

# GUIDEBOOK FOR FIELD TRIPS

18th Annual Meeting  
Southeastern Section  
THE GEOLOGICAL SOCIETY OF AMERICA

Lexington, Kentucky, April 1970

## Field Trip No. 1

*GEOLOGIC FEATURES OF SOUTHEASTERN KENTUCKY*

## Field Trip No. 2

*LITHOLOGY AND FAUNA OF THE LEXINGTON LIMESTONE (ORDOVICIAN)  
OF CENTRAL KENTUCKY*

## Field Trip No. 3

*BORDEN FORMATION (MISSISSIPPIAN) IN SOUTHEAST-CENTRAL  
KENTUCKY*

## Field Trip No. 4

*PALEOZOIC SECTION ON EAST FLANK OF CINCINNATI ARCH ALONG  
INTERSTATE 64, LEXINGTON TO OLIVE HILL, KENTUCKY*



KENTUCKY GEOLOGICAL SURVEY  
UNIVERSITY OF KENTUCKY, LEXINGTON

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**FIELD TRIP NO. 1**  
**GEOLOGIC FEATURES OF SOUTHEASTERN KENTUCKY**

**Part I: Landslide Geology Along South Slope of Pine  
Mountain, Pineville to Harlan**

Leader: **ALBERT J. FROELICH**  
U. S. Geological Survey, Middlesboro, Kentucky

The route (Fig. 1) follows the valley of Cumberland River, carved in rocks of Pennsylvanian age that form the south slope of Pine Mountain, which in turn forms the north limb of the Middlesboro syncline. The stratigraphic section traversed consists of resistant crossbedded sandstones of the upper part of the Lee Formation, overlain by a less resistant sequence of interbedded shales, siltstones, sandstones, coal beds, and underclays of the lower part of the Breathitt Group (Fig. 2). Regional dip is south-southeast except where interrupted by local cross structures (see Figs. 3 and 4, in pocket).

**STOP 1—START OF TRIP**

*Junction of U. S. 119 and 25E, Pineville, Ky.*

Following a discussion of the geology at this point the caravan will turn east and follow U. S. 119.

**ROAD LOG**

*Mileage*

0.0 Junction of U. S. 119 and 25E. Turn east on U. S. 119.

0.1 Cumberland River. After flowing westerly along the south slope of Pine Mountain for more than 60 miles, the river cuts through at Pineville Gap.

0.15 Part of Rocky Face fault zone, a left-lateral tear fault, upthrown to east. This is a major transverse structure which extends for about 15 miles across the Middlesboro syncline. (The syncline is the surface expression of the Cumberland overthrust block which terminates in the Pine Mountain overthrust fault

exposed along the north face of Pine Mountain.) Lee sandstone dips generally east in a structurally deformed nose.

0.5 Mainly east-southeast- and south-dipping Naese Sandstone Member of Lee Formation.

0.8 Lower part of Hance Formation of Breathitt Group in synclinal embayment of Laurel Hill monocline, a flexure parallel to and south of Pine Mountain.

1.2 Small northwest-trending fault in lower Hance Formation.

1.6 East Pineville. Alluvium and terrace gravel. Cuts ahead are in irregularly bedded Naese Sandstone overlain by Naese coal bed (not exposed) and basal Hance Formation.

2.5 Bell County High School on south side of road.

3.2 Broken beds in small wedge-shaped fault block.

3.8 Page School Center, on nearly flat-lying Naese Sandstone.

4.3 Carbonaceous shale and siltstone of lower Hance Formation.

4.9 Naese Sandstone.

5.2 Junction. Bridge across Cumberland River to south; cut through upper Naese sandstone and siltstone.

5.7 Gradational contact between lower Hance shale and siltstone and upper Naese siltstone and sandstone.

5.85 Poorly developed Naese coal zone exposed in cut 30 feet above road level. Zone consists of two 6-inch coal beds separated by 3.5 feet of carbonaceous shale.

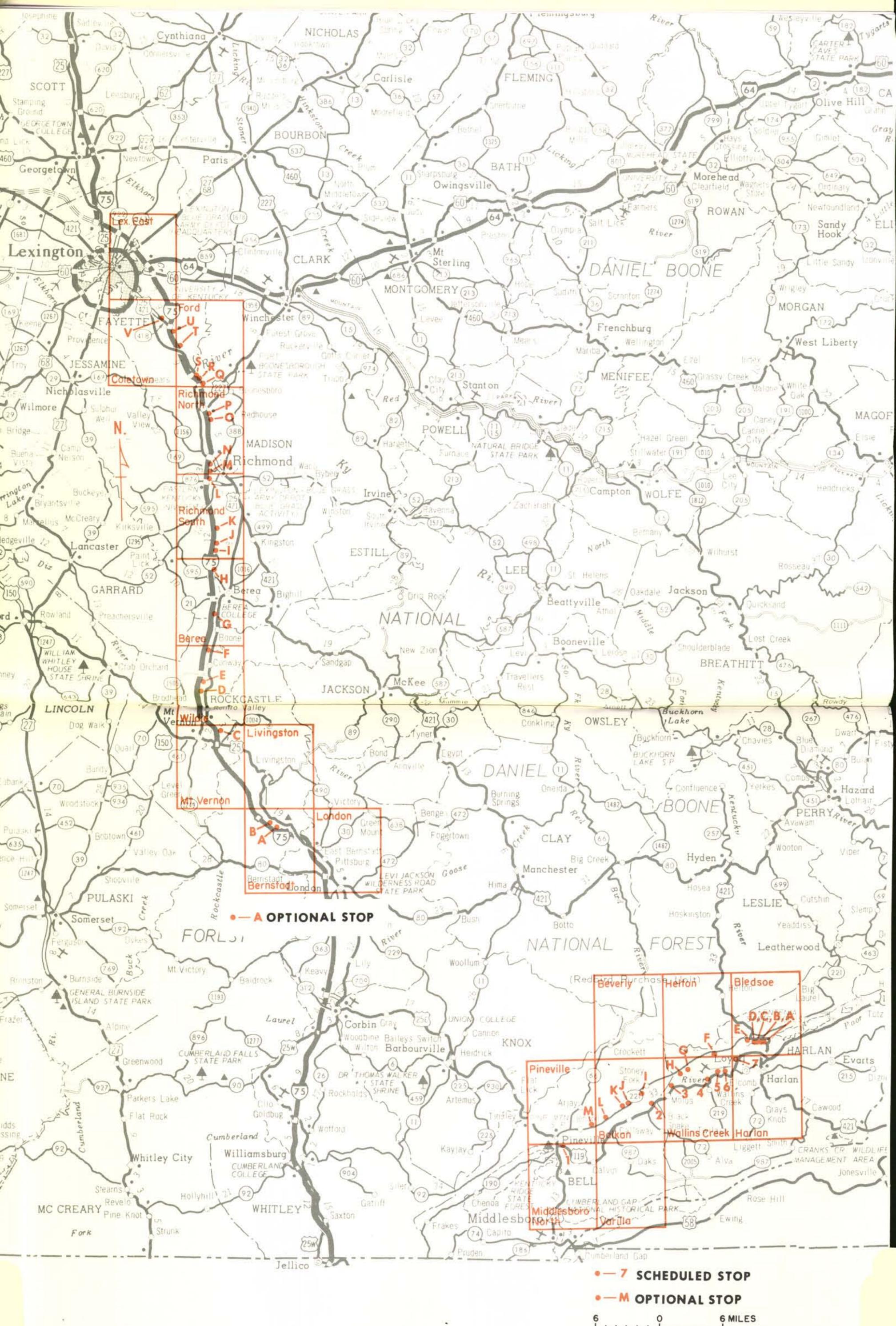


Figure 1. Route map.

PENNSYLVANIAN	* Breathitt Group	Hance Formation	Mason coal bed	600 <sup>+</sup>
			Splitseam coal bed	
			Clear Fork coal bed	
			Naese coal zone	
	Lee Formation	Naese Sandstone Member	50-250'	
Bee Rock Sandstone Member		50-250'		
		1000-1500'		
MISSISSIPPIAN	Pennington Formation		175' ±	
	Newman Limestone		550' ±	
	Grainger Formation		300' ±	
DEVONIAN	Chattanooga Shale		250' ±	

\* Breathitt Formation north of Pine Mountain

Figure 2. Generalized stratigraphic section for Pine Mountain.

- 6.5 Characteristic Naese Sandstone, gray, fine- to medium-grained, crossbedded.
- 7.1 Top of Naese Sandstone, base of Hance Formation; Naese coal bed.
- 7.2 Roadcuts in Naese coal bed and underlying Naese Sandstone. Type section of Naese coal: 15 inches of coal, 4 feet of gray and black shale with two 6-inch cannelloid shale seams, 30 feet above sandstone.
- 7.5 View of Cumberland River valley through "Seven Sisters"; type locality of Naese Sandstone.
- 7.75 \*Lenticular shale (0-20 feet) marking local unconformity within (?) Naese Sandstone Member of Lee Formation. Upper Naese (?) sandstone truncates shale and rests unconformably on lower Naese sandstone here.
- 8.05 Junction with Ky. 987. East plunge of Laurel Hill flexure. Naese (?) sandstone overlain by irregular shale, in turn overlain unconformably by Naese Sandstone.
- 8.1 Shale overlain by upper Naese sandstone (counterpart of cut at mile 7.75).
- 8.2 Junction, road to Bird Branch, near Pineville.
- 8.5 Top of Naese Sandstone, base of Hance shale; Naese coal bed on east nose of Laurel Hill fold.
- 8.7 Lower Hance: dark-gray carbonaceous shale and siltstone with ironstone concretions and coal stringers.
- 8.9 East end of Laurel Hill fold; good view of south slope of Pine Mountain. Bee Rock Sandstone Member of Lee Formation forms cliffs and hogbacks.
- 9.2 Coal bed with 8-inch underclay, 18 inches of coal, 6 inches of carbonaceous shale, 10 inches of coal, 24 inches of coaly shale, 20 feet of sandstone roof (channel fill); same coal on southeast cut overlain by 20 feet of gray shale below sandstone roof.
- 9.5 Crossbedded lower Hance (?) sandstone.
- 10.6 Southeast-dipping lower Hance shale, siltstone, and coal beds steepen abruptly from 20° to over 50°.
- 11.0 Recent rock fall in oversteepened ripple-marked sandstone.
- 11.15 Abundant root and stem impressions in shale below coal and above ripple-marked sandstone.
- 11.25 End of deep cut. Typical Hance Formation: dark-gray carbonaceous shale overlain by large erratic sandstone blocks (colluvium or old slide debris?).
- 12.6 Abandoned tippie of mine in the Mason coal bed, 0.3 mile south, across Cumberland River.
- 12.7 Unstable roadcut with slope stripped to grade on Clear Fork (?) coal bed.
- 13.3 Stable roadcut in Hance shale, stripped to grade.
- 13.8 Pure Oil service station.

\* Outcrop marked with white paint spot.

- 13.95 Junction to south, top of grade. Good view west (back) of steeply inclined Lee sandstones in Pine Mountain. Benches to east are in Cardinal coal area of Middlesboro syncline. Stable roadcut, with no offsetting of boreholes.
- 14.05 \*Clear Fork (?) coal bed, intensely cleated. Note slightly offset boreholes along shear slippage plane subparallel to bedding plane. Upslope benching has thus far been effective, but sandstone above coal may slide.
- 14.3 Junction, Ky. 72 south to Alva. Slumped bedrock to north.
- 14.45 \*Deep roadcut in Breathitt Group (lower Hance) shale and siltstone. Note boreholes with differential offset along bedding-plane slippage that becomes subparallel to bedding, rising to east. Splitseam (?) coal bed is 40 feet above road level. This is a potentially dangerous cut, as coal dips 5° to 10° south, rising 240 feet vertically to the north in 0.3 mile. There has been no benching on this cut, and the channel-sandstone roof is unstable.
- 14.55 Recent (1969) cut in slip of broken sandstone and colluvium.
- 15.0 Stop 2.

## STOP 2

### *Cut south of abandoned caved roadcut of 1967*

Fractured and broken sandstone roof over the Splitseam (?) coal bed failed and slid into the cut, reportedly burying a bulldozer. The slope continues to slide. Dip of the beds at road level is 8° to the southeast, increasing to 20° upslope in less than 0.1 mile.

The sequence here is a 20-inch coal bed on poorly developed underclay, 0-10 feet of gray silty shale roof, and 20-30 feet of channel sandstone grading upward into thin-bedded sandstone and siltstone. Water seeps from the base of the sandstone and from the coal.

The east side of the cut is probably bounded by an east-facing scarp. Colluvium slumped in 1969.

### *Mileage*

- 15.8 Recent slump in deeply weathered, colluvium-covered shale-siltstone-coal sequence of Hance Formation.
- 16.2 \*Unstable colluvium or landslide debris above shale overlying sandstone in roadcut.
- 16.3 Scarp, probable east-facing landslide scar.

- 16.9 Molus, Ky.
- 17.1 Impure coal zone 1 to 3 feet thick in fresh cut; part of Hance coal zone (?).
- 17.4 Twenty-six-inch Mason (?) coal bed at flexure where gently south-dipping strata steepen sharply on south side of Pine Mountain. Three coals are present in sandstone-siltstone-shale Hance sequence.
- 17.5 Striated joint face, representing cleared landslide scar, trends N 35° W, perpendicular to regional strike of strata in Pine Mountain.
- 17.6 Coal bed and lower scarp of old east-facing landslide scar.
- 17.7 Park for Stop 3.

## STOP 3

### *Joint-controlled scarps in the lower Hance Formation*

Five levels of joint-controlled scarps are cleared relicts of old east-facing landslide scars normal to the regional dip of Pine Mountain homocline. Joints contribute to landslides by breaking bedrock into discrete plates which may slide coherently. The view to the southwest at the flexure with the prominent Cumberland River meander contrasts with the straight course of the river to the east where no unstable lower Hance beds are present for 2 miles. Note the dark-gray shale on basal Hance sandstone, possibly the floor of the ancient slide.

### *Mileage*

- 18.1 Colluvium on basal Hance sandstone. Road parallels straight course of Cumberland River with relatively wide alluvial flood plain. Roadcuts are through same sandstone with local colluvial cover.
- 19.7 Lower Hance shale overlies sandstone at west edge of "Coldiron syncline," a local structural embayment in Pine Mountain homocline.
- 19.9 Roadcut exposure of lower Hance strata striking N 45° E, dipping 20° southeast. The strike angles into Pine Mountain regional trend at about 25° on flank of local cross-structure. Note trend of joints.
- 20.15 Junction of road to Coldiron, Ky. Trough of "Coldiron syncline."
- 20.4 \*Fossil locality. *Lingula*, etc., in dark-gray to black siltstone and shale 10 feet below 12-inch coal. (Note thick underclay below 8-inch coal above.)

\* Outcrop marked with white paint spot.

\* Outcrop marked with white paint spot.

- 20.5 Common east limb of "Coldiron syncline" and Laurel Creek anticlinal nose. Lower Hance strata strike N 45° W and dip 20-25° southwest. Note channel sandstone unconformably above siltstone-coal sequence at top of cut.
- 20.55 Naese (?) coal bed in gully below striated east-facing joint face (scarp).
- 20.6 Top of basal Hance sandstone, probably equivalent to Naese Sandstone to west. Sandstone is 98 feet thick, gray, fine to medium grained, crossbedded, with abundant coal spars and mica.
- 20.7 Base of sandstone, top of 40-foot shale with 6-inch coal beds at top and base.
- 20.75 Top of Bee Rock Sandstone Member of Lee Formation.
- 21.0 Crest of Laurel Creek anticlinal nose. Base of upper Bee Rock sandstone with thin coal bed in east cut; top of lower Bee Rock pebbly sandstone in gully below road level.
- 21.25 Bee Rock Sandstone at top; base of cut contains 40 feet of shale with 6-inch coals at top and base (as at mile 20.7).
- 21.28 Basal Hance sandstone (Naese?).
- 21.4 Naese coal bed on Naese (?) sandstone. Old landslide scar at west-facing scarp, a probable counterpart of that at mile 20.55.
- 21.8 East limb, Laurel Creek anticlinal nose; striated joint face.
- 21.9 Channel-fill sandstone unconformably on lower Hance shale and siltstone. This is a counterpart of the sandstone at mile 20.5 on opposite limb of fold.
- 22.1 Trough of synclinal sag with spectacular local unconformity below channel-fill sandstone.
- 22.4 \*Junction of road to Wallins Creek. To the north boreholes are offset along bedding-plane slippages.
- 22.5 Coal 24 inches thick at road level at crest of slight anticlinal rise.
- 22.65 Park for Stop 4.

**STOP 4***Boreholes offset along slippage planes*

Boreholes are prominently offset along bedding-plane slippage surfaces on both sides of roadcut.

\* Outcrop marked with white paint spot.

- 22.8 Offset boreholes in fractured and jointed Hance beds.
- 22.85 West edge of "ancient" Tremont landslide (scarp in fractured Hance strata). Note hummocky topography and large sandstone blocks with erratic "upslope" dip.
- 23.3 Scarp, west edge of 1967 Tremont landslide.
- 23.4 \*In-place (?) bedrock below floor of slide; siltstone and sandstone overlain by fissile shale.
- 23.45 Scarp, east edge of 1967 Tremont slide.
- 23.7 Park for Stop 5.

**STOP 5***East edge of "ancient" Tremont slide, southeast toe*

Note upslope dips in contrast to the regional southeast dip east of the creek and south of the Cumberland River. Rotational elements and ground-water seep are evident.

*Mileage*

- 23.95 Channel-fill sandstone above unconformity.
- 24.0 Junction of road to Tremont.
- 24.25 Junction of Camp Blanton road.
- 24.45 "Church slide" of 1968. Terrys Fork coal (nonbanded) on west flank of fold.
- 24.6 Park for Stop 6.

**STOP 6***Church slide of 1968*

This slide is wholly within bedrock of the Hance Formation. During road construction a 50-foot-thick plate of sandstone and siltstone failed and slid along a floor of Terrys Fork coal and underclay. The unstable bedrock upslope was removed; nevertheless the gently dipping strata are still unstable.

The offset boreholes here are at the site of the 1969 road failure in bedrock on the west flank of the "Wilhoit" faulted (?) anticlinal nose.

*Mileage*

- 24.7 Recent (1969) patch where reconstructed highway slumped.
- 24.9 Approximate axis of anticlinal nose.
- 24.95 Approximate trace of small fault (?), concealed but upthrown to west 30-50 feet.
- 25.05 Terrys Fork coal bed on east limb of anticlinal nose.

\* Outcrop marked with white paint spot.

- 25.1 Junction of road to Fresh Meadows. dipping strata near level of Terrys Fork coal bed. Rock falls are common but no major slide danger exists because strata dip away from road.
- 25.2 Terrys Fork "rider" coal beds at base of thick Hance shale. Note trend of joints in small local synclinal flexure.
- 25.7 Junction of road to Wilhoit. 28.7 Terrys Fork coal zone (much thicker than at mile 25.05) with three to four 1- to 3-foot coal beds in sandstone-shale-siltstone sequence.
- 26.2 Terrys Fork "rider" (6-inch coal bed), overlain by thick Hance shale, underlain by current-bedded sandstone.
- 26.4 Erratic bedding in siltstone-sandstone floor of Terrys Fork "rider." Possibly current-produced deltaic foreset beds. 28.9 \*Dangerously unstable roadcut undermining 20 feet of siltstone on floor of fissile shale dipping south toward road.
- 26.7 Junction of Ky. 840 to Loyall. 29.1 \*Terrys Fork coal bed in local sharp faulted flexure (upthrown 10 feet to west). This is a possible counterpart to "faulted" beds at Stop 7, possibly accounting for origin of Fourmile Creek valley.
- 26.85 West edge of colluvium-landslide debris. Note roadcut exposure and hummocky terrain.
- 27.3 Park for Stop 7. 29.3 Upper Terrys Fork coal zone. Interbedded sandstone and siltstone and irregularly thickening coal beds (much thicker sequence than at Stop 7).
- 29.45 Intensely jointed and fractured Hance shale above Terrys Fork coal zone.
- 29.7 Bridge over Cumberland River (Poor Fork).
- 29.8 Junction with U. S. 421. Turn left (north) on U. S. 421 to cross Pine Mountain.
- 34.6 Mount Aire Motel. LUNCH STOP.

**STOP 7***Structurally contorted shale-siltstone sequence*

Note steeply dipping erratic attitudes in shale-siltstone sequence above (?) regionally dipping stripped shale floor. This possibly is the west hinge of a superficial, gravity-induced "tear fault set."

*Mileage*

- 28.1 U. S. 119 follows flat strike valley of Four-mile Creek cut into updip flank of south-

---

\* Outcrop marked with white paint spot.

① SCHEDULED STOP  
② OPTIONAL STOP

Figure 3. Generalized geologic map of western segment of Pine Mountain trip.

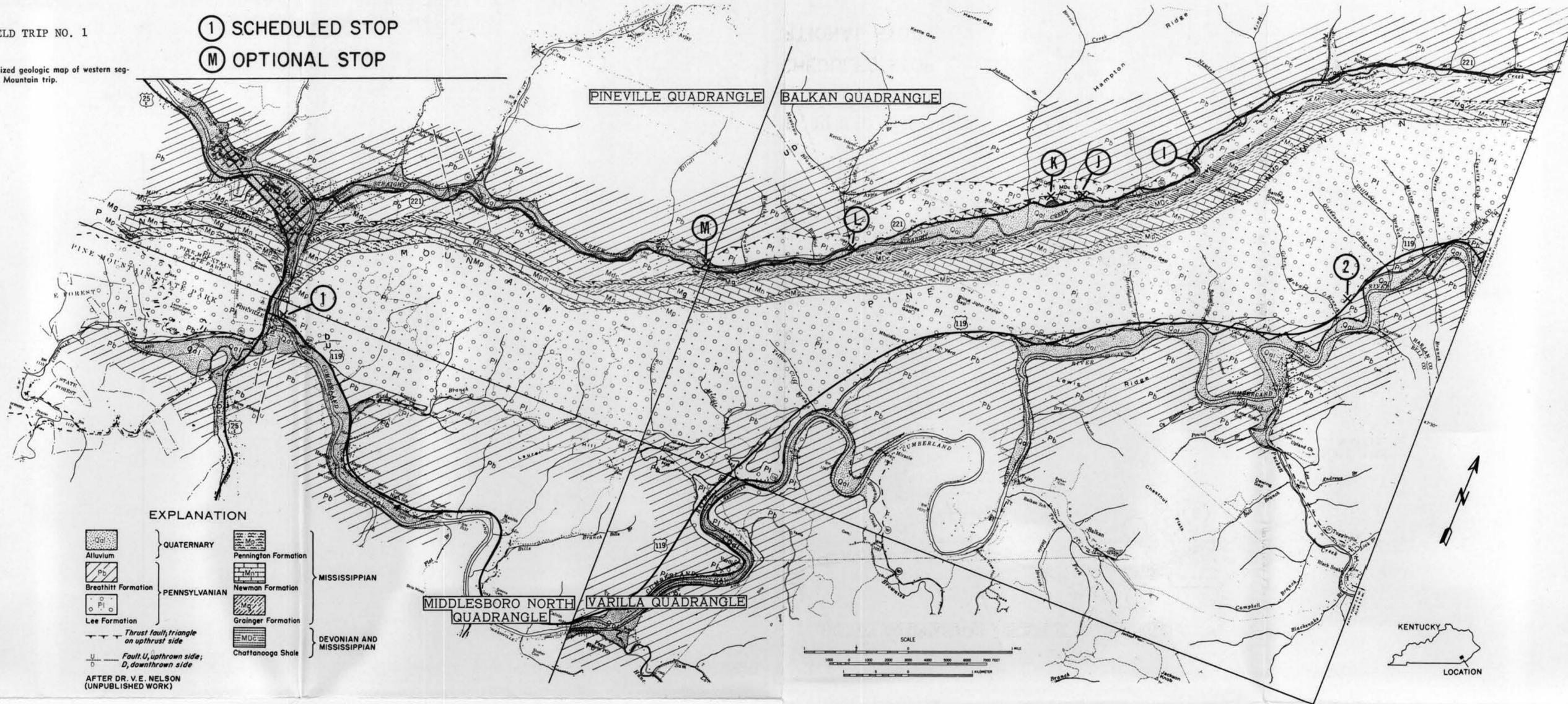
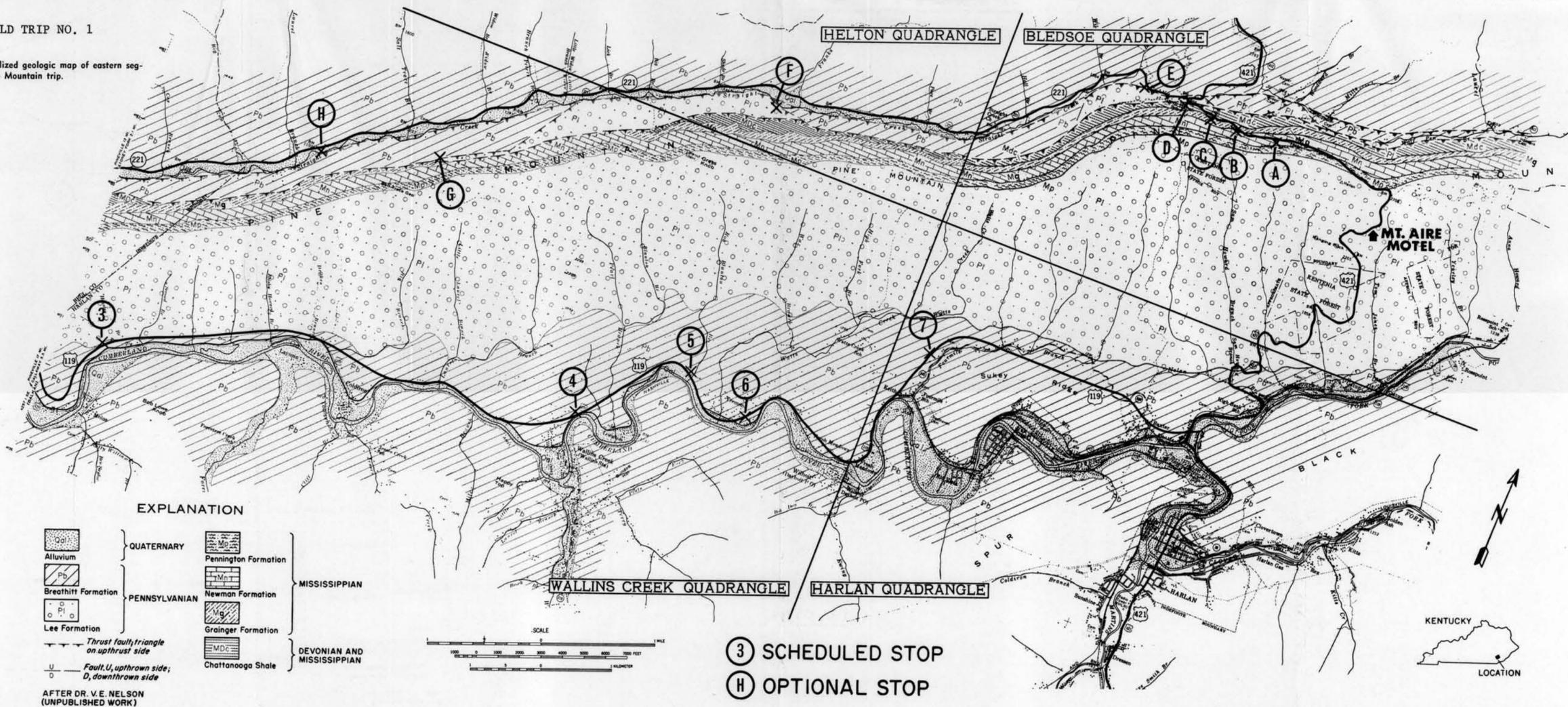


Figure 4. Generalized geologic map of eastern segment of Pine Mountain trip.



**Part II: Geology of Middle and Upper Paleozoic Rocks Along  
Pine Mountain Front, Harlan to Pineville; Paleozoic Rocks  
Along Interstate 75, London to Lexington**

M. C. NOGER  
LOUIS R. PONSETTO  
Kentucky Geological Survey, Lexington, Kentucky

Letters in the left margin of the road log indicate optional stops, shown in Figures 3 and 4 (in pocket).

**ROAD LOG**

*Mileage\**

- 0.4 Junction of U. S. 421 and Little Shepherd Trail. Lower Pennington sandstone on left.  
0.6 Road junction to left.

\* Measured from Mount Aire Motel (lunch stop).

- |   |     |   |
|---|-----|---|
|   | 0.7 | Outcrop of Newman Limestone.                                    |
| A | 1.8 | Quarry in Newman Limestone.                                     |
| B | 2.0 | Top of Grainger Formation.                                      |
|   | 2.4 | Texaco service station.   |
| C | 2.5 | Top of Chattanooga Shale.                                       |
| D | 2.7 | Pine Mountain overthrust fault.                                 |
|   | 2.8 | Intersection of U. S. 421 and Ky. 221;<br>turn left on Ky. 221. |
| E | 2.9 | Scattered outcrops of Breathitt Formation                       |

- in typical structurally deformed zone in front of Pine Mountain fault.
- F 5.0 Ridge to left of road reflects for about 3 miles an upturned slice of Lee Formation in front of main Pine Mountain fault.
- G 9.8 Grace Baptist Church. End of Lee fault slice.
- H 11.0 Overtaken syncline in Breathitt Formation at curve in road.
- 11.7 Big Run bridge. Railroad bridge to right.
- 14.7 Ritter Lumber Company camp.
- 14.9 Bridge.
- I 16.0 Entering Lee Formation at east edge of Kettle Island fault slice, one of the largest fault slices north of main Pine Mountain fault. Slice is crescent shaped and more than 5 miles long, bounded by massive pebbly Lee sandstone to the north. It has a lowland core of deformed and faulted Pennington, Newman, Grainger, and Chattanooga rocks.
- 16.4 Structurally complicated Lee sandstone and upper Newman (?) shale in railroad cut to right of road.
- 17.0 Railroad crossing.
- J 17.5 Overtaken Newman Limestone and Grainger shale exposure.
- K 18.0 Chattanooga Shale in fault contact with weathered Lee sandstone.
- 18.2 Bridge.
- L 20.0 Junction of Ky. 221 and Kettle Island road. Indurated Lee sandstone along west side of Kettle Island and Straight Creek faults, near juncture with White Mountain reverse fault.
- M 21.5 West edge of Lee Formation in Kettle Island fault slice.
- 23.6 Abandoned coke ovens and mines in Straight Creek coal of Breathitt Formation on right.
- 23.7 School.
- 24.5 Junction with Ky. 66; bear left on 66.
- 25.3 Railroad crossing.
- 25.6 Cumberland River bridge. Proceed on Ky. 66 through Pineville.
- 25.9 Intersection with U. S. 25E.

Turn right (northwest) and continue on U. S. 25E for approximately 20.5 miles to intersection with Ky. 229. Turn right (north) and follow Ky. 229 to intersection with U. S. 25E to London. Follow U. S. 25E

through London to intersection with Ky. 80. Bear left on Ky. 80 to intersection with Interstate 75. Turn right (north) on Interstate 75. From Pineville to London exposures consist of sandstones, shales, and coal beds of the Breathitt Formation.

A generalized stratigraphic section of the geology from London to Lexington is shown in Figure 5. The areal geology along Interstate 75 has been depicted in linear segments adapted from Geologic Quadrangle maps of the current Kentucky Geological Survey-U. S. Geological Survey program (Figs. 6-13, in pocket). Unless otherwise noted, all outcrops mentioned in this portion of the road log are on the east side of the northbound pavement.

Letters in the left margin of the road log indicate optional stops where mapped lithologic units can be studied; the X's represent prominent outcrops (for locations, *see* Figs. 6-13).

#### Milepost

##### LONDON QUADRANGLE

- 41.0 Ky. 80 and Interstate 75 interchange. Siltstones, shales, and Lily coal bed of the Breathitt Formation.
- 42.0 Bridge. Corbin Sandstone Member of Lee Formation below road level.

##### BERNSTADT QUADRANGLE

- X<sub>1</sub> 43.6 Corbin Sandstone Member.
- 44.4 Underpass (U. S. 25).
- 45.9 Underpass (U. S. 25).
- A 46.7 Contact of Lee and Breathitt Formations. Corbin Sandstone Member of Lee Formation is at road level. Shales and siltstones of Breathitt Formation are at top of cut.
- 46.9
- B 47.5 Corbin Sandstone Member of Lee Formation at top of cut, underlain by dark-gray shale unit with unnamed sandstone member at road level. Rockcastle Sandstone Member of Lee exposed below road level.
- X<sub>2</sub> 48.5 Corbin Sandstone occupying erosion channel in underlying shale unit. On east side of northbound lanes, shale unit and unnamed sandstone member of Lee Formation are exposed.
- 49.1 Underpass (interchange with Ky. 909).
- X<sub>3</sub> 49.2 Corbin Sandstone Member of Lee Formation at top of cut, underlain by shale with unnamed sandstone member near road level of entrance to Interstate 75. Shales and sandstones of Lee Formation in next cuts.
- 49.7

NOMENCLATURE OF EARLIER WORKERS McFarlan and Goodwin (1930) unless noted otherwise	SYS.	SER.	FORMATION MEMBER, & BED	LITHOLOGY	THICK- NESS IN FEET	DESCRIPTION		
	PENNSYLVANIAN	Lower and Middle Pennsylvanian	Breathitt Fm.		± 200	Shale, siltstone, sandstone, and coal: Shale, gray, locally carbonaceous. Siltstone, gray, thin-bedded. Sandstone, gray, fine-grained, micaceous, argillaceous, thin-bedded. Lily coal bed ranges from 6 to 36 inches in thickness where present.		
				Lily coal bed				
		Lower Pennsylvanian	Lee Formation	Corbin Sandstone Member		0-130	Sandstone, conglomerate, and shale: Sandstone, gray to buff, pink-weathering, quartzose, crossbedded. Conglomerate is characterized by white quartz pebbles.	
				Halsey Rough coal bed			Sandstones, siltstones, shale, and coal: Sandstones, gray, buff, pinkish-brown, fine- to medium-grained, quartzose, locally crossbedded; lenses pinch out abruptly. Siltstone, gray, thin-bedded. Shale, gray to buff. Coals are discontinuous. Where present, Halsey Rough coal bed ranges up to 36 inches in thickness, unnamed coal bed up to 12 inches, and New Livingston coal bed up to 24 inches.	
				Unnamed coal bed				
	New Livingston coal bed							
	Unnamed sandstone							
	MISSISSIPPIAN	Newman Limestone	Pennington Formation		70-80	Shale, sandstone, and limestone: Shale, green, red, or gray, clayey. Sandstone, greenish-gray, fine-grained, calcareous; occurs as lens. Limestone, yellowish-brown, fossiliferous.		
Glen Dean			Upper Member		10-110	Limestone and shale: Limestone, gray, fine- to coarse-grained, fossiliferous; in some places aphanitic, cherty. Shale, calcitic, greenish-gray.		
Gaspar		St. Genevieve Limestone Member		40-80	75-170	Limestone, oolitic, light-gray, crossbedded; in some places micrograined, even-bedded. Base is unconformity, characterized by thin layer containing abundant fragments of St. Louis Limestone.		
St. Genevieve		St. Louis Ls. Member		15		Limestone, brownish-gray, fine-grained, even-bedded, cherty.		
St. Louis		Renfro Member		50-90	Limestone, dolomitic, gray, argillaceous. Shale, greenish-gray, silty.			
		Wildie Member		15-25	Shale and interbedded siltstone and sandstone. Glauconitic at top and base.			
Mudraugh		Halls Gap Member		10-60	Siltstone and silty to clayey shale, greenish-gray. Curly worm trails and <i>Taonurug</i> abundant.			
Floyds Knob Formation		Borden Formation	Nancy Member	Gum Sulphur Bed		0-55	Shale, greenish-gray, commonly limonitic.	
Brodhead Formation				Conway Cut Bed		0-60	Siltstone, greenish-gray and bluish-gray, commonly limonitic.	
				Siltstone Bed		0-170	Shale, clayey, bluish-gray, mottled red and purple.	
		SILURIAN DEVONIAN	Covebit Mem.	Roundstone Bed		0-170	Siltstone, yellowish-gray and yellowish-brown, limonitic, indistinctly bedded. Unit splits into three tongues: Conway Cut Bed, Roundstone Bed, and unnamed siltstone bed.	
New Providence Formation				Nancy Member			Shale, clayey to silty, greenish-gray, fissile in part. Phosphate nodules at base.	
Ohio			New Albany Shale		80-110	Shale, black, carbonaceous, brittle. Phosphate nodules at top.		
Onondaga			Boyle Dolomite		0-15	Dolomite and dolomitic limestone, gray, cherty, fossiliferous.		
Crab Orchard Group (Foerste, 1935)			Crab Orchard Formation		5-35	Mudstone, green and gray, clayey, fissile. Dolomite, gray, silty in part.		
Brassfield Limestone (Hall and Palmquist, 1960)	Brassfield Dolomite			10-20	Dolomite, gray, argillaceous in part; cogwheel crinoid columnals near top.			
Liberty	Preachersville Member			70-85	115-	Mudstone and dolomite: Mudstone, dolomitic and calcitic, greenish-gray. Dolomite, argillaceous and calcitic, grayish-yellow.		
Waynesville Limestone (Hall and Palmquist, 1960)			Rowland Member		40-50	135	Mudstone, calcitic and dolomitic, light-greenish-gray.	
Oregonia	Ashlock Fm.		Upper	Reba Member		12-18	Limestone, gray, argillaceous, wavy-bedded, very fossiliferous; micrograined, even-bedded at base.	
Sunset				Terrill Member		10-18	Mudstone, calcitic and dolomitic, greenish-gray.	
Mount Auburn - Tate	Lower	Stingy Creek Mem.	Gilbert Member		65-75	125-135	Limestone intermixed with siltstone, rubbly, fossiliferous.	
			Grant Lake Member		75		Limestone, bluish-gray, micrograined to fine-grained, even-bedded.	
			Tate Member		65-75		Limestone and shale: Limestone, gray, fine- to medium-grained, wavy-bedded, fossiliferous. Shale, gray.	
							Grades laterally into Stingy Creek and Gilbert Members.	
Fairmount	Calloway Creek Limestone		25-105	Mudstone (90%) and limestone: Mudstone, dolomitic and calcitic, greenish-gray. Limestone, gray, micrograined.				
Garrard	Garrard Siltstone		35-45	Limestone (90%) and shale: Limestone, gray, fine- to medium-grained, argillaceous, fossiliferous. Shale, light-gray, calcitic.				
Cynthiana Fm.	Middle and Upper Ordovician	Lexington Limestone	Clays Ferry Formation		125-190	Siltstone, greenish-gray, calcareous, with flow rolls.		
			Upper tongue of Tanglewood Ls.		0-25	Shale, limestone, and siltstone: Shale, dark-gray. Limestone, gray, in very thin beds. Siltstone, greenish-gray, calcareous. Intertongues laterally with upper part of Tanglewood Limestone and Millersburg Members of Lexington Limestone.		
			Millersburg Member		0-65	Limestone (calcareous and calcirudite), gray, crossbedded in part.		
			Tanglewood Ls. Mem.		0-25	Limestone and shale: Limestone, nodular to irregularly bedded, very fossiliferous. Shale, gray, fossiliferous.		
			Brannon Member		10-31	Limestone (calcareous), gray, fossil-fragmental, crossbedded in part, partly phosphatic.		
			Lower tongue of Tanglewood Ls.		25-31	Limestone and clay shale: Limestone, gray, micrograined, silty in part. Shale, gray.		
			Grier Limestone Member		185-190	Limestone (calcareous), gray, fossil-fragmental, crossbedded in part, partly phosphatic.		
			Curdsville Ls. Mem.		25	Limestone, gray, cryptograined to coarse-grained, fossiliferous throughout, generally nodular.		
								Limestone (calcareous), gray, fossil-fragmental, crossbedded in part.
								Limestone, brownish-gray, micritic, birdseye in part. Bentonite bed ("Mud Cave") present at some places at top. Another bentonite bed generally persistent about 20 feet below upper contact.
Tyrone Limestone (Hall and Palmquist, 1960)	High Bridge Group	Tyrone Limestone		55-90	Dolomite, calcareous, mottled.			
Oregon Limestone (Hall and Palmquist, 1960)		Oregon Formation		30-65	Limestone and dolomite: Limestone, brownish-gray, cryptograined. Dolomite, brownish-yellow, characterized by honeycomb weathering.			
Camp Nelson Limestone (Hall and Palmquist, 1960)		Camp Nelson Limestone		165+				

Figure 5. Generalized stratigraphic section, London to Lexington. Adapted from published geologic quadrangle maps (see Figs. 6-13).

<i>Milepost</i>		<i>Milepost</i>	
X <sub>4</sub>	50.2 -50.4		Sandstones, shales, and siltstones of lower part of Lee Formation. Pennington Formation exposed below road level.
	50.7		Bridge over Rockcastle River.
			<b>BERNSTADT-LIVINGSTON QUADRANGLES</b>
X <sub>5</sub>	51.0 -53.0	X <sub>18</sub>	67.1 Nancy, Halls Gap, and Wildie Members of Borden Formation.
		E	67.7 Conway Cut Bed of Borden Formation on west side of southbound lanes.
		X <sub>19</sub>	70.0 Nancy Member of Borden Formation on west side of southbound lanes.
		F	70.5 Roundstone Bed of Borden Formation.
			<b>BEREA QUADRANGLE</b>
X <sub>6</sub>	53.4 -57.0	X <sub>20</sub>	73.1 Nancy Member and Conway Cut Bed of Borden Formation.
			73.4 Madison County-Rockcastle County line.
		G	74.3 New Albany Shale.
			75.6 Underpass (interchange with Ky. 21).
X <sub>7</sub>	57.5	X <sub>21</sub>	75.7 Entrance to northbound lanes of Interstate 75. Contact between New Albany Shale and Boyle Dolomite.
	58.6		
	58.7	H	77.8 Contact between Brassfield Dolomite and Drakes Formation.
X <sub>8</sub>			78.8 Road crosses small fault.
			<b>RICHMOND SOUTH QUADRANGLE</b>
X <sub>9</sub>	60.0	I	80.2 Contact: Drakes Formation and upper part of Ashlock Formation. Reba Member of Ashlock Formation is present in lower part of cut overlain by Drakes Formation.
X <sub>10</sub>	60.5		
C	60.9 -61.4	J	80.7 Contact of upper and lower parts of Ashlock Formation.
			80.8 Underpass.
			81.1 Overpass.
			81.3 Members of lower part of Ashlock Formation are present in next several cuts.
			82.0 Rest area.
			83.1 Underpass.
X <sub>11</sub>	61.8	K	84.4 Contact: lower part of Ashlock Formation and Calloway Creek Limestone.
	62.0		84.8 Overpass (interchange with Ky. 52).
X <sub>12</sub>	62.2	X <sub>22</sub>	85.1 Contact: lower part of Ashlock Formation and Calloway Creek Limestone.
	62.3		
	63.0	X <sub>23</sub>	85.5 Contact: lower part of Ashlock Formation and Calloway Creek Limestone.
X <sub>13</sub>	63.5		87.4 Underpass.
	64.1	L	88.2 Tate Member of Ashlock Formation.
	64.6		
	65.6		
	65.9		
D	66.0		

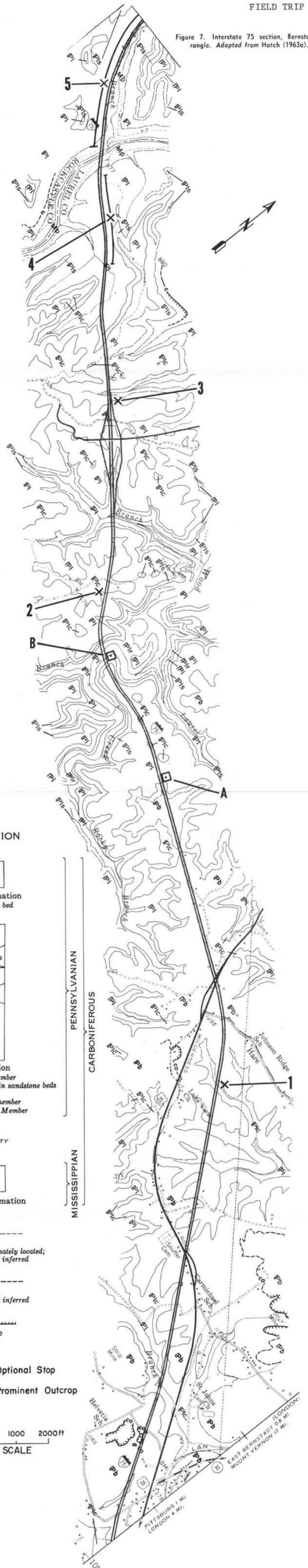
<i>Milepost</i>	
	<b>RICHMOND NORTH QUADRANGLE</b>
	88.3 Road crosses Tate Creek fault.
M	88.9 Grant Lake Member of Ashlock Formation.
	89.1 Overpass.
N	89.6 Contact: Terrill and Grant Lake Members of Ashlock Formation.
	90.0 Underpass (interchange with U. S. 25-U. S. 421).
X <sub>24</sub>	91.0 Contact: Terrill and Grant Lake Members of Ashlock Formation.
	91.6 Road crosses Richmond fault.
	92.0 Overpass.
X <sub>25</sub>	92.3 Rowland Member of Drakes Formation.
O	93.8 Reba Member of Ashlock Formation.
P	94.7 Contact: Terrill and Grant Lake Members of Ashlock Formation.
	94.8 Underpass (interchange with U. S. 227).
X <sub>26</sub>	95.7 Fossil localities.
	-96.8
	97.1 Underpass (interchange with U. S. 25-U. S. 421).
	<b>FORD QUADRANGLE</b>
Q	97.3 Garrard Siltstone.
	97.6 Clays Ferry Formation.
	97.8 Clays Ferry bridge over Kentucky River, crossing Kentucky River fault zone. Total displacement is about 300 feet.
R	98.0 Tyrone Limestone of High Bridge Group. Oregon Formation and Camp Nelson Limestone of High Bridge Group are exposed in cliffs below bridge.
S	98.4 Grier and Curdsville Limestone Members of Lexington Limestone.
	98.5 Underpass (interchange with U. S. 25-U. S. 421).
X <sub>27</sub>	98.6 Road crosses Lick Creek graben.
X <sub>28</sub>	99.0 Grier and Curdsville Limestone Members of Lexington Limestone.
T	100.5 Lower tongue of Tanglewood Limestone Member of Lexington Limestone.
	101.2 Underpass (U. S. 25 and Ky. 442).
X <sub>29</sub>	101.6 Lower tongue of Tanglewood Limestone Member of Lexington Limestone.
	<b>COLETOWN QUADRANGLE</b>
U	102.8 Contact: lower tongue of Tanglewood

<i>Milepost</i>	
	Limestone and Brannon Members of Lexington Limestone.
	103.2 Underpass.
X <sub>30</sub>	103.3 Small graben on west side of southbound lanes.
	103.8 Exit 15. Turn right onto exit 15, then turn left (west) on Ky. 418.
	<i>Mileage</i>
V	0.1 Millersburg Member of Lexington Limestone.
	1.1 Continue northwest on Ky. 418 to junction with U. S. 25-U. S. 421. Continue straight ahead (northwest) on U. S. 25-U. S. 421 to downtown Lexington and the Phoenix Hotel (on left).

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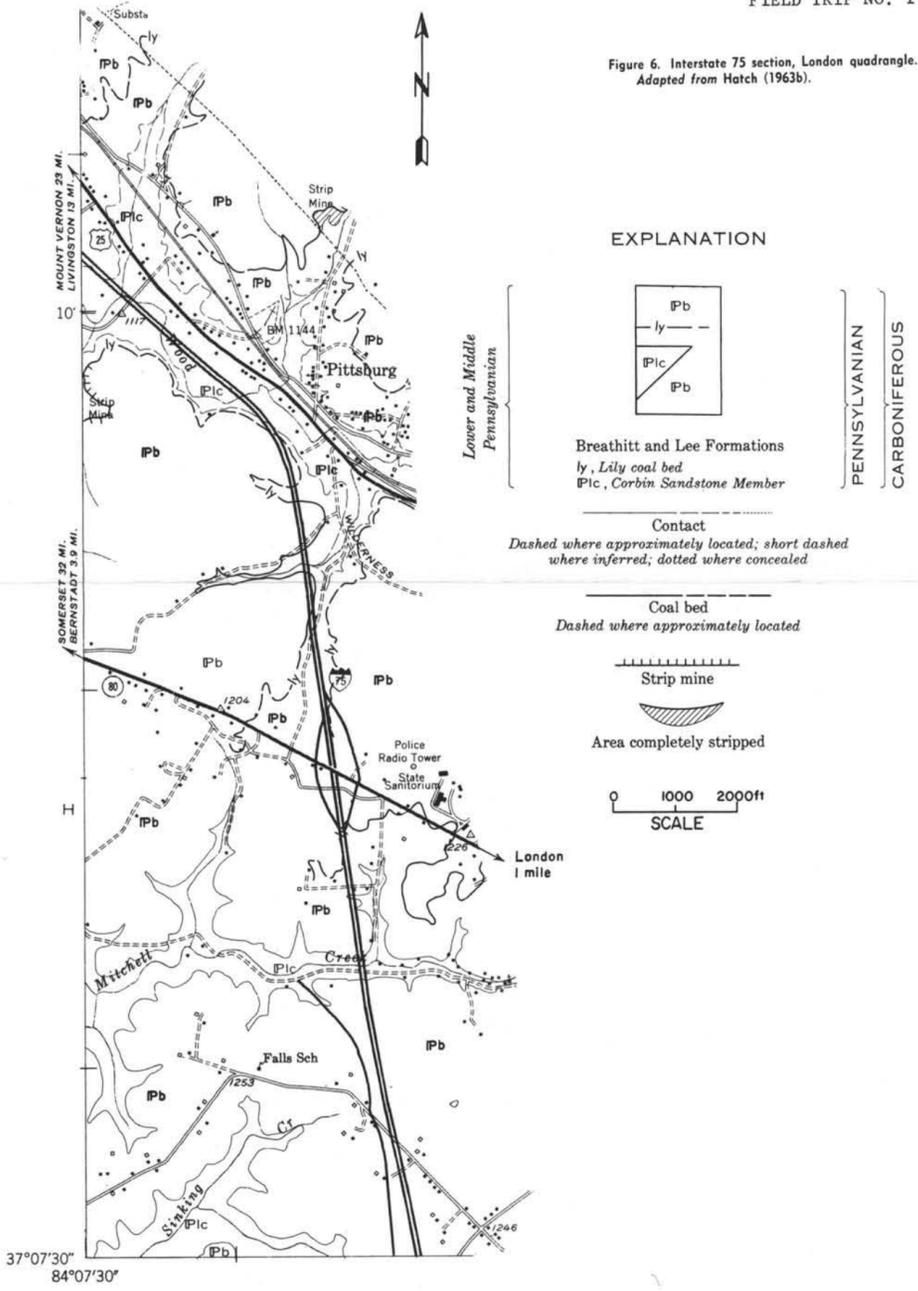
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Figure 7. Interstate 75 section, Bernstadt quadrangle. Adapted from Hatch (1963a).

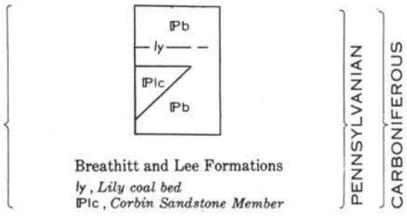


FIELD TRIP NO. 1

Figure 6. Interstate 75 section, London quadrangle. Adapted from Hatch (1963b).



EXPLANATION



Breathitt and Lee Formations  
 ly, Lily coal bed  
 P1c, Corbin Sandstone Member

Contact  
 Dashed where approximately located; short dashed where inferred; dotted where concealed

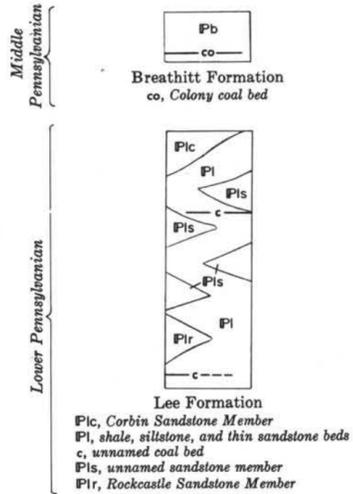
Coal bed  
 Dashed where approximately located

Strip mine

Area completely stripped

0 1000 2000ft  
 SCALE

EXPLANATION



Breathitt Formation  
 co, Colony coal bed

Lee Formation  
 P1c, Corbin Sandstone Member  
 P1, shale, siltstone, and thin sandstone beds  
 c, unnamed coal bed  
 P1s, unnamed sandstone member  
 P1r, Rockcastle Sandstone Member

UNCONFORMITY

Pennington Formation

Contact  
 Dashed where approximately located;  
 short dashed where inferred

Coal bed  
 Short dashed where inferred

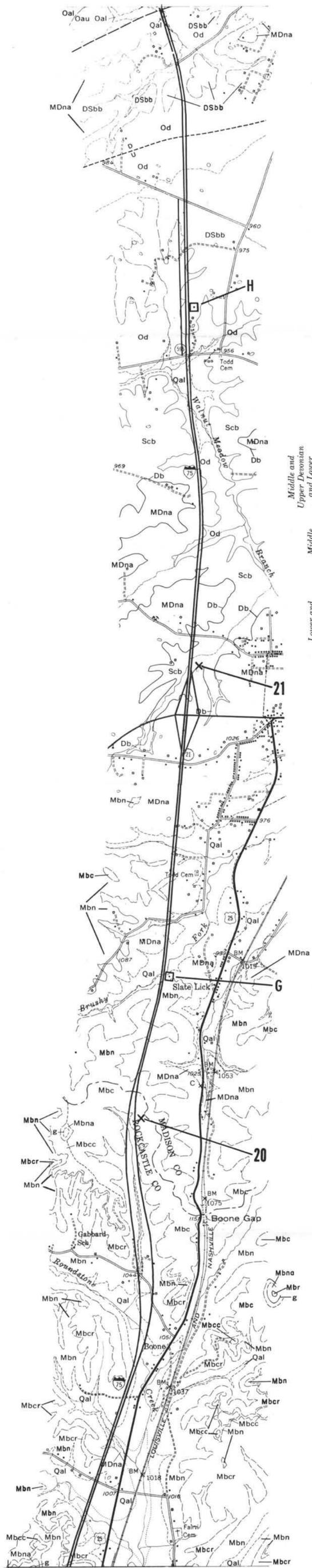
Strip mine

□ — A Optional Stop  
 X — 1 Prominent Outcrop

0 1000 2000ft  
 SCALE



Figure 10. Interstate 75 section, Berea quadrangle. Adapted from Weir (1967).



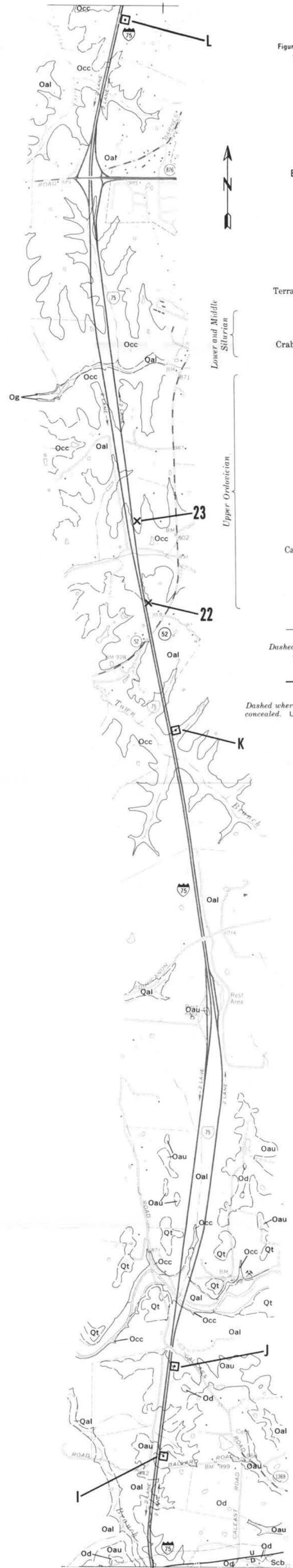
EXPLANATION

	Qal	Alluvium	QUATERNARY
	Mbr g Mbna Mbc Mbcc Mbcr Mbn	Borden Formation Mbr, Renfro Member Mbna, Nada Member g, glauconitic marker bed Mbc, Cowbell Member Mbcc, Conway Cut Bed Mbcr, Roundstone Bed Mbn, Nancy Member	MISSISSIPPIAN CARBONIFEROUS
	MDna	New Albany Shale	DEVONIAN
	Db	Boyle Dolomite Shown by line where too thin to show color	DEVONIAN
UNCONFORMITY			
	Scb	Crab Orchard Formation and Brassfield Dolomite	SILURIAN
	Od	Drakes Formation	ORDOVICIAN
	Oau Oal	Ashlock Formation Oau, upper part: Reba and Terrill Members Oal, lower part: Stingy Creek, Gilbert and Tate Members	ORDOVICIAN
<p>--- Contact Dashed where approximately located; short dashed where inferred; dotted where concealed</p> <p>--- Fault Dashed where approximately located; short dashed where inferred; dotted where concealed. U, upthrown side; D, downthrown side</p> <p></p>			

□—H Optional Stop  
X—21 Prominent Outcrop

0 1000 2000 ft.  
SCALE

Figure 11. Interstate 75 section, Richmond South quadrangle. Adapted from Greene (1966).



EXPLANATION

	Qal	Alluvium	QUATERNARY
	Qt	Terrace deposits and lag gravels	QUATERNARY
	Scb	Crab Orchard Formation and Brassfield Dolomite	SILURIAN
	Od	Drakes Formation	ORDOVICIAN
	Oau Oal	Ashlock Formation Oau, upper part Oal, lower part	ORDOVICIAN
	Occ	Calloway Creek Limestone	ORDOVICIAN
	Og	Garrard Siltstone	ORDOVICIAN
<p>--- Contact Dashed where approximately located; dotted where concealed</p> <p>--- Fault Dashed where approximately located; dotted where concealed. U, upthrown side; D, downthrown side</p>			

□—J Optional Stop  
X—22 Prominent Outcrop

0 1000 2000 ft.  
SCALE

Figure 12. Interstate 75 section, Richmond North quadrangle. Adapted from Simmons (1967).

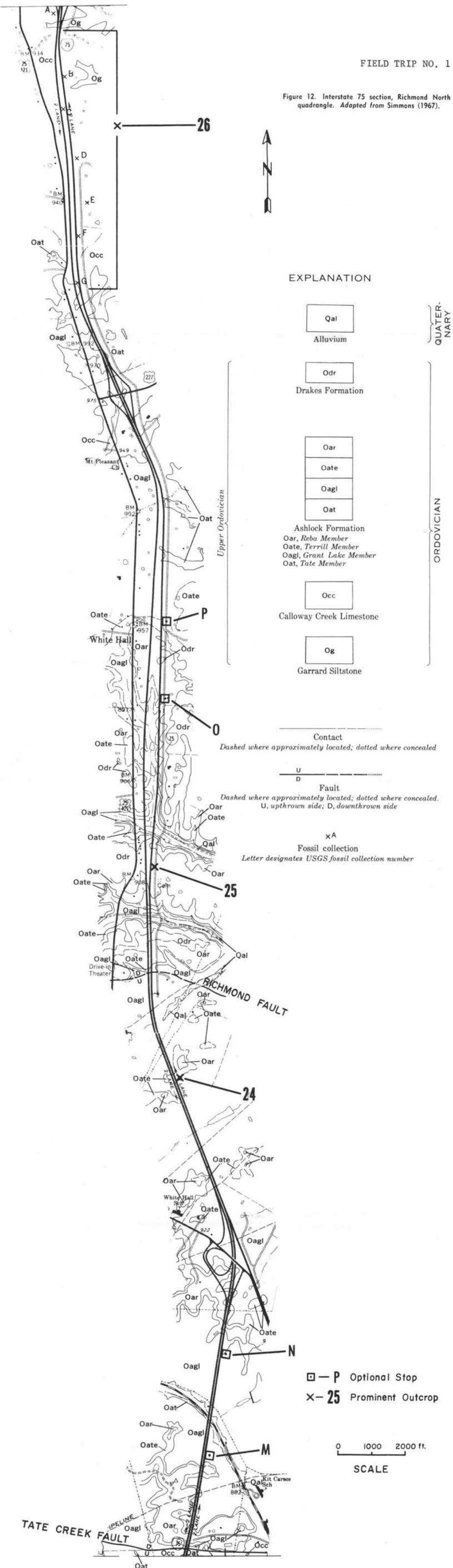
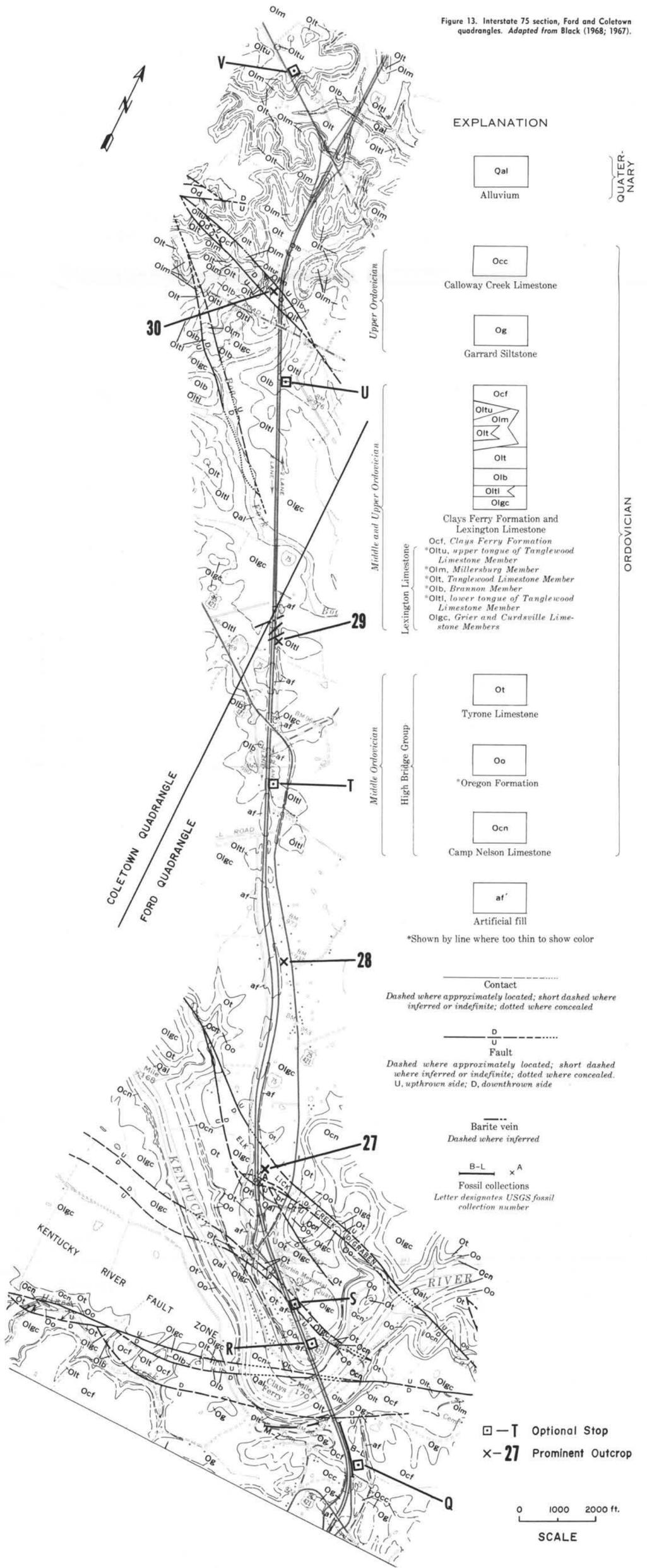


Figure 13. Interstate 75 section, Ford and Coletown quadrangles. Adapted from Black (1968; 1967).



FIELD TRIP NO. 2  
LITHOLOGY AND FAUNA OF THE LEXINGTON LIMESTONE  
(ORDOVICIAN) OF CENTRAL KENTUCKY\*

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OLGERTS L. KARKLINS  
U. S. Geological Survey, Lexington, Kentucky, and Washington, D. C.

**PURPOSE AND SCOPE OF FIELD TRIP**

Geologic mapping and related studies in central Kentucky as part of the cooperative mapping program of the U. S. Geological Survey and the Kentucky Geological Survey have revealed new information on the Lexington Limestone of late Middle and early Late Ordovician age. The internal lithostratigraphy of the Lexington and its relations to adjacent formations have been determined by detailed geologic mapping, and large numbers of fossil collections have been made from measured sections that are tied to the lithostratigraphic framework. Preliminary results of the lithostratigraphic studies were published by Black and others (1965), and some of the facies relations were demonstrated by the 1965 Annual Spring Field Conference of the Geological Society of Kentucky (Black and MacQuown, 1965).

The purpose of this field trip is to examine some of the aspects of the lithology and fauna of the Lexington Limestone that were discussed at the 1970 meeting of the Southeastern Section of the Geological Society of America. The route of the field trip and the locations of the stops are shown in Figure 1. The stratigraphic units to be seen are shown in Figure 2.

The section on bryozoan zonation is by Karklins; the rest of the report is by Cressman.

**ACKNOWLEDGMENTS**

Many geologists have participated in the mapping of central Kentucky. Particularly noteworthy are the contributions of D. F. B. Black of the U. S. Geological Survey and W. C. MacQuown, Jr., of the University

\* Publication authorized by the Director, U. S. Geological Survey.

of Kentucky, both of whom contributed to the mapping and section measuring and to the interpretation of the lithostratigraphy.

Fossils were collected by R. J. Ross, Jr., John Pojeta, R. B. Neuman, O. L. Karklins, and E. L. Yochelson, of the U. S. Geological Survey. Trilobites were identified by Ross, brachiopods by Neuman, bryozoans by Karklins, pelecypods by Pojeta, and gastropods by Yochelson; corals were identified by W. A. Oliver, Jr., and ostracodes by J. M. Berdan, both of the Geological Survey.

**LITHOSTRATIGRAPHY**

The Lexington Limestone consists of several major intertonguing rock types, each of which is indicative of a specific marine environment. Each member of the Lexington is characterized by one rock type, and the members, like the rock types, intertongue (Figs. 2 and 8). The various rock types and the stratigraphic units in which they occur are as follows.

*Calcilutite* (Fig. 3). The calcilutite is of two types; the first is light gray to light yellowish gray, commonly containing specks and small tubes of clear calcite (birdseye limestone), whereas the second is brownish gray and slightly fetid. Both may contain ostracodes and gastropods, and corals (*Tetradium*) may be abundant. Both the light and dark types are present in the Devils Hollow and Perryville Limestone Members of the Lexington; the light type is characteristic of the Tyrone Limestone. The calcilutites were deposited in shallow quiet water that in Lexington time was protected from waves and currents of the open shelf by calcarenite bars.

*Fossiliferous calcilutite*. Much of the Perryville Limestone Member consists of brownish-gray slightly fetid calcilutite containing abundant mollusks and

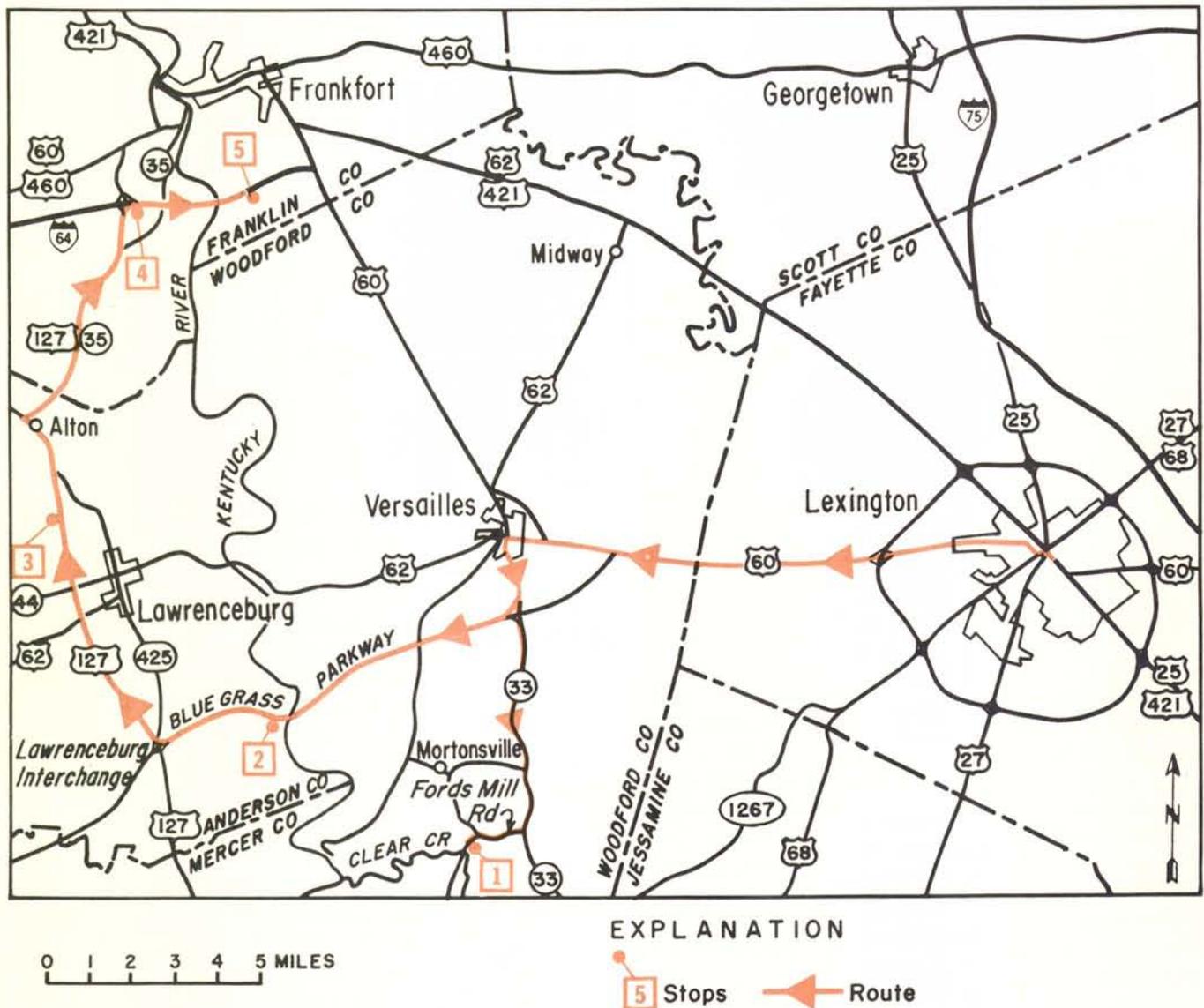


Figure 1. Route map.

some bryozoans and brachiopods. Corals (*Tetradium*) and stromatoporoids are common in some beds. The bedding ranges from planar to nodular. This type, which will not be seen on the field trip, was deposited in shallow quiet water protected from currents of the open shelf by calcarenite bars.

*Gastropodal calcirudite.* The calcirudite present in the Devils Hollow Member of the Lexington consists of closely packed gastropods, brachiopods, and bryozoans with vuggy sparry calcite cement. Crossbedding is common. It was probably deposited on the margins of a lagoon.

*Calcarenite* (Fig. 4). Most of the Tanglewood and Curdsville Limestone Members consist of pinkish-gray to brownish-gray bioclastic calcarenite and minor cal-

cirudite composed of broken, abraded, and sorted fragments of crinoids, brachiopods, bryozoans, and ostracodes cemented by sparry calcite. The calcarenite is phosphatic and averages 6 percent apatite, though the amount varies widely from bed to bed and lamina to lamina. The apatite (collophane) is present as fillings and replacements of fossil fragments. Some quartz sand is present in calcarenite of the Curdsville Limestone Member but not in that of the Tanglewood. Crossbedding is common. This type accumulated in turbulent water of the littoral zone and adjacent parts of the inner infralittoral zone.

*Fossiliferous limestone* (Fig. 5). The fossiliferous limestone commonly consists of sets about 0.5 foot thick of lenses and nodules of fossiliferous calcirudite

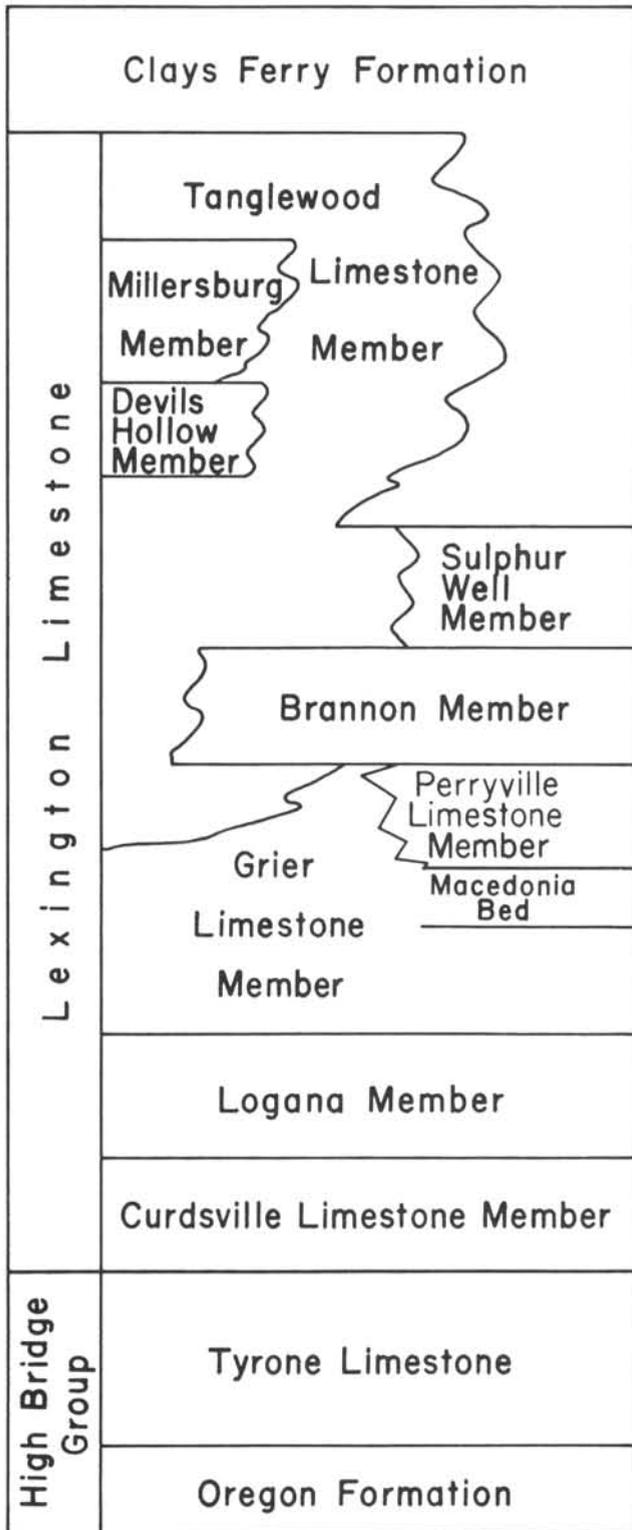


Figure 2. Stratigraphic nomenclature in field-trip area.



Figure 3. Calcilutite. Perryville Limestone Member of Lexington Limestone.



Figure 4. Calcarenite. Tanglewood Limestone Member of Lexington Limestone.

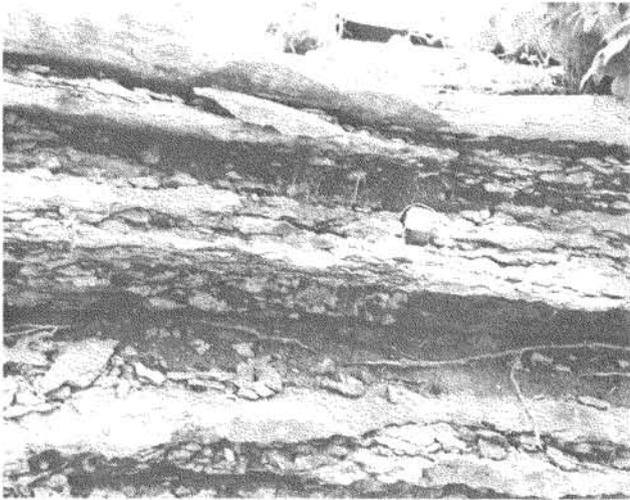


Figure 5. Fossiliferous limestone. Grier Limestone Member of Lexington Limestone.

to poorly sorted bioclastic calcarenite alternating with irregular beds of poorly sorted fossiliferous calcarenite. The fossiliferous calcarenite beds may be absent in some intervals. Bryozoans and brachiopods are the most conspicuous fossils. Shale is restricted to thin irregular partings. This type, which forms most of the Grier Limestone Member and the Sulphur Well Member of the Lexington, was deposited adjacent to calcarenite in moderately agitated water of the inner infralittoral zone.

*Nodular fossiliferous limestone and shale* (Fig. 6). Nodules of fossiliferous dolomitic calcisiltite set in a shale matrix characterize the nodular fossiliferous limestone and shale type, which is most common in the Millersburg Member of the Lexington. Interbeds of poorly sorted calcarenite are commonly present. Shale makes up about one-third of the unit. Bryozoans, brachiopods, and mollusks are abundant. It was deposited adjacent to calcarenite in the inner infralittoral zone.

*Brachiopod coquina*. The brachiopod coquina consists of a mass of closely packed dalmanellid brachiopod valves oriented parallel to bedding. It is present in the Logana Member and locally in the Grier Limestone Member, particularly in and adjacent to the Macedonia Bed, and was deposited at depths intermediate between those of the fossiliferous limestone and the interbedded limestone and shale.

*Interbedded limestone and shale* (Fig. 7). The interbedded limestone and shale type consists largely of argillaceous dolomitic calcisiltite interbedded with shale and is characteristic of the Logana and Brannon Members and the Macedonia Bed of the Grier Lime-



Figure 6. Nodular fossiliferous limestone and shale. Millersburg Member of Lexington Limestone.



Figure 7. Interbedded limestone (calcisiltite) and shale. Brannon Member of Lexington Limestone.

stone Member of the Lexington and of the Clays Ferry Formation. Some units are nearly unfossiliferous, whereas others contain abundant well-preserved fossils in a calcisiltite matrix. Interbeds of crinoidal limestone are common in parts of the Clays Ferry. It was deposited in quiet water of the outer infralittoral zone; parts may have been circalittoral, but the abundance of fossils in some beds suggests somewhat shallower water.

The stratigraphic relations of these rock types and of the members and formations they compose are shown in Figure 8. The intertonguing between the lithostratigraphic units shown in Figure 8 can be interpreted in terms of transgression and regression.

In early Lexington time, central Kentucky was a shallow marine shelf that sloped gently northward (Fig. 9A). Prevailing winds, determined from the paleomagnetic poles for the Ordovician (Collinson and Runcorn, 1960), and global wind-circulation patterns, were probably from the east-northeast. The predominant direction of transport of carbonate sand was to the southwest (S. V. Hrabar, written communication, 1969). Calcarenite of the Curdsville Limestone Member, the basal unit of the Lexington, was deposited in shallow turbulent water in the initial phase of a major transgression that culminated in deposition of calcisiltite and shale of the Logana Member. Subsequent slow regression resulted in deposition of fossiliferous limestone of the Grier Limestone Member on the central and northern shelf, calcarenite of the Tanglewood Limestone Member on the southern shelf, and calcisiltite of the Perryville Limestone Member in shallow water on the protected southern side of the calcarenite. As regression continued, each facies migrated northward.

In late Lexington time, the southern part of the area subsided (Fig. 9B). Calcarenite of the Tanglewood accumulated in and near a littoral zone at the crest of a high that extended from south of Winchester to Frankfort. The shelf sloped gently northward and somewhat more steeply southward from the high. Fossiliferous limestone and shale of the Millersburg Member were deposited immediately north of the calcarenite, and interbedded limestone and shale of the Clays Ferry Formation in deeper water farther north. South of the high the calcarenite passed directly to interbedded limestone and shale of the Clays Ferry. Transgression from both the south and north eventually resulted in deposition of the Clays Ferry Formation across the entire area.

In this field trip, the emphasis is on the lithic character of the stratigraphic units, and we will see only a few of the facies changes mentioned above. However, Figure 8 shows the relations of the Lexington in

the area of the field trip and in the broader area of central Kentucky.

*Preliminary bryozoan zonation of the Lexington Limestone.* The Lexington Limestone is divided into two biostratigraphic units on the basis of bryozoan assemblages. The bryozoan assemblages which characterize these two units are tentatively designated assemblage A and assemblage B, in ascending order. The biostratigraphic unit containing some or all of the species of assemblage A is informally designated bryozoan zone A, and the unit with some or all of the species of assemblage B is called bryozoan zone B.

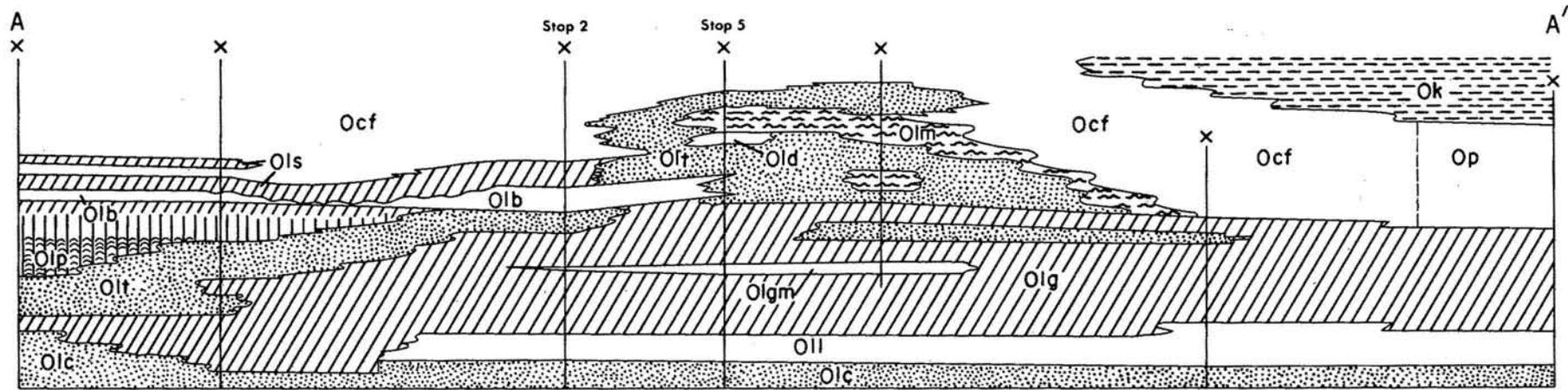
Bryozoan assemblage A contains the following taxa: *Batostoma* cf. *B. humile* Ulrich, *Eridotrypa* sp. form a, *Hallopora multitabulata* (Ulrich), *Hemiphragma* cf. *H. tenuimurale* Ulrich, *Heterotrypa* sp. form f, *Homotrypa* sp. form e, *Peronopora* cf. *P. granulifera* (Ulrich), *Prasopora falesi* (James), *Prasopora* cf. *P. simulatrix* Ulrich, and *Stictopora neglecta* (Ulrich). Bryozoan assemblage B is characterized by the following taxa: *Eridotrypa* sp. form cl, *Hallopora* sp. form bl, *Hallopora* cf. *H. o'nealli* (James), and *Heterotrypa* sp. form g.

Another group of bryozoans is made up of species that range across the boundary between zone A and zone B. This grouping includes *Constellaria* cf. *C. teres* Ulrich and Bassler, indeterminate species of *Amploxopora*, *Ceramophylla*, *Ceramopora*, and forms which seem to be morphologically intermediate between the species of assemblages A and B. Among the last are forms of *Eridotrypa*, *Hallopora*, and *Homotrypa*.

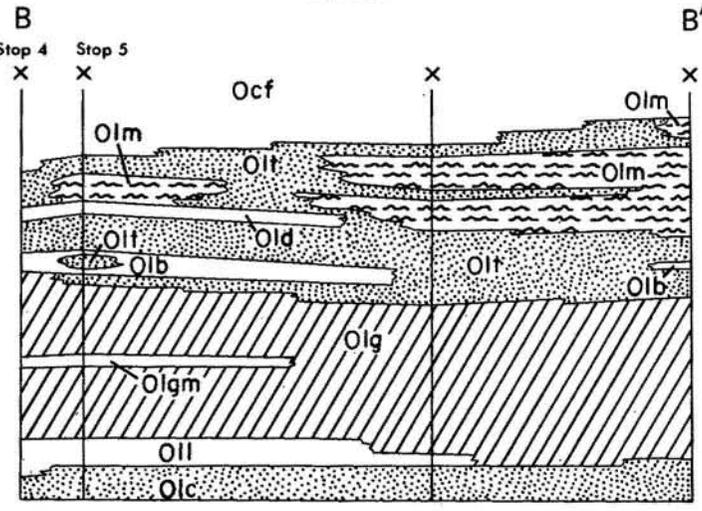
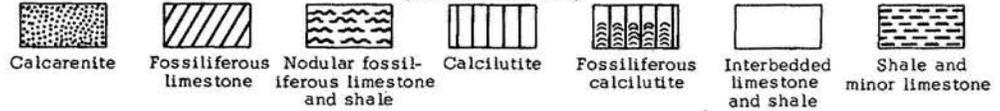
Although the species of the intermediate group are not used to define assemblages A or B, their presence indicates the approximate stratigraphic position of the boundary between the bryozoan zones when representatives of assemblages A and B are lacking in an outcrop area.

The boundary between bryozoan zones A and B is of more than passing stratigraphic interest because assemblage A contains bryozoans which are typically Middle Ordovician in appearance, whereas the bryozoans in assemblage B have the aspects of forms from the Upper Ordovician as that subdivision has traditionally been understood in the tristate area of Ohio, Indiana, and Kentucky.

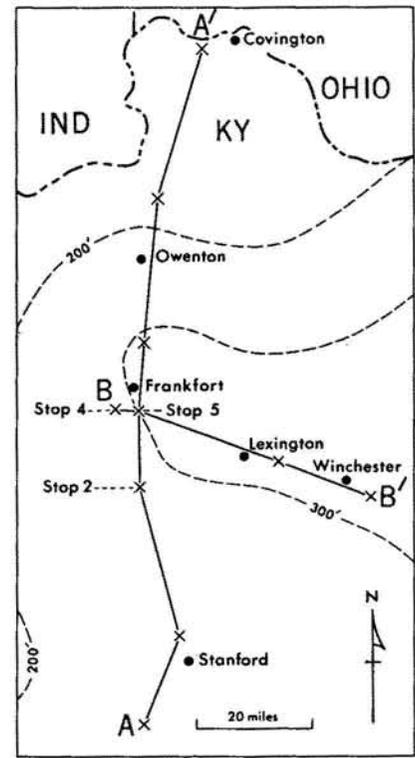
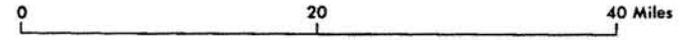
In the reference sections of the Lexington Limestone (Stop 5) the lower limit of bryozoan zone A is placed about 56 feet above the base of the formation or approximately 4 feet above the base of the Grier Limestone Member. The lower limit of this zone may be subject to change pending further investigation of the bryozoans from the Logana and Curdsville Limestone Members. The upper limit of zone A is placed



EXPLANATION  
Dominant rock type  
(not shown for Old)



- Ok, Kope Formation
- Op, Point Pleasant Formation
- Ocf, Clays Ferry Formation
- Lexington Limestone
  - Olt, Tanglewood Limestone Member
  - Oim, Millersburg Member
  - Old, Devils Hollow Member
  - Ols, Sulphur Well Member
  - Oib, Brannon Member
  - Oip, Perryville Limestone Member
  - Olg, Grier Limestone Member
  - Olgm, Macedonia Bed
  - Oll, Logana Member
  - Olc, Curdsville Limestone Member



INDEX MAP  
Dashed lines are isopachs  
of Lexington Limestone

Figure 8. Diagram showing stratigraphic relations of the Lexington Limestone in central Kentucky.

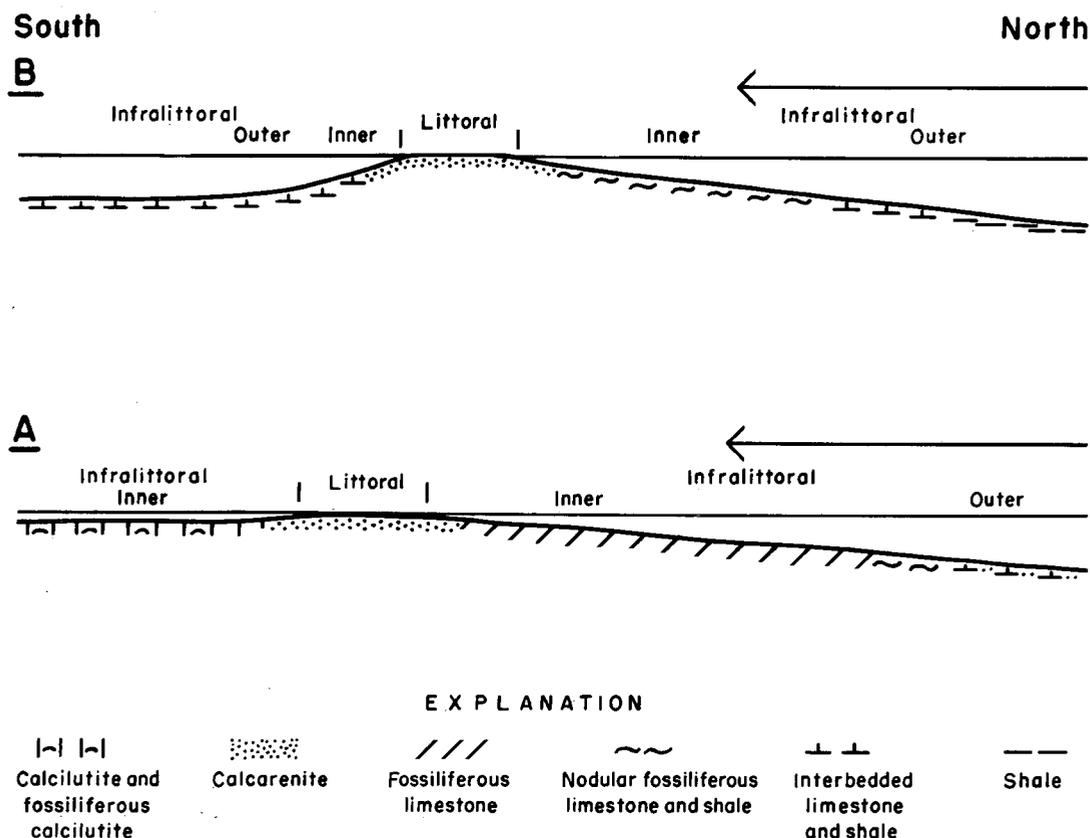


Figure 9. Facies relations and inferred environments during early Lexington time (A) and late Lexington time (B). Arrows show predominant direction of calcarenite transport and the north-south component of the prevailing wind.

between the highest occurrence of the species of assemblage A and the lowest occurrence of those of assemblage B. In the reference section of the Lexington Limestone the boundary between zones A and B occurs within the Brannon Member, approximately 4 feet below the top of the member. The upper limit of zone B is not defined because the species of assemblage B range through the upper part of the Lexington Limestone and the lower part of the Clays Ferry Formation which form the highest outcrops in the area under study.

Bryozoan assemblage A or B or both and the corresponding zones have areal extent and can be recognized laterally away from the reference sections of Lexington Limestone. Furthermore, the zonal boundary crosses lithologic facies.

**STOP 1**

*Quarry and roadcuts along Fords Mill Road on east side of Clear Creek. Tyrone Limestone and Curdsville Limestone Member of Lexington Limestone (Fig. 10)*

Stop 1 is in the Keene quadrangle, mapped by Cressman (1965).

The quarry exposes most of the Tyrone Limestone, which is about 100 feet thick. Calcareous dolomite of the Oregon Formation may be seen just below the bridge. Walk up the road to the contact of the Tyrone Limestone with the Lexington Limestone. Note the bentonite ("Pencil Cave" of drillers) 20 feet below the contact. Cephalopods collected in the Little Hickman quadrangle (south of Lexington) from just below the bentonite were dated by R. H. Flower (1967, written communication to D. E. Wolcott) as late Wilderness in age. Mud cracks are common throughout the Tyrone Limestone but cannot readily be seen in this type of exposure.

The Curdsville Limestone Member of the Lexington Limestone is exposed in the upper part of the roadcut. The contact between the Lexington and Tyrone is disconformable. The local relief on the disconformity is only 1 or 2 inches, but scattered fragments of limestone derived from the Tyrone are present in the basal 5 feet of the Curdsville, and as much as 5 feet of beds

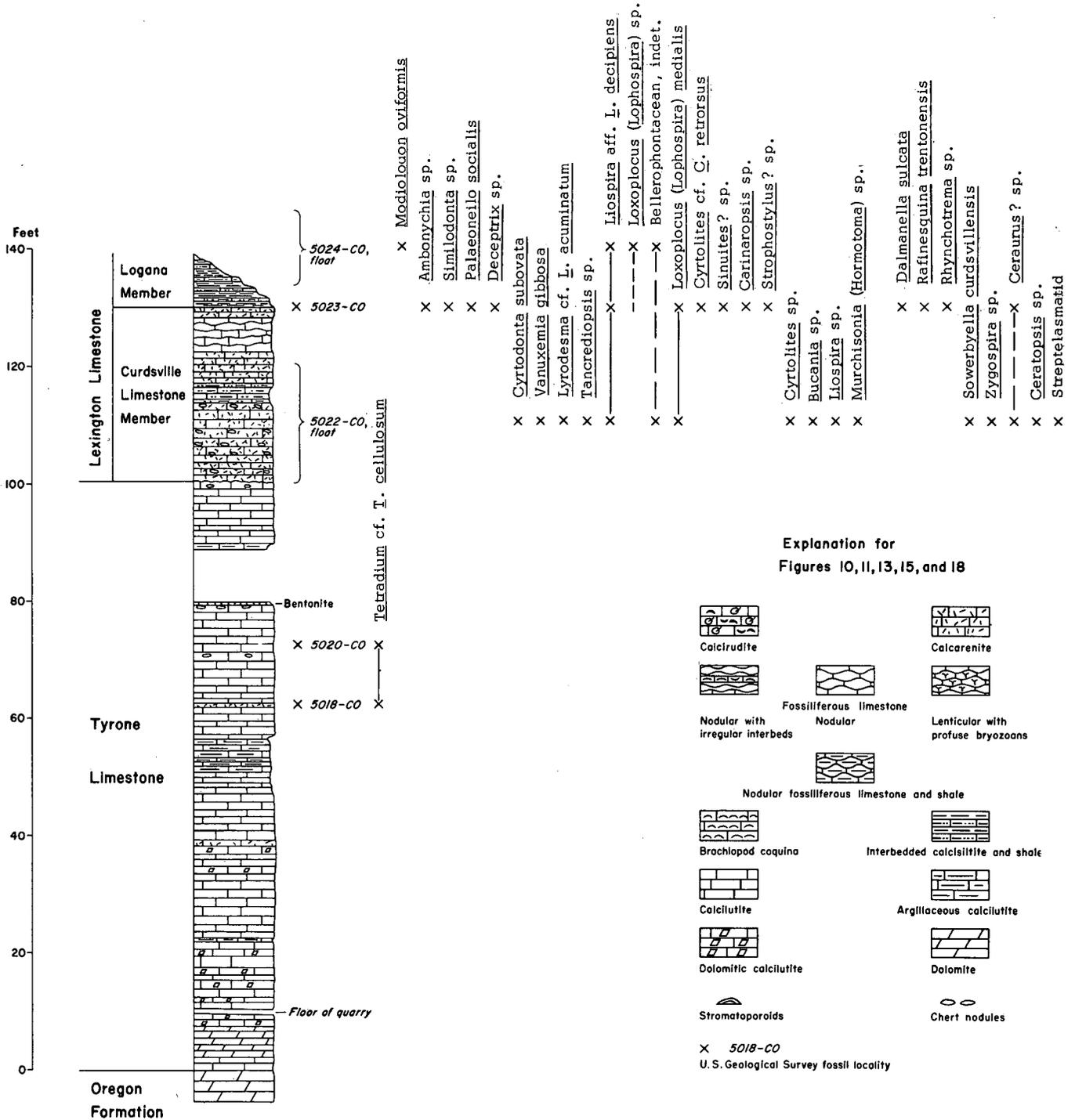


Figure 10. Section exposed at Stop 1.

present at the top of the Tyrone a few miles to the south are missing here.

The lower 20 feet of the Curdsville Limestone Member is mostly bioclastic calcarenite and calcirudite; chert nodules are common, and the lower 10 feet contains some quartz sand. The uppermost 10 feet of the member is mostly somewhat fossiliferous nodular limestone. The lower part of the Logana Member of the Lexington consists of interbedded calcisiltite and shale. Note the abundant pelecypods in some beds. The same sequence present vertically here in the lower Lexington (calcarenite to nodular fossiliferous limestone to calcisiltite and shale) may also be found laterally; the Logana Member passes southward into nodular fossiliferous limestone, which in turn passes southward into calcarenite.

## STOP 2

*Roadcut on westbound lanes of Blue Grass Parkway on west side of Kentucky River (Fig. 11, in pocket)*

Stop 2 is in the Salvisa quadrangle, mapped by Cressman (1968).

### A. Logana and Grier Limestone Members

The Logana Member here is about 25 feet thick. The base is by the bridge abutment about 10 feet below road level. The Logana consists of two closely related rock types—interbedded calcisiltite and shale and *Dalmanella coquina*. The *Dalmanella*, identified by R. B. Neuman as *D. sulcata* Cooper, is apparently restricted to the Logana and laterally equivalent rocks.

The Grier Limestone Member typically consists of sets of nodular to lenticular fossiliferous calcisiltite alternating with irregular beds of poorly sorted fossiliferous calcarenite. Bryozoans are particularly abundant. The bedding style is characteristic. The nodular bedding probably resulted from the activity of burrowing organisms.

### B. Tanglewood Limestone Member and Brannon and Sulphur Well Members

Walk downhill to Tanglewood Limestone Member. See Figure 2 for the stratigraphic relation of this tongue of the Tanglewood to the member elsewhere.

The Tanglewood Limestone Member consists of well-sorted bioclastic calcarenite. The grains are broken, abraded, and sorted fragments of crinoids, bryozoans, brachiopods, and ostracodes. Phosphatic grains, which make up an average of about 6 percent of the rock and are easily visible in hand specimens, consist of filled and replaced fragments of bryozoans and crinoids. The calcarenite is overlain by 7 feet of nod-

ularly bedded, somewhat fossiliferous calcisiltite that is similar to much of the Grier Limestone Member but is here included in the Tanglewood for mapping convenience.

The Tanglewood is overlain by interbedded calcisiltite and shale of the Brannon Member. Note the similarity of the sequence—calcarenite, nodular fossiliferous calcisiltite, interbedded calcisiltite and shale—to that of the Curdsville and Logana Members at Stop 1.

The Brannon Member thins rapidly southward from here, apparently as a result of erosion prior to deposition of the overlying Sulphur Well Member.

Walk up road and climb back to the top of the cut. The bryozoan limestone at the top of the cut is the Sulphur Well Member. In this vicinity the Sulphur Well is about 30 feet thick and is overlain by interbedded limestone (mostly calcisiltite) and shale of the Clays Ferry Formation. The contact between the Sulphur Well Member and the Clays Ferry is well exposed along the exit road from the turnpike at the Lawrenceburg interchange.

Note the large tilted block of calcarenite in the upper part of the Brannon Member in the cut across the highway (Fig. 12).

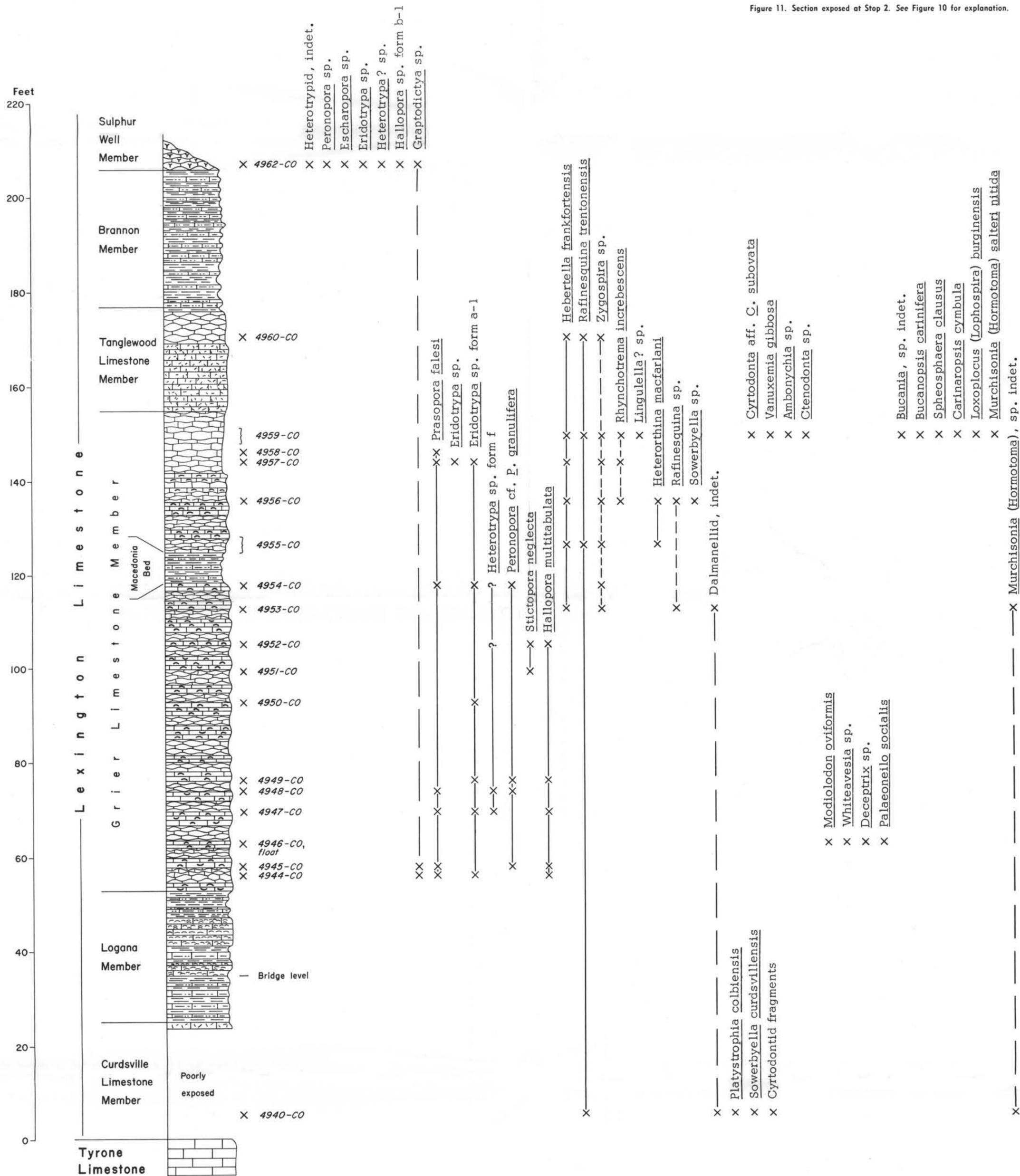
## STOP 3

*Roadcut on U. S. 127 bypass 1.7 miles north of intersection with Ky. 44. Contorted bedding in a tongue of the Clays Ferry Formation (Fig. 13)*

The base of the Brannon Member is in the stream to the south. Most of the Sulphur Well Member of Stop 2 has passed northward into calcarenite of the Tanglewood Limestone Member, which is exposed in a ditch on the west side of the highway. The bryozoan beds at the base of the roadcut are probably a tongue of the Sulphur Well. The main part of the roadcut consists of a tongue of the Clays Ferry Formation which is overlain by an upper tongue of the Tanglewood Limestone Member of the Lexington. The upper Tanglewood tongue pinches out to the southwest and the Clays Ferry tongue to the northeast.

Note the several types of distorted and disrupted bedding—the thick zone of nodular or pebbly argillaceous calcisiltite with a discordant base and a concordant top, the large tilted fragments of calcarenite at the base of the nodular zone, and the bulbous ball-and-pillow type in the upper part of the cut (Fig. 14). Distorted bedding is most likely to occur where intervals of interbedded calcisiltite and shale are overlain by calcarenites. Where the interval of calcisiltite and shale is more than a few feet thick, the distorted bedding is commonly at or near the top of the interval.

Figure 11. Section exposed at Stop 2. See Figure 10 for explanation.



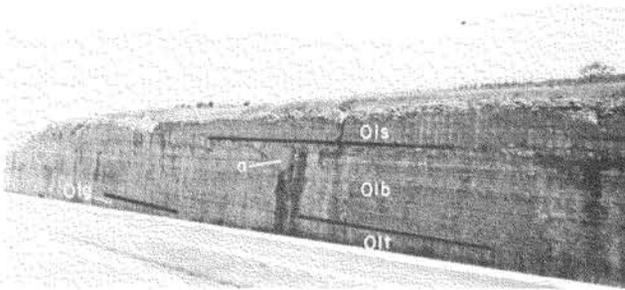


Figure 12. Upper part of Lexington Limestone at Stop 2B. Ols, Sulphur Well Member; Olb, Brannon Member; Olt, Tanglewood Limestone Member; Olg, Grier Limestone Member; a, calcarenite block slumped into upper part of Brannon Member.



Figure 14. Exposure at Stop 3. Olt, tongue of Tanglewood Limestone Member of Lexington Limestone; Ocf, tongue of Clays Ferry Formation; a, nodular argillaceous calcisiltite; b, tilted blocks of calcarenite; c, ball-and-pillow structure.

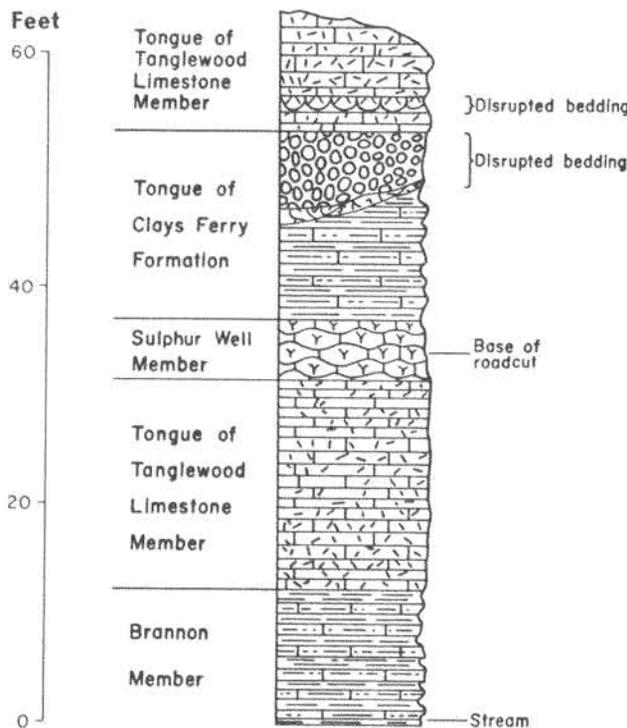


Figure 13. Section at Stop 3. Thicknesses estimated above tongue of Clays Ferry Formation. See Figure 10 for explanation.

**STOP 4**

Roadcuts on eastbound lanes of Interstate 64 at the Frankfort interchange. Brannon and Devils Hollow Members and part of Tanglewood Limestone Member of Lexington Limestone (Fig. 15)

The Brannon Member, 15 feet thick, is exposed in the first cut east of the entrance lane. The Brannon here consists of lower and upper units of interbedded calcisiltite and shale separated by a conspicuous zone of disrupted bedding (Fig. 16). Note both the large tilted blocks of calcarenite and the nodular or pebbly argillaceous calcisiltite. At the next stop, the upper

and lower units of calcisiltite and shale are separated by a tongue of calcarenite of the Tanglewood Limestone Member; a few miles to the southwest the Brannon consists of a single unit of interbedded calcisiltite and shale with disrupted bedding only at the top of the member (Fig. 17).

Walk up highway to first cut west of entrance road. The calcarenite and bryozoan calcirudite in the lower part of the cut are part of the Tanglewood Limestone Member. The thick-bedded gastropodal and brachiopodal calcirudite at the top of the cut is the Devils Hollow Member. The Devils Hollow Member occurs in a belt about 10 miles wide that trends northwest across the Inner Blue Grass; it grades northward and southward into calcarenite of the Tanglewood. The Devils Hollow consists of two principal rock types—gastropodal and brachiopodal coquina as at this exposure, and ostracode-bearing calcilutite as at Stop 5. These two types intertongue over short distances. In general, coquina predominates on the outer margins of the belt, whereas calcilutite predominates in the center. The Devils Hollow is tentatively interpreted as a lagoonal deposit; the calcilutite resulted from quiet-water deposition in the lagoon proper, whereas the coquina represents winnowed near-shore and beach deposits on the lagoon margin.

**STOP 5**

Eastbound lanes of Interstate 64 on east side of Kentucky River. Middle and upper parts of Lexington Limestone (Fig. 18, in pocket)

Stop 5 is in the Frankfort East quadrangle, mapped by Pomeroy (1968).

This is a reference section of the Lexington Limestone (Black and others, 1965, p. 7, 11-14). The base of the Lexington is exposed beneath the east abutment of the bridge over the Kentucky River.

At this section we will see the upper part of the

Figure 18. Section exposed at Stop 5. See Figure 10 for explanation.



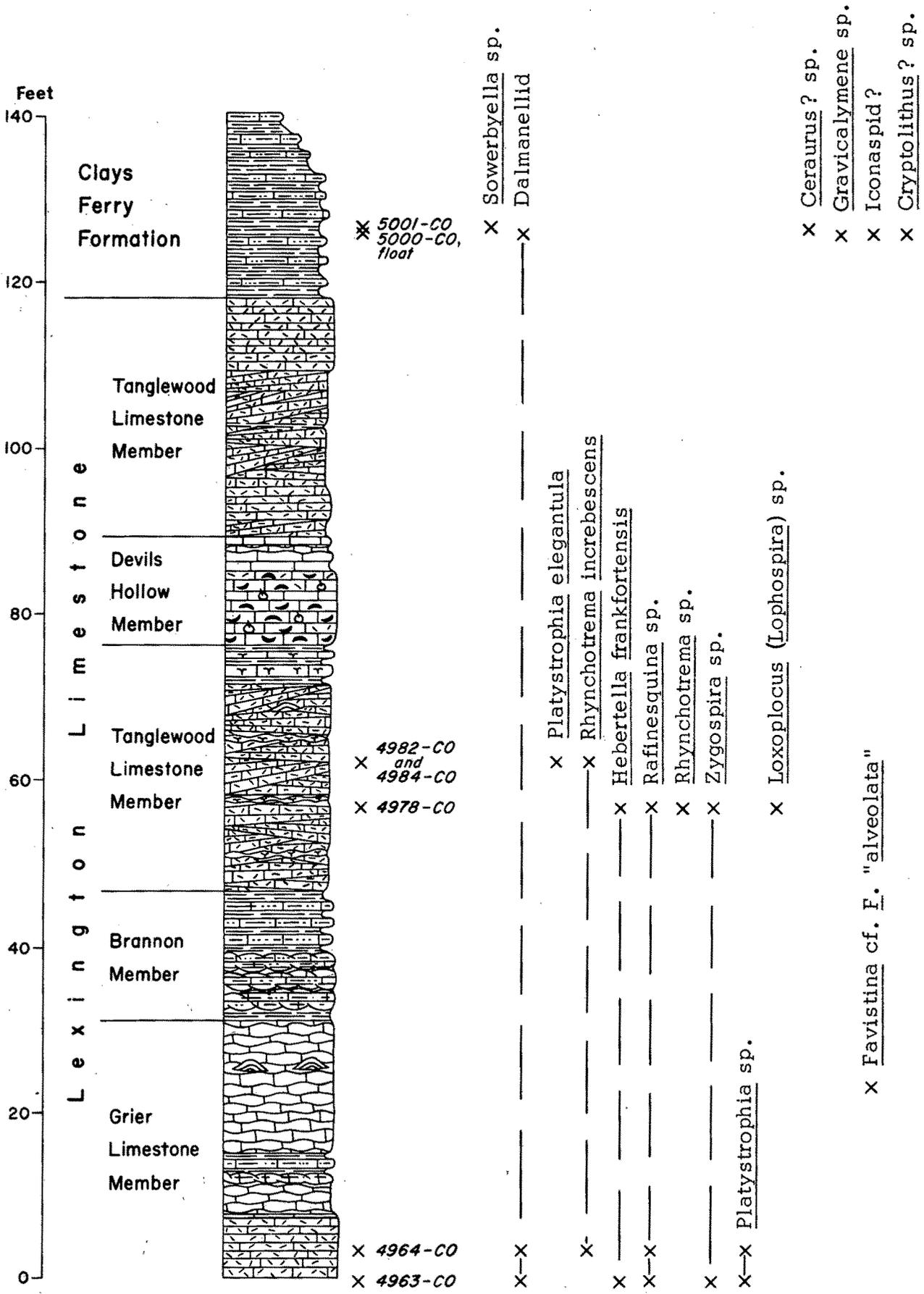


Figure 15. Section exposed at Stop 4. See Figure 10 for explanation.

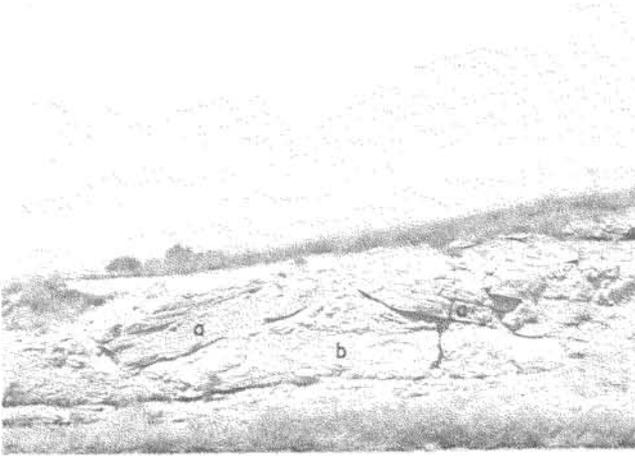


Figure 16. Disrupted bedding in Brannon Member at Stop 4; a, calcarenite blocks; b, nodular argillaceous calcisiltite.

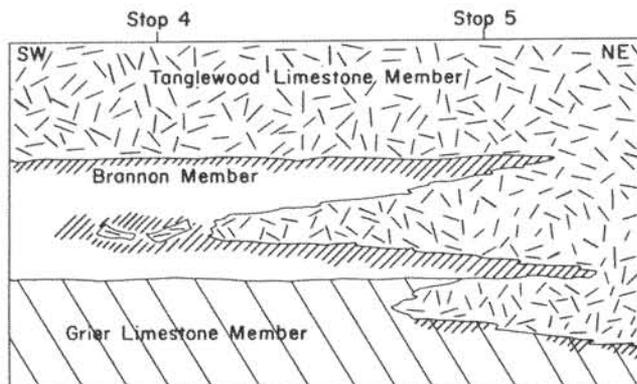


Figure 17. Sketch showing relation of disrupted bedding in Brannon Member to lithologic sequence and facies change. Shaded areas are zones of disrupted bedding.

Grier Limestone Member, the Brannon Member, the Devils Hollow Member, the Millersburg Member, and several tongues of the Tanglewood Limestone Member. The Brannon Member is represented by two thin tongues of calcisiltite, both with contorted bedding, separated by a tongue of the Tanglewood Limestone Member. The Brannon tongues pinch out a short distance to the northeast, and all the tongues of the Tanglewood below the Millersburg Member merge to a single unit.

The Millersburg Member resembles the Grier Limestone Member in bedding character and abundance of fossils but contains considerably more shale. Between here and Stop 4, the Millersburg Member passes into calcarenite (Fig. 8, section B-B').

The Millersburg Member is overlain by another tongue of the Tanglewood Limestone Member. The

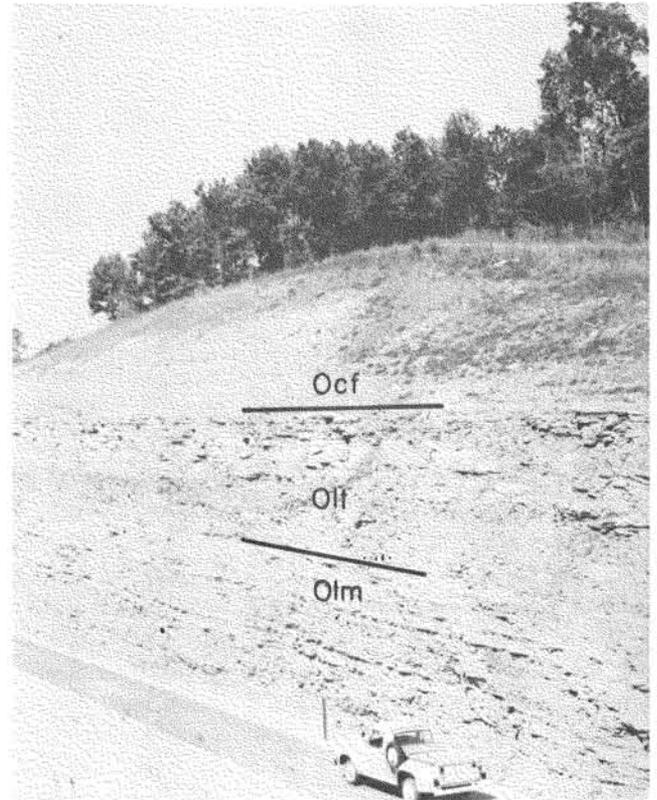


Figure 19. Upper part of Lexington Limestone and lower part of Clays Ferry Formation in westbound lanes of Interstate 64 at Stop 5. Ocf, Clays Ferry Formation; Olt, tongue of Tanglewood Limestone Member of Lexington Limestone; Olm, Millersburg Member of Lexington Limestone.

basal part of the Clays Ferry Formation may be seen at the top of the cut (Fig. 19). The relations of the various tongues of the Tanglewood are shown in Figure 8.

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**FIELD TRIP NO. 3**  
**BORDEN FORMATION (MISSISSIPPIAN) IN SOUTHEAST-CENTRAL  
KENTUCKY\***

**GORDON W. WEIR**  
U. S. Geological Survey, Berea, Kentucky

On this field trip we shall examine the chief lithofacies of the Borden Formation in southeast-central Kentucky (Fig. 1). In this region some of the Borden lithofacies are repeated in the section as discrete units, and some intergrade. The interrelations of the lithofacies reflect the complex patterns of a deltaic environment in part similar to that of the Borden Siltstone in Illinois described by Swann and others (1965) and Lineback (1966). In southeast-central Kentucky several of the Borden units have an initial dip to the southwest or west. The source of the bulk of the sediments was to the northeast or east.

#### **BORDEN FORMATION**

The Borden Formation in the region shown in Figure 1 is a clastic unit made up mostly of shale and siltstone overlain by cherty silty dolomite or dolomitic siltstone.

The Borden conformably overlies black carbon-rich shale. In most of this region the underlying formation is the New Albany Shale of Devonian or of Mississippian and Devonian age; along the Cumberland River drainage, as near Somerset, the underlying formation is the equivalent Chattanooga Shale of Devonian age.

The Borden Formation is conformably overlain by the Salem Formation of Late Mississippian age near Halls Gap. Between Halls Gap and Bighill the Borden is in part sharply overlain by and in part intertongues with the St. Louis Limestone Member of the Newman Limestone of Late Mississippian age. Between Bighill and Nada the Borden is everywhere sharply overlain by the St. Louis Limestone Member or Ste. Genevieve Limestone Member of the Newman Limestone.

The Borden Formation ranges from about 220 to

450 feet in thickness in southeast-central Kentucky. The formation is dominantly of Early Mississippian age but near Halls Gap it probably includes some beds of Late Mississippian age.

#### **PREVIOUS NOMENCLATURE**

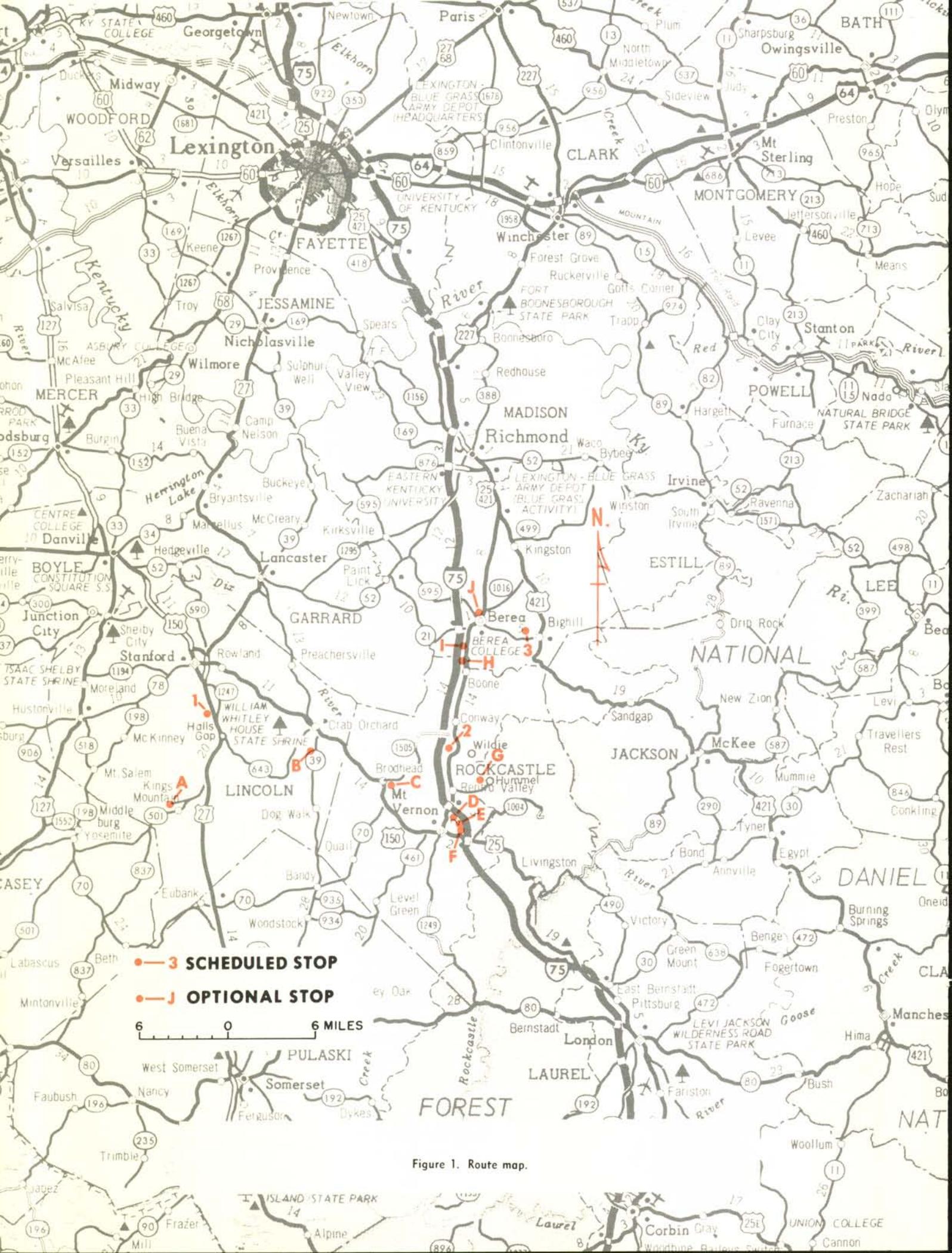
The previous and present nomenclature for the Lower Mississippian units will be compared at Stops 1 and 3. The names used by earlier workers for the Borden Formation in this region are summarized in Figure 2. Stockdale, in his comprehensive study of the Borden, used a system of nomenclature too complex to show fully here. (*See* summaries and comments on Stockdale's stratigraphic classification in McFarlan, 1943, p. 61-74; Moore, 1949, p. 11, 12, 21, and 33; and Weir and others, 1966, p. 2-7.) Stockdale's formations, facies, and members are generally not mappable lithologic units.

#### **MEMBERS OF THE BORDEN FORMATION**

In southeast-central Kentucky the Borden Formation generally consists from base upward of (1) shale, ranging from very clayey to very silty and locally calcitic; (2) siltstone, ranging from clayey to very finely sandy and locally calcitic to dolomitic and cherty; and (3) dolomite, commonly silty and calcitic, locally cherty, and commonly grading to siltstone or limestone. These rock types differ in proportion from place to place and characterize mappable rock-stratigraphic units that are members of the Borden Formation.

Members of the Borden now recognized in this region are, as shown in Figure 3, the Nancy Member (shale and minor siltstone), the Cowbell and Halls Gap Members (resistant siltstone), the Nada and Wildie Members (shale and siltstone), the Renfro Member (silty limestone and silty dolomite), and the

\* Publication authorized by the Director, U. S. Geological Survey.



- 3 SCHEDULED STOP
- J OPTIONAL STOP

6 0 6 MILES

Figure 1. Route map.

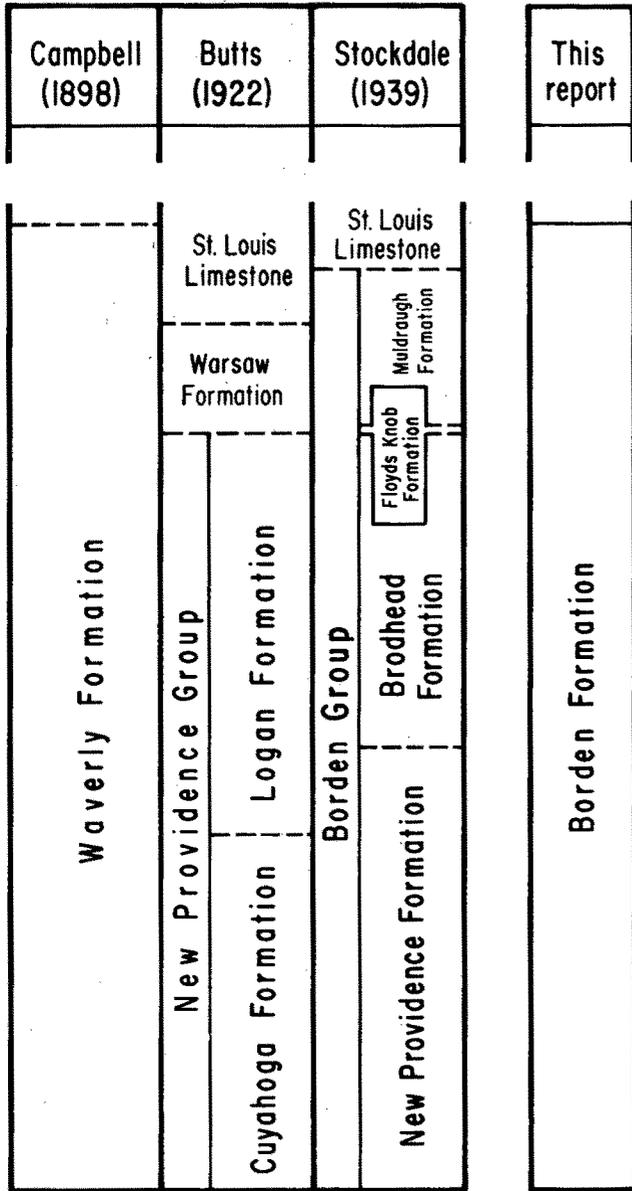


Figure 2. Previous nomenclature applied to the Borden Formation.

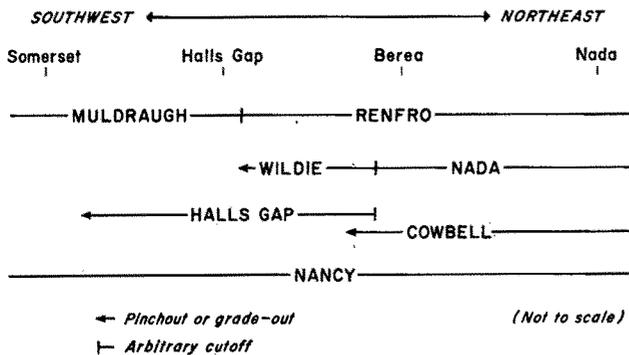


Figure 3. Diagram showing extent of members of Borden Formation in southeast Kentucky.

Muldraugh Member (cherty and dolomitic limestone, and cherty, limy, and dolomitic siltstone). Most of these members intertongue and intergrade.

### REGIONAL RELATIONS OF THE BORDEN FORMATION

The regional relations of the Borden Formation from near Nada to near Somerset are shown in Figure 4. The relations shown from near Halls Gap to near Berea are based on detailed mapping; the rest of the diagram is based on measured sections and may need to be modified. In this region the Borden Formation and its individual members thin southwestward. The Nancy Member is the only persistent member. The Cowbell thins southward and tongues out a short distance south of Berea. It is not connected with other similar siltstone units. The Nada Member maintains a fairly constant lithologic character to near Berea where at the west and south boundaries of the Berea 7½-minute quadrangle the Nada is separated by an arbitrary cutoff from the intergrading Nancy, Halls Gap, and Wildie Members. The Wildie Member crops out in only a few quadrangles; it grades into the Halls Gap Member near Halls Gap. The Halls Gap Member grades southward into the upper part of the Nancy Member north of Somerset so that near Somerset the Borden consists of but two members—the Nancy and the Muldraugh. The relations of the Renfro Member with overlying and adjacent units are complex. Between Halls Gap and Bighill the Renfro locally intertongues with the lower part of the St. Louis Limestone Member of the Newman Limestone; at the east edge of the Halls Gap 7½-minute quadrangle the Renfro is separated by an arbitrary cutoff from the intergrading Muldraugh Member of the Borden Formation and the Salem Formation. The Muldraugh Member in the area considered in this diagram is fairly constant in thickness and lithologic character.

The stratigraphic relations between Halls Gap and Indian Fort Mountain, the area of the field trip, are diagrammed in more detail in Figure 5. In this area the Borden is characterized by inclined intertonguing siltstone units. As shown in Figure 5, south of Berea the Cowbell Member splits into two mappable siltstone units, the Roundstone Bed and the Conway Cut Bed. These siltstone tongues have initial southward dips of about 40 feet per mile and pinch out within and near the base of the Nancy Member. The Gum Sulphur Bed of the Nancy Member is an isolated lentil of siltstone that also slopes southward. The Halls Gap Member, another siltstone unit, shows a lesser slope and thins and feathers out on the north near Berea.

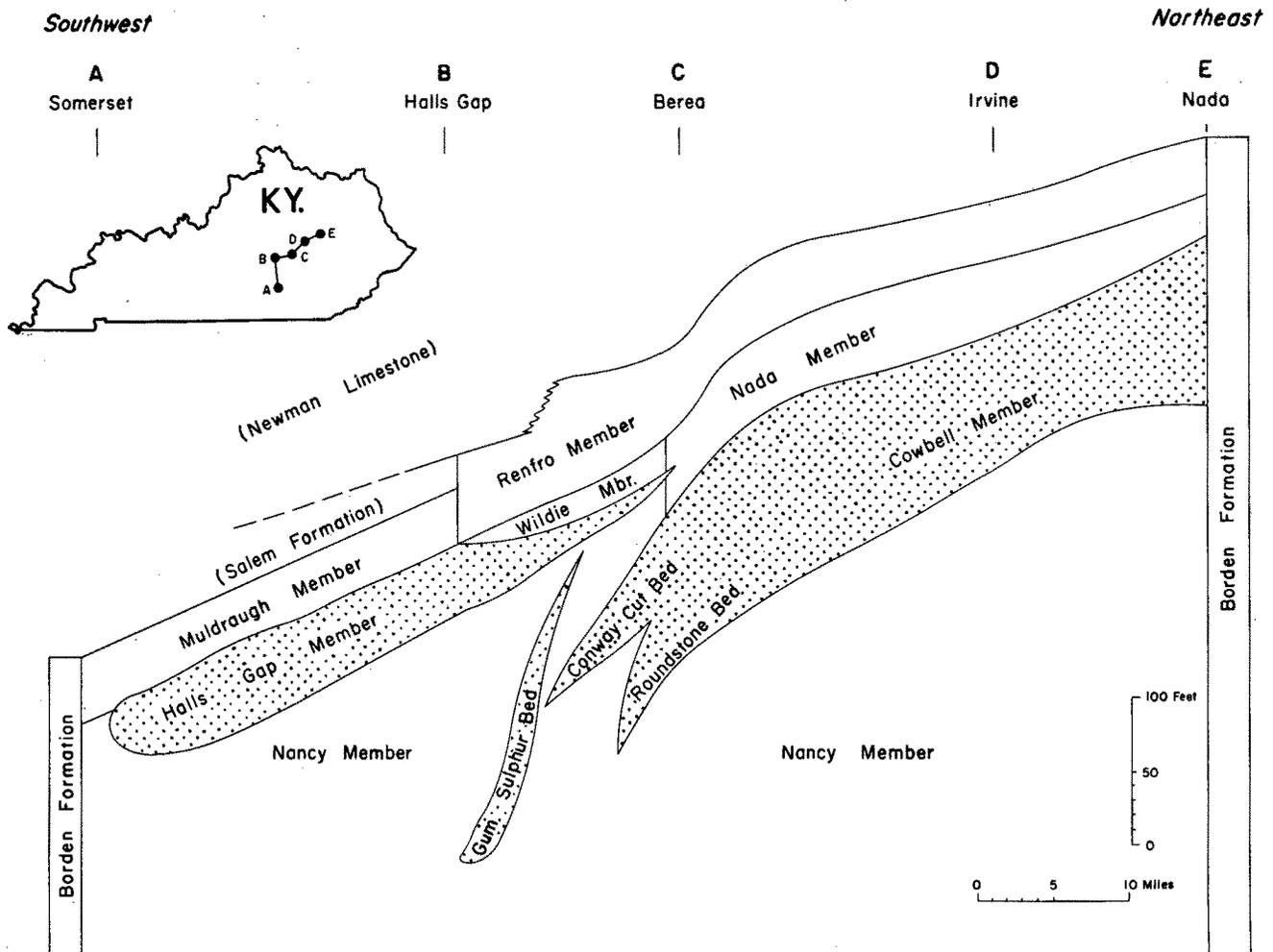


Figure 4. Cross-sectional diagram of Borden Formation in southeast-central Kentucky, Somerset to Nada. Siltstone units are stippled.

All these siltstone units are much alike and their relations were worked out only by detailed mapping.

### ROAD LOG

In addition to the main road log and regular stops, several optional extensions and stops have been added to make available a more complete picture of the regional geology. These optional portions are set apart by horizontal dashed lines.

#### Mileage Main log

- 0.0 Junction of U. S. 27 and U. S. 150. Drive south (toward Somerset) on U. S. 27. (See Figure 6 for nomenclature of pre-Mississippian units.)
- 0.1 Dolomitic mudstone of the Drakes Forma-

tion overlying nodular limestone and calcitic limestone of the Ashlock Formation. This roadcut is the type section of the Rowland Member of the Drakes Formation (Weir and others, 1965, p. 32-33).

- 0.4 Crossroad. Preachersville Member of Drakes Formation.
- 2.0 Restaurant, gas stations on left. Several small faults cross road near here.
- 2.2 New Albany Shale resting unconformably on Drakes Formation.
- 4.3 Brassfield Dolomite conformably overlying Drakes Formation.
- 4.7 Beginning of double southbound lanes of U. S. 27.
- 5.1 Unimproved dirt road on right.

**STOP 1**

*Halls Gap section of Borden Formation*

This section is an important reference section of the Borden Formation and is the type section of the Halls Gap Member (Weir and others, 1966, p. 28-31). The section is redescribed in Table 1, and a columnar section is provided in Figure 7. Experience in mapping in this area has suggested the following modifications and notes concerning subdivision of this section.

1. Unit 2 includes a greenish-gray very clayey shale, about 60 feet thick, and is a lithofacies of wide extent at the base of the Borden Formation. The clay shale has been mapped in this area and has been previously called the lower part of the Nancy Member; it is probably a unit of member rank and is lithologically similar and continuous with the New Providence Formation as used by Stockdale (1939) in west-central Kentucky. The clay shale is thick and conspicuous to the west but thins and probably pinches out to the south near Somerset and to the north near Berea.

2. Unit 14 is a transitional unit of siltstone that grades eastward into shale like that of unit 13 and grades westward into siltstone like that of unit 15.

3. Units 17 through 25 are equivalent to the Wildie Member of the Borden Formation in the Crab Orchard quadrangle a few miles east of this section (Gualtieri, 1967a). To the east this interval is mainly shale; to the west it is mainly siltstone like the siltstone of the Halls Gap. The name Wildie Member was applied to the shale lithofacies of this interval; the member is arbitrarily cut off at the west edge of the Crab Orchard quadrangle (see Weir and others, 1966, p. 19).

Nodular chert concretions within this interval are said to contain millerite, marcasite, and pyrite. The recess in the roadcut is the work of many rockhounds searching for the sulphide-bearing nodules.

4. The base of the Muldraugh Member (top of the Halls Gap Member) is placed at the top of unit 25, the highest glauconitic seam. This contact is the same as that designated by Stockdale (1939) at the type section of the Muldraugh near Phillipsburg, Ky. Cherty siltstone below the highest glauconitic seam was referred to the Muldraugh Member by Weir and others (1966, p. 22), but further study has shown that these cherty siltstones are patchy and are more like siltstone characteristic of the Halls Gap Member than of the Muldraugh Member.

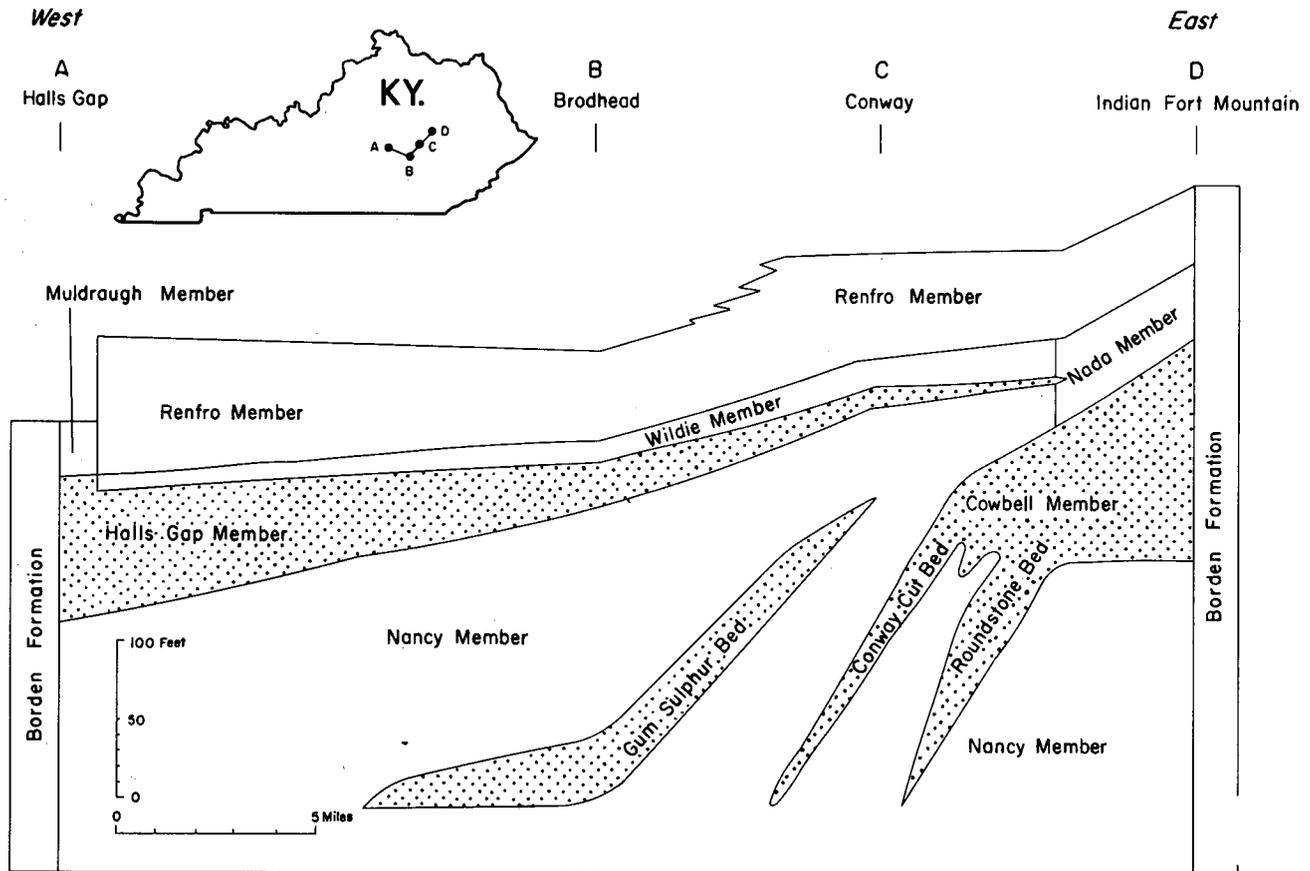


Figure 5. Cross-sectional diagram of Borden Formation in area of field trip, Halls Gap to Indian Fort Mountain. Siltstone units are stippled.

SYSTEM	SERIES	FORMATION, MEMBER, AND BED	LITHOLOGY	THICKNESS, IN FEET	
DEVONIAN	CARB	New Albany Shale		40-110	
	MISS				
SILURIAN	Middle Devonian	Boyle Dolomite		0-15	
	Middle Silurian	Crab Orchard Formation		0-35	
	Lower Silurian	Brassfield Dolomite		0-18	
ORDOVICIAN	Upper Ordovician	Drakes Formation		70-85	
					Preachersville Member
	Lower Ordovician	Ashlock Formation	Rowland Member		30-60
			Upper part	Reba Member	
		Terrill Member		10-15	
		Stingy Creek Member		10-15	
		Gilbert Member		15-18	
		Lower part	Tate Member		55-65
		Back Bed		3-6	
		Calloway Creek Limestone		6-8	
			125-135		
			95-105		
			65-75		
			15+		

Figure 6. Pre-Borden formations in field-trip area. Modified from Weir (1967).

This section is the easternmost good exposure of the Muldraugh Member, which becomes more silty and less cherty eastward. In the Crab Orchard quadrangle (Gualtieri, 1967a) the lateral equivalents of the Muldraugh are included, along with the lateral equivalents of the Salem Formation, in the Renfro Member of the Borden Formation.

5. The top of the Borden Formation (top of the Muldraugh Member) is placed at the top of unit 36 below a regionally persistent layer of sandstone, unit 37, forming the base of the Salem Formation. The limestones of units 28, 30, and 33 are lenses that locally characterize a zone that correlates with the Harrodsburg Limestone of west-central Kentucky. Weir and others (1966, p. 29) placed the formation contact at the base of unit 30, but these limestone lenses are too scarce to define a mappable horizon.

#### Mileage Main log

- 5.7 Side road right.
- 6.1 Ky. 643 on left. Stockdale (1939, p. 162-163) measured a section along Ky. 1247 which joins 0.2 mile to the north.
- 6.2 Halls Gap restaurant, gas station. Turn around and return to junction of U. S. 27 and U. S. 150 (or take optional extension to Optional Stop A, Kings Mountain cut. Distance measured from this point). Resume main log on U. S. 150 (to mileage point 12.4).

#### Mileage (Optional extension)

- 0.0 Outcrops along roads on this extension are mostly shale, limestone, and calcitic sandstone of Salem Formation.
- 4.0 Ky. 501. Gas stations, motel, restaurant. Turn right toward Kings Mountain.
- 5.7 Road junction. Leave Ky. 501; bear right on unnamed road.
- 6.9 Paved road curves sharply left. Take unimproved dirt road nearly straight ahead.
- 7.1 Dirt road circle. Park.

#### OPTIONAL STOP A

##### Kings Mountain railroad cut

View from top shows large-scale crossbedding in Nancy and Halls Gap Members. The lenses are commonly hundreds of feet long and dip southerly. Such crossbedding may be present in much of the Borden but is too large-scale to be recognized in most outcrops. The crossbedding may represent foresets on the Borden delta.

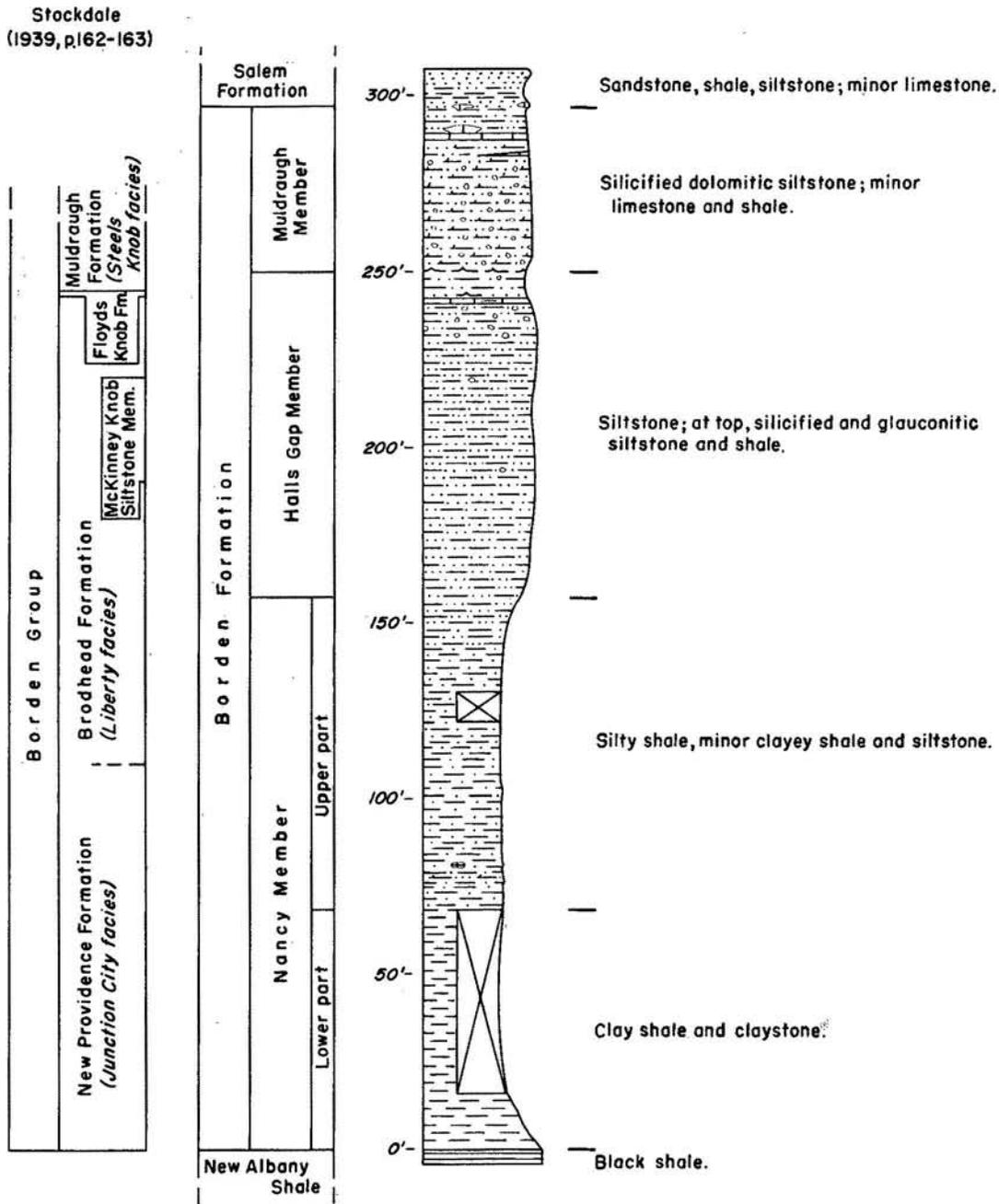


Figure 7. Borden Formation exposed along U. S. 27 near Halls Gap (Stop 1).

The Halls Gap-Muldraugh lithology is transitional; the contact is placed at a glauconite seam which forms a conspicuous dark recess in the cut. Top of the Borden Formation, poorly exposed in this area, is at base of sandstone about 15 feet below level of car park.

Return to junction of U. S. 27 and U. S. 150. Resume main log on U. S. 150 to mileage point 12.4.

*Mileage Main log*

- 12.4 Junction of U. S. 27 and U. S. 150. Turn right (east) on U. S. 150 toward Crab Orchard and Mount Vernon. Outcrops from here through Rowland are of Drakes Formation.
- 13.9 Rowland.
- 15.2 Road junction. Silurian and Devonian rocks. Brassfield Dolomite at base and Boyle Dolo-

- mite at top weather to red soils; Crab Orchard Formation in middle weathers to grayish-yellow soil.
- 16.1 Hill slopes are in Drakes Formation, grayish-yellow soils.
- 17.5 Walnut Flat Creek. Upper part of Ashlock Formation.
- 17.7 Fault. Drakes Formation on north, Boyle Dolomite on south.
- 18.2 Fault. Boyle Dolomite on north, Drakes Formation on south.
- 19.5 Brassfield Dolomite and Crab Orchard Formation. Minor faulting nearly parallel to highway.
- 20.1 Brassfield Dolomite resting on Drakes Formation.
- 20.8 Road right to William Whitley House, thought to be the first brick house built west of the Alleghenies. Boyle Dolomite.
- 20.9 Outcrops of Crab Orchard Formation.
- 23.4 Town of Crab Orchard. Continue right on U. S. 150 toward Brodhead and Mount Vernon.
- 24.0 Junction with Ky. 39 on right. (Optional extension to Optional Stop B south on Ky. 39. Log continues on U. S. 150. Flats are in Boyle Dolomite and New Albany Shale.)

-----

*Mileage (Optional extension)*

- 0.5 New Albany Shale.
- 1.1 Fault. Crab Orchard Formation.
- 1.4 Boyle Dolomite and New Albany Shale.
- 1.8 Unimproved road forks to right. Pull off and park here; walk up hill.

**OPTIONAL STOP B**

*Outcrops of Gum Sulphur Bed*

Basal contact of Borden is covered but can be located within a few feet relative to highest black shale of the New Albany and lowest greenish-gray clay shale of the Borden Formation.

The Gum Sulphur Bed (Fig. 8) is a minor unit within the Nancy Member but it illustrates the considerable depositional slope characteristic of Borden stratigraphic units. Figure 9 shows the thicknesses of the Gum Sulphur lens based on outcrop data. Figure 10 is an isopach map of the Nancy Member below the Gum Sulphur Bed and serves to illustrate the configuration of the base of the Gum Sulphur relative to the top of the black shale. This indicates a depositional

slope of 10 to 50 feet per mile; compaction of shale of the Nancy Member between the top of the New Albany and base of the Gum Sulphur probably has lessened the initial slope.

The Gum Sulphur Bed does not show any flow markings found in a few other units of the Borden in this area. This lack of flow markings may be the result of organic reworking of the sediments suggested by the abundance of curly "worm" marks and *Zoophycos* ("rooster-tail" marking) in this bed. Limestone concretions here in siltstone are a local feature, not characteristic of the Gum Sulphur Bed.

The Gum Sulphur Bed feathers out along a north-west-trending line of pinchout about 0.4 mile west of the highway (Gualtieri, 1967a).

*Mileage (Optional extension)*

- 2.2 Hilltop, road to left, alternate parking and turnaround for this stop.
- 4.4 Junction of Ky. 39 and U. S. 150. Turn right toward Brodhead. Resume main log.

-----

*Mileage Main log*

- 25.8 New Albany Shale overlying Boyle Dolomite.
- 25.9 Bridge over railroad.
- 26.8 Borden Formation overlying New Albany Shale. Upper few feet of black shale contains conodonts and orbiculoid brachiopods (Gualtieri, 1967b).
- 27.1 Lincoln County-Rockcastle County line.
- 27.8 Village of Gum Sulphur. Across the valley of the Dix River the Gum Sulphur Bed of the Nancy Member (about 40 feet thick) forms ledges about 40 feet above the black shale.
- 33.1 Gum Sulphur Bed forms near-vertical face in roadcuts on right from here in to Brodhead (Fig. 8).



Figure 8. Characteristic weathering of siltstone of the Gum Sulphur Bed of the Nancy Member of the Borden Formation. Roadcut on U. S. 150, 0.5 mile west of Brodhead.

35.1 Center of Brodhead. Turn right, continuing toward Mount Vernon on U. S. 150 (or take optional extension to Optional Stop C by continuing straight ahead across railroad tracks).

*Mileage (Optional extension)*

0.3 Junction with road to water tower on right. Park near here. Walk up toward tower.

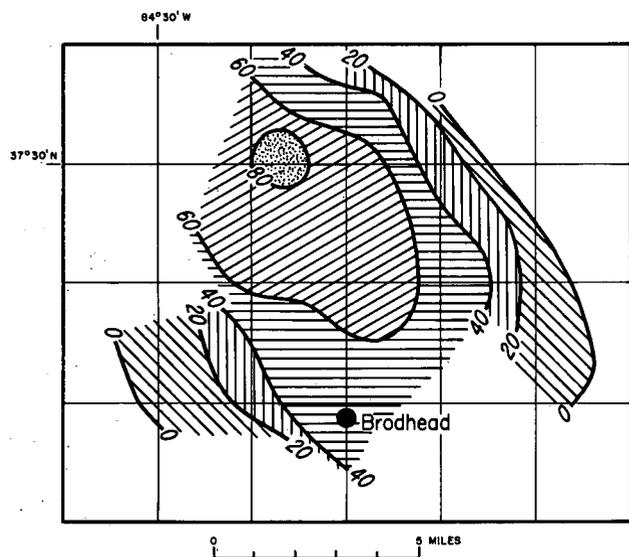


Figure 9. Isopach map of Gum Sulphur Bed. Contour interval is 20 feet.

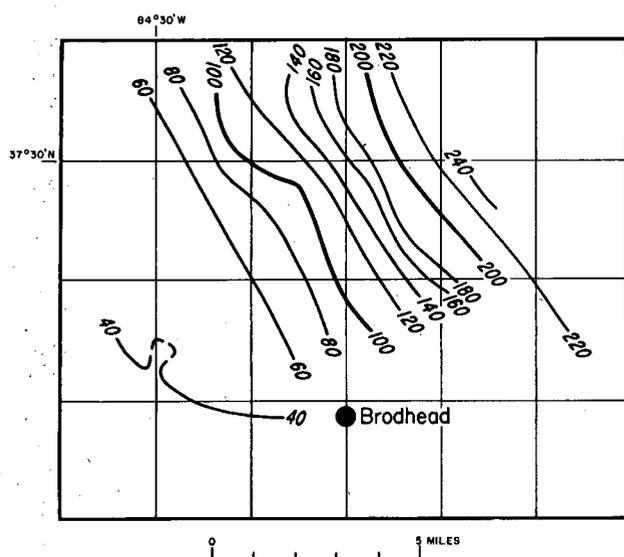


Figure 10. Isopach map of that part of Nancy Member below Gum Sulphur Bed. (Approximate depositional slope of base of Gum Sulphur Bed.) Contour interval is 20 feet.

**OPTIONAL STOP C**

*Type section of Brodhead Formation of Stockdale (1939)*

The section as redescribed by Gualtieri is shown in Table 2. The name Brodhead Formation was abandoned because (1) the unit was not defined in terms of its lithology; (2) as originally defined it was not a mappable unit; and (3) the name has been applied to several unconnected units. Return to Brodhead, turn east on U. S. 150 and resume main log.

*Mileage Main log*

- 37.0 Ky. 70 on right. Grayish-yellow outcrops in railroad cuts to north are dolomitic and limy siltstones of Renfro Member of Borden Formation.
- 37.5 Ky. 1250 on right. Halls Gap, Wildie, and Renfro Members poorly exposed along road up hill ahead.
- 38.1 Hilltop. Dark-red soil with light-colored platy fragments of chert is weathered St. Louis Limestone Member of Newman Limestone. (See Figure 11 for nomenclature of Upper Mississippian units.)
- 39.6 Maretburg Baptist Church.
- 40.0 Ste. Genevieve Limestone Member of Newman Limestone.
- 41.4 Ky. 451 on right. Upper member of Newman Limestone in hilltop cut ahead.
- 41.9 Quarries left and right are mostly in Ste. Genevieve Limestone.
- 42.6 Junction of U. S. 150 and U. S. 25, Mount Vernon. Turn left (north) on U. S. 25 toward Berea.
- 43.1 Mount Vernon fault (not exposed) in Ste. Genevieve Limestone; down about 30 feet on north.
- 43.3 Ste. Genevieve Limestone in cut; St. Louis Limestone in hollow.
- 43.6 Ste. Genevieve at road level in cut in saddle; upper member of the Newman Limestone above.
- 43.8 Hill. St. Louis Limestone Member of Newman Limestone and Renfro Member of Borden poorly exposed near road.
- 44.6 Junction: Interstate 75. (Outcrops are Renfro Member of Borden Formation. Turn right for optional extension to Optional Stops D, E, and F.)  
Main log mileage continues ahead on U. S. 25.

SYSTEM	SERIES	FORMATION AND MEMBER	LITHOLOGY	THICKNESS, IN FEET	
CARBONIFEROUS	PENNSYLVANIAN	Lee Formation	[Lithology: Sandstone and shale with thin beds]	100+	
		Pennington Formation	[Lithology: Limestone with thin beds]	0-55	
	MISSISSIPPIAN	Newman Limestone	Upper member	[Lithology: Limestone with thin beds]	10-105
			Ste. Genevieve Limestone Member	[Lithology: Limestone with thin beds]	40-80
			St. Louis Limestone Member	[Lithology: Limestone with thin beds]	5-90

Figure 11. Post-Borden formations in field-trip area. Modified from Gualtieri (1967b).

Mileage (Optional extension)

0.1 Optional Stop D.

**OPTIONAL STOP D**

Roadcut showing Renfro Member of Borden Formation and St. Louis and Ste. Genevieve Limestone Members of Newman Limestone

Compare with weathered Renfro (grayish orange) cropping out along U. S. 25.

Mileage (Optional extension)

0.7 West side of fill. St. Louis Limestone Member of Newman Limestone overlies Renfro Member of Borden Formation; contact about 10 feet above road level. Note fine-grained limestone, resembling St. Louis, within Renfro at base of outcrop.

1.2 East side of fill.

**OPTIONAL STOP E**

Roadcut showing upper part of Newman Limestone (Fig. 12)

Contact between the Ste. Genevieve Limestone Member and upper member of the Newman Limestone is near road level. The base of the upper member is marked by a layer of oolitic limestone containing scattered granules and small pebbles of gray chert. At the top of the Ste. Genevieve is a layer of micro-grained limestone having a faint to marked breccia texture (Bryantsville Breccia of Malott, 1952, as used by McFarlan and Walker, 1956). Both of these features of the contact zone are locally absent or poorly developed; at such localities the contact between the Ste. Genevieve and upper member of the Newman Limestone is indistinct.



Figure 12. Newman Limestone in cut on Interstate 75 about 0.7 mile southeast of junction with U. S. 25 about 2 miles south of Mount Vernon (Optional Stop E). Dark layer at base is Ste. Genevieve Limestone Member (Mng); above it is upper member (Mnu) which comprises several distinct units of limestone separated by conspicuous thin beds of shale. Sandstone and shale of Lee Formation (Pl) of Pennsylvanian age rest unconformably on Newman Limestone at top of cut.

The upper member of the Newman Limestone consists of several cyclic units of clastic limestone. Commonly the units are a few tens of feet thick and are made up of coarse to medium pellets, oolites, and grains, but grade at the top to micrograined limestone, commonly having a breccia texture, and are terminated by a layer of greenish-gray calcitic shale a fraction of an inch to a few feet thick. McFarlan and Walker (1956) correlated the units of limestone with limestone formations and the units of shale with sandstone formations of Late Mississippian age in western Kentucky. None of these subordinate units of the upper member of the Newman Limestone have proved mappable in this area, mainly because lithologic criteria by which to discriminate them are lacking or unrecognized.

Shale and sandstone of the Lee Formation rest directly on the Newman Limestone here. The Pennington Formation, consisting of shale and minor sandstone and siltstone, was eroded away before the Lee was deposited. Although the Pennington is present on some nearby hills, it will not be seen on this field trip.

*Mileage (Optional extension)*

- 3.2 Junction with exit ramp.

**OPTIONAL STOP F**

*Beds of shale in upper member of Newman Limestone*

The shale layer at road level marks the top of a subordinate unit in the upper member of the Newman Limestone; about 20 plus feet above is a thicker shale unit marking the top of another subordinate unit of the upper member. Note the gradational nature of the shale-limestone contacts, the brecciation of the underlying fine-grained limestone, and the variation of the shale layer along strike. Does the base of each shale layer represent a submarine unconformity?

*Mileage (Optional extension)*

- 3.3 Junction with U. S. 25. Turn left (south), then a few hundred feet turn left back on to Interstate 75, heading north.
- 6.6 Exit ramp from Interstate 75. Wildie Member of Borden Formation. No "Rockcastle freestone" here. (See notes on "Rockcastle freestone" at Optional Stop G and Stop 2.)
- 6.7 Junction with U. S. 25. Turn right (north).

*Mileage Main log*

- 45.1 Renfro Valley buildings.
- 45.2 Junction—secondary road on right. (Turn right for extension to Optional Stop G.)

*Mileage (Optional extension)*

- 2.2 "Rockcastle freestone" ledges in Wildie Member about 20 feet above road. (See Optional Stop G and Stop 2 for notes on "Rockcastle freestone.") Roadcut is in Halls Gap Member of the Borden Formation.
- 2.8 Sharp curve to right. "Rockcastle freestone" layer about 5 feet above road forms projecting ledge.
- 3.0 Turn right over bridge over Roundstone Creek.
- 3.6 Junction of dirt roads. Turn hard left.
- 4.0 Park off road.

**OPTIONAL STOP G**

*"Rockcastle freestone" quarry*

Furrow casts and load casts are the dominant markings on the undersides of beds of the "Rockcastle freestone" (an informal name used in the building-stone trade). This finely sandy siltstone splits smoothly along some bedding planes and was much used as a building stone in Berea and Mount Vernon and nearby settlements.

Figure 13 shows the known thickness and orientation of flow markings in the "Rockcastle freestone."

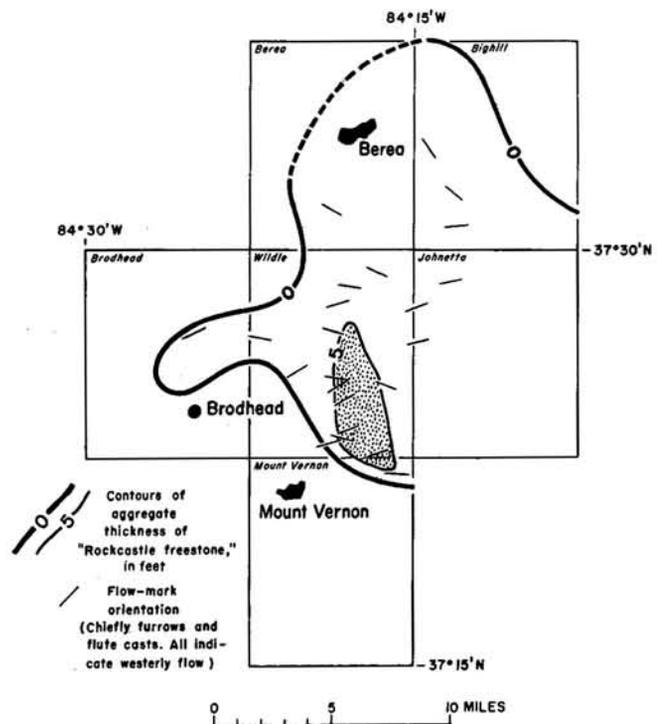


Figure 13. Map showing thickness of and flow marks in the "Rockcastle freestone" of quarrymen.

This quarry is in the thicker part of the unit. Exposures along the railroad west of the quarry show some of the markings in place.

The "Rockcastle freestone" is interpreted to be a deltaic turbidite having an eastern source.

Return to U. S. 25 by the same route.

*Mileage Main log*

- 47.0 View left is of characteristic rolling topography of uplands underlain by Mississippian limestone.
- 48.4 Roadside park on right, below crest of hill. Park here.

**STOP 2**

*Renfro Valley North section, Borden Formation*

This is the type section of the Renfro Member of the Borden Formation and a reference section of the Wildie Member (Table 3). Near the base is the Gum Sulphur Bed of the Nancy Member of the Borden (Figs. 9, 10); it is much thinner here than near Brodhead (12 feet versus 45 feet) and much higher above the top of the black shale (220 feet versus 40 feet).

Note southward divergence of beds within the rather shaly Halls Gap Member; this member pinches out a few miles to the north.

Glauconitic seams marking the base and the top of the Wildie Member form a conspicuous zone here. The lower part of the Wildie Member here contains about 3½ feet of very finely sandy siltstone, quarried elsewhere in this area and known popularly as the "Rockcastle freestone" (Fig. 14). Note furrow marks



Figure 14. Wildie Member of Borden Formation in roadcut on U. S. 25 about 3.5 miles north of Renfro Valley (Stop 2). Siltstone beds below pick (lower center) are in "Rockcastle freestone."

on underside of lowest layer. Figure 13 shows the thickness and the orientation of flow markings in this "freestone" facies. The "Rockcastle freestone" is probably a deltaic turbidite having an eastern source. The rock is similar to the Berea Sandstone of Ohio, the siltstone in the Farmers Member of the Borden Formation in northeast-central Kentucky, and siltstone in the Kenwood Sandstone of Butts (1915) in the lower part of the Borden Formation in west-central Kentucky; these similar rocks also show current markings.

*Mileage Main log*

- 49.0 Gum Sulphur Bed of Nancy Member of Borden Formation. Siltstone forms minor ledge.
- 49.5 Cross Roundstone Creek. Village of Roundstone to right.
- 50.4 Cross Roundstone Creek. Siltstone is Conway Cut Bed of Cowbell Member of Borden Formation; see Figure 5 for relations of this unit.
- 50.8 Outcrop is Conway Cut Bed. Abundant *Zoophycos* ("rooster-tail" marking).
- 52.6 Conway.
- 55.0 Crossroad.
- 55.1 On left, outcrop of clayey shale characteristic of basal part of Borden Formation.
- 56.2 On left, outcrop of silty shale characteristic of upper part of Nancy Member.
- 56.7 Parking area on right for Optional Stop H.

**OPTIONAL STOP H**

*Contact of Cowbell and Nancy Members of Borden Formation*

About 15 feet above road level is contact between Cowbell and Nancy Members of the Borden Formation. Striation casts in siltstone in Nancy Member are oriented about east-west.

*Mileage Main log*

- 56.9 Road failure. Apparently shale and siltstone fill on top of silty shale of Nancy Member; deep railroad cut to right.
- 57.0 On left, iron-rich concretions conspicuous in Nancy Member.
- 57.6 Park for Optional Stop I.

**OPTIONAL STOP I**

*Base of Borden Formation*

On left, contact between Borden Formation and New Albany Shale. Brownish-gray phosphatic nodules

common in basal foot of Borden Formation. Conodonts in upper part of black shale.

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*Mileage Main log*

- 60.0 Junction with Ky. 21. Turn right, continuing east through Berea on U. S. 25 and Ky. 21.
- 60.3 On left, Sinclair gas station, Lester Street, USGS field office is on street floor in first house from highway on Lester Street. You are welcome!
- 60.5 Post office on left.
- 60.7 Ellipse Street on left. Knapp Hall of Berea College on right. Park for Optional Stop J.
- 

**OPTIONAL STOP J**

*Old stone wall on left*

Wall here built of blocks of "Rockcastle freestone" is a museum of current and organic markings.

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*Mileage Main log*

- 60.8 Berea College campus.
- 60.9 Turn right at first traffic light on Ky. 21 (Prospect Street) and proceed eastward between Boone Tavern on left and Union Church on right.
- 62.5 Brushy Fork Creek.
- 64.1 Crossroad. On right, Silver Creek Baptist Church. Contact between Borden Formation and New Albany Shale is obscure in flats ahead.
- 65.4 On left, parking lot for Indian Fort theatre.
- 65.7 On left, unimproved road up Indian Fort Mountain. The section we shall examine is partly along this road.
- 65.8 On right, parking area for three or four cars.

**STOP 3**

*Borden Formation, Indian Fort Mountain section*

This is the type section for the Cowbell Member of the Borden Formation (Table 4; Fig. 15). Of the members examined at Stop 1 only the Nancy Member is present here (Fig. 5).

The Cowbell Member is lithologically like the Halls Gap Member but the members are separate units. The Cowbell Member is older than the Halls Gap Member. Both members and the Gum Sulphur Bed of the Nancy Member represent an outpouring of silt on the Borden delta.

The Nada Member comprises lateral equivalents of the Wildie Member and the upper part of the Nancy Member. Its southern limit is the south edge of the Berea quadrangle (Weir, 1967). The Nada is made up mostly of shale, dominantly greenish gray but commonly in part grayish red or grayish purple. At this section the Nada contains a few lensing siltstone beds of the "Rockcastle freestone" of quarrymen; furrow casts are on the underside of the basal siltstone bed.

The lithology and stratigraphic relations of the Renfro Member of the Borden Formation and of the St. Louis Limestone Member of the Newman Limestone are similar to Stop 2.

Top of this section is end of the trip. Above the St. Louis is about 30 feet of the Ste. Genevieve Limestone Member of the Newman Limestone; the upper member of the Newman Limestone is mostly covered. Capping the knob is the Livingston Conglomerate Member of the Lee Formation (Pennsylvanian), a channel fill in a scour cut into the Newman Limestone.

On the flat top of this knob are remnants of ancient ramparts of piled stones, popularly known as Indian Fort. The most conspicuous wall is cut through by the road which this trail follows. From the north point of the knob are fine views of the Blue Grass and Knobs physiographic regions of Kentucky.

Stockdale Weir and others  
 (1939, p.175-176) (1966, p.24-28)

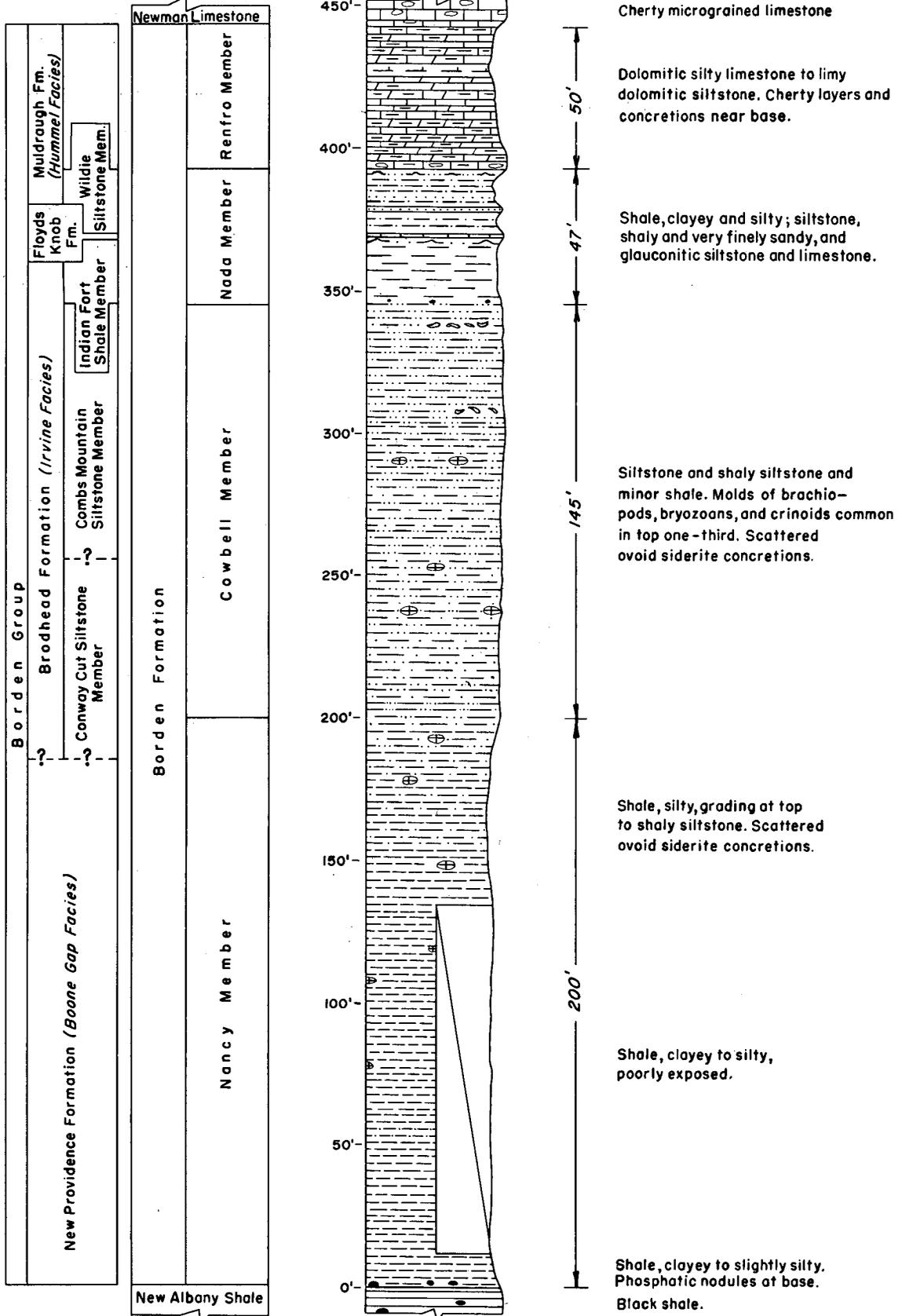


Figure 15. Borden Formation, Indian Fort Mountain section.

TABLE 1. HALLS GAP SECTION

Measured up hill along U. S. 27 at Halls Gap, Lincoln County, Ky. (Halls Gap quadrangle). Measured with barometer, Jacob staff, and tape by G. W. Weir and J. L. Gualtieri, assisted by J. C. Dills, July 1962. Modified by G. W. Weir from Weir and others (1966, p. 28-31).

	Feet
Salem Formation (incomplete):	
38. Residuum, grayish-yellow to grayish-orange; ferruginous, clayey. Not measured; about 3 ft thick.	
37. Sandstone, grayish-orange (10YR 7-8/4),* weathering yellowish-orange (10YR 5-6/6) and light-brown (5YR 5/6); silty, fine- to medium-grained; slightly calcitic, probably leached, in irregular thin beds, commonly 1/2 to 1 in. thick; sparse ripple marks; dark-brown petrolierous (?) stain common. Ranges from about 2 to 4 ft in thickness	3.6
36. Siltstone, yellowish-gray (5Y 6-7/2), weathering grayish-orange (10YR 6-8/4), limonitic; in obscure crude beds 1/2 to 2 in. thick	1.3
35. Shale, similar to overlying siltstone of unit 36; crudely laminated; contains abundant spherical to discoidal siliceous geodes as much as 1 ft in diameter	1.8
34. Shale, slightly silty, mostly medium-bluish-gray (5B 5/1), in part dusky-yellow-green (5GY 5/2); laminated; outcrop yields abundant small chips; intergrades with overlying shale	1.6
33. Sandstone (60 percent) containing lentils of limestone (40 percent). Sandstone, calcitic, light-olive-gray (5Y 6/1), weathering grayish-orange (10YR 7/4) to yellowish-brown (10YR 4/4-6), and moderate-olive-brown (5Y 4/4); silty to medium-grained; probably originally very calcitic but now mostly leached; in obscure thin beds; contains siliceous geodes as much as 1.5 ft in diameter; grades into limestone. Limestone, silty, light-gray (N7) and greenish-gray (5G 6/1); covered with grayish-yellow wash; silty, micrograined to very fine-grained; in lenses as much as 1.8 ft thick and 7 ft long; intergrades with calcitic silty sandstone; contains large siliceous geodes; unfossiliferous; resistant; forms projecting ledge	1.8
Measured Salem Formation (incomplete)	<u>10.1</u>

## Borden Formation:

## Muldraugh Member:

32. Shale, similar to unit 34	1.7
31. Shale (40-60 percent), siltstone (30-40 percent), and limestone (0-30 percent). Shale, yellowish-gray (5Y 6-7/2), weathering grayish-orange (10YR 6-8/4); crudely laminated; contains partings of light-gray limestone; dominant in lower part of unit; intertongues with siltstone. Siltstone, similar to shale; in crude thin beds, 1 to 3 in. thick; contains partings and lentils of silty, fine-grained limestone; mostly in upper part of unit. Limestone, light-brownish-gray (5YR 6/1) and where silty, grayish-yellow (5Y 7/4); made up mostly of coarse fragments of crinoid columnals and other fossil debris; locally glauconitic; in lenses a few inches to about 2 ft thick and a few feet long; in lower part of unit; more resistant than rest of unit	5.8

TABLE 1.—Continued

	Feet
30. Limestone, medium-light-gray (N6), medium- to coarse-grained; in obscure lensing beds, 3 to 6 in. thick, closely packed in a single set. Fossils common, chiefly large brachiopods, crinoid columnals, and bryozoans; abundant fossil debris, largely crinoid and brachiopod fragments. Base uneven; unit ranges from about 2 to 3 ft in thickness	2.4
29. Siltstone, dolomitic, bluish-white (5B 9/1) to very light-gray (N8) weathering very pale-orange; bedding obscure; irregular fracture; outcrop yields angular blocks commonly 2 to 6 in. across. Contains discoidal nodules of light-gray chert, commonly 4 to 6 in. long; 1 to 2 in. thick	4.8
28. Limestone, similar to unit 30. Contains sparse irregular lentils of dolomitic siltstone. Sparse brachiopods and horn corals. As much as 2 ft thick; pinches laterally to thin shale parting	1
27. Siltstone, silicified, dolomitic, light-gray (N 7) and very light-gray (N 8), weathering grayish-orange to dark-yellowish-orange; rubbly-weathering; very abundant pyrite as sparse nodules and as disseminated grains and concretions of grains in irregular bodies and lentils. Siliceous pyritic geodes, sparse to abundant, as much as 4 in. in diameter. A few silty shale partings in upper part	26.7
26. Siltstone, silicified, dolomitic, light-bluish-gray (5B 7/1), weathering same and yellowish-gray; very fine wavy laminae. Contains pyrite nodules, siliceous geodes, and pyritic siliceous geodes. Abundant glauconite in basal 0.5 ft	4.8
Total Muldraugh Member	<u>47.2</u>
Halls Gap Member:	
25. Shale, glauconitic, silty, dark-greenish-gray (5G 4/1). A conspicuous seam, 0.1 to 0.2 ft thick	.2
24. Siltstone, dark-greenish-gray (5G 4/1), limonitic at top. Abundant glauconite	.8
23. Siltstone, greenish-gray (5G 6/1), structureless to finely laminated. Abundant glauconite	4.6
22. Shale, glauconitic, silty, similar to unit 25	.2
21. Shale, silty, medium-bluish-gray (5B 5/1)	.4
20. Limestone, dolomitic, silty, light-gray (N 7), weathering grayish-orange; structureless. Contains abundant films and grains of bright-green glauconite; lenses, 1.5 to 2 ft thick; interfingers with shale at top	1.8
19. Shale, similar to unit 21	.8
18. Limestone, dolomitic, light-bluish-gray (5B 7/1), weathering gray to very pale-orange. Contains abundant grains of bright-green glauconite and a few siliceous geodes	.7
17. Limestone, silty, dolomitic, light-bluish-gray (5B 7/1); abundant light-olive-gray (5Y 6/1) to brownish-gray (5YR 4/1) phosphatic (?) nodules. Abundant grains of bright-green glauconite; sparse siliceous and calcitic geodes	.2
16. Siltstone, silicified, dolomitic, and silty clayey shale; light-greenish-gray (5GY 8/1) and grayish-orange (10YR 7/4), weathering grayish-orange; beds lenticular, interfingering. Geodes, 1 to 3 in. across, in upper part	8.3

\* Color name with numbers based on color chart by Goddard and others (1948).

TABLE 1.—Continued

	Feet
15. Siltstone, very pale-orange (10YR 8/2) to grayish-orange (10YR 7/4), limonite-stained, crudely laminated to thin-bedded, imperfectly fissile. Base of unit marked by 5-foot-thick zone of concretions of finely crystalline limestone; blunt lentils as much as 3 ft long and 18 in. thick. Sparse siliceous geodes; pyrite nodules common near top .....	74.5
Total Halls Gap Member .....	<u>92.5</u>
Nancy Member:	
Upper part:	
14. Siltstone, greenish-gray (5GY 6/1) and medium-light-gray (N 6); limonite-stained partings. More resistant siltstone ribs prominent in lower part of unit, less distinct upwards. Base marked by zone of concretions of limy siltstone, as thick as 2 ft and as long as 8 ft .....	14.5
13. Shale, clayey to silty, dark-greenish-gray (5GY 4/1), weathering light-olive-gray; limonite-stained partings; imperfectly fissile .....	12
12. Covered .....	8
11. Shale, similar to unit 13 .....	25.7
10. Siltstone, limonitic (may have been calcitic), yellowish-gray (5Y 7/2) to dark-yellowish-orange (10YR 6/6) .....	.2
9. Shale, similar to unit 13 but more silty. About 3 ft above base more resistant silty beds form ledge about 2 ft thick .....	11.4
8. Siltstone, calcitic, light-olive-gray (5Y 6/1); forms ledge .....	.2
7. Shale, similar to unit 9 .....	3.9
6. Siltstone, sideritic, light-olive-gray (5Y 6/1), weathering to limonite; 0.1 to 0.3 ft thick .....	.2
5. Shale, similar to unit 9 .....	4.8
4. Siltstone, calcitic, light-olive-gray (5Y 6/1), weathering light-brownish-gray; 0.3 to 0.5 ft thick .....	.4
3. Shale, similar to unit 9. In upper part sparse small calcite nodules; in lower part siderite lentils, as long as 10 ft and as thick as 1 ft, weathering to limonite .....	7.7
Lower part:	
2b. Mostly covered, probably claystone similar to unit 2a .....	42
2a. Claystone, light-greenish-gray (5GY 7/1); laminated, nonresistant .....	15.5
Total Nancy Member .....	<u>146.5</u>
Total Borden Formation .....	<u>286.2</u>
New Albany Shale:	
1. Shale, carbonaceous, black (N 1), laminated. Not measured.	

TABLE 2. BRODHEAD SECTION

	Feet
Measured up steep road passing close to municipal water tank; road joins Ky. 1505 near abandoned quarry in basal unit about 0.1 mile east of city center, Brodhead, Rockcastle County, Ky. (Brodhead quadrangle). Measured by J. L. Gualtieri and J. C. Dills, August 1962.	
Borden Formation (incomplete):	
Renfro Member (incomplete):	
16. Ocherous residuum with sparse outcrops of limy or dolomitic siltstone. Not measured.	
Total Renfro Member (estimated) .....	50±
Wildie Member:	
15. Siltstone, glauconitic, dusky-yellow-green (10GY 3/2) .....	.4
14. Shale, clayey to silty, and silty shale, dusky-yellow (5Y 6/4) and pale-olive (10Y 4/2), poorly exposed .....	10.2
13. Siltstone, yellowish-gray (5Y 7/2) .....	.3
12. Covered .....	2.7
11. Siltstone, glauconitic, olive-black (5Y 2/1), grayish-olive-green (5GY 3/2) on surface .....	.5
10. Siltstone, glauconitic, with sand- to pebble-sized phosphatic nodules and silicified fossil debris ..	.3
Total Wildie Member .....	<u>14.4</u>
Halls Gap Member:	
9. Siltstone and shale, silty and clayey, dusky-yellow (5Y 6/4), yellowish-gray (5Y 7/2), greenish-gray (5GY 6/1), and pale-olive (10Y 6/2); limonite-stained in part; micaceous; crudely laminated; curly "worm" markings common. More resistant than overlying unit; forms steep slope; outcrop yields irregular platy to blocky fragments .....	42.8
8. Siltstone, greenish-gray (5GY 6/1), much surface limonite stain; similar to overlying unit but more resistant; forms minor ledge .....	12
Total Halls Gap Member .....	<u>54.8</u>
Nancy Member (incomplete):	
7. Shale, clayey to silty, dark-greenish-gray (5GY 4/1), weathering lighter gray, limonite-stained on fracture surface .....	8.7
6. Siltstone, light-olive-gray (5Y 6/1), faint limonite stain on partings; forms minor ledge .....	2.5
5. Shale, clayey, silty, medium-dark-gray (N 4), weathering greenish-gray; similar to unit 7 .....	9.3
4. Shale, silty, to clayey siltstone, light-olive-gray (10Y 6/1); limonite on some partings; abundant worm trails; forms minor ledge .....	1.5
3. Shale, clayey to silty, yellowish-gray (5Y 7/2), limonite-stained on some parting surfaces. Abundant iron-rich concretions as much as 18 in. long .....	18.5
2. Shale, slightly silty, similar to unit 7. Mostly covered .....	65
Note: Base of Brodhead Formation of Stockdale (1939) was placed 40 ft above top of Gum Sulphur Bed—that is, about 25 ft below top of unit 2. Top of Brodhead Formation of Stockdale (1939) placed at top of unit 9. This section also described by Stockdale (1939, p. 136).	
Gum Sulphur Bed (incomplete):	
1. Siltstone, light-gray (N 7), limonite-stained on exposed surfaces; obscurely laminated; outcrop yields platy fragments. Forms rounded ledge. Base not exposed; base of local exposure. Not measured; estimated .....	20±
Measured Nancy Member (incomplete) .....	<u>125±</u>

TABLE 3. RENFRO VALLEY NORTH SECTION

Measured along U. S. 25 beginning about 0.2 mile southwest of the village of Roundstone, about 3 miles north of Renfro Valley, Rockcastle County, Ky. (Wildie quadrangle). Renfro and Wildie Members measured with hand level and tape by S. O. Schlanger and J. L. Gualtieri, March 1962; Halls Gap and Nancy Members measured by J. L. Gualtieri, assisted by J. C. Dills, August 1962. Revised slightly from Weir and others (1966, p. 32-35).

	Feet
Newman Limestone (incomplete):	
St. Louis Limestone Member:	
49. Limestone, dark-gray (N 3), aphanitic to micro-grained; abundant nodules of black chert and silicified heads of lithostrotionoid corals. Sparse endothyrid foraminifers about 10 ft above base .....	14
48. Limestone, very light-gray (N 8) and light-gray (N 7), coarse-grained, clastic; abundant moderately sorted crinoid, brachiopod, and bryozoan debris .....	5
Measured St. Louis Limestone Member (incomplete) ..	<u>19</u>
Borden Formation (incomplete):	
Renfro Member:	
47. Limestone, clayey, light-olive-gray (5GY 6/1), fine-grained. Weathers to punky yellowish-orange silt. Base poorly exposed .....	4
46. Shale, pale-olive (10Y 6/2); plastic when wet; poorly exposed .....	1.5
45. Limestone, clayey and silty, grayish-yellow (5Y 8/4), aphanitic; weathers to dark-yellowish-orange (10YR 6/6) punky silty claystone .....	4
44. Limestone, light-gray (N 7), weathering yellowish-gray (5Y 7/2); medium- to coarse-grained, clastic; fragments of brachiopod shells and crinoids common. Probably grades southward into argillaceous limestone like that in unit 43 .....	2.4
43. Limestone, clayey, yellowish-gray (5Y 7/2), aphanitic; cut by many irregular veins of clear calcite; 0.1 ft green shale at base. Probably thickens southward .....	3.5
42. Limestone, clayey and silty, yellowish-gray (5Y 7/2) and light-olive-gray (5Y 6/1) to pale-yellowish-orange (10YR 8/6), very fine-grained to aphanitic; bedding irregular and lensing; spalls parallel to exposed face; weathers to punky yellow silty clay. Contains many large masses of clear light-brown calcite. Upper 2.5 ft is contorted and contains twisted thin beds of green shale. Top uneven .....	13
41. Shale, dusky-yellow-green (5GY 5/2) .....	.3
40. Limestone, clayey, light-olive-gray (5Y 6/1) and yellowish-gray (5Y 7/2), similar to unit 42. Base irregular, marked by 0.1 to 0.2 ft of green-stained limestone containing irregular patches and veinlets of quartz .....	4.8
39. Limestone, greenish-gray (5GY 6/1), very fine-grained to aphanitic; a single bed; base gradational .....	1
38. Limestone, medium-light-gray (N 6), poorly sorted, medium-grained, clastic. Interbedded greenish-gray (5G 6/1) shale. Sparse endothyrid foraminifers about 3 ft below top .....	4.2
37. Limestone, clayey, yellowish-gray (5Y 7/2) .....	3.2
36. Siltstone, calcitic and dolomitic, dusky-yellow-green (5GY 4/2), thin-bedded; yields platy fragments. Poorly exposed; thickness approximate .....	5.5

TABLE 3.—Continued

	Feet
35. Limestone, olive-gray (5Y 3/2); poorly sorted calcarenite .....	.9
34. Limestone, very clayey, yellowish-gray (5Y 7/2) and pale-yellowish-orange (10YR 8/6); similar to unit 42. Basal 1.0 ft contains calcite- and quartz-filled geodes .....	3.7
33. Shale, dusky-yellow-green (5GY 5/2); pinches out laterally .....	.6
32. Limestone, clayey, light-olive-gray (5Y 5/2) and dusky-yellow (5Y 6/4) .....	.5
31. Shale, silty, grayish-yellow (5Y 4/8) to light-olive (10Y 5/4) .....	1.6
30. Siltstone, calcitic, yellowish-gray (5Y 7/2) and dark-yellowish-orange (10YR 6/6); forms single bed .....	1.3
29. Shale, dusky-yellowish-green (5GY 5/2) and grayish-olive (10Y 4/2), nonresistant; plastic when wet. Upper 0.2 ft glauconitic. Single siltstone bed 0.5 ft thick, 0.5 ft above base .....	3.7
28. Limestone, dolomitic, clayey, dark-yellowish-orange (10YR 6/2), finely crystalline; scattered fragments of bryozoans and brachiopods. Contains nodules, a few inches in diameter, of gray chert with included fossil debris. Unit irregular in thickness .....	2.8
27. Siltstone, grayish-yellow (5Y 8/4) and yellowish-gray (5Y 7/2), brittle. Contains conspicuous subspherical quartz-filled geodes as much as 1 ft in diameter .....	9
26. Limestone, dark-yellowish-orange (10YR 6/6), punky; scattered fragments of crinoids and brachiopods; pinches and swells .....	1
25. Shale, grayish-green (10GY 5/2), irregular, probably discontinuous .....	.3
24. Limestone, dolomitic, pale-yellowish-orange (10YR 8/6); fossil debris in streaks. Thin partings of pale-olive (10Y 6/2) clay shale. Contains platy to nodular masses of partly iron-stained gray chert oriented parallel to bedding .....	9.7
Total Renfro Member .....	<u>82.5</u>
Wildie Member:	
23. Limestone, very silty, yellowish-gray (5Y 8/1) to dark-yellowish-orange (10YR 6/6) glauconite-streaked; a single bed .....	1.5
22. Siltstone, glauconitic, dusky-green (5G 3/2) to greenish-black (5GY 2/1), grading downward into glauconite-streaked gray siltstone .....	.5
21. Claystone, dusky-yellow-green (5GY 5/2) and pale-olive (10Y 6/2) .....	4.7
20. Siltstone, light-greenish-gray (5G 8/1), laminated, interbedded with greenish-gray shale .....	.7
19. Shale, silty; at top, dark-greenish-gray (5G 4/1), mottled grayish-red-purple (5RP 6/2); grades downward into dark-greenish-gray (5G 4/1). Small discoidal phosphatic nodules about 3 ft above base .....	8.9
18. Siltstone, locally slightly calcareous, light-olive-gray (5Y 5/2), dense; in thin even beds; breaks into small blocks. Contains partings and irregularly lensing thin beds as much as 7 in. thick of greenish-gray silty shale, mostly in upper one-third of unit. Base of unit is discordant owing to northward thinning of beds of shale in units 12 through 17 .....	5.2

TABLE 3.—Continued

	Feet
17. Siltstone, glauconitic, greenish-black (5G 2/1)....	.5
16. Shale, light-olive-brown (5Y 5/6) .....	.6
15. Siltstone, siliceous, dark-greenish-gray (5G 4/1)..	.6
14. Claystone, silty, glauconitic, greenish-black (5G 2/1) .....	.2
13. Limestone, glauconitic, dark-yellowish-orange (10YR 6/6), streaked with dark-greenish-gray (5GY 4/1). At base is a concentration of round to subangular, shiny, dark-brown to black phosphatic nodules .....	.6
Total Wildie Member .....	<u>24</u>
Halls Gap Member:	
12. Siltstone and silty shale, micaceous, partly limy, light-bluish-gray (5B 7/1), weathering same or greenish-gray; finely laminated; breaks into platy fragments. Worm (?) trails common; shale units thin northward .....	16.5
Total Halls Gap Member .....	<u>16.5</u>
Nancy Member (incomplete):	
11. Shale, silty to clayey, dark-greenish-gray (5GY 4/1), imperfectly fissile; abundant bryozoans; as much as 4 ft thick .....	2.5
10. Siltstone, greenish-gray (5G 6/1), finely laminated; breaks into small blocks. Limonite-stained joint surfaces .....	1.2
9. Shale, similar to unit 11 .....	3.9
8. Siltstone, micaceous; similar to unit 10. <i>Zoophycos</i> ("rooster-tail" marking) common .....	1.3
7. Shale, similar to unit 11. Abundant lentils, as thick as 1 ft, of very fine-grained limestone, light-olive-gray (5Y 6/1), limonitic; bryozoans abundant; crinoid stems common .....	21.2
6. Covered, probably shale .....	23
5. Gum Sulphur Bed: Siltstone, greenish-gray (5GY 6/1); limonite-stained joint surfaces; imperfectly fissile; fossiliferous, mainly brachiopods. At base are lentils, as thick as 1 ft, of grayish-olive (10Y 4/2) fossiliferous, very fine-grained limestone. Siliceous nodules, as much as 2 in. in diameter, common .....	12
4. Shale, silty, greenish-gray (5GY 6/1) and dark-greenish-gray (5G 4/1); breaks into rough plates and small blocks; limonite-stained joints; less resistant than above but more resistant than below .....	7.4
3. Shale, silty, medium-bluish-gray (5B 5/1) weathering about same and pale-olive; imperfectly fissile .....	2.9
2. Shale, silty; similar to unit 4; abundant limonite spots; <i>Zoophycos</i> common; forms conspicuous resistant bed .....	1.8
1. Shale, silty, medium-bluish-gray (5B 5/1) to dark-greenish-gray (5GY 4/1), weathering same or lighter; imperfectly fissile; spalls along curved surfaces; abundant limonite spots. About 6 ft above base is resistant rib of clayey shale about 1 ft thick. Base of local exposure, not base of member .....	12.8
Measured Nancy Member (incomplete) .....	<u>90</u>
Measured Borden Formation (incomplete) .....	213

TABLE 4. INDIAN FORT MOUNTAIN SECTION

	Feet
Units 1 and 2 measured along road to reservoirs in Cowbell Creek joining Ky. 21 about 0.9 mile west of village of Bighill, Madison County, Ky. (Bighill quadrangle); units 3 and 4 measured westward along Ky. 21 to top of hill; units 5 through 8 measured along forest road up south point of Indian Fort Mountain, beginning about 300 feet west of high point on highway; units 9 through 19 measured along abandoned road branching off newer forest road; section then offset to foot trail up southwest spur of south point of Indian Fort Mountain; units 20 through 22 measured along this trail; units 23 and 24 measured over cliff on northwest side of this trail. Measured with barometer, Jacob staff, and tape by C. W. Weir and J. L. Gualtieri, assisted by D. R. Siegle, June 1963. Revised slightly from Weir and others (1966, p. 24-28).	
Newman Limestone (incomplete):	
St. Louis Limestone Member:	
24. Limestone, cherty, very light-brownish-gray (5YR 7/1) and olive-gray (5Y 5/1) to yellowish-gray (5Y 8/1), chiefly micrograined, in part fine- to medium-grained. Common to abundant grayish-orange chert in irregular masses commonly about 1 ft long and 2 in. thick and as replacement of abundant colonial corals .....	7.7
23. Limestone, very light-greenish-gray (5GY 7/1), fine- to medium-grained; sparse medium to coarse grains of orange chert; in beds 1 to 8 in. thick; sparse small brachiopods. Some clayey layers 1 to 4 in. thick interbedded with thin seams of grayish-yellow-green (5GY 7/2) claystone; common crinoids and bryozoans in clayey limestone and as impressions in the claystone. Base undulatory; thickness ranges from 2 to 2.5 ft. ....	<u>2.3</u>
Total St. Louis Limestone Member of Newman Limestone .....	<u>10</u>
Borden Formation:	
Renfro Member:	
22. Limestone, clayey, dolomitic, dark-yellowish-orange (10YR 6/6), very fine-grained, silty and clayey; in uneven beds 1 to 4 in. thick; fairly resistant except in top 5 ft. ....	17
21. Poorly exposed, probably most is yellowish clayey dolomitic limestone similar to overlying and underlying units. About 1 ft above base is clayey limestone, pale-greenish-yellow (10Y 3/2), very fine-grained; contains abundant discoidal nodules of chert as much as 3 in. across and ½ in. thick. About 4 ft above base is limestone, light-olive-gray (5Y 6/1), micrograined to very fine-grained; a resistant bed about 0.2 ft thick .....	5.5
20. Limestone, clayey, dolomitic, generally similar to limestone of unit 22 but nonresistant, mostly punky-weathering. Scattered irregular patches of light-gray chert about 1 in. thick and as much as 12 in. long at 12 to 15 ft above base. On original line of section basal layer of clayey limestone, 0.1 to 0.3 ft thick, is silicified to pinkish-gray (5YR 8/1) chert .....	27.5
Total Renfro Member .....	<u>50</u>
Nada Member:	
19. Claystone, glauconitic, silty, grayish-yellow-green (5GY 7/2); disseminated grains and streaks of grayish-olive-green (5GY 3/2) glauconite; non-resistant .....	.3

TABLE 4.—Continued

TABLE 4.—Continued

	Feet
18. Siltstone, pale-olive (10Y 6/2), weathering light-olive-gray (5Y 5/2) with surface blotches of grayish orange or grayish yellow; coarse silt; internal layering obscure; nonfissile, a "free-stone"; contains a few worm (?) markings; forms prominent ledge. Abundant small irregular concretionary nodules embedded in upper surface; dark-gray (N 3), weathering lighter gray; silicified; probably phosphatic; mostly 1/4 to 3/4 in. in diameter. Unit thickens to 0.8 ft 10 ft east of line of section .....	.4
17. Siltstone, clayey, yellowish-gray (5Y 7/4), very thinly bedded; splits along irregular planes about 1/4 in. apart; forms slope .....	2.4
16. Siltstone, similar to unit 18 .....	.5
15. Siltstone, clayey, similar to unit 17 .....	9.3
14. Siltstone, similar to unit 18 .....	.2
13. Siltstone, clayey, similar to unit 17 .....	.8
12. Siltstone, similar to unit 18 .....	.8
11. Siltstone, similar to unit 17 but less clayey .....	7.7
10. Mudstone, silty (60 percent), leached limestone (30 percent), and siltstone (10 percent). From base upward: Siltstone with abundant silt-sized to medium grains of greenish-black glauconite, mostly dusky-green (5G 3/2), in less glauconitic portions pale-yellowish-brown (10YR 6/2); about 2 in. thick. Mudstone, silty, glauconitic, poorly exposed; about 20 in. thick. Leached limestone, weathered to dark-yellowish-orange (10YR 6/6). Unit is Floyds Knob Formation as used by Stockdale (1939, p. 175) .....	2.6
9. Shale, clayey; near base dark-greenish-gray (5GY 4/1), mottled brownish-black (5YR 2/1); upper half moderate-olive-brown (5YR 4/4) and grayish-red (10R 4/2) to moderate-brown (5Y 4/4); very slightly silty; laminated; outcrop yields thin chips less than 1/2 in. across. Phosphatic nodules, greenish-gray (5GY 6/1), ovoid, commonly about 1/2 in. in diameter and 1 in. long; abundant on weathered slope in basal few feet of unit. Well to poorly exposed; nonresistant; forms narrow bench at base, moderate slope above .....	22
Total Nada Member .....	47
Cowbell Member:	
8. Siltstone, mostly pale-olive (10Y 6/2) and light-olive-gray (5Y 6/1), grading at top to grayish-olive (10Y 4/2) with common dark-brown limonite stain on bedding planes and fracture surfaces; bedding partly obscure, mostly in slightly uneven beds 1/4 to 2 in. thick; splits along bedding and along irregular fracture surfaces 1/4 in. to 3 in. apart; outcrop yields plates and irregular blocks commonly 1/4 to 1/2 in. thick and 1 to 3 in. across; moderately resistant, forms steep slope. Fossils common near base and abundant near top, chiefly small brachiopods less than 1 in. wide, crinoid columnals, and sparse small tubular bryozoans a few mm wide; mostly preserved as molds. Top of unit marked by pronounced flattening of slope .....	43

	Feet
7. Siltstone, clayey, moderate-yellowish-brown (10Y 5/4) to pale-olive (10Y 6/2); very fine mica-ceous flakes in basal 10 ft; less resistant than underlying or overlying units but otherwise generally similar to them; poorly exposed in eroded roadbed. Dark-brown ovoid limonite concretions, with conspicuous layered structure, about 3 to 4 in. thick and 10 to 12 in. long, occur about 35 ft above base. Unfossiliferous .....	47
6. Siltstone (85 percent) and clayey siltstone (15 percent); at base moderate-olive-brown (5Y 4/4); mostly yellowish-gray (5Y 7/2) to greenish-gray (5GY 6/1) or pale-olive (10Y 6/2); dark-brown limonite stain common on bedding planes and fracture surfaces; clayey in basal 7 ft; mostly in very thin beds 1/8 to 1/2 in. thick; splits along bedding planes and irregular surfaces about 1 1/2 in. apart; outcrop yields chips and plates 1 to 3 in. across; fairly well exposed along forest road; moderately resistant, forms steep slope. Limonite concretions, yellowish-gray and dark-brown, in solid spindly bodies as much as 1 1/4 in. in diameter and 3 in. long, occur sparsely about 37 ft above base; in part sideritic; some have casts of small gastropods at centers. Concretionary bodies of very limy siltstone, greenish-gray (5GY 6/1), as much as 1 ft thick, 1.5 ft long; weather to rounded surfaces at 51 ft above base. Fossils sparse, consisting of gastropods, curly worm (?) marks, and <i>Zoophycos</i> ("rooster-tail" marking) in upper part of unit .....	55
Total Cowbell Member .....	145
Nancy Member:	
5. Shale, clayey, grading upward to silty clay shale; mostly dark-greenish-gray (5GY 4/1) to brownish-gray (5YR 4/1) with sporadic reddish streaks; near top chiefly pale-yellowish-brown (10YR 6/2) to dark-yellowish-brown (10YR 4/2); very slightly silty grading to silty at top; in laminae 3 to 5 mm thick; splits along laminae or irregular surfaces 1/4 to 1 in. apart; outcrop yields small platy fragments 1/16 to 1 in. across and irregular blocks commonly about 1 in. thick and 3 in. long; mostly weathers to yellowish-gray soil with minute shale fragments; poorly exposed; nonresistant, forms gentle slope. Upper boundary broadly gradational through about 30 ft as clay shale grades upward to siltstone; contact arbitrarily placed at base of lowest relatively persistent siltstone ..	28
4. Shale, greenish-gray (5GY 6/1) and pale-olive (10Y 6/2), weathering same; very slightly silty; more fissile than underlying shale, yields chips a few millimeters thick and a few inches across. Iron concretions common, sporadically distributed; interiors olive-gray (5Y 5/1), surfaces shades of red and brown; ovoidal, commonly 3 to 6 in. in diameter, 6 to 12 in. long. Well exposed in roadcut at top of hill on highway. Sparse to common curly worm (?) marks in upper part of unit .....	38

TABLE 4.—Continued

	Feet
3. Shale, clayey, pale-olive (10Y 6/2) and near top olive-gray (5Y 5/1), weathering chiefly yellowish-gray (5Y 7/2). Mostly covered, about 25 percent outcrop; seems similar to underlying unit .....	122
2. Shale, clayey, chiefly pale-olive (10Y 6/2), dusky-yellow at base; mostly clayey but slightly silty at base; in rough laminae 1/16 to 1/4 in. thick; yields small chips a few mm thick and 5 to 15 mm across. Sparse phosphatic nodules at base; moderate-yellowish-brown (10YR 5/2) interior, light-gray (N 4) surface; fine silt; ovoidal, about 1 in. maximum diameter .....	12
Total Nancy Member .....	200
Total Borden Formation .....	442
New Albany Shale (incomplete):	
1. Shale, dark-gray (N 3), weathering lighter gray and brownish-gray (5YR 4/1); laminated; brittle, yielding small plates a few mm thick and as much as 3 in. across on weathered outcrops. Not measured; about 20 ft exposed locally.	

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**FIELD TRIP NO. 4**  
**PALEOZOIC SECTION ON EAST FLANK OF CINCINNATI ARCH**  
**ALONG INTERSTATE 64, LEXINGTON TO OLIVE HILL, KENTUCKY**

**Part I: Lexington Eastward to Valley of Licking River\***

**GORDON W. WEIR**  
 U. S. Geological Survey, Berea, Kentucky

**ROAD LOG**

*Milepost*

79.0± Interstate 75, Interstate 64 interchange. Turn east on Interstate 64 toward Winchester and Ashland, Ky. The geology of the next 9 miles is shown on geologic maps of the Lexington East quadrangle (MacQuown and Dobrovoly, 1968) and the Clintonville quadrangle (MacQuown, 1968). Small scattered outcrops along Interstate 64 are mostly rubbly-weathering, gray, nodular-bedded, fine- to medium-grained limestone and shale of the Millersburg Member of the Lexington Limestone. Intertongued with the Millersburg is fairly resistant, ledge-forming, light-gray, medium- to coarse-grained skeletal limestone of the Tanglewood Limestone Member of the Lexington Limestone. The best exposures of the Lexington Limestone are near Winchester (miles 91.9 and 93.0). Some of the higher hilltops are capped by thin-bedded, fine-grained limestone and shale of the Clays Ferry Formation. An almost fully exposed section of the Clays Ferry Formation is to be seen north of Winchester (miles 100.1-101.5).

87.2 Exit to Lexington Army Depot.

87.3 Underpass.

90.5 Exit to Winchester via Van Meter Road. From this point to near Morehead the field trip passes through unmapped quadrangles. Road log based on stratigraphic reconnaissance

by R. C. Greene, J. H. Peck, G. C. Simmons, and G. W. Weir; stratigraphic nomenclature in part tentative. Some of the regional relations of lithofacies of the Upper Ordovician rocks along this route have been sketched by Weir and Peck (1968). Figure 1 shows the route traversed by Parts I and II of this field trip.

90.6 Underpass.

91.9 Entrance from Van Meter Road.

**OPTIONAL STOP A**

*Lithologies of the Lexington Limestone*

Rubbly-weathering, nodular-bedded, fossiliferous, silty fine-grained limestone is Millersburg Member of Lexington Limestone. Near top of cut are interbeds of coarse-grained fossil-fragmental calcarenite, probably tongues of the Tanglewood Limestone Member of the Lexington Limestone. Nodular-bedded limestone, the characteristic lithotype of the Millersburg, recurs higher in the section in the Grant Lake Limestone (mile 109.9) and in the Bull Fork Formation (mile 114.3).

*Milepost*

93.1 Underpass.

93.5 Exit to Winchester via U. S. 227.

93.7 Underpass.

94.0 Entrance from U. S. 227. Poor exposures of basal part of Clays Ferry Formation; unit better exposed at mile 98.2.

94.6 Folded and faulted beds are limestone, siltstone, and shale of the Clays Ferry Formation.

\* Publication authorized by the Director, U. S. Geological Survey.

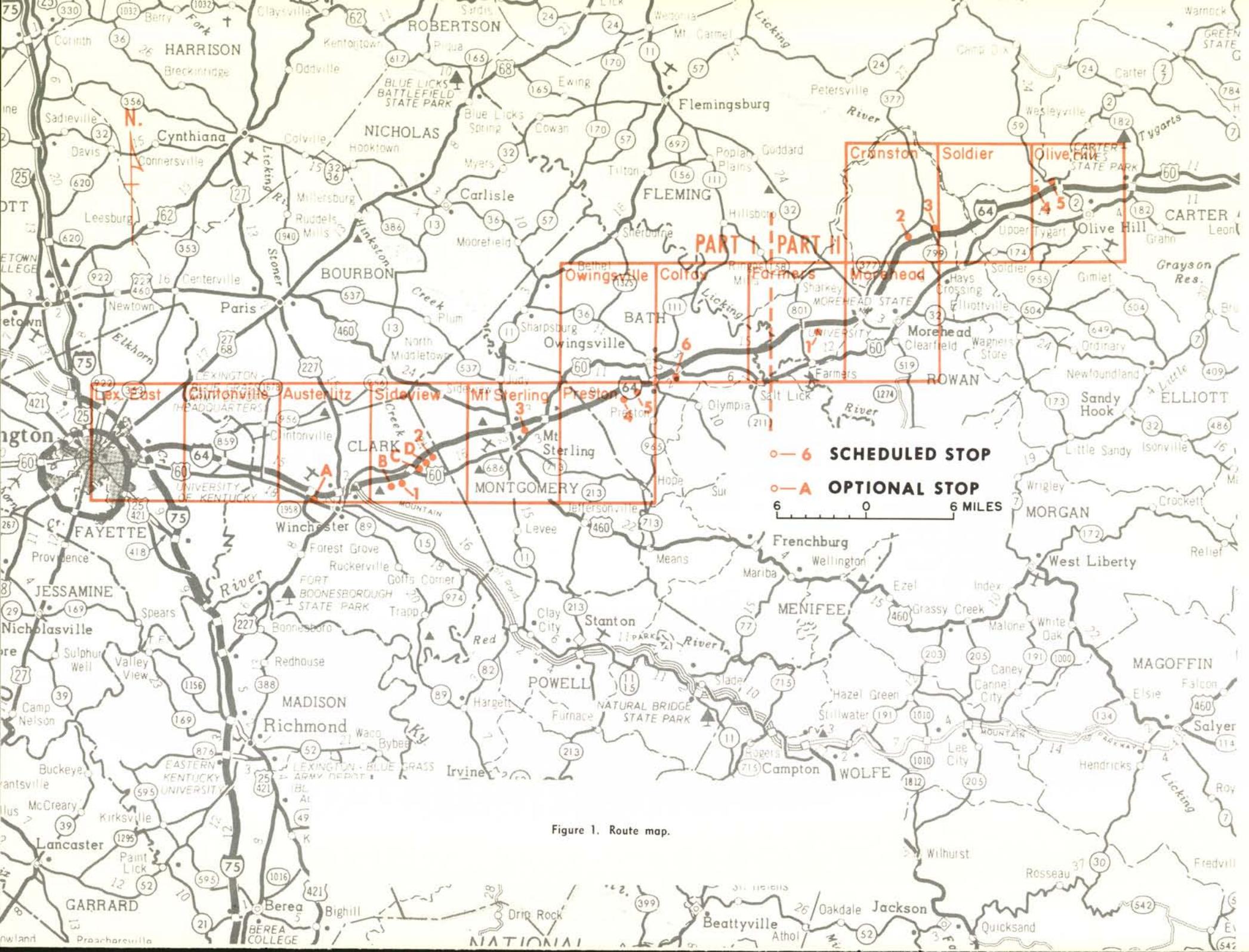


Figure 1. Route map.

- 94.7 Underpass. Clays Ferry Formation. Beds nearly horizontal.
- 95.0 Junction with Mountain Parkway. Top of Lexington Limestone in first cut on parkway.
- 95.5 Rest area to right. Outcrops from this point to near Montgomery County line are, unless otherwise noted, Clays Ferry Formation.
- 96.7 Underpass.
- 97.1 Zone of ball-and-pillow structures ("flow rolls") in limy siltstone of Clays Ferry Formation. Deformed siltstone beds are similar to Garrard Siltstone which is about 100 feet above this zone.
- 98.2 Clays Ferry Formation conformably overlying Lexington Limestone.

#### OPTIONAL STOP B

##### *Contact between Clays Ferry Formation and Lexington Limestone*

Contact is conformable, fairly sharp. Elsewhere in central Kentucky these formations intertongue and intergrade (Black and others, 1965; Black and MacQuown, 1965). Percentage of limestone in basal Clays Ferry is higher here than is characteristic of this formation.

##### *Milepost*

- 98.8 Stop 1.

#### STOP 1

##### *Characteristic lithology of the Clays Ferry Formation*

Clays Ferry Formation generally consists of thin beds of micrograined to coarse-grained limestone, in part sheathed with laminae of limy silt, intercalated with thin sets of calcitic shale. Percentage of shale and siltstone much higher than near base.

##### *Milepost*

- 99.3 Underpass.
- 100.1 Bridge over Stoner Creek.

#### OPTIONAL STOP C

##### *Section of Clays Ferry Formation*

Nearly complete exposure of Clays Ferry Formation in next 1.5 miles. Contact between Clays Ferry Formation and Lexington Limestone is exposed under bridge.

##### *Milepost*

- 101.0 Optional Stop D.

#### OPTIONAL STOP D

##### *Lithology characteristic of Kope Formation*

Note in outcrops along westbound lanes that shale units are thicker and more conspicuous. The Clays Ferry Formation at its type section on Interstate 75 about 15 miles southeast of Lexington is characterized by fairly thin units of shale, commonly 1 to 3 feet thick (Weir and Greene, 1965). Generally equivalent strata along the Ohio River are assigned to the Kope Formation, which is characterized in part by fairly thick shale units (Weiss and Sweet, 1964). The Kope and Clays Ferry presumably intergrade laterally, but the detailed relations between them are unknown and probably will remain obscure because these formations crop out poorly. The relatively thick shale units cropping out in this section suggest that the Kope Formation may here in part overlie the Clays Ferry Formation.

##### *Milepost*

- 101.5 Underpass.

#### STOP 2

##### *Contact between Garrard Siltstone and Calloway Creek Limestone*

Garrard is dominantly very limy siltstone, characterized by ball-and-pillow structure (Fig. 2); the formation apparently pinches out a short distance northwest of Owingsville. Contact between Calloway Creek Limestone and Garrard is commonly gradational through 5 to 20 feet; arbitrarily placed at base of lowest relatively persistent bed of limestone. Northward the closely intercalated thin planar and nodular beds of limestone characteristic of the Calloway Creek give way to thicker planar beds of limestone separated by sets of shale and siltstone characteristic of the Fairview Formation (Peck, 1966). The Calloway Creek and Fairview thus intergrade laterally and are separated by an arbitrary vertical cutoff tentatively placed near Owingsville.

##### *Milepost*

- 101.8 Montgomery County line. See Figure 3 for generalized stratigraphic section for Mount Sterling-Owingsville area.
- 101.9 Clays Ferry Formation outcrop.
- 103.0 Bridge over creek.
- 103.5 Calloway Creek Limestone in roadcut for the next several miles.
- 106.5 Grant Lake Limestone (Peck, 1966), overlying Calloway Creek Limestone. Lithology is gradational. Contact, about 3 feet below top

Previous nomenclature (Hall and Palmquist, 1960; McFarlan and Campbell, 1955)	System	Formation and member		Lithology	Thickness, in feet
Ohio Shale	Devonian	Ohio Shale			140-180
Boyle Limestone		Boyle Dolomite			0-10
Crab Orchard Group	Silurian	Crab Orchard Formation			40-70
Brassfield Limestone		Brassfield Dolomite			20±
Elkhorn Formation	Ordovician	Drakes Formation	Preachersville Member		40-80
Whitewater and Liberty Formations, undifferentiated					
Waynesville Limestone		Bull Fork Formation	Sunset Member		40-80
Arnheim Formation					0?-25
Mc Millan Formation		Grant Lake Limestone	Tate Member Back Bed		80-100
					20-50
Fairview Formation		Calloway Creek Limestone (or Fairview Formation)			60-100
Garrard Sandstone		Garrard Siltstone			0-10
Million Shale		Clays Ferry Formation (and/or Kope Formation?)			150-200

Figure 2. Generalized stratigraphic section in area between Mount Sterling and Owingsville.



Figure 3. Planar-bedded limestone and shale of Calloway Creek Limestone (above hammer) overlying contorted beds (ball-and-pillow structure) of Garrard Siltstone. Westbound lanes of Interstate 64 at mile 101.5, opposite Stop 2.

of cut, placed so as to separate nodular-bedded, silty, micrograined to medium-grained limestone of Grant Lake from the more planar-bedded limestone and shale of the Calloway Creek.

- 106.9 Turnoff to Flemingsburg and Mount Sterling.
- 107.1 Underpass. Grant Lake Limestone overlying Calloway Creek Limestone; contact about 3 feet above road. Nodular bedding is characteristic of Grant Lake.
- 107.6 Tate Member of Grant Lake Limestone.
- 107.8 Tate Member of Grant Lake Limestone as at mile 107.6.
- 107.9 Grant Lake Limestone overlying Calloway Creek Limestone. Lithology transitional.
- 108.5 Underpass.

### STOP 3

#### *Tate Member of Grant Lake Limestone*

Limy mudstone and rubbly-weathering limestone. Rubbly-weathering limestone near middle of cut is Back Bed of the Tate Member (Fig. 4). This bed persists as an identifiable unit to near Stanford about 80

miles southwest and to near Owingsville about 20 miles to the northeast. The limy mudstone of the Tate grades out into limestone in the Sherburne quadrangle (Outerbridge, in press), about 10 miles north of Owingsville. Near Winchester most of the Ashlock Formation grades laterally into the Grant Lake Limestone, a sequence of limy and dolomitic mudstone and limestone (Weir and others, 1965). Southwest of Winchester the Tate is a member of the Ashlock Formation.

#### *Milepost*

- 108.9 Calloway Creek Limestone in cuts along westbound lanes.
- 109.2 Transition between Grant Lake Limestone and Calloway Creek Limestone in lower part of cut along westbound lanes.
- 109.7 Exit to U. S. 60.
- 109.9 Underpass. Rubbly-weathering, nodular-bedded, silty limestone characteristic of the Grant Lake Limestone. More silty and more clearly nodular bedded than at base.
- 111.0 Grant Lake Limestone in cut. Regional dip is to northeast.
- 111.2 Grant Lake Limestone in cut.
- 111.5 Sunset Member (micrograined limestone and siltstone) of Bull Fork Formation overlying Grant Lake Limestone. Large stromatoporoids locally abundant at base of Sunset and at top of Grant Lake. Contact placed so as to separate planar to lenticular beds of micrograined limestone of Sunset from more distinctly nodular-bedded, more silty, micrograined to fine-grained limestone of Grant Lake. (See Stop 4 at mile 115.0.) Bull Fork

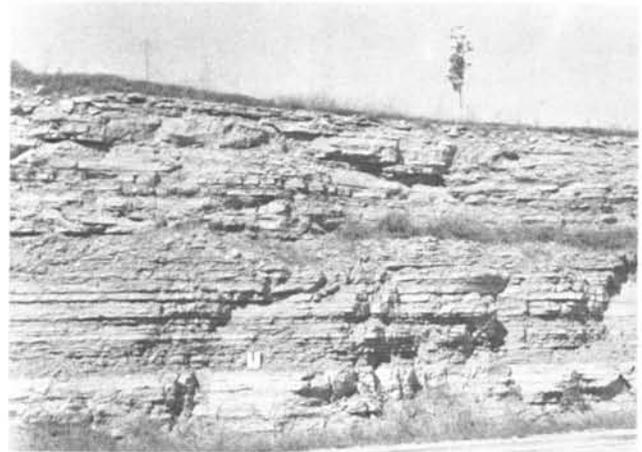


Figure 4. Tate Member of Grant Lake Limestone. Back Bed of Tate Member (above hammer) is limestone unit in middle of cut. Westbound lanes of Interstate 64 at mile 108.5, opposite Stop 3.

Formation is characterized by planar- to nodular-bedded micrograined and fine- to medium-grained, commonly silty, fossiliferous limestone interbedded with thin sets of shale. (See Stop 6 at mile 120.1.)

- 111.9 Sunset Member of Bull Fork Formation overlying the Grant Lake Limestone. Contact is near middle of cut about 5 feet below shaly siltstone.
- 112.4 Bull Fork Formation in cuts on both sides of highway. Blocky-weathering planar beds make up a readily identified local unit.
- 113.1 Bath County line.
- 113.2 Preachersville Member of Drakes Formation in cut. Preachersville consists of dolomitic mudstone and resistant planar beds of muddy dolomite (Weir and others, 1965).
- 113.4 Brassfield Dolomite (Lower Silurian) at top of cut. Light-brown, orange-weathering, fine- to medium-grained dolomite in fairly even beds separated by partings and minor seams of gray shale. A few beds in lower part contain thin concretionary layers of white chert. (See Stop 5 at mile 116.9.)
- 113.6 Preachersville Member of Drakes Formation in cut.
- 113.9 Underpass. Preachersville Member of Drakes Formation in cut.
- 114.0 Preachersville Member of Drakes Formation in cut.
- 114.2 Drakes Formation conformably overlying Bull Fork Formation. Contact about 20 feet above road level. (See Stop 6 at mile 120.1.)
- 114.3 Bull Fork Formation here includes a unit of nodular-bedded limestone similar to units noted previously in the Grant Lake Limestone and the Millersburg Member of the Lexington Limestone.
- 114.6 Minor faults in Bull Fork Formation displace section down about 20 feet on north.
- 114.8 Drakes Formation overlying Bull Fork Formation. Contact just above road level.
- 114.9 Contact between Drakes Formation and Bull Fork Formation is about 15 feet above road.
- 115.0 Stop 4.

#### STOP 4

##### *Sunset Member of Bull Fork Formation*

Resistant fine-grained and micrograined limestone and limy siltstone make up Sunset Member. Top 3

feet of Grant Lake Limestone just below conspicuous stromatoporoid-bearing unit at north end of cut. (See general remarks at mile 111.5.)

##### *Milepost*

- 115.2 Bridge over creek.
- 115.7 Bridge over creek.
- 115.9 Bull Fork Formation. Blocky-weathering, planar-bedded unit noted previously is conspicuous here.
- 116.0 Bull Fork Formation. Top of blocky-weathering, planar-bedded unit.
- 116.4 Sign "Owingsville, Frenchburg exit, 2 miles." Preachersville Member of Drakes Formation in cut. Near top is Brassfield Dolomite; top-most exposures are of the Crab Orchard Formation (Lower and Middle Silurian), including, at the base, claystone of the Plum Creek Member overlain by the Oldham Limestone Member as used by Foerste (1906).
- 116.5 Cherty dolomite of the Brassfield Dolomite at road level.
- 116.9 Stop 5.

#### STOP 5

##### *Contact between Drakes Formation and Brassfield Dolomite*

Brassfield Dolomite overlies Preachersville Member of Drakes Formation at road level. Crab Orchard Formation underlies grassy slope ahead to right; chert-bearing dark-red soil at top of cut is weathered Boyle Dolomite (Middle Devonian).

##### *Milepost*

- 117.4 Bridge.
- 117.7 Bull Fork Formation in cuts on westbound lanes.
- 118.2 Brassfield Dolomite poorly exposed just above road. A few patches of greenish-gray shale and orange-brown dolomite are characteristic of outcrops of Crab Orchard Formation. Red soil at top of cut above westbound lanes is probably from weathered Boyle Dolomite.
- 118.4 Exit to Owingsville via Ky. 36. Preachersville Member of Drakes Formation in cut.
- 118.7 Underpass.
- 119.0 Entrance from Ky. 36.
- 119.2 Bridge.
- 119.6 Bull Fork Formation in cuts. Conspicuous zone, 1 to 2 feet thick, of stromatoporoid-bearing beds.

- 119.9 Preachersville Member of Drakes Formation (about 60 feet thick) fully exposed. Gradationally overlies Bull Fork Formation about 15 feet below top of cut.
- 120.1 Exit to Owingsville via U. S. 60.

**STOP 6**

Contact between Bull Fork Formation and Drakes Formation; cut-and-fill structure in Bull Fork Formation

Contact is just above bench about 15 feet above south end of cut. Contact placed at top of unit of mudstone containing lenticles of fossiliferous limestone (see Fig. 5). Dolomite and mudstone above is Preachersville Member of Drakes Formation. Rowland Member of Drakes Formation, dolomitic and calcitic mudstone (Weir and others, 1965), is not present here; it apparently grades northward into the lower part of the Preachersville Member near Mount Sterling. Walk down section along exit road to U. S. 60. Examine characteristic lithology of Bull Fork Formation and

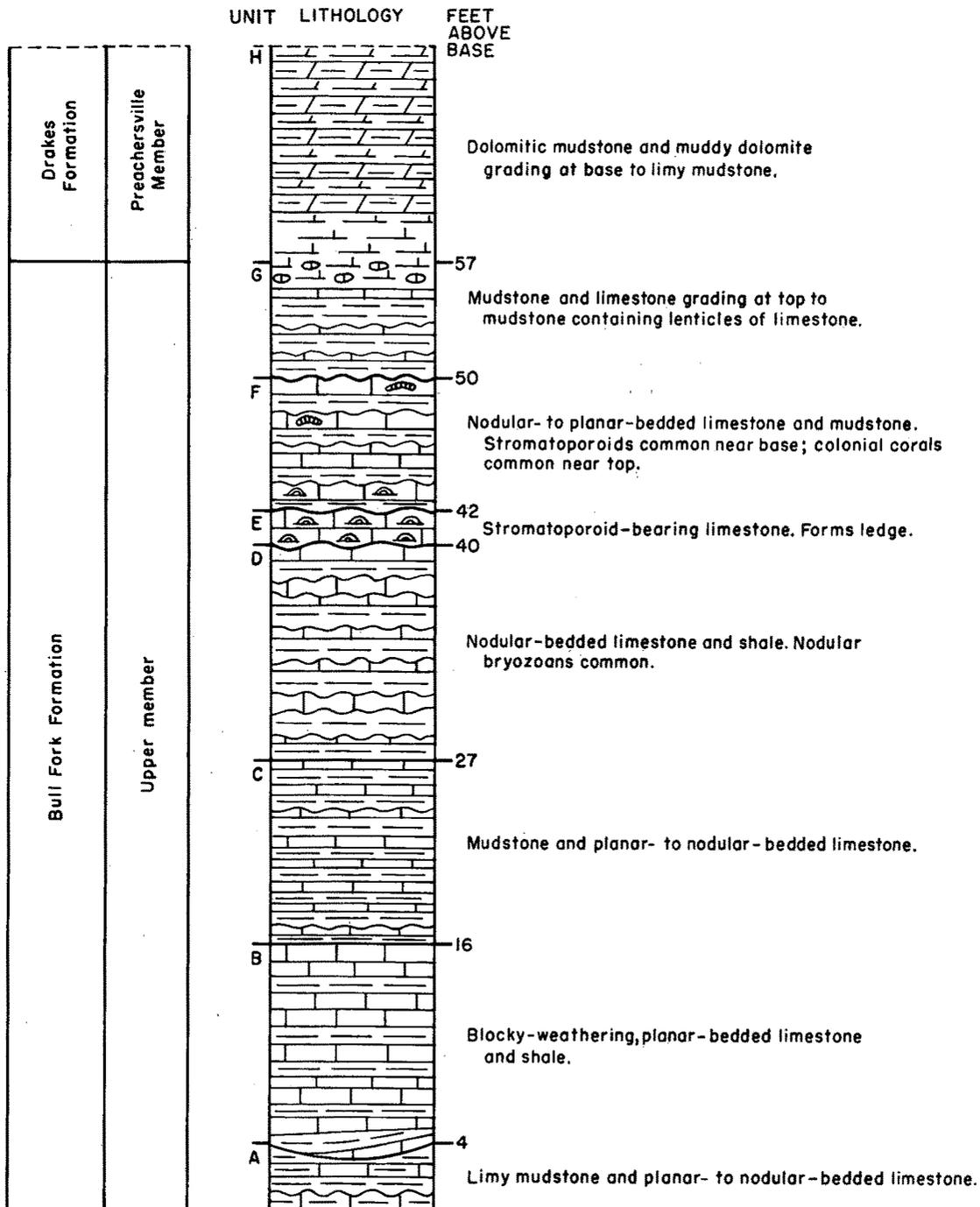


Figure 5. Section exposed along exit road to U. S. 60 (Stop 6).

cut-and-fill structure near intersection. Stromatoporoid-bearing unit conspicuous at road level on Interstate 64 is apparently restricted to area only a few miles in diameter. Below the stromatoporoid zone is rubbly-weathering, nodular-bedded silty limestone similar to lithologies of the Grant Lake Limestone and Millersburg Member of the Lexington Limestone. Below the nodular-bedded limestone, at the north end of the first cut and the south end of the second cut, is a unit of blocky-weathering, planar-bedded limestone that has been recognized widely in the Owingsville area. This unit makes up the fill of the cut-and-fill structure near the junction with U. S. 60. Cut-and-fill structures are not known elsewhere in the Bull Fork Formation.

#### Milepost

- 120.3 Underpass.
- 120.6 Entrance from U. S. 60.
- 120.9 Preachersville Member of Drakes Formation. Brassfield Dolomite at top of cut in westbound lanes.
- 121.2 Poorly exposed greenish-gray shale and grayish-orange dolomite of the Crab Orchard Formation in cut. These outcrops are characteristic of the exposures from here to north of the Licking River. The highway passes through an area of low relief constructed on Silurian Brassfield and Crab Orchard Formations and locally mantled with Quaternary deposits.
- 122.2 Underpass.
- 124.7 Fair exposure of Crab Orchard Formation in cut.
- 126.0 Underpass (Ky. 211). Valley of the Licking River. Extensive alluvial flats.
- 126.4 Bridge over the Licking River.
- 127.8 Underpass.
- 127.9 Ohio Shale (Upper Devonian) unconformably overlying Crab Orchard Formation. Boyle Dolomite is missing. Exposed Crab Orchard Formation here made up of light-gray shale and thin beds of dark-gray, very fine-grained dolomite. Characteristic lithology of Ohio Shale is black, carbon-rich, thinly laminated shale. About 6 feet above base of Ohio is a local unit, 9 feet thick, of greenish-gray shale with thin interbeds, about 1 inch thick, of black shale.
- 128.0 Top of greenish-gray shale unit in Ohio Shale.

## Part II: Valley of Licking River Eastward to Olive Hill Interchange

JOHN C. PHILLEY

Morehead State University, Morehead, Kentucky

#### Milepost

- 128.7 Ohio Shale with greenish-gray shale unit near base of cut.
- 129.2 Ohio Shale.
- 129.6 Ohio Shale.
- 129.9 Section in roadcut along westbound lanes, from bottom to top: Ohio Shale, Bedford Shale, Sunbury Shale, and Farmers Member of Borden Formation.
- 130.2 Basal part of Nancy Member of Borden Formation.
- 130.3 Underpass (Ky. 801).
- 130.8 Nancy Member.
- 131.5 Nancy Member.
- 131.9 Exposures of Farmers Member of Borden Formation and underlying Sunbury Shale.
- 132.3 Stop 1.

#### STOP 1

*Bratton Branch section: Farmers Member of the Borden Formation (Figs. 6 and 7)*

At this stop, along the westbound lanes, as well as in many of the roadcuts eastward, the basal member of the Borden Formation, the Farmers, is well exposed. Also, the underlying Sunbury Shale and the upper part of the Bedford Shale are exposed.

The Farmers was recently redefined by Peck (in press) to include not only the exceptionally even-bedded siltstone but the underlying thin shale unit that had been previously called (Hyde, 1915) the Henley Shale Member of the Cuyahoga Formation and had been excluded from the Farmers Siltstone Member of the New Providence Formation as defined by Stockdale (1939).

*Taonurus*, the problematic trace fossil, and substra-tal lineations are found on bedding surfaces of many

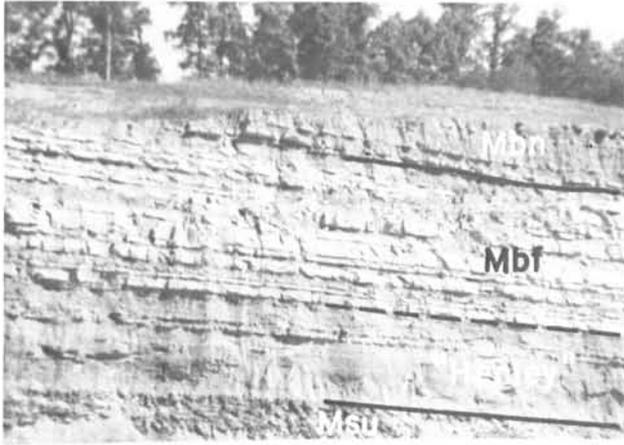


Figure 6. Exposures at the Bratton Branch section, Stop 1 (mile 132.3, westbound lanes). Mbn, Nancy Member of Borden Formation; Mbf, Farmers Member of Borden; Msu, Sunbury Shale.

of the siltstone layers. Worm-grazing trails and water-agitated vegetation are popular explanations for *Taonurus*.

Moore and Clarke (in press) determined the paleocurrent direction from substratal lineations of the Farmers Member in eastern Kentucky and southern Ohio (Fig. 8). The directions showed slight local variations, but everywhere the trend was from east to west with a mean vector between N 100° W and N 80° W. A consistent movement of the siltstone constituents was indicated toward what is now the center of the Cincinnati arch, down a paleoslope from east to west. Furthermore, the paleocurrent data suggest a source in the region of the present Appalachian fold system.

Substratal lineations, subtle graded bedding, and other features suggest a turbidity-current origin for these siltstone beds. These were compared by Moore and Clarke (in press) to some 19 flysch-type features listed by Cline (1966, p. 94) to support the conclusion that the siltstone beds of the Farmers are turbidites.

Casual observation of the published U. S. Geological Survey-Kentucky Geological Survey geologic quadrangles in northeastern Kentucky reveals that the Farmers Member, particularly the siltstone beds, thickens markedly eastward. For example, in the Head Of Grassy quadrangle (Morris, 1966), about 15 miles to the northeast, the member is more than 200 feet thick.

Below the Farmers Member is the black fissile carbonaceous Sunbury Shale, which is underlain by the greenish-gray Bedford Shale containing numerous pyrite nodules. However, the Bedford is poorly exposed here, and the Berea Sandstone, which is present in eastward quadrangles, has apparently pinched out. The stratigraphic relationship between the Berea

Sandstone and the Bedford Shale is illustrated in Figure 9.

#### Milepost

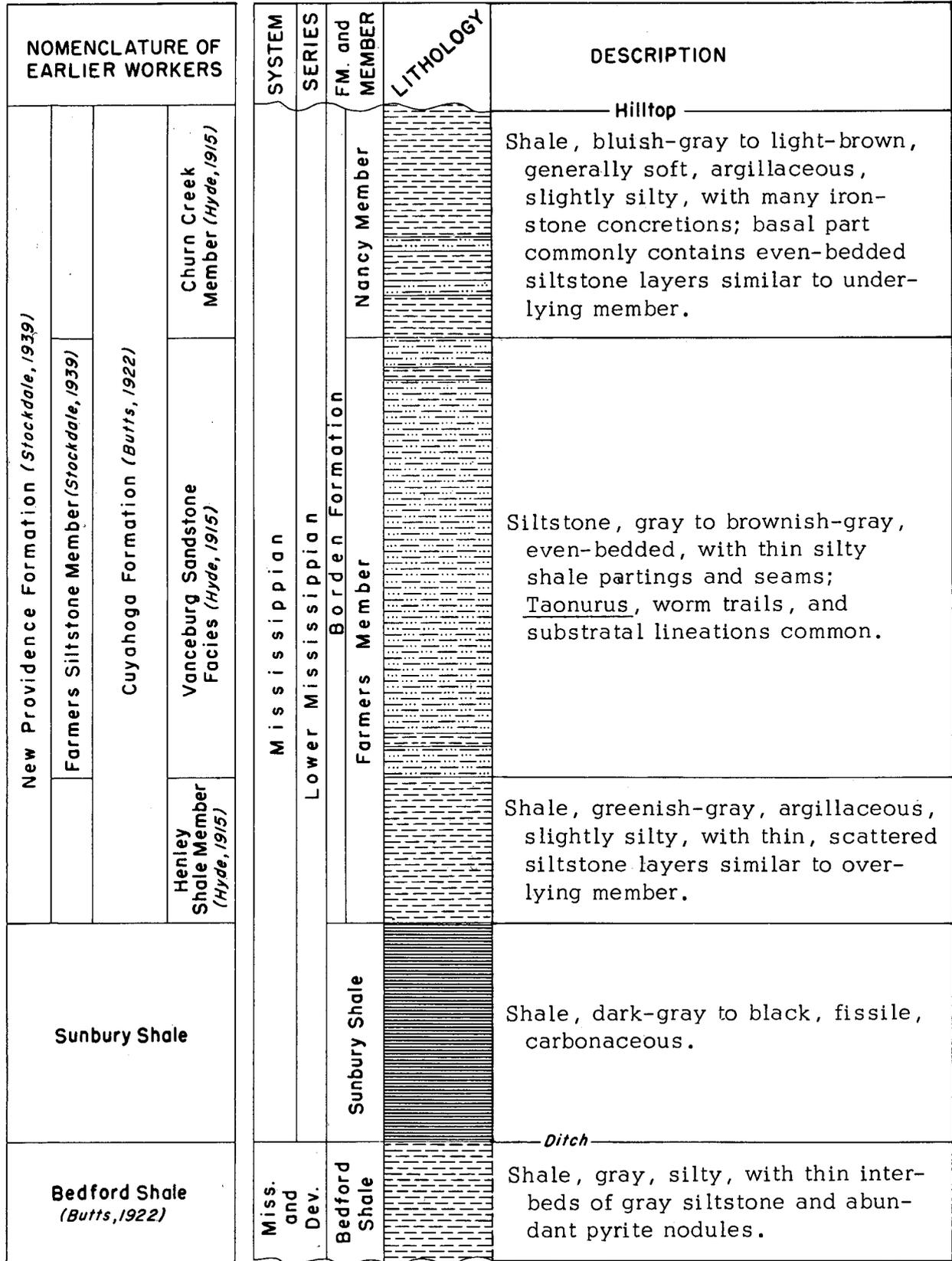
- 133.0 Farmers Member overlain by Nancy Member.
- 134.0 Farmers Member.
- 134.8 Overpass (Ky. 32).
- 135.0 Farmers Member well exposed along south side of North Fork of Triplett Creek. Sunbury exposed poorly along creek banks. Extensive terraces held up by resistant siltstone layers of Farmers Member.
- 135.9 Farmers Member.
- 136.3 Farmers Member. Peculiar "anticlinal structure" in roadcut along eastbound lanes.
- 136.9 Nancy Member. Note resistant siltstone layers and ironstone concretions.
- 137.5 Nancy Member. Ironstone concretions.
- 138.4 LUNCH STOP. Rest area. Boundary between Farmers and Nancy Members of the Borden Formation.
- 139.4 Contact between Farmers and Nancy Members.
- 139.7 Contact between Farmers and Nancy Members.
- 140.0 Nancy Member.
- 140.8 Nancy Member.
- 141.0 Enter Haney Branch.
- 141.4 Stop 2.

#### STOP 2

*Haney Branch section: Contact between the Nancy and Cowbell Members of the Borden Formation (Figs. 10 and 11)*

This stop illustrates the subtle, gradational boundary between the Nancy and Cowbell Members of the Borden Formation (Fig. 10). The Nancy Member is about 130-140 feet thick, and the overlying Cowbell Member is about 240-250 feet thick.

Near its base the Nancy is a gray clay shale containing a few even-bedded siltstone layers similar to the underlying Farmers Member. Toward its top the Nancy becomes more silty and grades into the overlying massive siltstone and silty shale of the Cowbell Member. Locally, the Nancy contains abundant ironstone concretions ranging up to a foot or so in diameter and some thin discontinuous limestone beds. Landslides and slumps have occurred where valley slopes are steep or where excavated cuts are oversteepened in the Nancy Member.



Vertical scale: 1 inch = 10 feet

Figure 7. Bratton Branch section (Stop 1).

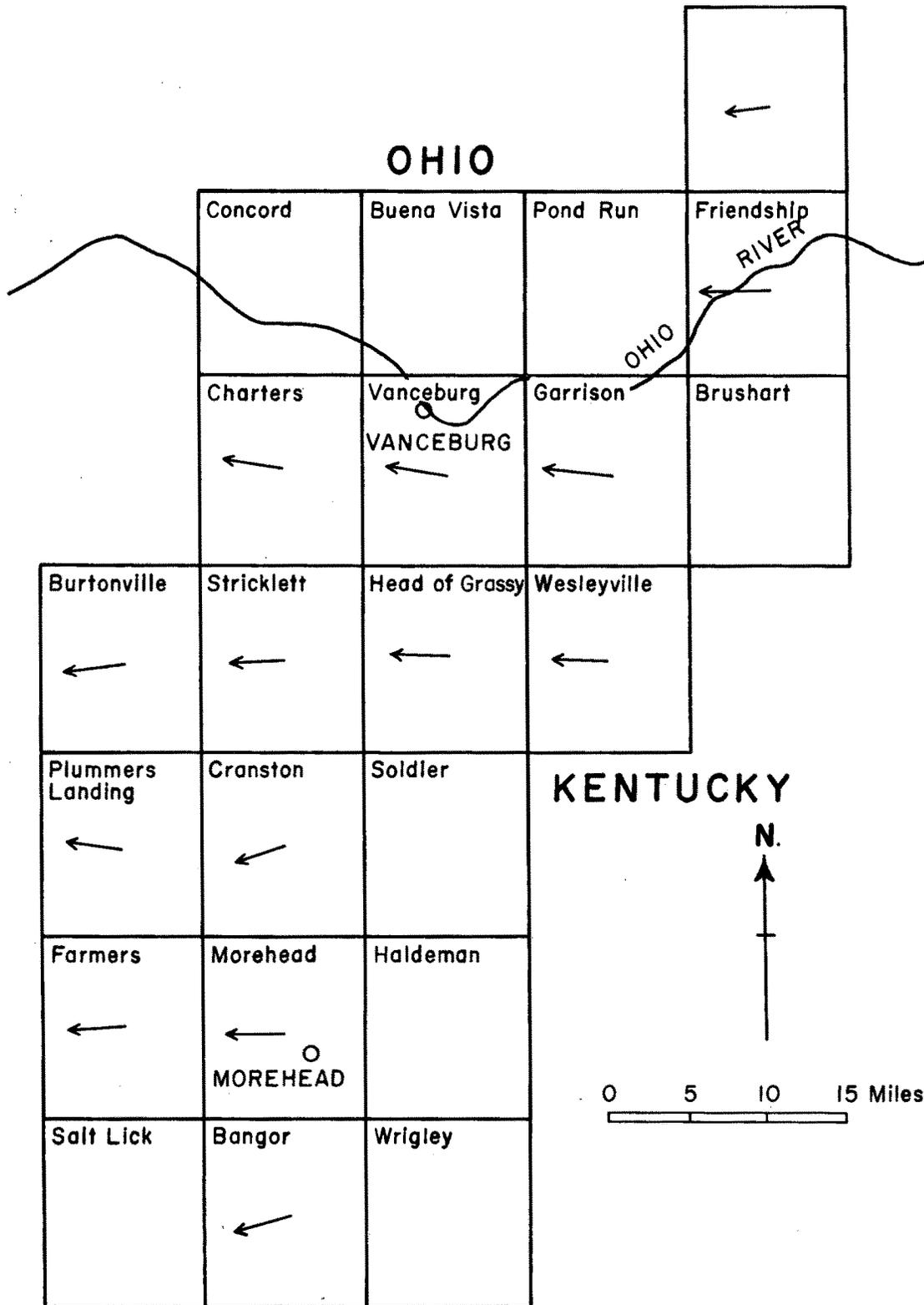


Figure 8. Paleocurrent directions determined from substratal lineations in the Farmers Member of the Borden Formation (Moore and Clarke, in press).

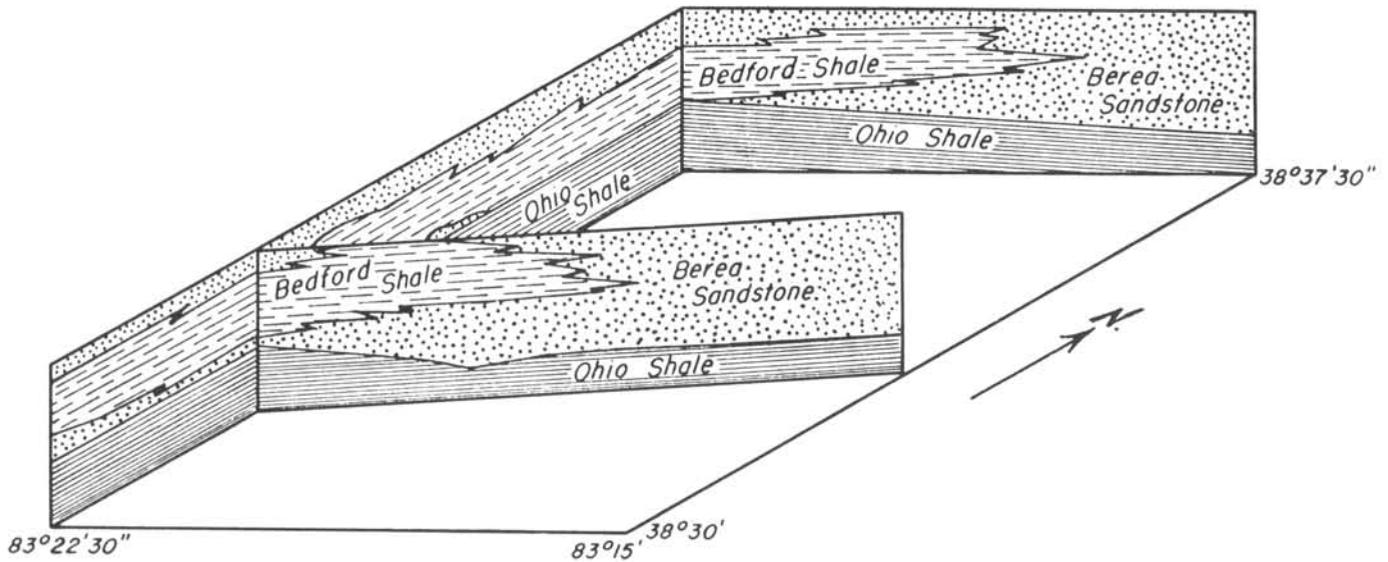


Figure 9. Generalized diagram showing the relationships between the Berea Sandstone and the Bedford Shale. (Stop 1 is a more westward location where the Berea Sandstone is completely absent.) The Berea thickens eastward at the expense of the Bedford. Adapted from Morris and Pierce (1967).

The Cowbell Member is primarily a massive, resistant, indistinctly bedded siltstone that contains locally some shale similar to the underlying Nancy Member. Along Interstate 64 in roadcuts along the westbound lanes between here and the next underpass, a thin shale unit occurs slightly above the middle of the member (miles 142.5, 142.7).

Both members are sparsely fossiliferous, the Nancy more so than the Cowbell. However, "curly worm marks" (Stockdale, 1939, Pl. 4, Fig. 1) and *Taonurus* are found throughout both members. In the Cowbell abundant and diverse fossils (brachiopods, crinoids, bryozoans, and a few trilobites) are preserved as molds and casts in restricted zones and pockets. Some fossils replaced by calcite, pyrite, galena, and sphalerite are concentrated in sporadically distributed concretions.

#### Milepost

- 141.7 Nancy Member overlain by Cowbell Member.
- 142.5 Cowbell Member containing shale unit, near hilltop.
- 142.7 Cowbell Member containing shale unit, near road level.
- 143.1 Cowbell Member containing much interbedded shale.
- 143.3 Underpass (Ky. 799).
- 143.5 Stop 3. First, second, and third hillside cuts.
- 144.0

#### STOP 3

*Perry Branch sections: Exposures of the upper members of the Borden Formation, the Newman Limestone, and Lower Pennsylvanian rocks (Fig. 11)*

The group will assemble along the westbound lanes of Interstate 64 at the first hillside cut east of the Ky. 799 overpass. This exposure and the exposures in the next two hillside cuts farther to the east will be examined.

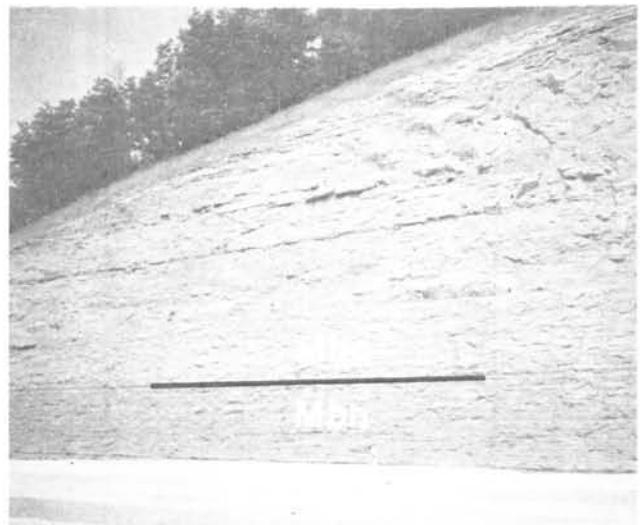


Figure 10. Excellent exposure of the very subtle gradational contact between the Nancy (Mbn) and Cowbell (Mbc) Members of the Borden Formation at Stop 2 (mile 141.4, westbound lanes).

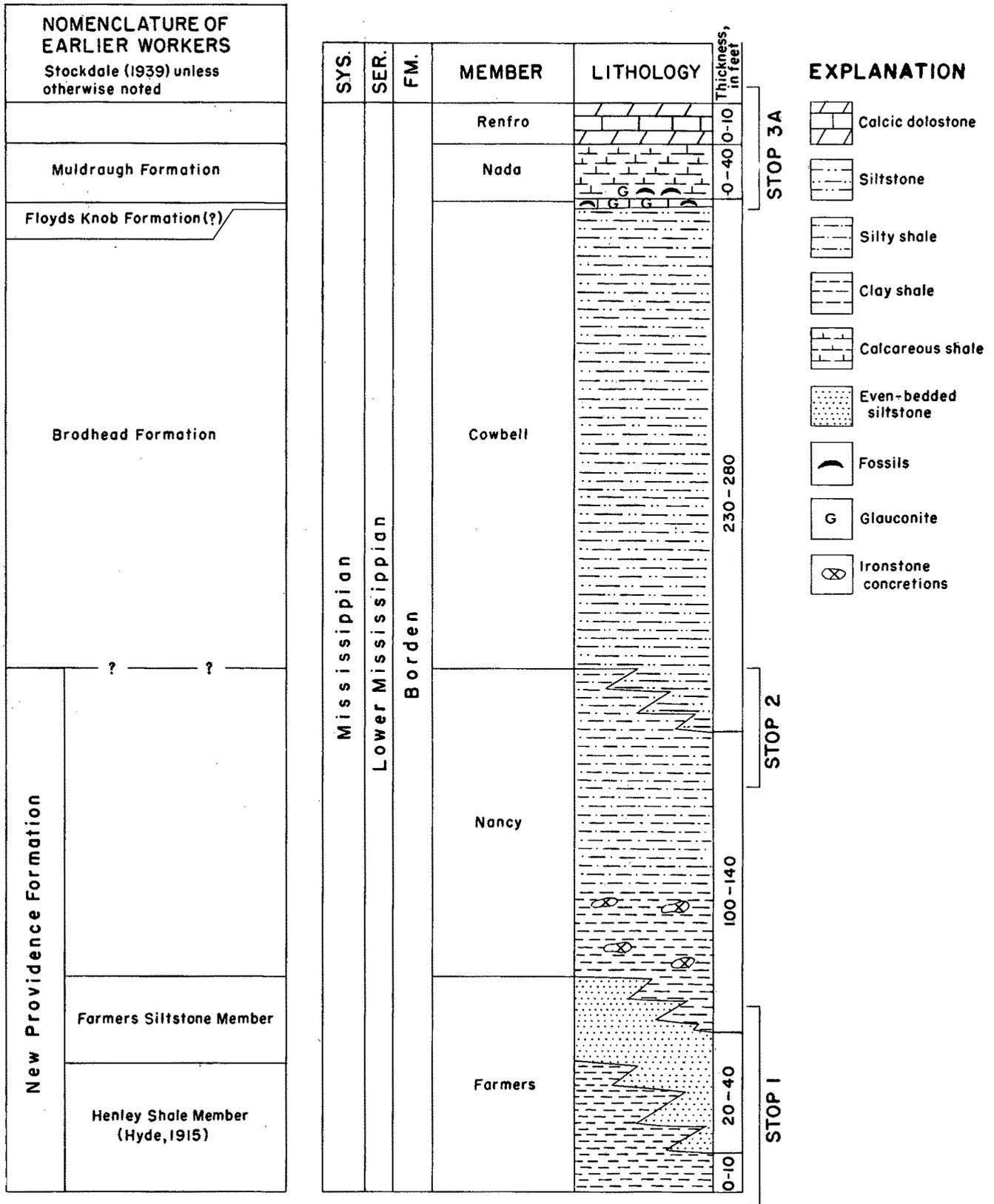


Figure 11. Generalized stratigraphic section for Stops 1, 2, and 3A.

## STOP 3A

First hillside cut: Nada and Renfro Members of Borden Formation overlain by Newman Limestone (Fig. 12)

The Nada and Renfro Members of the Borden Formation are well exposed and are overlain by the lower part of the Newman Limestone which caps the hill. The Nada Member, about 40 feet thick, is composed of red and green calcareous shale that contains thin intercalated layers of glauconite-streaked siltstone and very fossiliferous glauconite-streaked limestone. A red shale zone characterizes the actual base of the member and serves as a convenient marker in the surrounding quadrangles. A glauconite-streaked limestone zone containing patches of black phosphatic material embedded with coprolites (?) and unaltered lingulid brachiopods has been found locally beneath the red shale marker horizon. This may be equivalent to Stockdale's (1939) Floyds Knob Formation.

The Renfro Member, the uppermost member of the Borden, is primarily a yellow- to orange-weathering, aphanitic to finely crystalline silty and dolomitic limestone. It is generally less than 10 feet thick in the surrounding area, becoming much thicker to the southwest. A few miles east of Halls Gap the member is about 100 feet thick (Weir and others, 1966, p. 21). However, the relationship of the Renfro to the overlying Newman Limestone is not completely understood. At some places the upper contact appears to be conformable, as is suggested along Interstate 64, whereas at other places an intertonguing relationship with the overlying Newman appears to exist (Weir and others, 1966, p. 20). In the Tygarts Valley quadrangle (Sheppard, 1964), a nearby quadrangle to the northeast, the contact appears to be gradational.

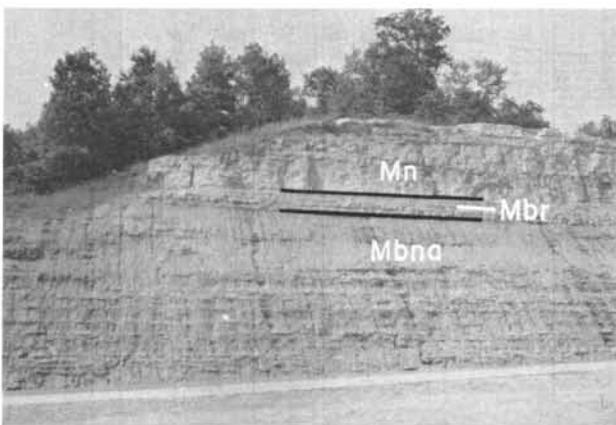


Figure 12. Complete exposure of Nada (Mbna) and Renfro (Mbr) Members of the Borden Formation at Stop 3A. Hill is capped by lower part (unit 1) of the Newman Limestone (Mn). (Mile 143.5, westbound lanes.)

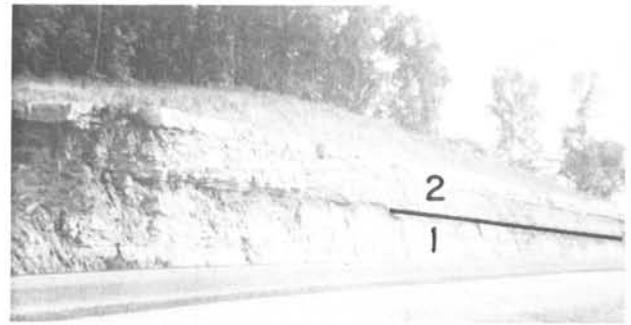


Figure 13. Exposure of units 1 and 2 of the Newman Limestone at Stop 3B, illustrating abrupt lateral changes in unit 2 (mile 143.7, westbound lanes).

## STOP 3B

Second hillside cut: lower part of Newman Limestone (Figs. 13 and 14)

Previous attempts to correlate these Mississippian limestones with those of western Kentucky have not been completely acceptable. Consequently, the Newman Limestone is somewhat arbitrarily divided into four units for discussion purposes. In the second hillside cut the first three units (Fig. 14) are exposed.

*Unit 1.* The conspicuously dark-colored limestone about 10 feet above the base of the exposure caps the limestone unit that has been previously correlated with the St. Louis Limestone (*see* Butts, 1922; Stockdale, 1939; McFarlan and Walker, 1956). This correlation has been based primarily on the occurrence of certain species of lithostrotionoid corals, some of which have been found in outcrops here and some of which have been reported from the Ste. Genevieve Limestone (Patterson and Hosterman, 1962, p. 17).

The unit is about 15 feet thick and seldom more than 20 feet. Closer inspection of the upper 5 feet reveals that the dark-colored limestone contains "complexly involute and contorted" laminations and brecciations that have been attributed by earlier investigators to "submarine flowage" (Patterson and Hosterman, 1962, p. 17). Others have suggested that the laminations represent stromatolitic and other algal-related structures associated with tidal environments that have been disrupted and disturbed by wave activity. However, more recently, it has been suggested that they may be at least in part subaerial laminated crusts (*see* Multer and Hoffmeister, 1968). Large vugs up to several feet in diameter, filled with large calcite crystals impregnated with pyrite, have been noted in this unit.

The remainder of the unit below the dark zone is much lighter colored and more distinctly bedded, and it contains jasperoidal chert layers, nodules, and

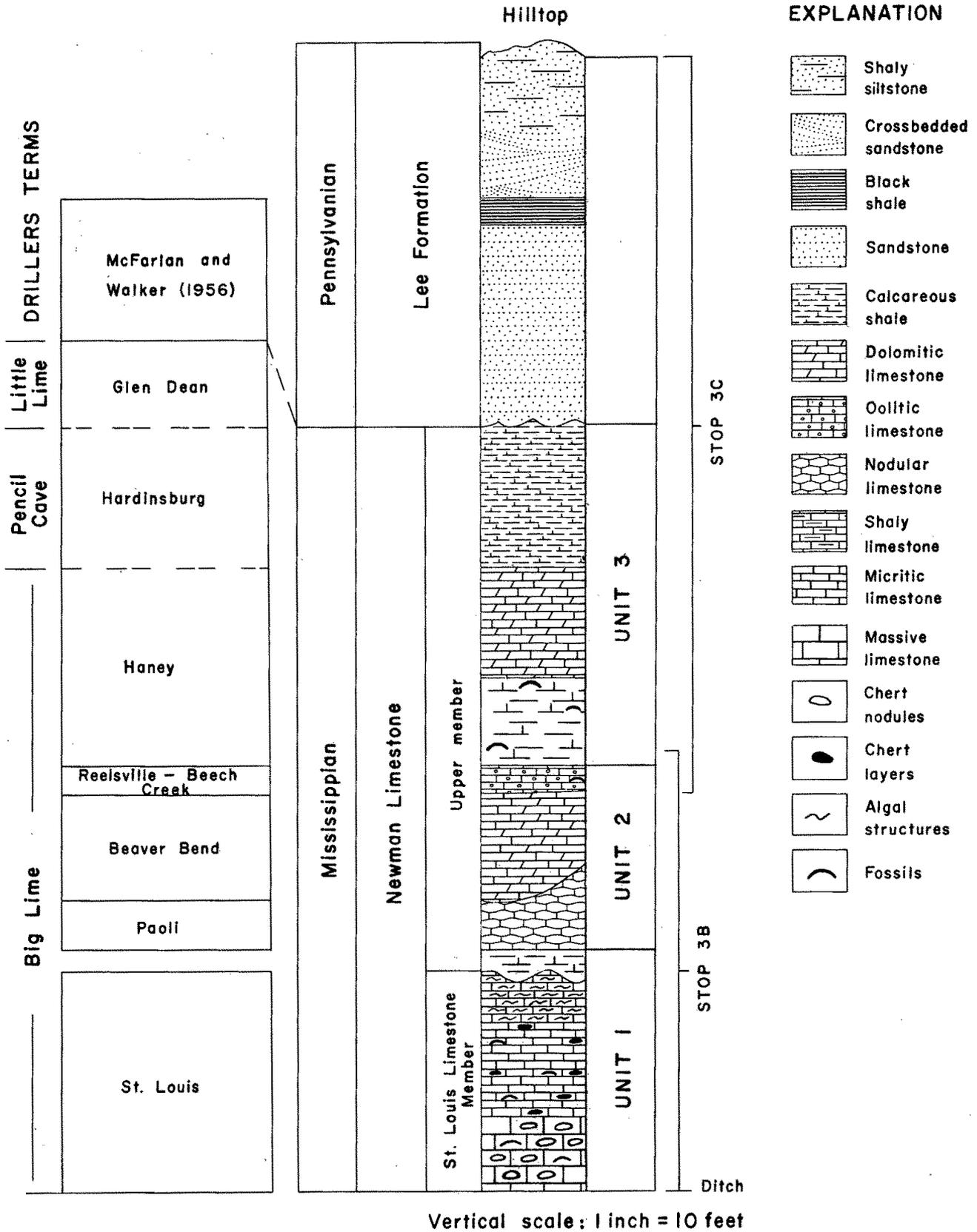


Figure 14. Stratigraphic section for Newman Limestone at Stops 3A, 3B, and 3C.

masses, as well as abundant and diversified silicified fossils (bryozoans, crinoids, and corals).

*Unit 2.* The upper contact of unit 1 is an unconformable one marked by numerous solution channels and cavities filled with red and green calcareous shale that constitutes the basal part of unit 2 (Fig. 17). This shale is never more than 4 or 5 feet thick, and in many places it is completely absent.

The limestone above the thin red and green shale displays remarkably abrupt lateral changes that can be easily noted in this hillside cut. The lower part is composed of thin-bedded, fine-grained, mottled limestone separated by thin shale seams and partings. Ripple marks, dessication cracks, and delicate algal (?) laminations have been noted on some limestone beds. The upper part is a brownish, fine-grained dolomitic limestone containing numerous small calcite eyelets and veinlets. At the west end of this hillside cut, the upper brownish limestone dominates the interval at the expense of the lower part; at the east end the reverse occurs (Fig. 13). This pattern is duplicated in part in the eastward roadcuts.

The top bed of unit 2 is a conspicuously white limestone, about 2 feet thick, having a high foraminiferal content that tends to emphasize its oolitic appearance. Large crinoids and the blastoid *Pentremites* are usually associated with this bed. Although it is thin here, in Rowan and Carter Counties it is quarried extensively where its thickness ranges up to 20 feet and where its calcium carbonate content exceeds 95 percent (McGrain and Dever, 1967, Fig. 6).

### STOP 3C

*Third hillside cut: upper part of Newman Limestone (Fig. 15)*

At the west end of this hillside cut the top bed (the white oolitic bed) of unit 2 discussed at Stop 3B can

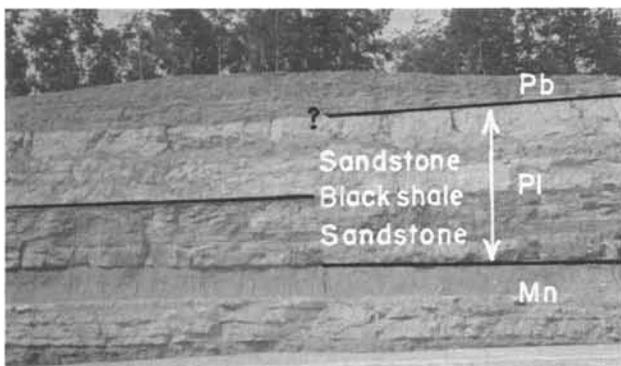


Figure 15. Exposure at Stop 3C showing unit 3 of the Newman Limestone (Mn), overlain by Pennsylvanian sandstones and shales. Pl, Lee Formation; Pb, Breathitt Formation. (Mile 144, westbound lanes.)

be seen. This hill is capped by Pennsylvanian sandstone and shale that apparently occupy erosion channels in the upper part of the Newman Limestone.

*Unit 3.* The remainder of the Newman Limestone in this exposure constitutes unit 3 and is represented by red and green shale that contains about 8 feet of dolomitic limestone. Abrupt lateral changes occur within this limestone body. The shale beneath the limestone is very fossiliferous and very calcareous, whereas the shale above is not as fossiliferous nor as calcareous. At places in the surrounding area unit 3 is represented entirely by limestone and at others by shale. In the subsurface this interval is known to drillers as the "Pencil Cave."

Overlying unit 3 is a massive 13-foot-thick sandstone similar in character to Pennsylvanian sandstones (Figs. 16 and 21). Missing from this section is part, if not all, of the uppermost member of the Newman Limestone.

### Milepost

- 144.5 Newman Limestone overlain by Pennsylvanian sediments. Note solution channels in Newman Limestone at top of unit 1 (see Fig. 17).
- 145.0 Weigh station. Exposures of the Nada and Renfro Members of the Borden Formation and nearly all the Newman Limestone. Note sinkholes in the Newman Limestone along eastbound lanes.
- 145.6 Pennsylvanian black shale resting unconformably on Newman Limestone (Fig. 18).
- 145.9 Thick, even-bedded, micaceous sandstone of Pennsylvanian age (Fig. 19).
- 146.3 Thick, even-bedded, micaceous sandstone of Pennsylvanian age.

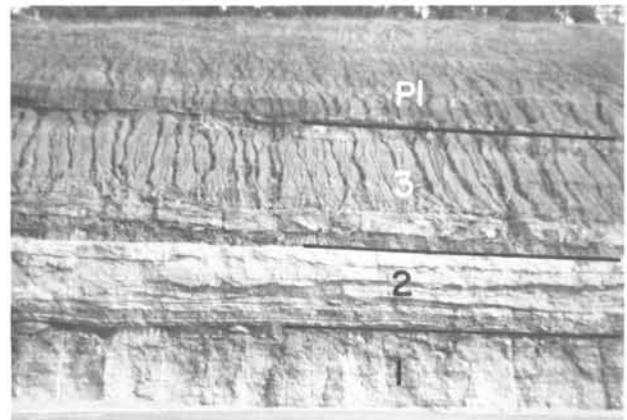


Figure 16. Units 1-3 of Newman Limestone, overlain by Pennsylvanian (Pl) black shale, in first roadcut beyond Stop 3C (mile 144.5, westbound lanes). See Figure 21 for generalized stratigraphic relationships.



Figure 17. Solution cavity in unit 1 of Newman Limestone (mile 144.5, westbound lanes).



Figure 18. Pennsylvania black shale (PI) filling channel cut into upper part of Newman Limestone (Mn) at mile 145.6, eastbound lanes. See Figure 21 for generalized stratigraphic relationships.

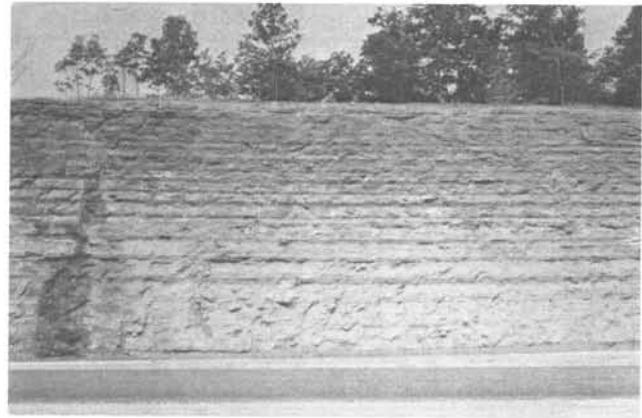


Figure 19. Even-bedded micaceous sandstone of the Lee Formation (Pennsylvanian) at mile 145.9. See Figure 21 for generalized stratigraphic relationships.



Figure 20. Sandstone-filled channel cut deeply into the Newman Limestone (Mn) at mile 146.9 (eastbound lanes). PI, Lee Formation; Mbna, Nada Member of Borden Formation. See Figure 21 for generalized stratigraphic relationships.

- 146.7 Pennsylvania black shale along eastbound lanes.
- 146.9 Channel filled with Pennsylvania sandstone cutting into Newman Limestone. Renfro Member of the Borden Formation is either absent or poorly exposed; Nada Member is well exposed along eastbound lanes (Fig. 20). (See Figure 21 for interpretation of stratigraphic relationships for outcrops since Stop 3C.)
- 147.0 Red shale marker zone in Nada Member.
- 147.2 Cowbell Member containing much interbedded shale.
- 147.3 Cowbell Member.

- 148.4 Pennsylvanian sediments lying unconformably on Borden Formation. Little or no Newman Limestone present.
- 149.1 Overpass (Ky. 1024). Cowbell Member exposed on both sides of overpass.
- 149.7 Pennsylvania black shale with sandstone lenses.
- 150.4 Pennsylvanian sediments lying unconformably on Borden Formation.
- 150.8 Pennsylvania black shale with sandstone lenses.
- 151.2 Pennsylvanian sediments lying unconformably on lower part of Newman Limestone.
- 151.3 Stop 4.

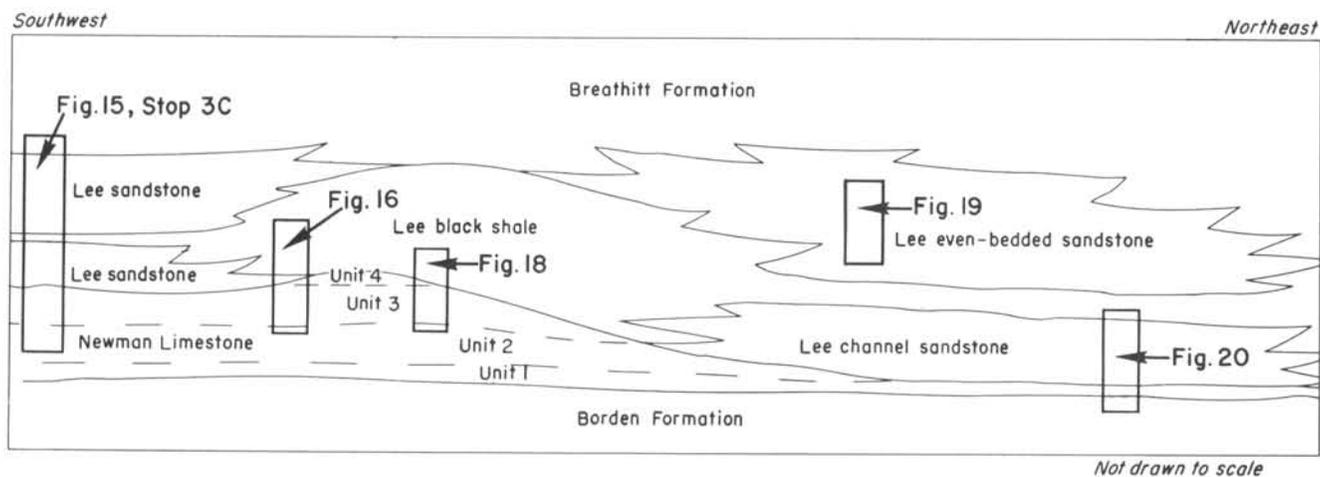


Figure 21. Cross-sectional diagram of generalized stratigraphic relationships between Newman Limestone and Pennsylvanian rocks. Positions of numbered figures on the diagram show relative location and stratigraphic span of photographs of selected sections.

#### STOP 4

*Smith Run Section: Mississippian-Pennsylvanian unconformity (Fig. 22)*

At this exposure along the eastbound lanes of Interstate 64, the Newman Limestone is represented by contorted beds of limestone and shale deposited in solution channels in the Renfro Member of the Borden Formation. This situation is duplicated in nearby roadcuts.

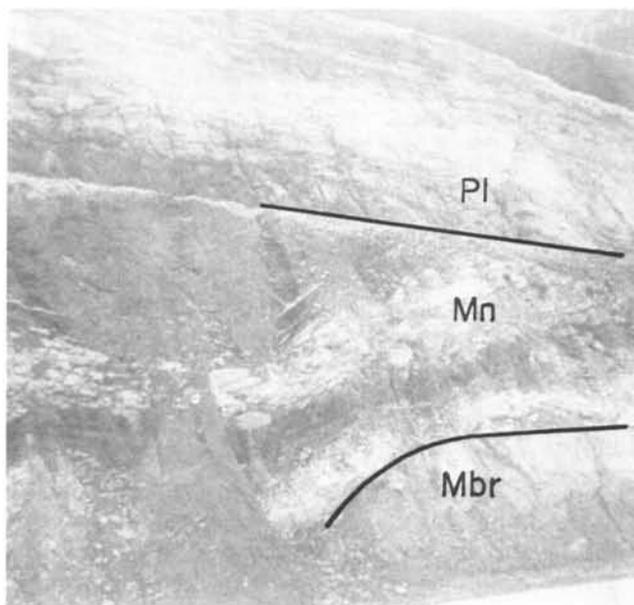


Figure 22. Contorted beds at Mississippian-Pennsylvanian unconformity (mile 151.3). Pl, Lee Formation (Pennsylvanian); Mn, Newman Limestone (Mississippian); Mbr, Renfro Member of Borden Formation.



Figure 23. Sandstone pinchout in Pennsylvanian black shale (mile 152.3, westbound lanes).



Figure 24. Armstrong Hill section (Stop 5) showing fully exposed Newman Limestone (units 1-3).

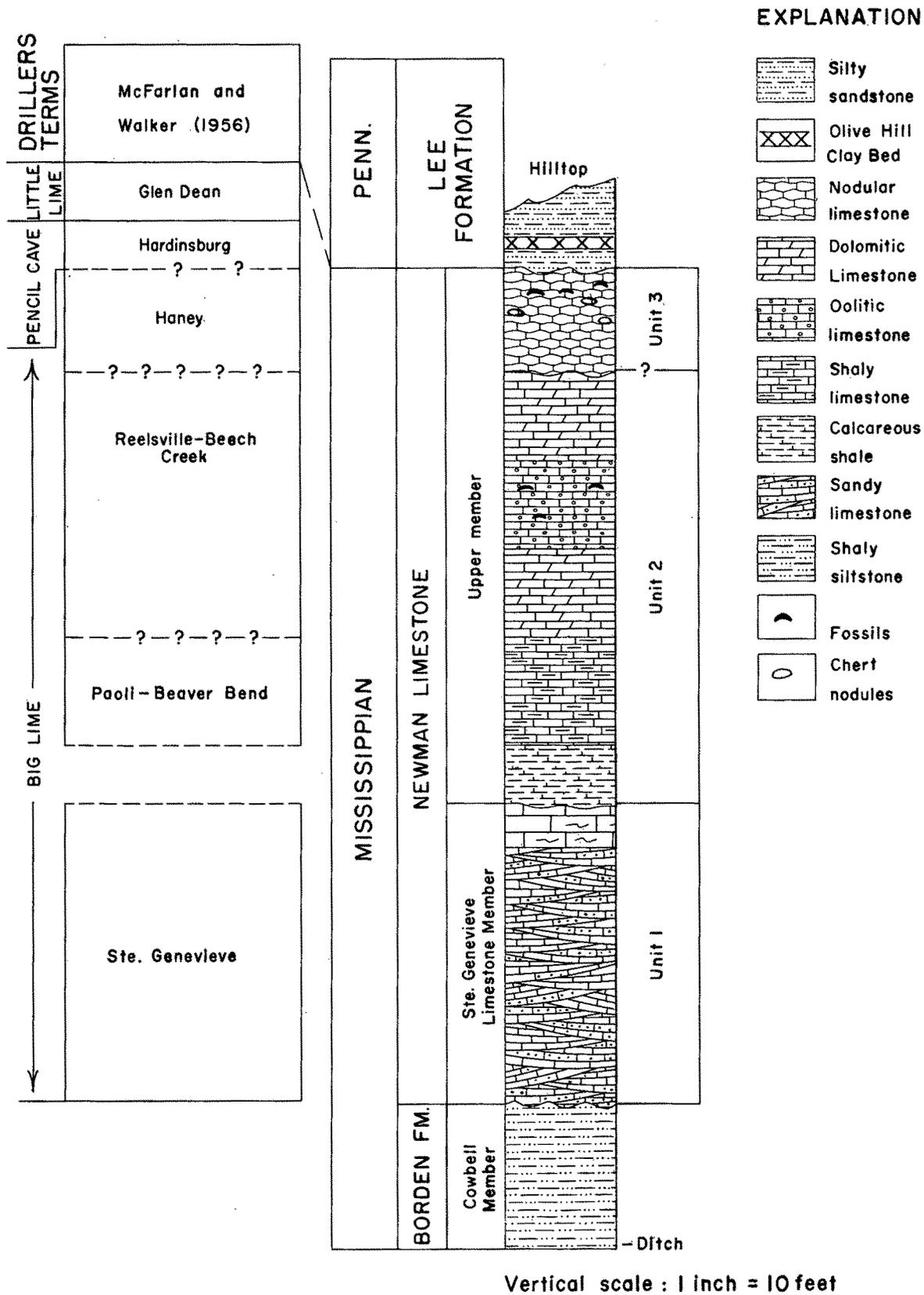


Figure 25. Stratigraphic section for Armstrong Hill (Stop 5).

*Milepost*

- 151.7 Pennsylvanian sediments lying unconformably on lower part of Newman Limestone.
- 152.0 Pennsylvanian black shale.
- 152.3 Pennsylvanian black shale containing well-defined pinchout of sandstone (Fig. 23) in westbound lanes.
- 152.7 Pennsylvanian sediments lying unconformably on lower part of Newman Limestone.
- 153.1 Nada Member of Borden Formation in westbound lanes.
- 153.4 Exit to Ky. 2. Turn left on Ky. 2; cross Interstate 64 overpass.
- 153.8 Stop 5.

**STOP 5**

*Armstrong Hill section: Roadcuts in the Newman Limestone along Ky. 2 north of the Olive Hill interchange on Interstate 64 (Figs. 24 and 25)*

This stop permits a comparison of the limestone section here with those examined at the Perry Branch section, Stop 3. The sections are similar because they can be divided into three units and because the uppermost part is apparently missing. However, close examination reveals important differences.

*Unit 1.* The unit is capped by a thinner, not-so-dark, fine-grained limestone that contains stromatolitic structures and brecciation similar to those described for the top of unit 1 at Stop 3B. The entire unit is thicker, and the lower 15 feet is distinctly crossbedded, very sandy, and partly oolitic (Fig. 26). Sand grains and large angular fragments appear to be composed of

dark limestone and red chert, suspiciously similar to the dark limestone and red chert of unit 1, the "St. Louis," at Stop 3B. This unit is resting unconformably on the Cowbell Member of the Borden Formation; the Nada and Renfro Members are absent.

Based primarily on its lithologic character, this unit has been correlated with the Ste. Genevieve Limestone (Butts, 1922; McFarlan and Walker, 1956). On the Tygarts Valley quadrangle, Sheppard (1964) presented a generalized diagram depicting stratigraphic relationships of the Mississippian and Pennsylvanian rocks (Fig. 27). Of particular interest is the interpre-



Figure 26. Crossbedded "Ste. Genevieve" (Mng) limestone resting unconformably on the Cowbell Member (Mbc) of the Borden Formation (Stop 5).

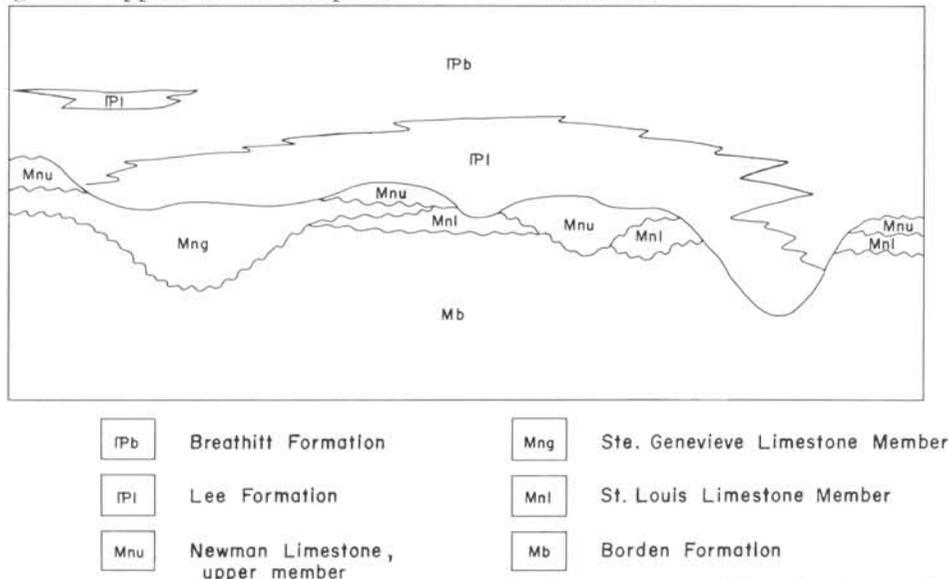


Figure 27. Generalized diagram showing unconformable relationships of rocks of Mississippian and Pennsylvanian ages (see also Fig. 28). Of particular interest are relationships of the members of the Newman Limestone. Adapted from Sheppard (1964).

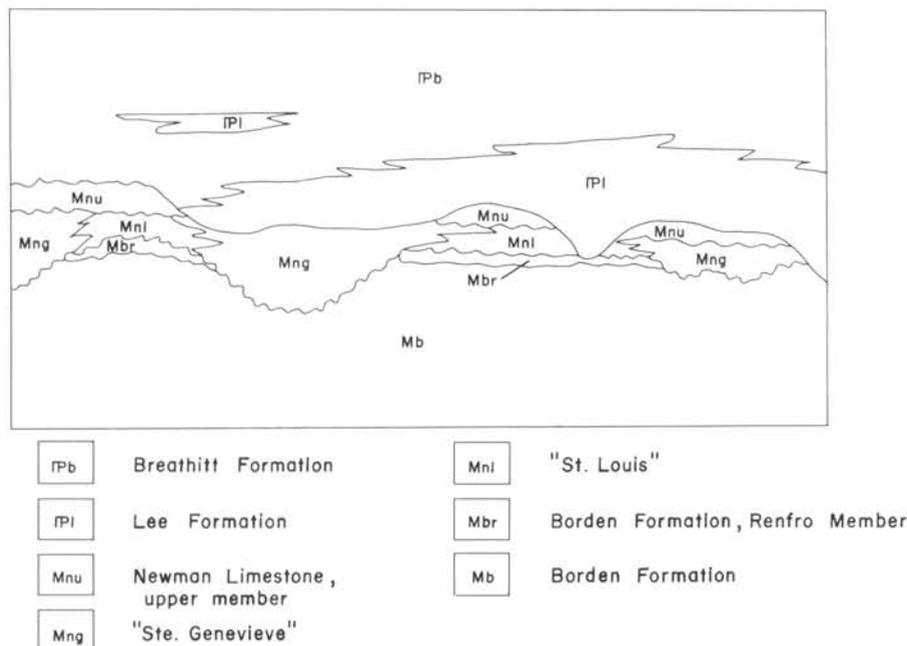


Figure 28. Generalized diagram showing alternate interpretation of unconformable relationships of rocks of Mississippian and Pennsylvanian ages (compare with Fig. 27). This hypothesis suggests a tidal-facies relationship between the "St. Louis" and "Ste. Genevieve." Modified from Sheppard (1964).

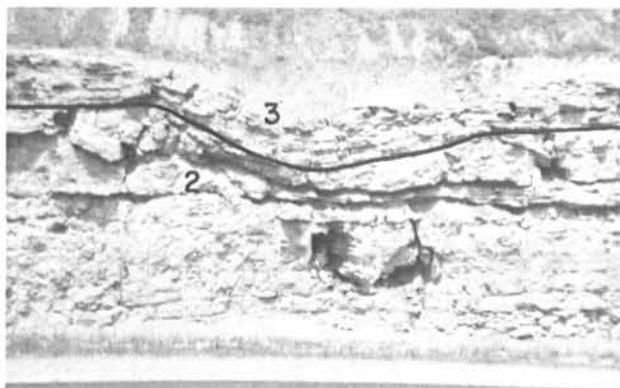


Figure 29. Solution feature in the Newman Limestone (Stop 5). Positions of units 2 and 3 are indicated.



Figure 30. Limestone and chert nodules in unit 3 of the Newman Limestone (Stop 5).

tation that the Ste. Genevieve has been deposited in a channel or channels that have penetrated the underlying St. Louis and Borden formations. Field evidence offers support for this interpretation. However, the distribution of the zone or zones containing stromatolitic and algal-related structures could suggest that the "St. Louis-Ste. Genevieve" relationship in northeastern Kentucky is a tidal-facies relationship (Fig. 28). Such a hypothesis deserves more investigation.

*Unit 2.* Abrupt lateral changes are not as obvious in this exposure as they were in the Perry Branch sections. The shale at the base of the unit does change laterally in color from red and green to grayish, and it does not overlie unit 1 as unconformably. The white oolitic bed capping the unit is thicker and is dolomitic above and below. A well-developed solution feature occurs within this unit (Fig. 29).

*Unit 3.* This unit is much thinner, owing, perhaps, to erosion. It is represented by about 7-8 feet of limestone and virtually no shale. The upper part contains peculiar nodules of coarser grained limestone and reddish-gray chert surrounded by vague compacted algal (?) laminations (Fig. 30). Abundant fossils are found particularly above the nodular limestone at the top of the unit.

The unit is overlain by the Olive Hill Clay Bed of Pennsylvanian age which is the source of clay for the refractories located at nearby Olive Hill (Patterson and Hosterman, 1962).

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