angles, strongest component of movement seems to have a strike-slip throw approximately 45° from vertical.
- 1086-1119 Dolomite, finely crystalline, well streaked with irregular darker material, abundant interlaminated argillaceous partings, dips rather consistent at approximately 45°, fairly numerous fractures with slickensides indicating both strike-slip and dip-slip movement and variations of each.
- 1119-1137 Dolomite, essentially as above, several zones rather highly disturbed with irregular bedding, bottom contact probably fault contact, fault contact at bottom dipping at approximately 70°.

Note: Very little vuggy material seen between 1041 and this point, seems to be decreasing in recrystallization though the units are still entirely dolomite.

- 1137-1165 Dolomite, essentially as above, bedding very irregular, varies from 70°-10°, dips in bottom portions tending to become more flat, few zones partly vuggy, consider the unit very highly disturbed, fairly well fractured with some slickensides.
- Note: This seems to be the bottom, at least temporarily, of the very fine grained to sublithographic dolomite, material below much less dense and lacks mottling, contact between two rather sharp.
- 1165-1189 Dolomite, tan, finely crystalline, somewhat stylolitic with rather abundant interlaminated argillaceous partings, rather distinct from above, lacks the mottling and tan coloration, dips appear to be rather regular, dipping at approximately 40°, dips less steep near bottom, grades rather quickly into below, somewhat recrystallized, slightly vuggy and porous at bottom.
- 1189-1218 Dolomite, tan, vuggy throughout, rather altered in appearance, dolomite principally fine grained, little drusy dolomite scattered, drusy in vuggy zones, appear to be selected streaks of different lithology which has been altered, bedding difficult to discern, appears to be dipping at about 20°.
- 1137-1165 Dolomite, essentially as above, bedding very irregular, varies from 70°-10°, dips in bottom portions tending to become more flat, few zones partly vuggy, consider the unit very highly disturbed, fairly well fractured with some slickensides.
- Note: This seems to be the bottom, at least temporarily, of the very fine grained to sublithographic dolomite, material below much less dense and lacks mottling, contact between two rather sharp.
- 1165-1189 Dolomite, tan, finely crystalline, somewhat stylolitic with rather abundant interlaminated argillaceous partings, rather distinct from above, lacks the mottling and tan coloration, dips appear to be rather regular, dipping at approximately 40°, dips less steep near bottom, grades rather quickly into below, somewhat recrystallized, slightly vuggy and porous at bottom.
- 1189-1218 Dolomite, tan, vuggy throughout, rather altered in appearance, dolomite principally fine grained, little drusy dolomite scattered, drusy in vuggy zones, appear to be selected streaks of different lithology which has been altered, bedding difficult to discern, appears to be dipping at about 20°.
- 1405-1436 Dolomite, partly calcareous, consists of interbedded brown crystalline dolomite as above and rather argillaceous portions with greenish gray cast, few zones with texture identical to limestone described above except it is entirely dolomite, few zones with mottled greenish gray shaley material, dips throughout less than 10°, occasional seam of gypsum along bedding plane.
- Note: Possible top of Wells Creek
- 1436-1455 Dolomite, rather well laminated, finely crystalline, brownish gray, few interbedded zones of somewhat silty, shaley, greenish gray dolomite, dips average approximately 10°.
- 1455-1464 Dolomite with interbedded greenish gray to dark gray shale, all very fine grained, bedding somewhat contorted in lower portions, probably sedimentary features.
- 1464-1475 Dolomite, tan to brownish gray, partly crystalline, partly fairly well laminated with greenish gray argillaceous streaks, somewhat mottled throughout, bedding dipping at less than 10°.
- 1475-1484 Limestone, light tan, well mottled by dark bluish gray streaks, fairly abundant interbedded argillaceous material dipping approximately 5°, little fairly massive pyrite on bedding planes, probably syngenetic.
- 1484-1508 Interbedded, pale greenish gray argillaceous dolomite and tan, very fine grained dolomite, little interbedded limestone, occasional greenish gray streak of shale, drusy dolomitic from 1501-1503, bottom contact appears to be at approximately 55° angle, rather sharp.
- 1508-1513 Breccia, partly pebble conglomerate, probably represents trash zone between Wells Creek and Knox, upper contact sharp at about 55°, possible injection breccia, bottom contact dipping about 25°.
- Knox Group - Mascot Formation
- 1513-1516 Dolomite, brownish gray, finely crystalline, somewhat broken and shatter brecciated, few interbedded shaley streaks.

- 1516-1511 Dolomite, light gray, very dense, very finely crystalline, sublithographic, occasional shale parting, dips approximately 15°, small shaley pebble dike at bottom, bottom 1.5' somewhat brecciated.
- 1511-1566 Dolomite, very finely crystalline, very dense, light tan, light gray, occasional interbedded, thin greenish shale streak, occasional interbedded sandy streak, typical of Knox, bedding somewhat variable, dips probably average 15°, some quite steep, unable to determine if sedimentary features.
- 1566-1570 Breccia, principally coarse fragments in a sandy, dolomite rock flour matrix, few chert fragments, lithologies of dolomite same as above and below, unit consists of mostly fragments, one fairly large fragment of chert.
- 1570-1580 Dolomite, very dense, fine grained, light tan to light gray, essentially as above, dips average about 15°.
- 1580-1657 Dolomite, all very dense, varies from gray to white, very fine grained, sublithographic, few argillaceous partings, few interbedded sandy streaks, few interbedded shaley streaks, occasional white tripolitic chert as band, occasional dark brownish gray chert band, little scattered pyrite as distinct dark gray to black blebs, bedding averages about 10°.
- 1657-1694 Breccia, tightly interlocked coarse fragments of dolomite separated by patches of finer breccia, matrix principally dolomite, medium crystalline, appears to have been recrystallized, few fragments of sandstone and chert, breccia texture somewhat hazy in bottom 10', bottom contact vague.
- Note: The breccia zone described above seems to be beginning of coarser crystalline material.
- 1694-1712 Dolomite, principally light gray to white, medium crystalline, somewhat vuggy throughout, more vuggy from 1707-1712, fair zinc shows between 1706-1710 in vuggy portions, zinc occurs as nearly colorless pale yellow crystals on dolomite crystals in vugs and as aggregates of crystals on small fractures and disseminated throughout the rather coarsely crystalline dolomite, hard to detect because nearly colorless, H<sup>+</sup> zone may go slight more than 0.5% Zn,
- 1712-1720 Dolomite, light gray to white, medium crystalline, stylolitic, bedding appears to be nearly flat.
- 1720-1738 Dolomite, light gray, nearly white, fine and medium crystalline, dips difficult to discern, less than 10°, little interbedded sandy and greenish shale.
- 1738-1748 Breccia, principally coarse fragments of dolomite in a sandy rock flour matrix, lithologies somewhat mixed, dolomite appears to have been recrystallized, few pyrite stringers in top 6", few pyrite shows as streaks filling fractures at 1745.
- 1748-1754 Breccia, monolithologic, tan crystalline dolomite, fragments separated by white crystalline fine dolomite, 6" of chert matrix type sandstone at bottom.
- 1754-1765 Dolomite, partly brecciated, consists of pale greenish gray very fine grained dolomite and brown to tan crystalline dolomite, few zones rather well brecciated, all with somewhat disturbed appearance, little chert at bottom, fair trace of pyrite at 1760.5, zone at bottom 2' with sandy matrix.
- 1765-1782 Principally very fine grained, light greenish gray dolomite, fairly well mottled, little interbedded, more coarsely crystalline material, some interbedded monolithologic breccia, few interbedded sandy zones, several fractures with movement indicating dip-slip movement, occasional banded chert nodule, dips at approximately 5°.
- 1782-1804 Breccia, mostly monolithologic, little mixed breccia, principally with white dolomitic rock flour matrix, few fine portions with fairly abundant matrix, fragments essentially monolithologic throughout, few portions with somewhat mixed fragments, breccia texture commonly rather hazy, upper contact appears to be essentially flat, bottom contact vague.
- 1804-1823 Dolomite, white to light gray, medium crystalline, somewhat stylolitic, bedding appears to be dipping between 5° and 10°, few interlaminated green argillaceous partings.

- 1823-1833 Dolomite, essentially as above, somewhat wuggy, small patch of breccia at 1829 with abundant pyrite in matrix, grades to below, odd patches of vague breccia texture in bottom portions.
- 1833-1849 Dolomite, light gray, medium crystalline, somewhat stylolitic, generally rather massive, occasional green argillaceous partings, few zones with faint crackle brecciation, small shale dike at bottom.
- 1849-1865 Dolomite, light gray, mostly medium crystalline, rather cherty with translucent gray nodules and some chalky white chert, partly brecciated as crackle breccia, monolithologic, somewhat wuggy and porous in bottom 4'.
- 1865-1882 Dolomite, principally light gray, fine and medium crystalline, few large chert nodules which are gray and very oolitic, partly brecciated throughout as crackle breccia, few interbedded sandy zones and sandy streaks, dips approximately 10°, few traces of pyrite.
- 1882-1890 Principally chert with little interbedded dolomite, few interbedded sandy streaks, chert light gray and white, chalky and gray, very oolitic chert, chert somewhat broken in portions, unit may make fair marker bed.
- 1890-1915 Dolomite, principally light gray, crystalline, somewhat crackle brecciated in upper portions, interbedded with very fine grained light tan to light gray dolomite with interlaminated sandy streaks, somewhat cherty throughout, fairly abundant dark gray, very oolitic chert, bottom few feet very sandy.

Property David Newton, Shelby County, KY Project Jeneth Knob Hole No. JK 78-2  
 Sheet Number 1 Elevation ~ 750 Started April 26, 1978  
 Carter Coordinates 19-U-53 2425' FSL X 500' RWL Completed May 12, 1978  
 Dip Vertical Ultimate Depth 1200'

- 0-35 Overburden.
- Drakes Formation - Rowland Member
- 35-82 Interbedded, fossiliferous argillaceous limestone and shale, limestone gray to pale greenish gray, all rather argillaceous and fossiliferous, little glauconite scattered throughout as blebs, specks and irregular patches, shale gray to light greenish gray, rather fossiliferous, all rather soft.
- 82-89 Breccia, subrounded limestone fragments in a argillaceous shaly matrix, fragments principally medium and coarse, matrix material very argillaceous, constitutes approximately 30% of total, probably fault breccia.
- 89-112 Limestone, greenish gray, very argillaceous, fairly abundant specks and blebs of glauconite, few zones with abundant argillaceous material, rather argillaceous throughout, little interbedded shale, grades to below, probably repeating Rowland.
- Note: Dips to this point relatively flat, approximately 10°.
- Grant Lake Limestone
- 112-130 Shale, mostly light greenish gray, little dark gray, all very calcareous, little interbedded limestone, all rather soft, somewhat fissile, mostly fossiliferous, dips variable from 15°-20°.
- 130-170 Very calcareous shale, greenish gray, very abundant interbedded fossiliferous streaks, fossiliferous throughout, little interbedded nodular limestone, estimate 60%-70% shale, bedding planes irregular surfaces, estimate dip at 10°-15°.
- 170-223 Shale, very calcareous, essentially as above, possibly somewhat more fossiliferous than above.
- 223-235 Shale, essentially as before, considerable more interbedded fine grained, light gray limestone, estimate limestone at 50%.
- 235-250 Shale, greenish gray to olive, soft, little interbedded limestone, all very calcareous, shale rather fossiliferous, fairly well laminated, dips estimated at 10°-15°.
- 250-300 Shale, essentially as above, somewhat less green color, mostly gray, mostly very fossiliferous, estimate 30%-40% limestone and fossil material, shale portions very calcareous, lime portions very argillaceous, dips difficult to discern, estimate 10°.
- Calloway Creek Limestone
- 300-329 Very fossiliferous shale and pebble conglomerate, fragments principally fossil fragments, shale and argillaceous material dark gray, rather soft and rather fissile, faulted at bottom.
- Clays Ferry
- 329-412 Principally shale, dark gray to dark olive, very calcareous, rather abundant interbedded fossiliferous limestone, all rather soft, somewhat fissile, average dips to about 20°, estimate 60%-70% shale, top 3' conchoidal.
- 412-440 Shale, as above, well fractured, highly disturbed throughout, abundant slickensides on fractures, dips erratic, all angles, possible shear fault zone.
- 440-457 Shale, as above, more highly sheared, more abundant slickensides on polished surfaces, still part of same sheared fault zone.
- 457-475 Badly sheared shale as above, degree of shearing tends to be diminishing toward bottom, dips somewhat variable, tend to be flattening toward bottom.

- 475-512 Shale, essentially as before, somewhat more interbedded, fossiliferous limestone, bedding dipping at approximately 20° throughout, bottom contact rather distinct.
- 512-520 Limestone, fairly coarse aggregate of rounded pebbles in a crystalline limestone matrix, fairly abundant interlaminated shale streaks and partings, all fossiliferous throughout, bedding at 15°.
- 520-555 Interbedded shale and limestone, about 50/50, shale gray, fairly soft, fairly well laminated, limestone all very fossiliferous, light gray, limestone and shale both fossiliferous, limestone light gray, bedding at about 15° angle, grades rather quickly into below.
- Lexington Limestone - Sulphur Wells member
- 555-582 Limestone, calcarenite, fairly abundant interbedded and interlaminated argillaceous partings, limestone consists principally of lime pebbles and fossil fragments, some interbedded greenish gray shale and fairly distinct rounded lime pebbles, bedding fairly consistent dipping at about 20°-25°.
- Brannon Member
- 582-592 Limestone, gray, finely crystalline, few interlaminated shaly partings, little rock flour breccia from 587-588, flat-lying, possible sedimentary, bottom contact rather distinct.
- 592-604 Shale, brown, well laminated, fairly abundant interbedded limestone, bottom portions consist principally of very argillaceous, tan to brownish gray limestone, bottom contact rather distinct.
- Cordsville Member? (Logano missing)
- 604-624 Limestone, fragmental, upper portions appear brecciated but probably consist principally of fossil fragments, grades to somewhat nodular, limestone fairly abundant, argillaceous partings in middle portions, somewhat recrystallized and dolomitized in bottom 5', all gray throughout, dips fairly flat, probably average about 10°, dolomitized portions in bottom sometimes have fairly heavy pyrite on dolomite druse.
- 624-643 Limestone, fossiliferous, gray, partly crystalline, few zones somewhat dolomitic, tends to grade into dolomitic limestone at bottom, few interlaminated argillaceous partings, dips estimated at 10°, few thin, (approximately 1/4") seams of gypsum along bedding planes.
- 643-657 Dolomite, gray to light gray, mostly fine, little medium, principally light gray crystalline dolomite, middle portions rather brecciated in appearance, possibly recrystallized altered mixed lithology breccia, few interlaminated argillaceous partings and streaks, dips estimate at less than 10°, few thin seams of gypsum along bedding planes, 1/2" seam at bottom, bottom contact very sharp.
- High Bridge Group - Tyrone Formation
- 657-669 Dolomite, principally finely crystalline, brown to brownish gray dolomite with interbedded greenish gray dolomite, greenish gray somewhat argillaceous, few zones tan dolomite rather vuggy.
- 669-678 Limestone, partly dolomitic, very finely crystalline to sublithographic, few zones fairly well dolomitized, Pencil Cave from 673-67h, 1/2" brownish gray chert at top and bottom of Pencil Cave.
- 678-690 Dolomite grading to limestone in bottom half, dolomite consists of fine light brownish gray crystalline dolomite, somewhat vuggy and pitted which grades to tan, sublithographic limestone in bottom, dips minus 10°.
- Note: Would tend to divide High Bridge down to Wells Creek into two units. Tyrone above this point and Camp Nelson below.
- 690-694 Limestone, sublithographic, brown, well laminated, partly greenish gray and argillaceous, abundant interlaminated darker brown streaks.
- 694-725 Limestone, principally sublithographic, tan and light gray, little interbedded shaly and fossiliferous, partly burrowed in appearance, little interbedded dolomite.

- 725-740 Dolomite, finely crystalline, tan and mottled light gray, fairly well laminated, few irregular, nodular brown patches at bottom.
- 740-751 Dolomite, crystalline, medium, drusy, mostly porous and vuggy, highly recrystallized.
- 751-778 Dolomite, tan, very finely crystalline with abundant irregular dark gray mottling, few zones somewhat recrystallized, highly disturbed from 759-765.  
 Note: Dips all approximately 5° or less.
- 778-783 Dolomite, very fine, very argillaceous, gray and brown, fossiliferous (similar to 230-305 in hole 3).
- 783-827 Dolomite, crystalline, medium and fine, brown and tan, generally porous and partly vuggy, irregularly bedded, breaks with hackly fracture along bedding planes.
- 827-858 Dolomite, gray, little tan, very finely crystalline, well bedded with thin beds separated by wavy argillaceous partings, little vuggy toward bottom.
- 858-884 Dolomite, crystalline, porous, partly vuggy, medium and fine, trace amber sphalerite in vugs at 873.5.
- 884-903 Dolomite, interbedded very fine, gray and brownish gray and medium crystalline, tan, porous, partly vuggy and drusy dolomite, one speck yellow sphalerite at 895, grades quickly into below.
- 903-923 Limestone, sublithographic, tan with abundant irregular darker dolomitic streaks (typical Plattin - Murphreesboro).
- 923-930 Limestone, sublithographic, tan, partly fossiliferous, little interbedded greenish argillaceous, green mottled, essentially as above.
- 930-998 Limestone, essentially as above, 2' shaly at top, somewhat more interlaminated argillaceous material toward bottom, grades abruptly to below.
- 998-1008 Dolomite, fine, gray, well laminated with interlaminated argillaceous partings.
- 1008-1055 Dolomite, medium and fine crystalline, tan and brownish gray, partly vuggy, generally porous. (gross texture of dolomite similar to limestones and probably are limestone equivalents).
- 1055-1081 Dolomite, as above, little dense at top.
- 1081-1091 Limestone, sublithographic, brown and tan, increasing interlaminated argillaceous material in bottom portions, grades quickly to below.
- 1091-1108 Dolomite, partly calcareous, very argillaceous in upper 2', fairly well bedded throughout, fine and little medium crystalline, brownish gray.  
 Note: May be part of Wells Creek
- 1108-1138 Dolomite, fine crystalline, little medium, brownish gray, several interbedded argillaceous zones with faint green mottling, fairly well laminated with abundant argillaceous streaks.  
 Wells Creek
- 1138-1200 Dolomite, very finely crystalline, streaked and mottled, little greenish gray argillaceous material, all rather uniform, little scattered pyrite.

TOTAL DEPTH

Property Schmidt, Shelby County, KY Project Jeptha Knob Hole No. JK 78-3  
 Sheet Number 1 Elevation 995' Started May 14, 1978  
 Carter Coordinates 23-J-53 1550' FNL X 200' FEL Completed May 17, 1978  
 Dip Vertical Ultimate Depth 1200'

Set BX casing at 12'. Core size BX to total depth.

- 0-12 Overburden.
- 12-26 Dolomite, tan, finely crystalline, upper portions rather vuggy with dolomite druse, bedding highly disordered throughout, typical Camp Nelson with Camp Nelson type burrows and mottling, faint traces of crystalline pyrite.
- 26-46 Dolomite, tan, very fine crystalline, dips principally vertical, somewhat disordered at bottom, typical Camp Nelson, little dolomite druse in vuggy portions, bottom contact rather sharp.
- 46-56 Dolomite, light gray to white, very finely crystalline, fairly well mottled, unable to distinguish bedding.
- 56-77 Dolomite, highly disordered, moderately drusy, relatively porous, highly recrystallized, few large vugs lined with druse, unable to distinguish bedding.
- 77-117 Dolomite, typical Camp Nelson lithologies, partly highly recrystallized and vuggy, bedding highly disordered, typical Camp Nelson burrows and mottling, bottom contact rather sharp.
- 117-155 Breccia, very highly altered, dolomitized, very porous and vuggy, few patches with traces of pyrite, breccia texture rather well preserved in places, other parts difficult to discern, lithologies possibly well mixed, unable to determine, vuggy portions may partly represent clasts that have been leached out, vugs generally lined by dolomite druse, entire unit very porous, top contact sharp dipping at approximately 45 degree angle.
- 155-180 Breccia as above, little pyritic at bottom, pyrite consists of crystalline druse on dolomite druse, possible faint trace of chalcopyrite associated with pyrite.
- 180-187 Breccia, consists principally of patches and zones of drusy dolomite as above and dark gray argillaceous dolomite with few shaly partings, bottom contact rather sharp, somewhat gougey, possibly nearly flat fault contact.
- 187-195 Dolomite, medium crystalline, tan to brownish gray, partly vuggy, somewhat fractured in upper portions, bedding variable, principally steep (resembles Tyrone).
- 195-203 Various dolomites, principally fine grained, brownish gray, upper portions very shaly, partly vuggy, bedding at various angles, principally steep, unit probably represents lower part of Camp Nelson, abundant slickensides in gougey material along fractures, argillaceous material in upper portion vaguely resembles Pencil Cave material.
- 203-211 Dolomite, light gray, very finely crystalline, somewhat silty in appearance, bedding very steep and somewhat variable, faint greenish cast, possible Wells Creek fragment.
- Note: Material below the breccia zone probably megabreccia consisting principally of large clasts.
- 211-230 Various fragments of dolomite, principally well altered, partly vuggy and porous, lithologies rather well mixed, fair amounts of argillaceous material, bottom contact possible fault contact, few zones with fine disseminated pyrite, (would interpret this as megabreccia).

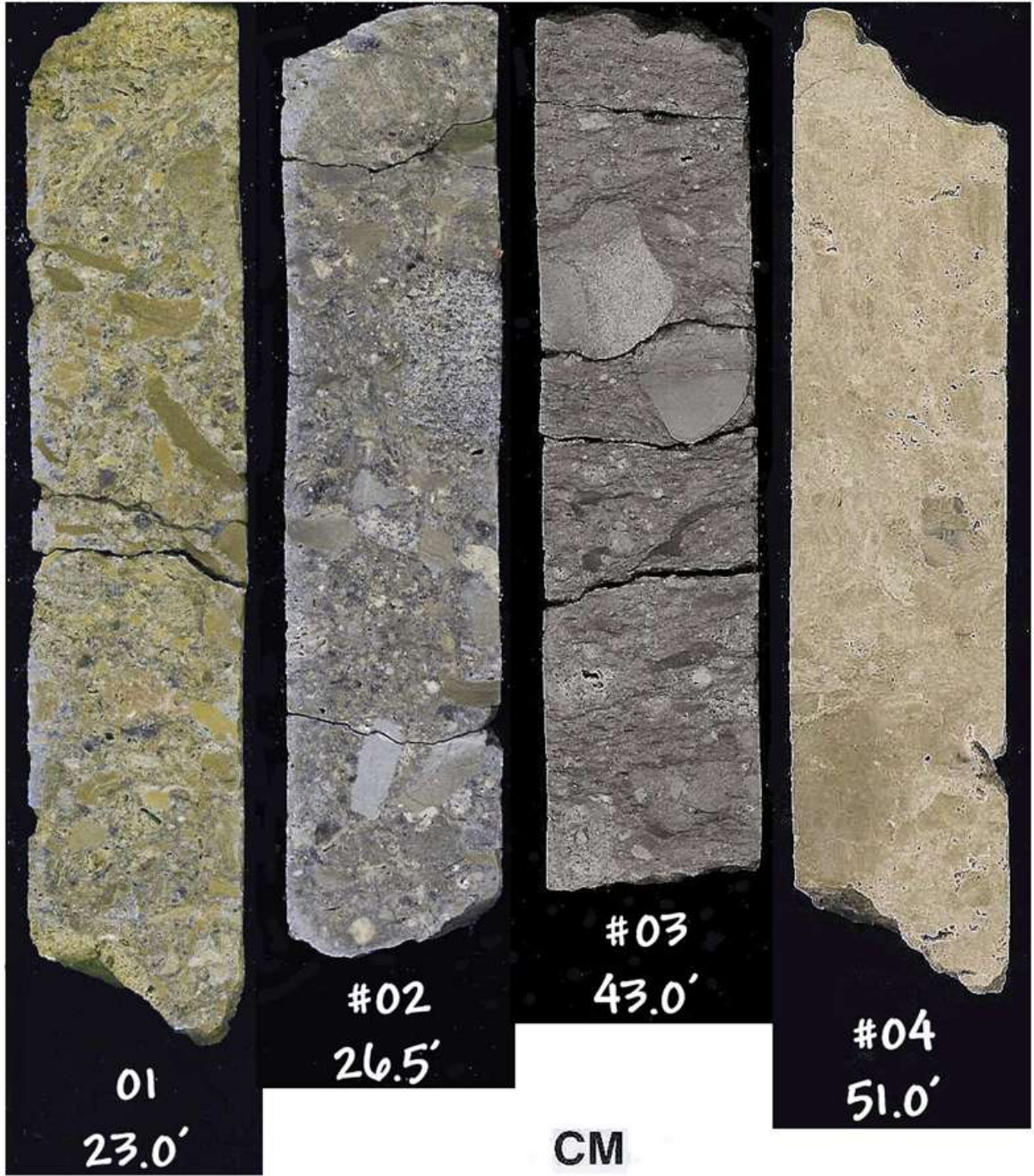
- 117-155 Breccia, very highly altered, dolomitized, very porous and vuggy, few patches with traces of pyrite, breccia texture rather well preserved in places, other parts difficult to discern, lithologies possibly well mixed, unable to determine, vuggy portions may partly represent clasts that have been leached out, vugs generally lined by dolomite druse, entire unit very porous, top contact sharp dipping at approximately 45 degree angle.
- 155-180 Breccia as above, little pyritic at bottom, pyrite consists of crystalline druse on dolomite druse, possible faint trace of chalcopyrite associated with pyrite.
- 180-187 Breccia, consists principally of patches and zones of drusy dolomite as above and dark gray argillaceous dolomite with few shaly partings, bottom contact rather sharp, somewhat gougey, possibly nearly flat fault contact.
- 187-195 Dolomite, medium crystalline, tan to brownish gray, partly vuggy, somewhat fractured in upper portions, bedding variable, principally steep (resembles Tyrone).
- 195-203 Various dolomites, principally fine grained, brownish gray, upper portions very shaly, partly vuggy, bedding at various angles, principally steep, unit probably represents lower part of Camp Nelson, abundant slickensides in gougey material along fractures, argillaceous material in upper portion vaguely resembles Pencil Cave material.
- 203-211 Dolomite, light gray, very finely crystalline, somewhat silty in appearance, bedding very steep and somewhat variable, faint greenish cast, possible Wells Creek fragment.
- Note: Material below the breccia zone probably megabreccia consisting principally of large clasts.
- 211-230 Various fragments of dolomite, principally well altered, partly vuggy and porous, lithologies rather well mixed, fair amounts of argillaceous material, bottom contact possible fault contact, few zones with fine disseminated pyrite, (would interpret this as megabreccia).
- 230-239 Dolomite, tan, very finely crystalline, somewhat porous, several patches very porous, several scattered gray to light gray chert nodules, rather well fractured, bottom contact rather abrupt, several zones with slickensides, occasional disseminated pyrite associated with fractures, block resembles Tyrone.
- 239-252 Dolomite, tan, very finely crystalline, well mottled and vuggy, typical of Camp Nelson, bottom portions well laminated, bottom contact rather sharp, nearly flat, little ground core at bottom contact.
- 252-304 Argillaceous dolomite, pale greenish gray to gray, appears to consist of argillaceous dolomite pebble conglomerates and very fine grained thinly bedded dolomite, bedding principally parallel to core, few thin interlaminated argillaceous partings, fairly well fractured, rather abundant smooth polished fracture surfaces with slickensides, bottom portions more thinly laminated and less argillaceous, bottom contact probably fault, dipping at 45 degree angle.
- Note: Lithology fairly distinct, unable to find lithologic equivalents in JK 78-2, shaly unit at 780 vaguely resembles this unit but probably is too thin.
- 304-341 Dolomite, tan, very finely crystalline, well streaked and mottled with darker bluish gray material, few zones more medium crystalline, moderately fractured throughout, oxidized, vuggy, and very pyritic with disseminated pyrite druse from 332-335, sulphides in this zone consists of pyrite and marcasite filling fractures, vugs and cavities and disseminated throughout, bedding at erratic angles, principally steep, commonly parallel to core.
- Note: This unit closely correlates in lithology to the unit from approximately 350-375 in JK 78-2.
- 341-368 Dolomite, essentially as above, fairly well recrystallized, somewhat more coarsely crystalline, few zones vuggy and fractured with little massive pyrite on fracture at 353.5, bedding at various angles, rather well fractured, rather strong slickensides along various fractures, strong fault at 346.
- 368-384 Dolomite, fairly well recrystallized, rather highly altered, rather highly altered, rather highly fractured, very vuggy, large vugs filled with massive and crystalline calcite which is coated by abundant drusy crystalline pyrite, pyrite rather massive in bottom 2' (and marcasite), estimate pyrite throughout at 7%. Sample No. 821 (371-377) results attached

- 384-410 Disordered dolomite blocks, all principally steeply dipping, principally tan, fine to medium crystalline, little argillaceous, greenish gray, like 252-304, dips principally steep.
- 410-429 Dolomite, nearly vertical, partly porous and vuggy, partly medium crystalline, dips variable, principally near vertical, tend to be somewhat more flat toward bottom.
- 429-436 Dolomite, argillaceous, pale greenish gray, bedding principally approximately 45 degrees, rather contorted, bottom 1.5' somewhat fractured, all very similar to zone between 252-304 which may correlate with 78-2 from 778-783.
- 436-441 Dolomite, tan, very fine grained with dark bluish gray mottled streaks, dips nearly flat, possible contact at bottom.
- Note: Dips appear to have decreased rather rapidly from approximately 425 to this point, above that zone dips were principally vertical whereas from 425-441 dips tend to be approximately 45 degrees.
- 441-494 Dolomite, tan to light brownish gray, finely crystalline, somewhat saccharoidal, few patches and zones rather vuggy and porous, bedding fairly consistent at approximately 45-50 degrees, bottom contact probably fault contact, unit somewhat more highly disturbed in bottom 10', rather similar in lithology to 78-2 from 1008-1080, fair correlation.
- Lower Camp Nelson
- 494-528 Mixed dolomites, highly disturbed, principally dipping at -70°, all somewhat recrystallized, fairly well fractured, some very well laminated with abundant vugs and medium crystalline material between argillaceous laminations, bottom 3' resembles Tyrone.
- 528-539 Breccia zone, probably fault breccia, all well sheared and fractured, partly oxidized, breccias consist of fine, rock flour breccias, patches surrounding larger fragments of brown to tan dolomite, highly disturbed Pencil Cave material with breccia from 532-534, unable to locate chert that is usually associated with Pencil Cave.
- 539-554 Dolomite, light brownish gray, finely crystalline, rather dense, massive, rather highly disturbed fractured, few zones partly porous and vuggy, probably Tyrone.
- Note: Probably still going through disordered blocks, lithologies above this Tyrone clearly favor those of the Camp Nelson. Probable Pencil Cave at 533 and this zone of probable Tyrone gives fair correlation.
- 554-590 Dolomite, highly fractured, highly disturbed, principally fairly porous and vuggy along fractures, lithologies rather variable but principally resemble upper parts of Camp Nelson, moderate calcite mineralization along fractures in vuggy portions, show of sphalerite in coarse calcite and fracture with some associated fine grained, light to pale yellow bladed barite at 562.5, several zones moderately pyritic along fractures with possible very faint traces of chalcopyrite, pale yellow to white bladed barite crystals in fractures lightly scattered throughout.
- 590-635 Dolomite, highly disturbed, fractured, principally resembles Camp Nelson lithologies though somewhat darker gray probably due to dolomitic alteration, little pyrite and traces of bladed barite in vugs, considerable less mineralization than above.
- 635-725 Dolomite, very highly disturbed and lithologies somewhat mixed, all rather well altered, recrystallized, few zones and patches rather vuggy with dolomite druse, several vugs with aggregates of blady and fibrous crystals, probably barite, bedding at all angles, moderately well fractured, lithologies probably favor lower part of Camp Nelson, correlation questionable, occasional vug with crystalline pyrite druse toward bottom, grades gradually into below.
- 725-740 Dolomite, dark brownish gray and mostly medium crystalline, somewhat vuggy and recrystallized, fairly numerous argillaceous partings principally nearly parallel to core, considered highly disturbed, dips nearly vertical.

- 740-770 Dolomite, essentially as before, rather well pitted, vuggy and porous, bedding at all angles, principally steep, fairly well fractured, traces of pyrite and calcite on vugs.
- 770-775 Dolomite, well banded with dark greenish gray, bands highly contorted, dark greenish gray bands of argillaceous material similar to greenish gray band at 959 in 78-2.
- 775-830 Dolomite, tan, brownish gray, medium crystalline, essentially as above, resembles lower Camp Nelson, partly vuggy, well pitted and coarsely crystalline, all highly disturbed, highly fractured, dips principally less than 60 degrees, little white bladed barite on fractures.
- 830-885 Dolomite, essentially as above, bedding variable, commonly nearly vertical, all rather vuggy, recrystallized, fairly common aggregates of fibrous crystals in vugs, possibly barite.
- Note: All dolomites described above are all rather porous. Hole 78-1 seemed to encounter more porous or drusy dolomite. These dolomites would make excellent hosts if exposed to mineralizing solutions.
- 885-910 Dolomite, essentially as above.
- 910-922 Dolomite, medium crystalline, porous, soft, fairly abundant argillaceous material, dark brownish stained, seems rather petroliferous, 3" of black shale dipping at 45 degrees at bottom.
- 922-994 Dolomite, light tan to light brownish gray, medium crystalline, rather porous, somewhat vuggy throughout, dips rather consistent at approximately 45 degrees, somewhat massive at 969, somewhat mixed in places, little bladed barite in vugs and along fractures, unit vaguely resembles dolomite approximately from 1010-1080 in 78-2.
- Note: Degree of disturbance seems to be diminishing.
- 994-1042 Dolomite, finely crystalline, brownish gray, rather highly disturbed, partly vuggy with dolomite druse, few interbedded streaks of drusy dolomite, resembles material above, little bladed mineral probably barite scattered throughout in fractures and vugs, grades rather abruptly into below.
- 1042-1061 Dolomite, upper portions finely crystalline with abundant interlaminated wavy argillaceous material, all dipping at approximately 45°, bottom portion with faint greenish cast, argillaceous material vaguely resembles Wells Creek.
- 1061-1126 Dolomite, very highly disturbed, dips principally between 60° and 80°, dolomite somewhat porous, recrystallized, few zones vuggy and drusy, highly disturbed throughout, lithologies varied, few greenish blocks possibly Wells Creek, bottom contact rather abrupt.
- 1126-1158 Dolomite, tan, crystalline, fairly abundant interlaminated argillaceous streaks, upper portions very well laminated, partly vuggy, partly fractured, little dolomite druse along vugs, bottom contact fairly distinct.
- 1158-1200 Dolomite, tan, gray and light gray with slight greenish gray cast, fairly abundant argillaceous material, 6" of greenish gray shaly material at 1184, dips somewhat variable, rather consistent, probably average about 30° with maximum of about 45°.

TOTAL DEPTH

**Plates of Selected Split and Polished Cores from the Ozark  
Mahoning JK78-1 Core**



01  
23.0'

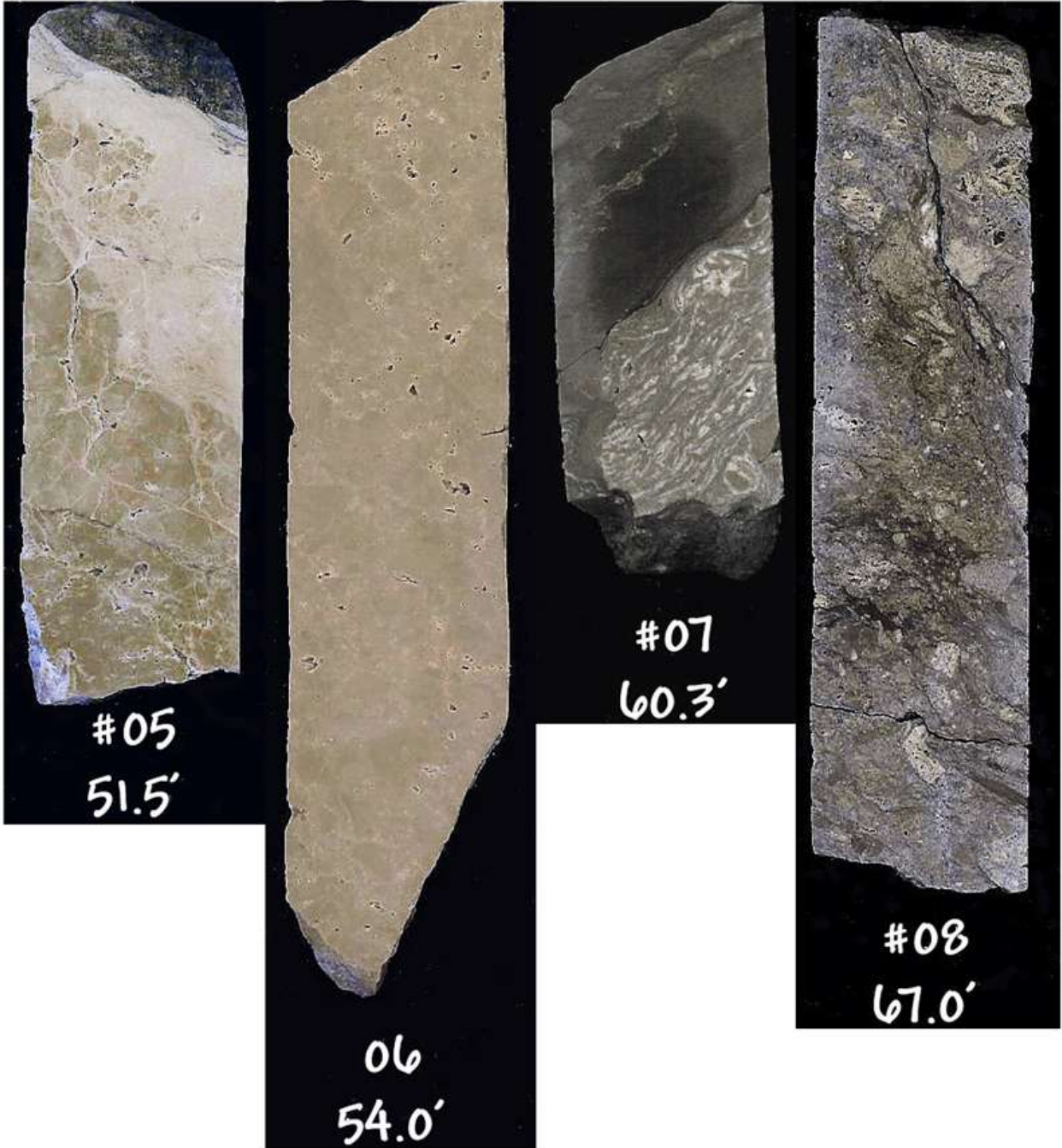
#02  
26.5'

#03  
43.0'

#04  
51.0'

CM





#05  
51.5'

06  
54.0'

#07  
60.3'

#08  
67.0'

CM





#09  
72.6'



#10  
74.4'



A

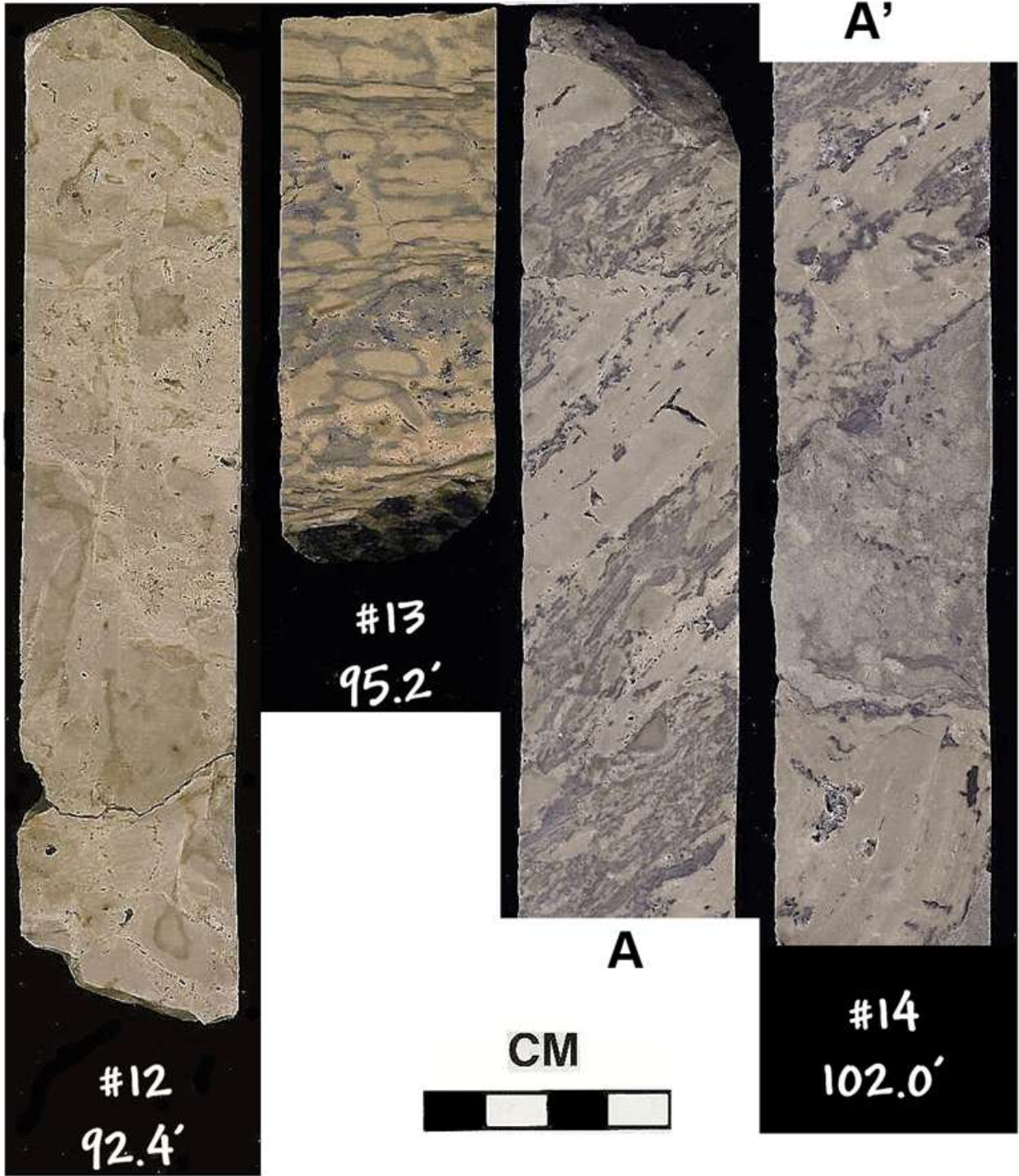


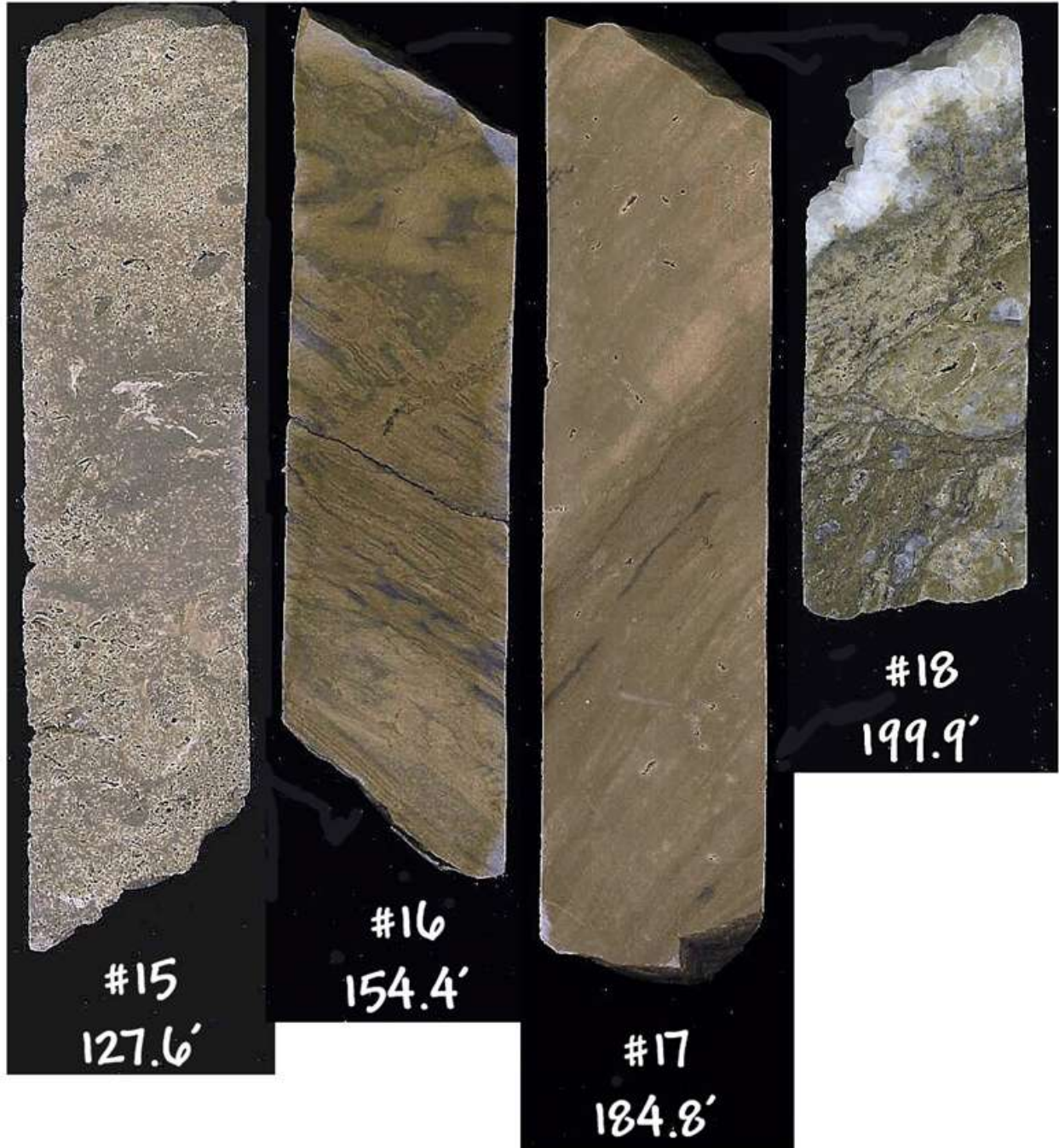
#11  
80.3'

A'

CM







#15  
127.6'

#16  
154.4'

#17  
184.8'

#18  
199.9'

CM





A

A'



#19  
201.6'

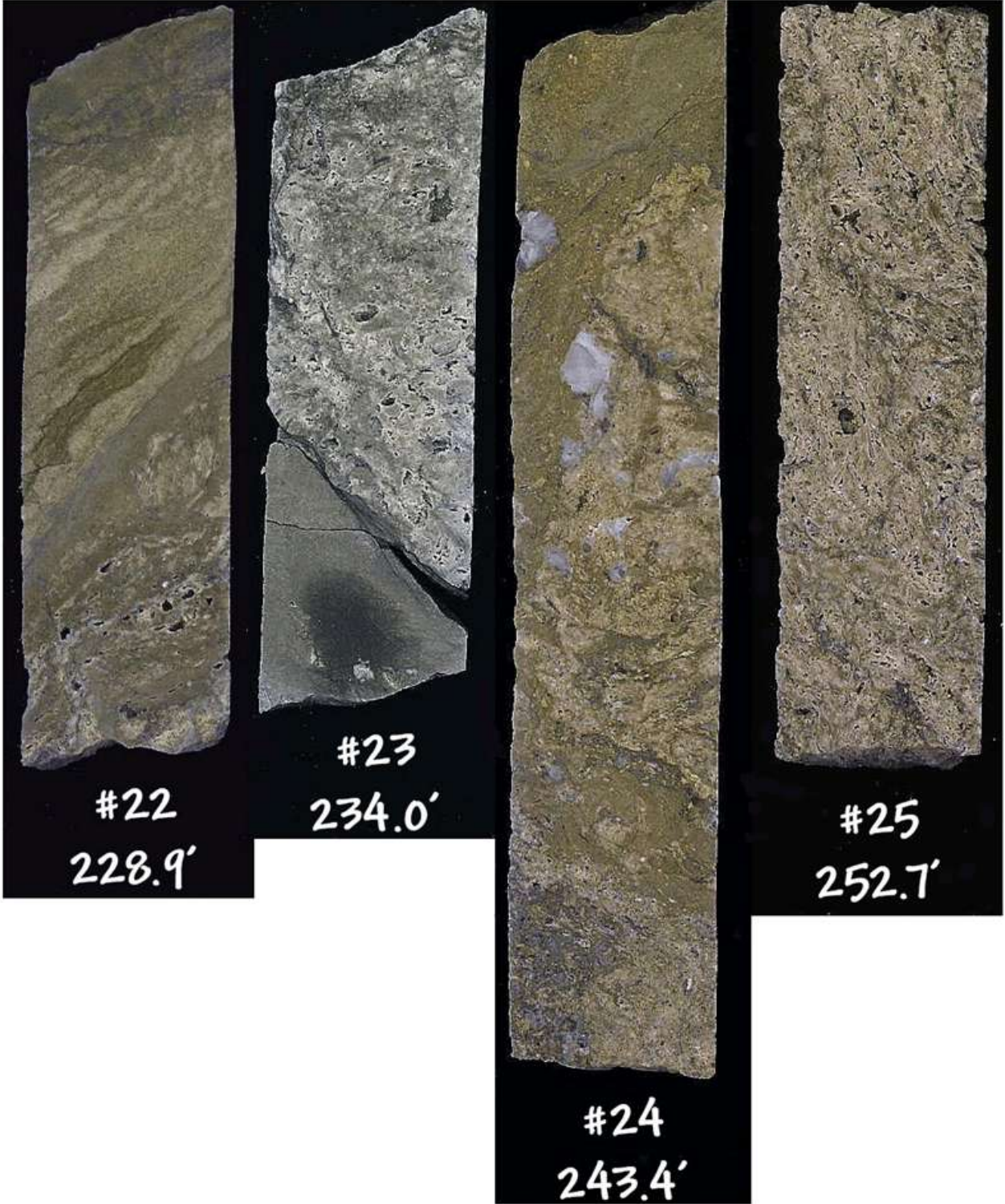
CM



#20  
204.1'



#21  
215.3'



#22  
228.9'

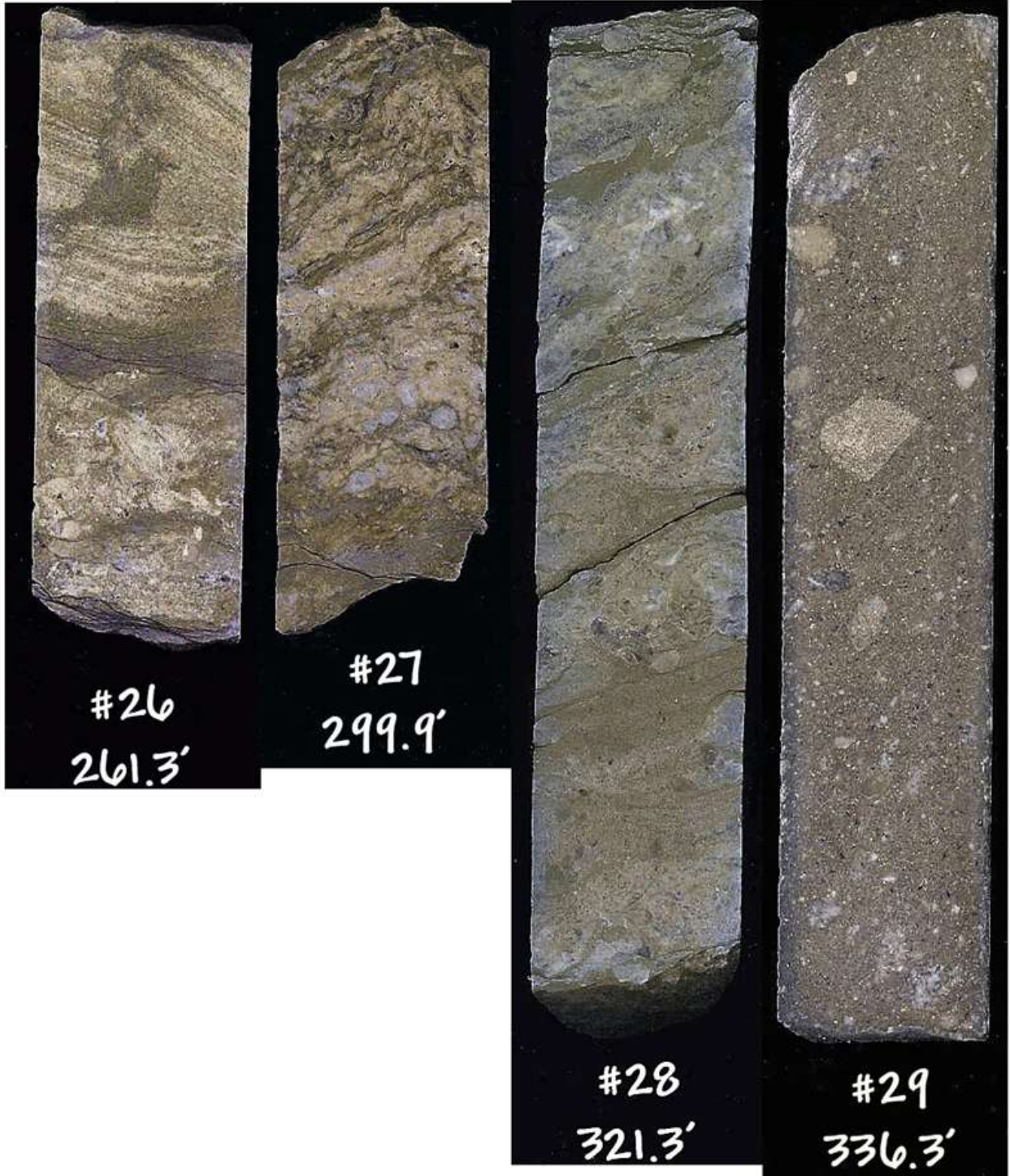
#23  
234.0'

#24  
243.4'

#25  
252.7'

CM





#26  
261.3'

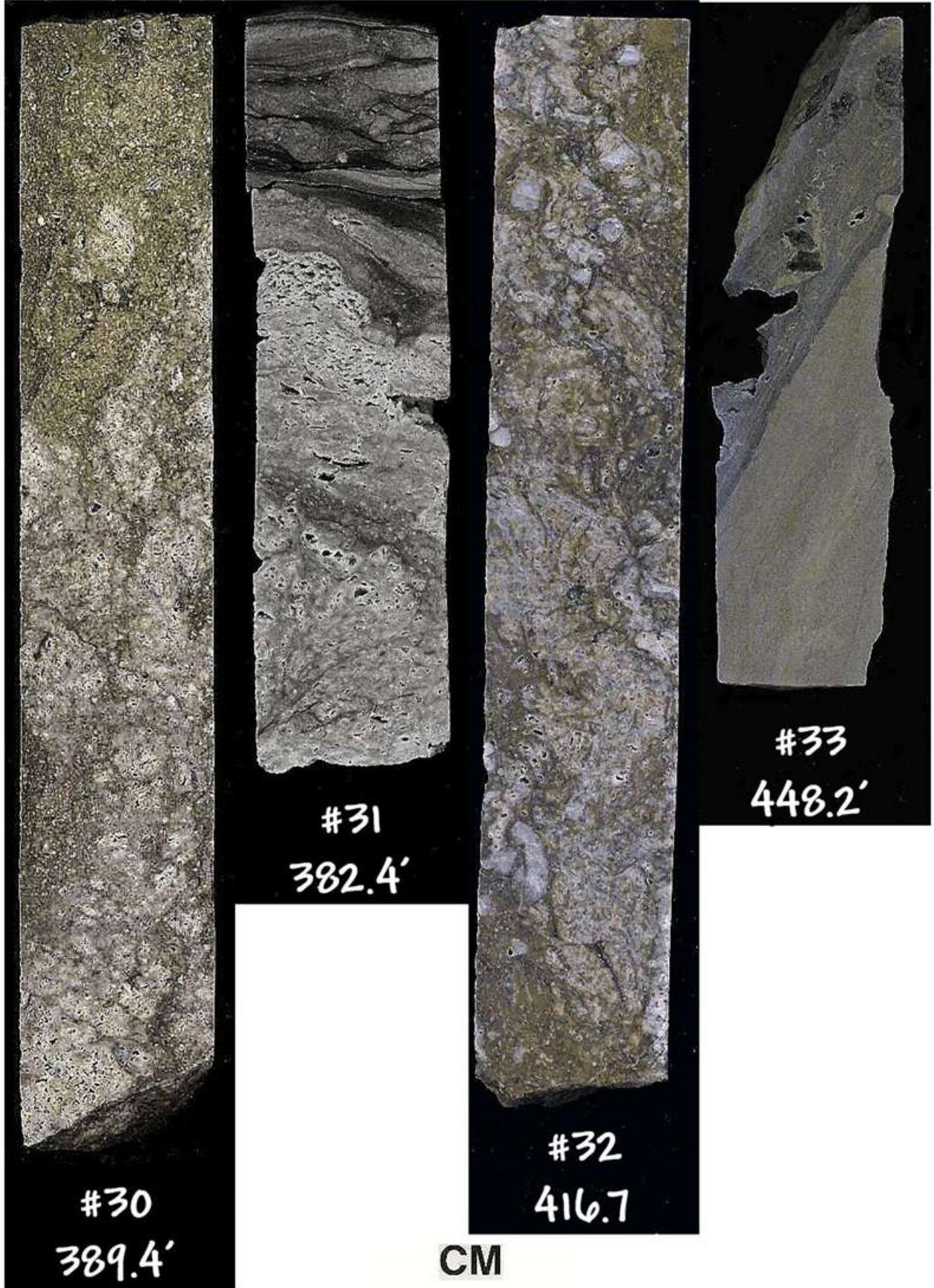
#27  
299.9'

#28  
321.3'

#29  
336.3'

CM





#30  
389.4'

#31  
382.4'

#32  
416.7

#33  
448.2'

CM





#34  
461.6'



#35  
519.0'



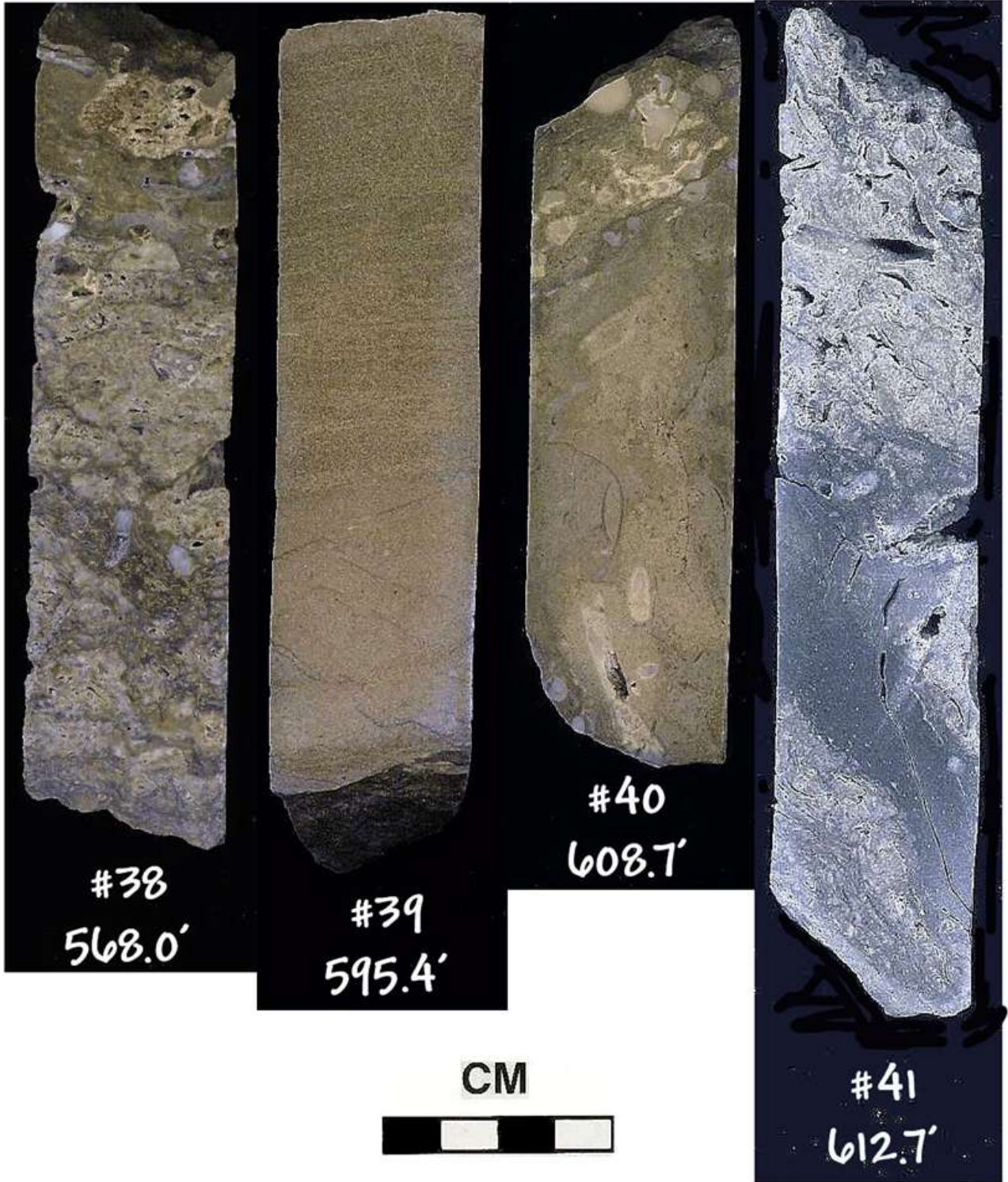
#36  
539.4'



#37  
553.3

CM





#38  
568.0'

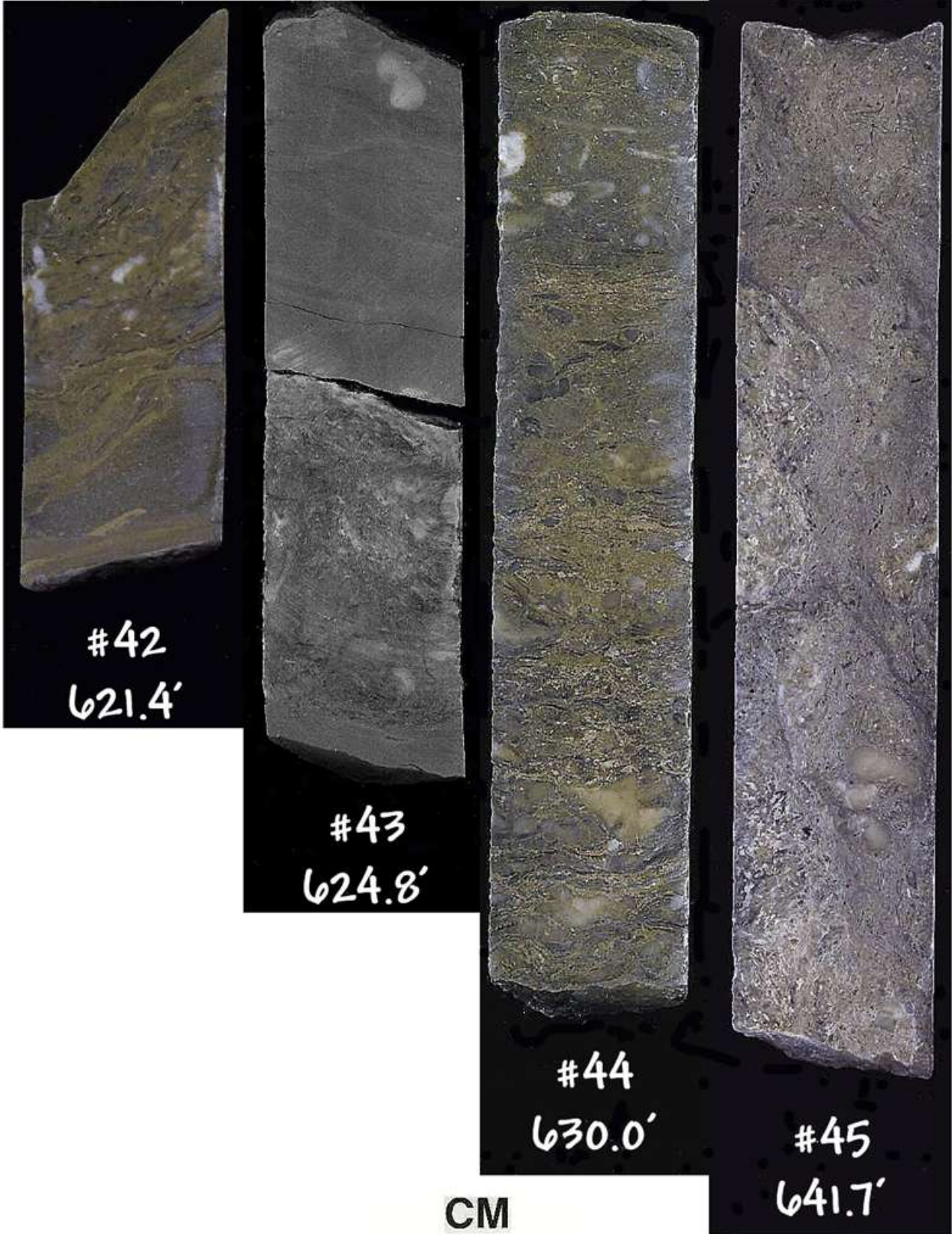
#39  
595.4'

#40  
608.7'

#41  
612.7'

CM





#42  
621.4'

#43  
624.8'

#44  
630.0'

#45  
641.7'

CM





#46  
643.6'



#47  
645.3'

CM



## Appendix B

The following plates were constructed to aid in fossil identification at field stops in the Grant Lake Limestone. All of the fossils shown on the plates were found at the field stops. You can visit the fossil pages on the Kentucky Geological Survey Web site for more information on Upper Ordovician fossils. Pictures and aids to identifying Upper Ordovician fossils in northern Kentucky are also available through the Cincinnati fossils and stratigraphy Web site, as well as the Kentucky Paleontological Society and Cincinnati Drydredger's Web sites.

**Plate B1.** Common brachiopods of the Grant Lake Limestone at stops 2a and 2b. Three species of *Vinlandostrophia* (previously *Platystrophia*) may be found. *V. ponderosa* has a rounded to V-shaped hingeline. *V. laticosta* has a straight hingeline of moderate length. *V. cypha* (not shown) has been reported from the unit but was not identified during initial reconnaissance of the outcrops. It has a long, straight hingeline. *Hebertella occidentalis* is another large orthid brachiopod. It has finer ribbing than *Vinlandostrophia*. *Raphinesquina alternata* is a relatively flat-valved concave-convex strophomenid brachiopod. Strophomenid shells commonly are encrusted by bryozoans and other fossils. See Table 1 for a complete listing of brachiopods from this unit.

**Plate B2.** Other common fossil of the Grant Lake Limestone at stops 2a and 2b. Bryozoans are abundant. Branching, platy, and encrusting forms have all been identified. Generic placement generally requires microscopic analysis. Pelecypods are also common. Internal molds of ovate modioliform clams are most common, but several distinct large clams with fossilized valves can also be identified. *Caritodens?* (*Pterinea*), possibly *C. demissa*, has a broad lobate shell with a slight "wing" or extension near the hingeline. Valves commonly exhibit fine concentric growth layers. *Ambonychia*'s shell tends to be narrower toward the hinge and has an elevated umbo (back point of the shell). It exhibits well-developed ribbing along the long axis of the valves. Orthocerid (straight-shelled) cephalopods are uncommon and generally small. See Table 1 for a complete listing of other fossils from this unit.

Plate B1



*Vinlandostrophia ponderosa*



*Vinlandostrophia laticosta*



*V. laticosta*  
(with an "overbite")



*Hebertella occidentalis*



1 cm



*Rafinesquina alternata*



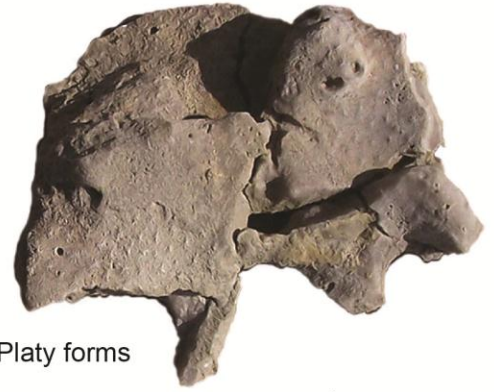
**Common Brachiopods**

Plate B2

**Bryozoans**



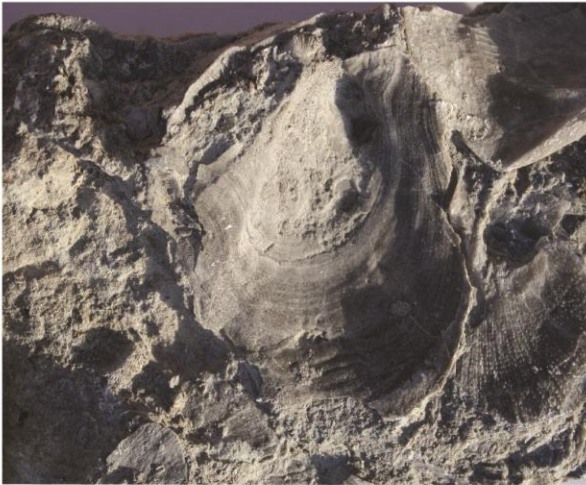
Ramose (branching) forms



Platy forms

1 cm

**Molluscs, pelecypods (bivalves)**



*Caritodens (Pterinea)*



*Ambonychia*



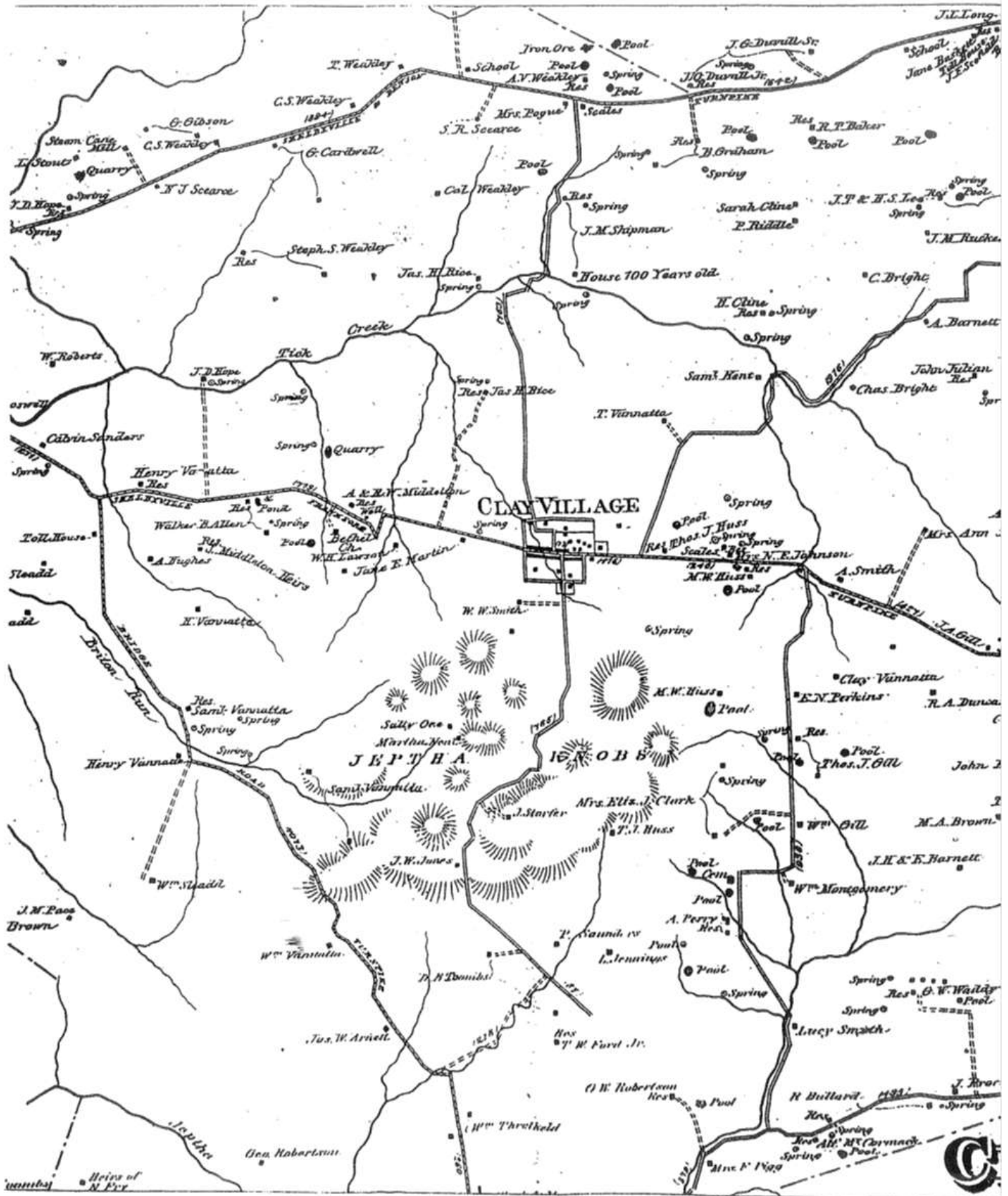
Modioliform internal molds



**Molluscs, cephalopods**



Orthocerid



D.L. Lake's "Atlas of Henry & Shelby Cos, Kentucky" -- 1882  
 [Locates: Landowners, Turnpikes, Springs, Toll Houses, Ponds, Scales,  
 Quarries, Iron Ore] iv

Map taken from "A History of Jephtha Knob, Cross Keys Inn, Old Bethel Church, and Wildlife of the Area." (All located near Clay Village in Shelby County, Kentucky). Published by Calvin T. Schmidt, 2004, 45 p.