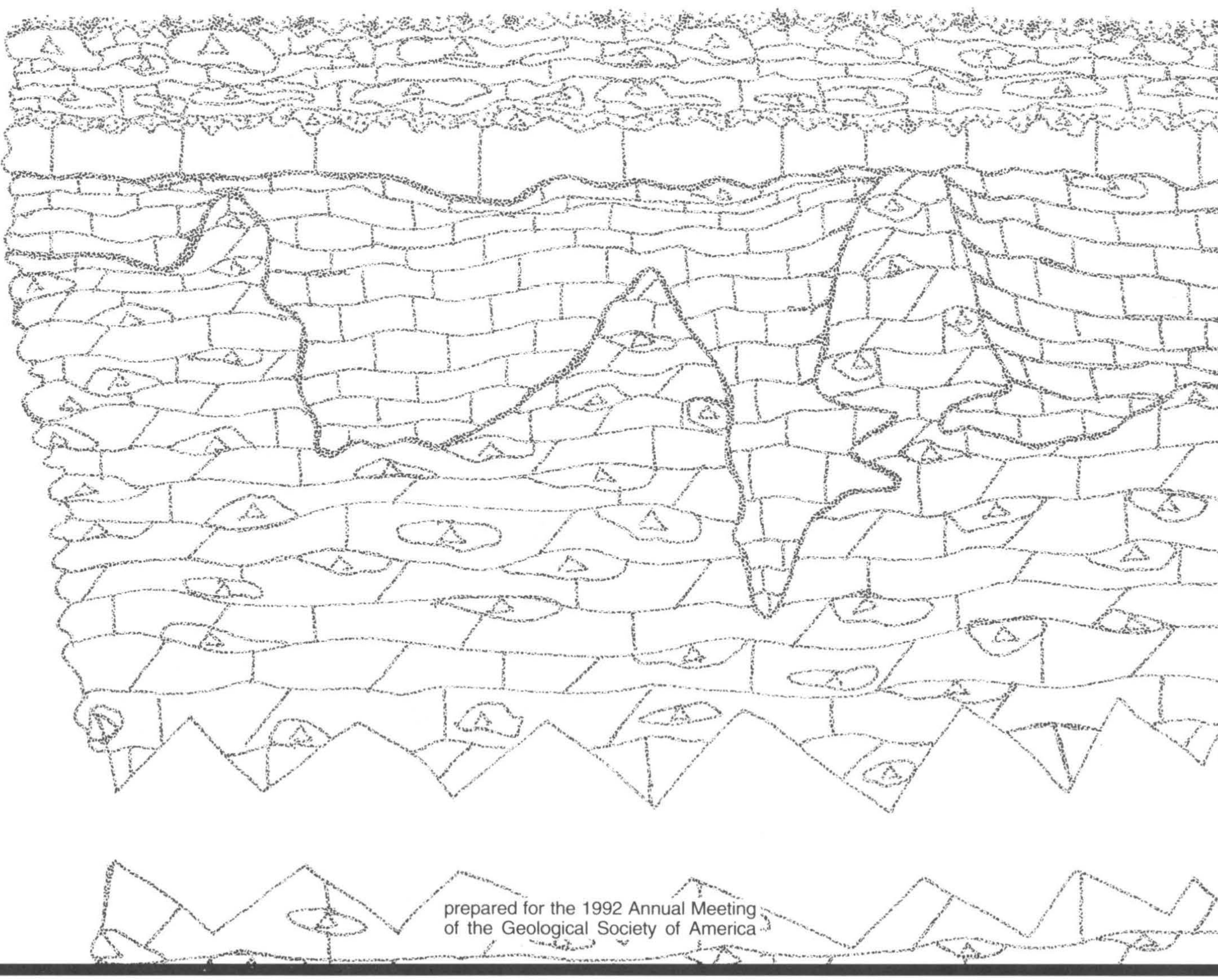
MISCELLANEOUS REPORT NO. 6

ORDOVICIAN, SILURIAN, AND MIDDLE DEVONIAN STRATIGRAPHY IN NORTHWESTERN KENTUCKY AND SOUTHERN INDIANA—SOME REINTERPRETATIONS

by

James E. Conkin, Barbara M. Conkin, and John Kubacko, Jr.



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by

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Cover illustration: Upper part of the Louisville Limestone and lower part of the Jeffersonville Limestone exposed at Poplar Level Road and Trevilian Way, Louisville, Kentucky (see fig. 19).

Cartographic assistance: Robert L. Stewart, Edward V. Kuehnle, Lisa Van Doren, and Michael R. Lester

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INTRODUCTION

The nine stops on this trip in Kentucky and southern Indiana (fig. 1) present sections of Middle and Upper Ordovician, Middle Silurian, and Lower and Middle Devonian rocks which contain significant metabentonites and paracontinuities that, along with certain fossils, provide the bases for reinterpretation of several boundaries. These are the Middle-Late Ordovician, Laurel Dolomite-Waldron Shale, Waldron Shale-Louisville Limestone, and Jeffersonville Limestone-Speeds Limestone boundaries, as well as boundaries within the Jeffersonville Limestone and the Sellersburg Group. As a result of these reinterpretations and our field studies in Indiana, Kentucky, Ohio, New York, Tennessee, Mississippi Valley states, and Ontario, more precise correlations can be made among rocks of Middle Ordovician through Middle Devonian age in eastern North America. Figure 2 presents a stratigraphic column of the formations to be seen in the field-trip area.

Details of the stratigraphic relationships seen along the Louisville Limestone-Jeffersonville Limestone paraconformity in the field-trip area (where the term paraconformity was first applied by Dunbar and Rodgers, 1957) reveal that the relationships are less simple than previously assumed. Detailed study of the lithostratigraphy of the Louisville Limestone shows that there is as much as 80 feet of the Louisville missing along the paraconformity, east and northeast of its type area.

In places where the more dolomitic lower part of the Louisville (the Big Rock Member) is in contact with the dolomitic Geneva facies of the Jeffersonville, identification of the position of the paraconformity was previously difficult, particularly in the subsurface. By use of the monotypic agglutinate foraminiferan Inauris tubulata, Conkin, Conkin, and Thurman, 1979, which is restricted to the lower Jeffersonville, the position of the paraconformity can be recognized easily.

The field-trip area includes a portion of the Outer Bluegrass region of Kentucky. In the area of Stops 1-4, the hill tops of the rolling upland (the Lexington Peneplain) are at 870 to 900 feet elevations, well above the 470 feet elevation of the entrenched Kentucky River; the deep valleys were eroded in Ordovician limestones and shales of the western flank of the Cincinnati Arch, the major structural feature of the region. Jeptha Knob, which resulted from the Early Silurian impact of a meteorite or comet (Seegar, 1968), is visible to the north of I-64, 3.3 miles east of the Franklin-Shelby County line. The knob rises some 300 feet above the general upland level. In the vicinity of Stops 5-9, in Jefferson County, Kentucky, and southern Indiana, Silurian and Devonian limestones form a gentle westward upland slope that declines from elevations of 700 feet at stop 5 to 580 feet in the bluffs above the 420-foot level of the Ohio River near Stops 8 and 9.

FIELD-TRIP STOPS

Stop 1: Liter's quarry east of County Road 389, 0.8 mile south of County Road 22, Henry County, Kentucky. The Cynthiana-Eden boundary is displayed, marked by the crinoid holdfast Parapodolithus sardesoni attached to the upper surface of the Cynthiana.

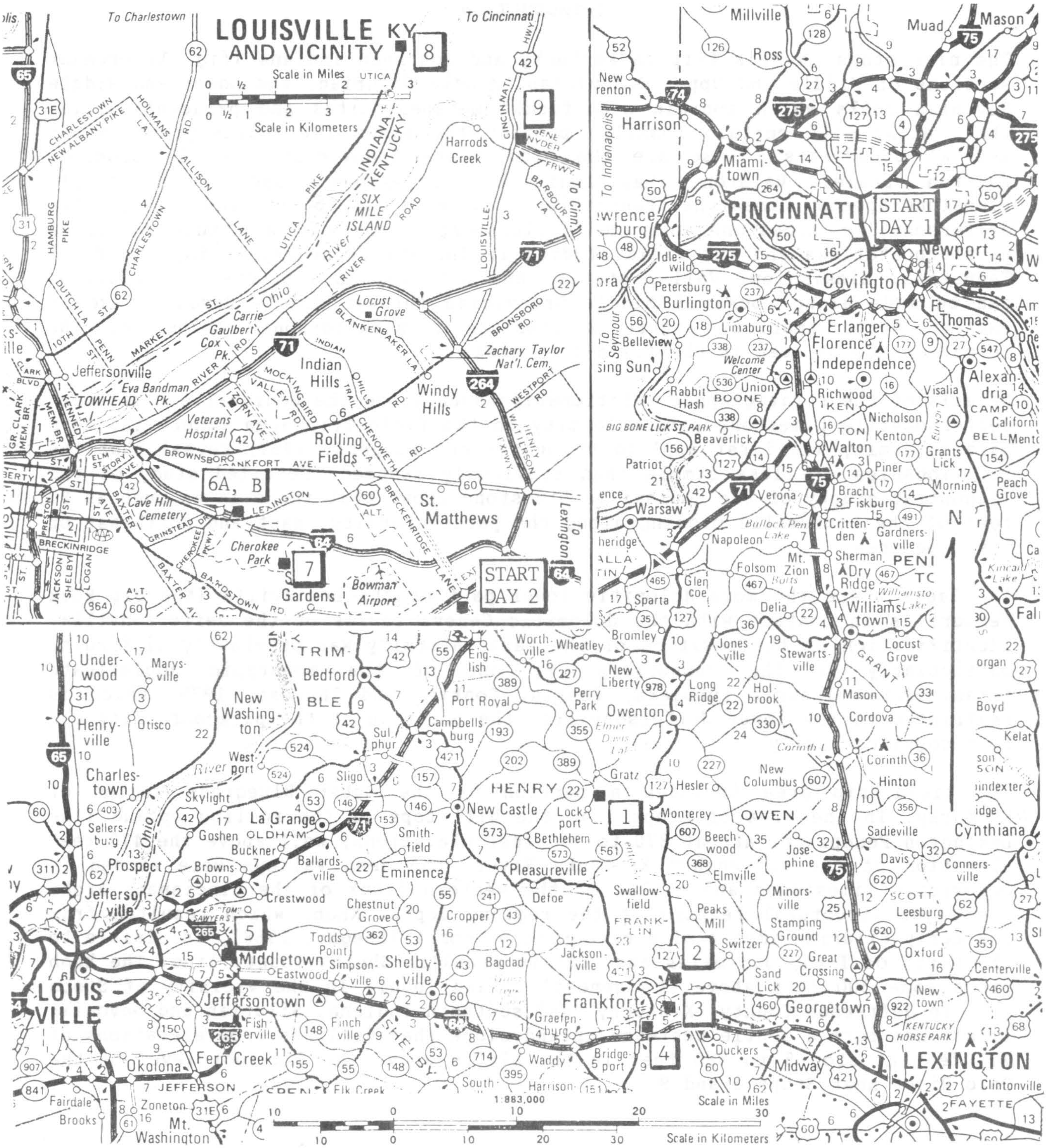


FIGURE 1.--Field-trip stops in northwestern Kentucky and southern Indiana.

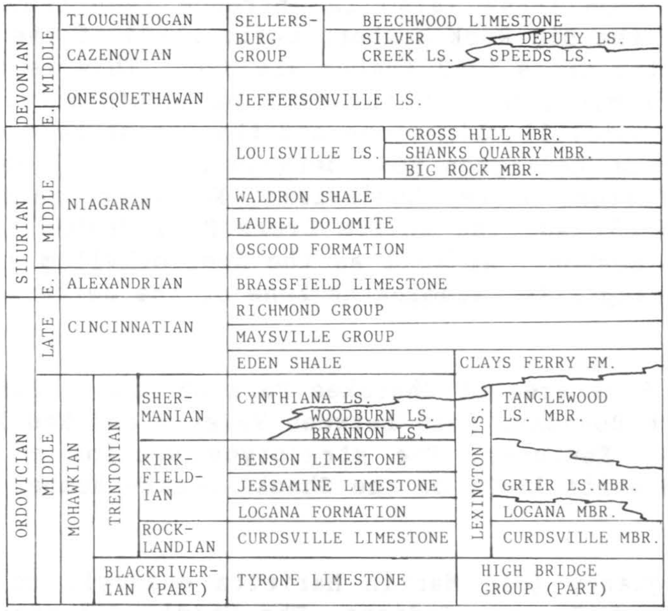


FIGURE 2.--Stratigraphic units of the field-trip area.

Stop 2: Dead Horse Road quarry (abandoned) at intersection of Dead Horse Road and Cove Spring Road, and roadcut on U.S. Hwy 127N at junction of 127 and Cove Spring Road, Frankfort, Franklin County, Kentucky. The upper Tyrone, Curdsville, Logana, and Jessamine formations are seen, as well as the paracontinuities between the Tyrone-Curdsville and the Curdsville-Logana and the Dead Horse Road Quarry, Pencil Cave, Mud Cave, and Capitol Metabentonites.

Stop 3: Old Kentucky State Capitol Museum, at Lewis Street and Broadway, Frankfort, Kentucky. Geologic maps and typical fossils of various Kentucky areas are on display in the basement. This display was prepared and most of the specimens donated by the senior author; this was a reorganization of a much smaller display prepared by Dr. Willard Rouse Jillson, former State Geologist of Kentucky. Notable is a bronze bust of Nathaniel Southgate Shaler (1841-1906), born in Newport, Kentucky, a Professor at Harvard (1869-88) and head of the Kentucky Geological Survey from 1873 to 1880.

Stop 4: Stratotype section of the Sleepy Hollow Branch Metabentonite, on County Road 767, 0.8 mile west of junction of County Roads 767 and 420, opposite Collins Lane, near Frankfort, Franklin County, Kentucky. The Brannon Limestone and the Woodburn-Tanglewood limestones are seen, with "mud-rollers" in the Brannon and the Sleepy Hollow Branch Metabentonite in the Woodburn.

Stop 5: Jefferson County quarry, on Avoca Road, 0.5 miles east of English Station Road, just north of Middletown, Jefferson County, Kentucky. The Middle Silurian Laurel, Waldron, and Louisville formations, the Laurel-Waldron paracontinuous boundary, and the Waldron-Louisville disconformity are seen.

Stops 6A and 6B: Stratotypes of the Shanks Quarry and Cross Hill Members of the Louisville Limestone, eastern Louisville, Jefferson County, Kentucky. Stop 6A: Old Shanks quarry at intersection of Grinstead Drive and the Grinstead

Drive exit ramp from I-64W (also is entrance ramp from Lexington Road to I-64W). Unit 10 of the Big Rock Member, units 11-23 of the Shanks Quarry Member, and unit 24A of the Cross Hill Member are seen. This is the site of Dunbar and Rodgers (1957) original use of the term paraconformity, as displayed between unit 24A of the Louisville Limestone and the Emsian part of the Jeffersonville. Stop 6B: Roadcut on Lexington Road between Cross Hill and Top Hill Roads, 0.3 mile east of Grinstead Drive, Louisville, Kentucky; part of the Shanks Quarry Member (units 16-23) and the entire Cross Hill Member (units 24A and 24B) of the Louisville Limestone, as well as the Aemulophyllum exiguum-Emmonsia ramosa Zone to Upper Paraspirifer acuminatus Zone of the Jeffersonville Limestone, are seen.

Stop 7: The Big Rock area of Cherokee Park on Middle Fork of Beargrass Creek, northwest of Park Boundary Road between Valetta and Red Fox Roads, Louisville, Jefferson County, Kentucky. The stratotype section of the Big Rock Member (units 1-10) and units 11-15 of the Shanks Quarry Member are seen in the cliff along the creek.

Stop 8: Nugent quarry (old Martin Marietta quarry), on Utica Pike, 0.9 mile NNE of Utica, Clark County, Indiana. The Middle Silurian Laurel, Waldron, and Louisville formations, the Lower-Middle Devonian Jeffersonville, and the Middle Devonian Speeds and Silver Creek Limestones are seen, as well as six paracontinuities, the Louisville-Jeffersonville paraconformity, and the Kawkawlin, Onondaga Indian Nation, Lake Chelan, and Tioga (restricted) Metabentonites.

Stop 9: Roadcuts at Prospect Hill on US Hwy 42 and along the exit ramp at the north end of Gene Snyder Freeway (I-265) northeast of Louisville, Jefferson County, Kentucky. Unit 10 of the Big Rock Member of the Louisville Limestone is seen paraconformably overlain by the Jeffersonville Limestone, which is itself paracontinuously overlain by the Silver Creek Limestone. Seven paracontinuities, six bone beds, and the Kawkawlin, Onondaga Indian Nation, and Lake Chelan Metabentonites are seen.

PARACONTINUOUS STRATIGRAPHY AND CHRONOSTRATIGRAPHY

Stratigraphic reinterpretations presented herein were made by using paracontinuities to determine the field positions of the Middle-Late Ordovician boundary, the Laurel Limestone-Waldron Shale and the Waldron Shale-Louisville Limestone boundaries in the Middle Silurian, and the Jeffersonville Limestone-Speeds Limestone boundary in the Middle Devonian, as well as boundaries between internal units within the Jeffersonville and Sellersburg Group as seen in the field-trip area.

The concept of the paracontinuity was proposed by Conkin and Conkin (1973) and defined as a geographically widespread, small, but significant, physical break (discontinuity) and a coincident small, but significant, evolutionary gap, detectable in the field, and functioning as the closest practical approximation to a chronostratigraphic boundary. Conkin (1986) further refined the concept and differentiated four orders of magnitude of paracontinuities based on the hierarchical rank of the missing stratigraphic unit (fig. 3). He estimated the amount of time loss by the magnitude of the coincident evolutionary gap. Paracontinuities are viewed as representing widespread marine transgressions over the low-lying cratons. They are intimately related, and their presence is

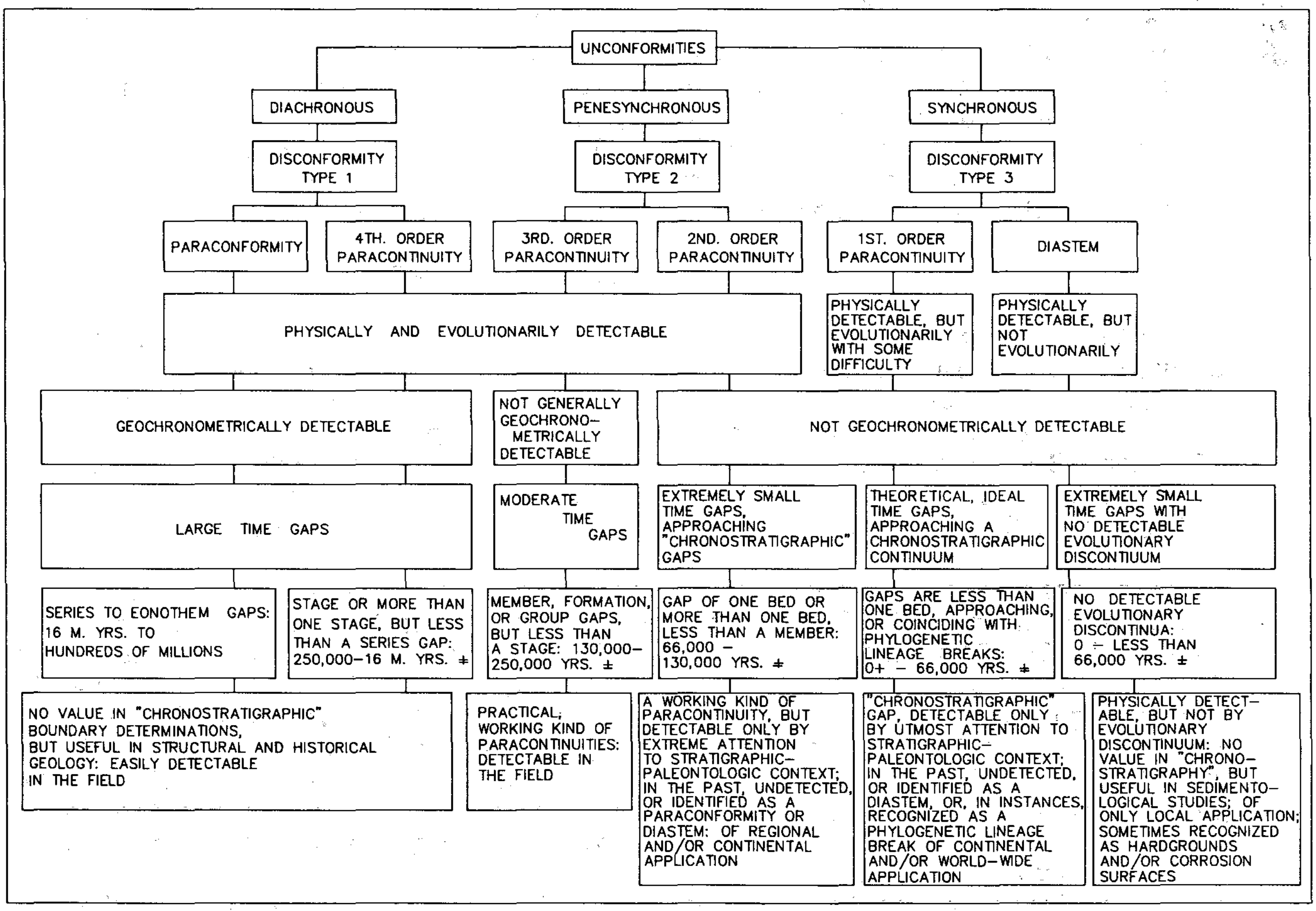


FIGURE 3.--Orders of paracontinuities.

confined, to areas affected by the dynamics of shorelines. Transgressions can, in some cases, follow each other directly and need not be separated by regressions; this is the case within much of the Middle Devonian of the field-trip area.

Diastems and hardground surfaces, associated or not with corrosion surfaces (Weiss, 1954), are of value in local and regional stratigraphy, but by themselves are of no real value in chronostratigraphic boundary determination, for by definition they exhibit no recognizable evolutionary gap. If, however, they exhibit slight, but significant, faunal (time) gaps, they are paracontinuities instead of diastems and have chronostratigraphic value. Corrosion surfaces or corrosion zones are chemical modifications of any kind of unconformable surface, but as generally understood, they are noticeably present along diastems and/or hardgrounds. Corrosion zones are thus modifications of other unconformable surfaces of any magnitude time-loss.

If paracontinuities are enmeshed within a matrix of multiple, precisely stratigraphically determined, and geographically widespread metabentonites (as is the case within the Middle Ordovician and Devonian), an unmatched approach to chronostratigraphy is achieved. This approach counteracts some negative aspects of biostratigraphy, such as variations in the faunal elements, ecological influences, subjectivity in determination of genera and species, migration of organisms in time and space, incomplete study of fossils, insufficient attention to placement of fossils in the substantive stratigraphic sequence, and nonrecognition of the presence and significance of small-scale widespread coincident physical and faunal discontinuities. Boundary determination and subsequent correlation based on the concept of the paracontinuity has been termed paracontinuous stratigraphy (Conkin, 1991).

MIDDLE-LATE ORDOVICIAN BOUNDARY

The Clays Ferry Formation (Weir and Greene, 1965) has no precisely and consistently defined base in the substantive stratigraphic sequence. In fact, the lower part of the Clays Ferry Formation embraces part of the Middle Ordovician (Shermanian) Cynthiana Limestone and part of the Upper Ordovician (Edenian) Eden Shale. In some instances, even the basal beds of the Maysville Group have been included in the upper Clays Ferry. The Kope Formation (Weiss and Sweet, 1964), suffers from the same problem as does the Clays Ferry.

Although many diastemic wave-cut surfaces are present within the upper parts of the various named lithofacies of the Cynthiana Limestone and within the lower parts of the Eden Shale, one particular wave-marked surface is not merely diastemic but is paracontinuous in that a significant faunal gap is coincident with it (pl. 1, figs. B, C, F-H). Its position in the stratigraphic section is recognizable by the crinoid holdfast Parapodolithus sardesoni Conkin, Conkin, and Davidson, 1992, (pl. 1, figs. A, D-F) which is attached to the physical surface of this paracontinuity. This paracontinuity marks the position of the earliest Late Ordovician (Edenian) marine transgression, and its physical surface truncates the uppermost strata of the variously named lithostratigraphic members (facies)of the Middle Ordovician (Mohawkian) Cynthiana Formation (Tanglewood of recent usage). This stratigraphic relationship is shown in figure 4.

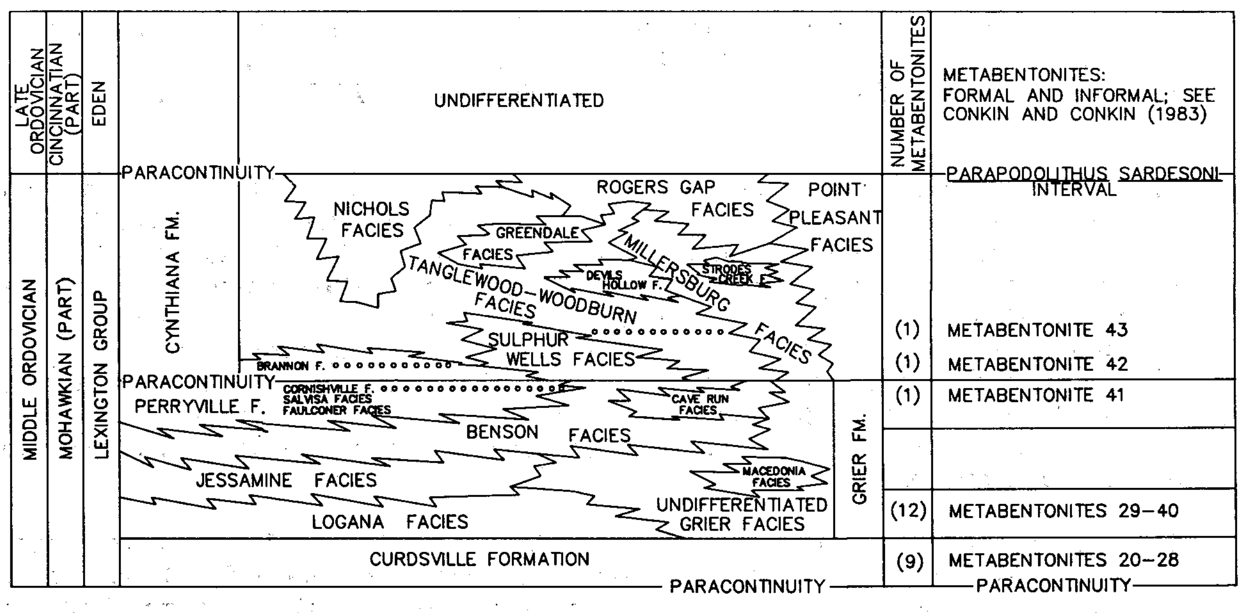


FIGURE 4.--Cynthiana lithofacies and Cynthiana-Eden paracontinuity (F=facies).

When this Parapodolithus sardesoni-encrusted paracontinuous surface is recognized in the field, it is seen to separate the late Mohawkian macrofossil fauna below (marked notably by Cyclonema varicosa and Fusispira cf. F. sulcata) from the early Cincinnatian macrofossil fauna above (marked notably by Sowerbyella rugosa and Ectenocrinus simplex). The geographically widespread wave-cut surface of paracontinuity formed by the earliest Cincinnatian transgression afforded an ideal site of attachment for the larvae of P. sardesoni. The holdfasts are invariably encountered along this paracontinuous surface in all areas of outcrop of the Cynthiana-Eden around the Cincinnati Arch in Kentucky (fig. 5). At Liter's Quarry near Lockport, Henry County, Kentucky (Stop 1), P. sardesoni is attached to a series of wave-cut surfaces over an interval of about 3.8 feet in the basal Eden (fig. 6). The lowest cut surface marks the position of the coincident faunal gap between the underlying upper Middle Ordovician Cynthiana and overlying lower Upper Ordovician Eden. One limestone slab found just west of Bridgeport, Franklin County, Kentucky, along U.S. Highway 60 bears 120 specimens of P. sardesoni as single individuals, or clusters of individuals, attached to the top surface of the Cynthiana.

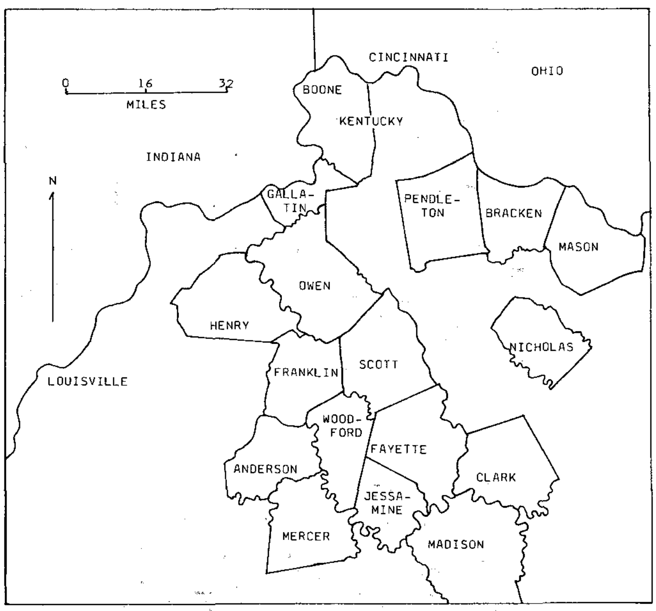


FIGURE 5.--Counties in Kentucky where Parapodolithes sardesoni has been found. This species marks the Middle Ordovician (Cynthiana)-Late Ordovician (Eden) paracontinuous boundary in Kentucky.

Parapodolithus sardesoni is of very rare occurrence lower in the Ordovician--one or two specimens have been found lower in the Cynthiana in Kentucky; on the diastemic surface under the late Blackriverian Pencil Cave Metabentonite in Smith County, Tennessee, and Frontenac County, Ontario; and under the Rockvale Metabentonite (Conkin and Conkin, 1992) in the Blackriverian Lebanon Formation of Cannon County, Tennessee. However, its consistent occurrence in appreciable numbers is coincident with the paracontinuity separating the Cynthiana from the Eden which defines the Middle-Late Ordovician boundary.

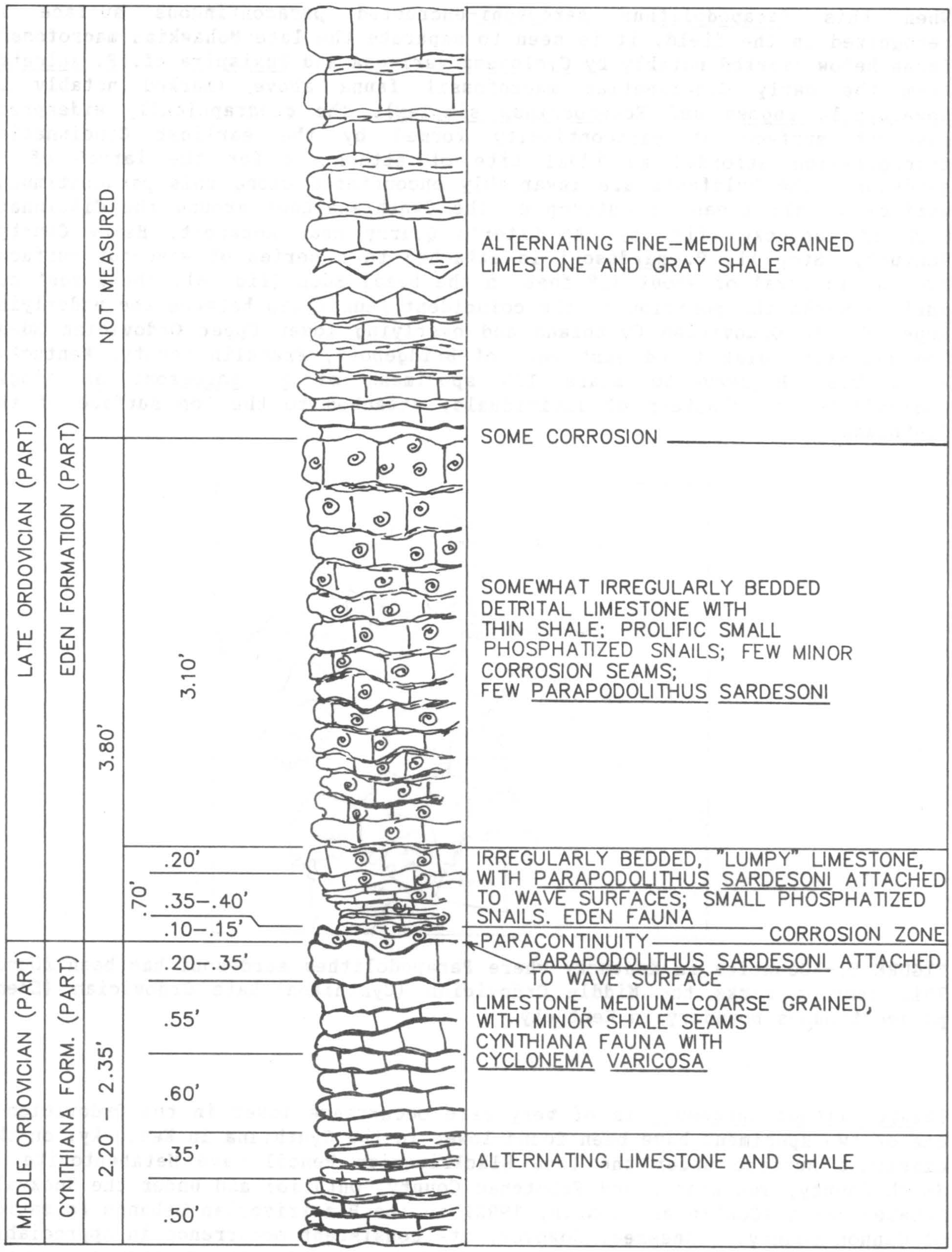


FIGURE 6.--Measured section at Liter's quarry (Stop #1), near Lockport, Henry County, Kentucky.

Not only is the determination of the Middle Ordovician (Shermanian)-Late Ordovician (Edenian) paracontinuous boundary substantiated by a macrofossil discontinuum at the Cynthiana-Eden boundary, but the physical surface of this paracontinuity marks the closest field-determinable approximation to the Shermanian-Edenian boundary as defined by midcontinent conodont zonation (Sweet and Bergström, 1976). In fact, this Parapodolithus sardesoni-defined paracontinuous boundary more precisely defines the Middle-Late Ordovician chronostratigraphic boundary than does conodont zonation, which places it somewhere within midcontinent conodont zone 10, strictly a biozonal determination, and not at a precisely definable and consistently recognizable stratigraphic position in the field.

ORDOVICIAN METABENTONITES

Stratigraphically significant metabentonites seen on the field trip are the late Blackriverian Pencil Cave and Mud Cave in the upper part of the Tyrone Limestone and the early Kirkfieldian Capitol Metabentonite in the Curdsville Limestone (Conkin and Dasari, 1986). Recently, Conkin and Conkin (1992) have recognized the Shermanian Sleepy Hollow Branch Metabentonite in the lower Woodburn Limestone (Tanglewood of recent terminology) and the late Blackriverian Dead Horse Road Quarry Metabentonite in the upper Tyrone, approximately 3 feet below the Pencil Cave Metabentonite. Other metabentonites are recognized locally; Conkin and Conkin (1984a) recognized 43 metabentonites in the Rocklandian through Shermanian of Kentucky. The Dead Horse Road Quarry, Pencil Cave, Mud Cave, and Capitol Metabentonites are seen at Stop 2 (pl. 2; figs. 7 and 8), and the Sleepy Hollow Branch Metabentonite is seen at Stop 4 (pl. 3; fig. 9).

Conkin (1991) presented a correlation of prominent Middle Ordovician metabentonites in eastern North America. This correlation, based on paracontinuous stratigraphy, is somewhat modified here (fig. 10) to reflect the understanding that the Leray Limestone of New York is merely a local facies in the lowest part of the Rocklandian Watertown Limestone, and thus the Blackriverian-Rocklandian boundary is at the Lowville-Watertown contact.

Inclusion of the Leray Limestone as the cherty lowest part of the Watertown Limestone of New York and southern Ontario resolved a long-standing problem in eastern North American Ordovician stratigraphy, namely the precise position of the Blackriverian-Rocklandian boundary. The upper Tyrone (above the late Blackriverian Pencil Cave Metabentonite and below the Rocklandian Curdsville Limestone) is a correlative of the late Blackriverian upper Lowville Limestone of New York and southern Ontario (which bears the Pencil Cave Metabentonite at its base). Thus, a consistent and harmonious stratigraphic position for the Blackriverian-Rocklandian paracontinuous boundary is recognizable in the field at the contact of the upper Lowville (upper Tyrone-upper Carters-upper Plattin) with the Watertown (Curdsville-Spechts Ferry) over an area of more than a million square miles in the eastern United States extending from New York to the upper Mississippi Valley and from Kentucky to Alabama and Georgia and in southern Ontario.

On the basis of paracontinuous stratigraphy (Conkin and Conkin, 1983; Conkin and Kubacko, 1987; and Conkin, 1990, 1991), the "Deicke" Metabentonite at the base of the Rocklandian Carimona Member of the Spechts Ferry Formation of the upper Mississippi Valley states of Minnesota, Iowa, and Wisconsin has been

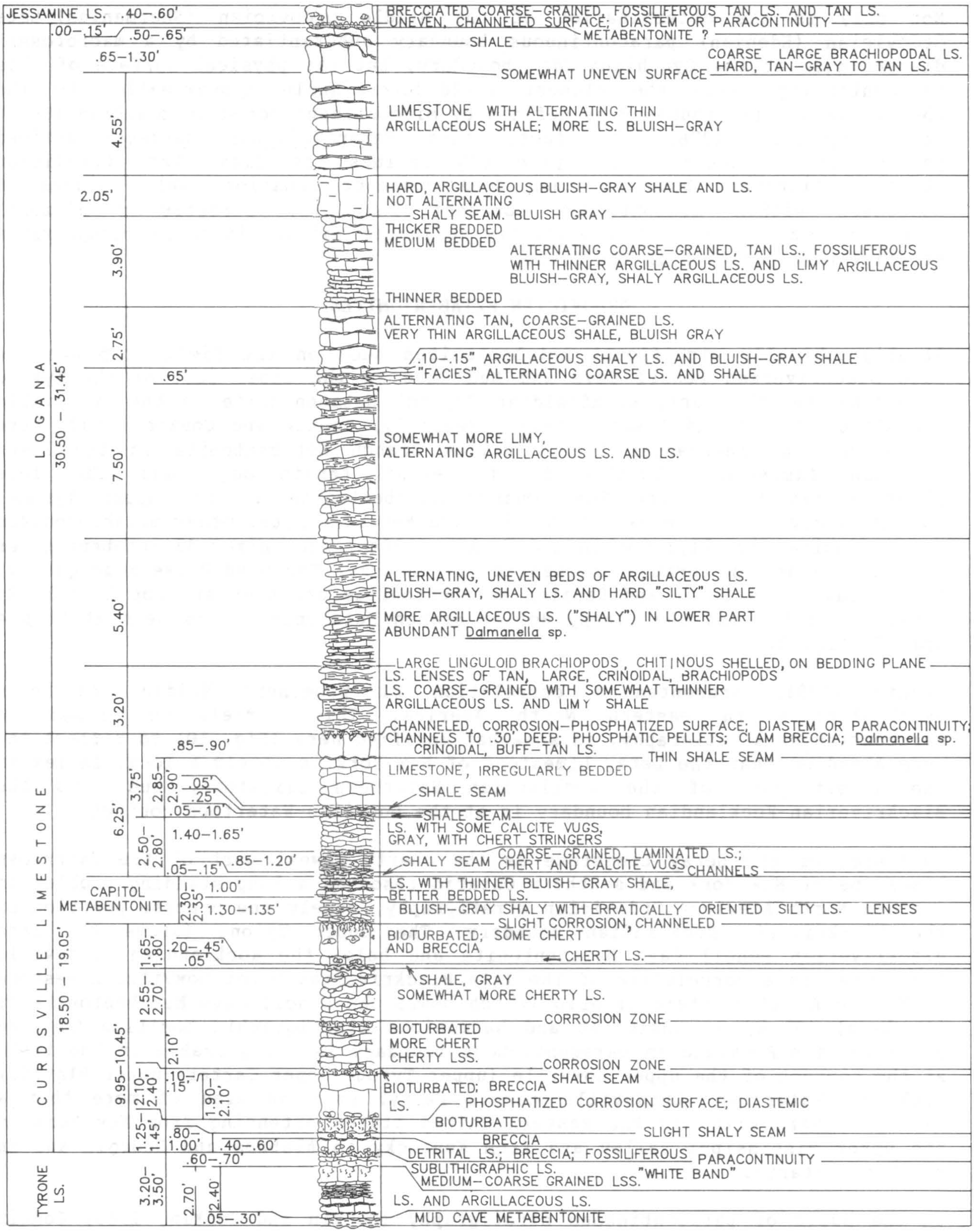


FIGURE 7.--Measured section at Stop 2 along U.S. Hwy 127N ay Cove Spring Road (Dead Horse Road), north of Frankfurt, Franklin County, Kentucky.

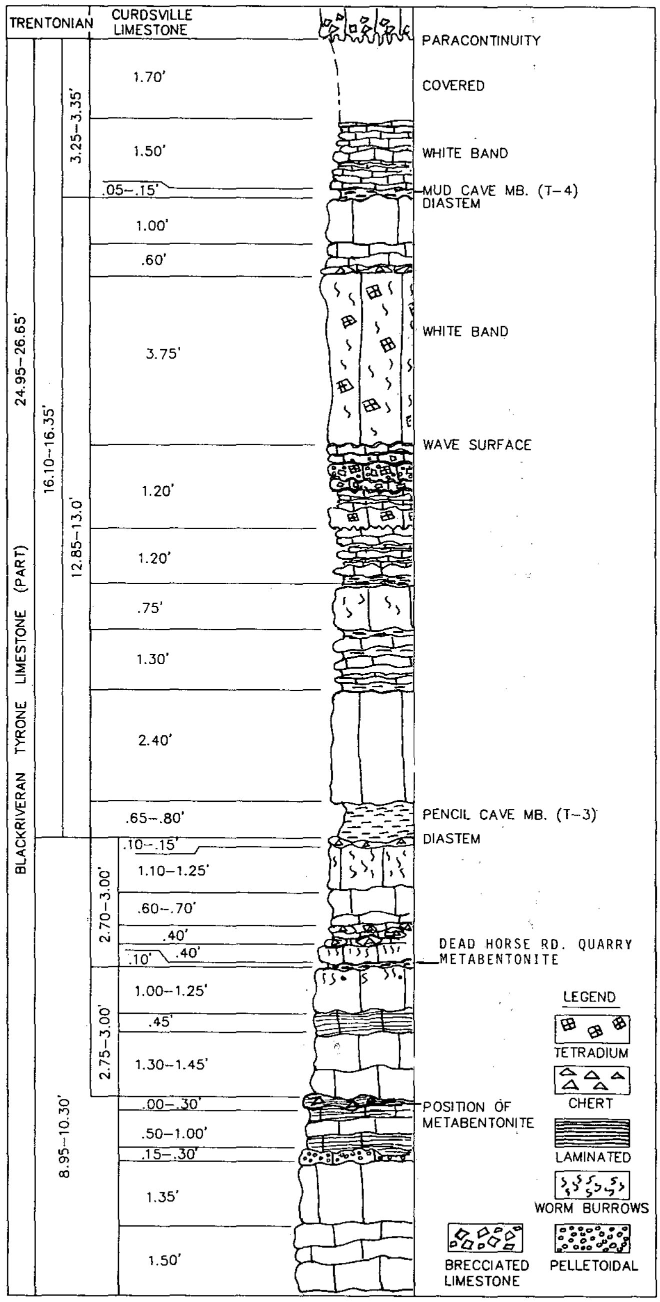


FIGURE 8.--Measured section at Stop 2 at Dead Horse Road quarry, off Hwy 127N, north of Frankfort, Franklin County, Kentucky.

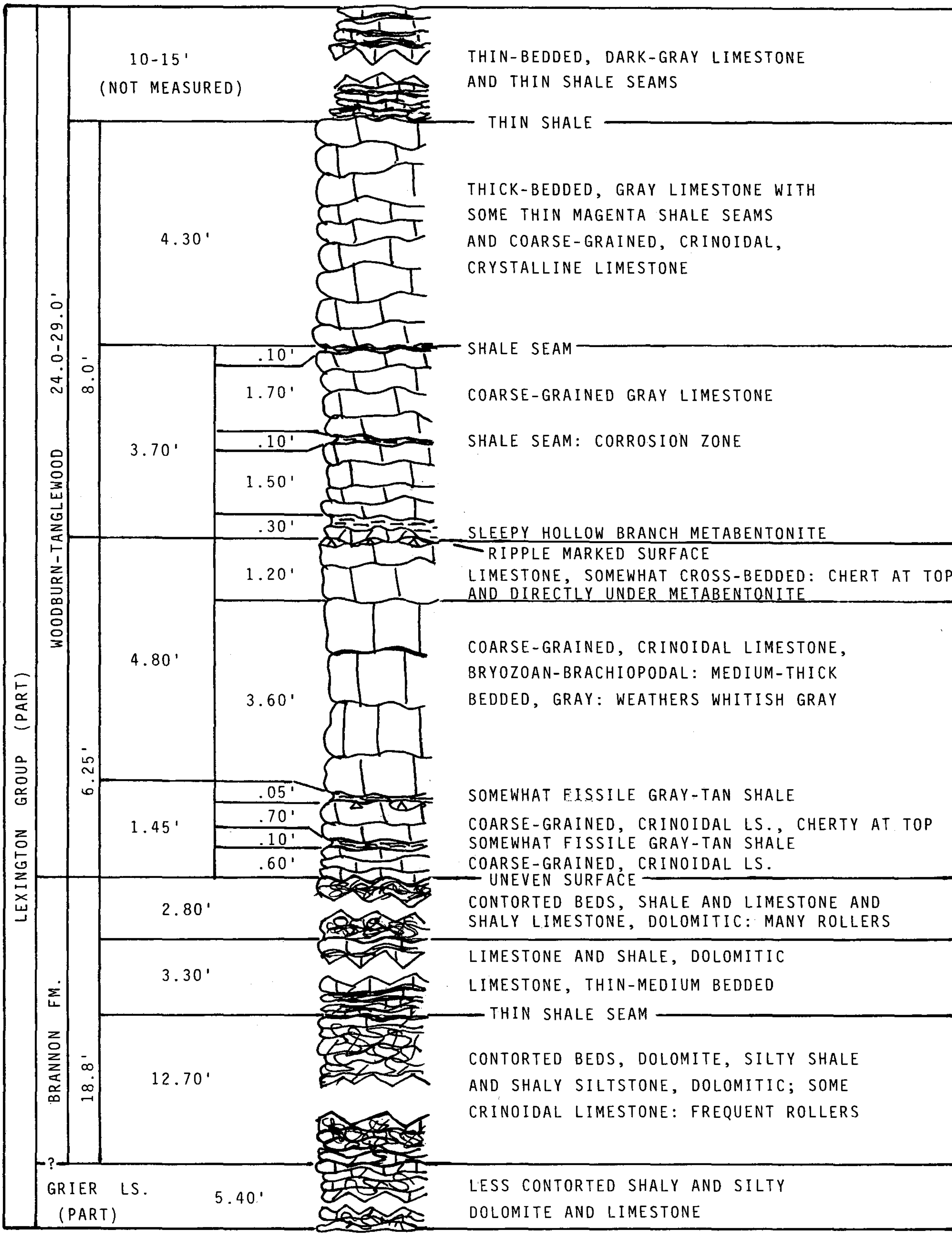
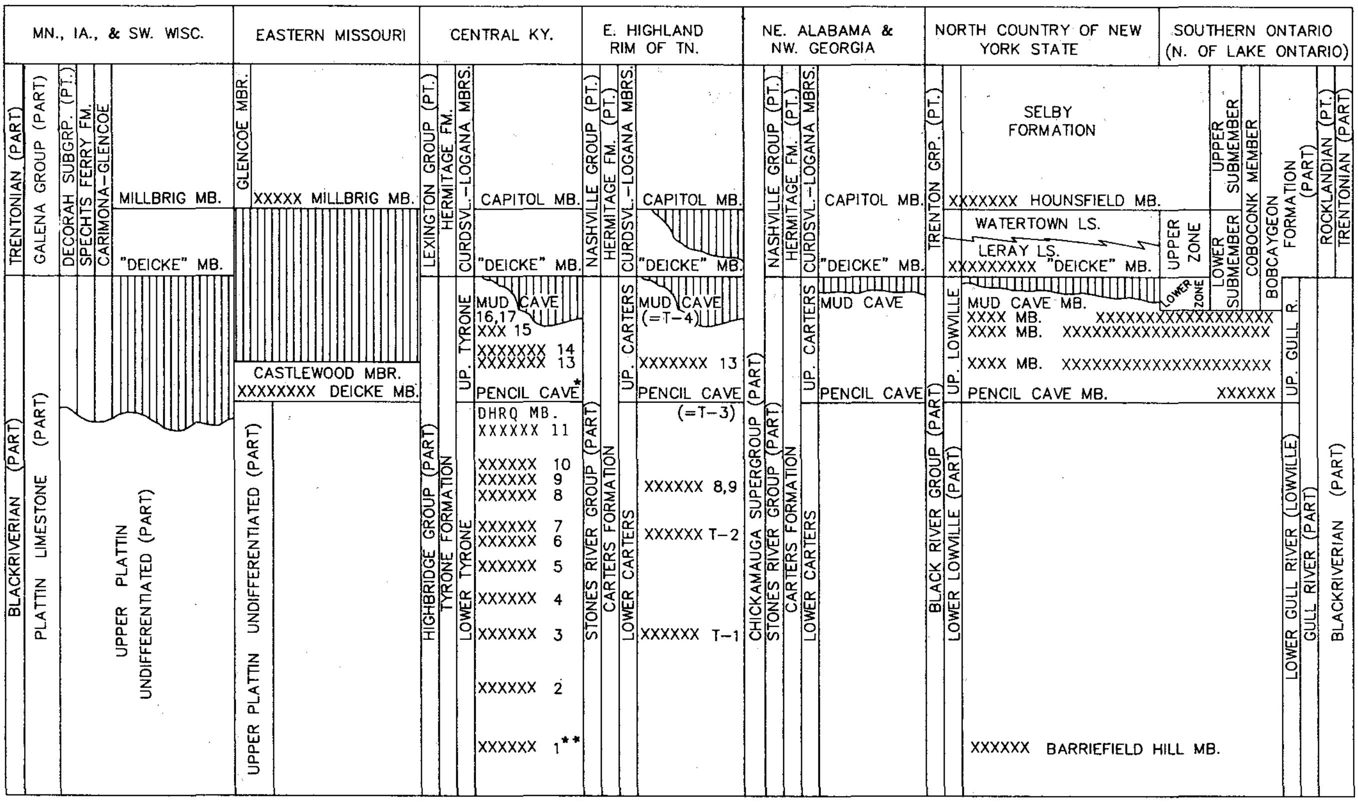


FIGURE 9.--Measured stratotype section at Stop 2 at Dead Horse Road quarry, off Hwy 127N north of Frankfort, Franklin County, Kentucky.



* BOONESBOROUGH MB. 12 (T-3)
** BOONESBOROUGH MB. 1

FIGURE 10.--Correlation of eastern North American Ordovician (Mohawkian) metabentonites (modified from Conkin, 1991).

differentiated from the late Blackriverian Pencil Cave Metabentonite at the base of the upper Tyrone of Kentucky, the upper part of the Carters of Tennessee, the Castlewood Member of the Plattin limestones of Missouri, and the upper Lowville of New York and southern Ontario. Kolata, Frost, and Huff (1986), on the basis of the statistical technique of discriminant analysis of trace elements, considered the early Rocklandian "Deicke" Metabentonite of the upper Mississippi Valley to be a correlative of the type Deicke Metabentonite at the base of the Castlewood Member; at the same time, they equated the type Deicke Metabentonite with the late Blackriverian Pencil Cave Metabentonite of Kentucky and Tennessee (not by trace elements, but by subsurface logs). Cerrito, Conkin, Kubacko, and Fernane (1992) indicated two problems associated with discriminant analysis: upward bias in the discriminant function, which can be overcome by cross validation, and difficulty in assigning the number of groups (meaning that some groups of metabentonites may be unrecognized), which can be overcome by the statistical method of kernel density estimation. Continuing, but unpublished, work on kernel density estimation technique applied to the early Rocklandian "Deicke" Metabentonite and the type Deicke Metabentonite confirms the conclusions arrived at by paracontinuous stratigraphy, namely that the "Deicke" Metabentonite of the upper Mississippi Valley and the Deicke Metabentonite of Missouri are two separate metabentonites and are in stratigraphically distinct positions--the "Deicke" is early Trentonian (Rocklandian) and the type Deicke is late Blackriverian (Pencil Cave correlative). Inasmuch as the type Deicke Metabentonite is a junior synonym of the Pencil Cave Metabentonite, the name Deicke Metabentonite should be abandoned in favor of Pencil Cave. The "Deicke" Metabentonite at the base of the Rocklandian Curdsville Limestone is not well expressed in Kentucky; it is, however, moderately well expressed in the equivalent stratigraphic position at the base of the Hermitage of Tennessee and the base of the Watertown Limestone of New York and Ontario (Conkin, 1991).

The recently recognized (Conkin, 1991) Barriefield Hill Metabentonite in the lower Lowville Limestone (12 to 16 feet above the Pamelia-Lowville paracontinuity) in southern Ontario and northern New York is suggested as a correlative of Conkin and Conkin's (1983) Boonesborough Metabentonite No. 1, which occurs about 8-12 feet above the base of the lower Tyrone (fig. 10).

Plate 4 displays some of the definitive pyroclastic euhedra from Mohawkian metabentonites.

SILURIAN OF THE FIELD-TRIP AREA

The Silurian of the field-trip area includes the upper Lower Silurian Brassfield Limestone, which paracontinuously overlies the Richmond Group. The Brassfield on the northwest side of the Cincinnati Arch is younger that the type Brassfield on the east side of the Arch and evidence exists that it is Middle Silurian in age, for in eastern Jefferson County and Oldham County, Kentucky, there is some interfingering of Brassfield and Osgood lithologies. A Middle Silurian sequence, consisting of the Osgood Formation through the Louisville Limestone, follows the Brassfield. No Upper Silurian Wabash Formation equivalents are present in northwestern Kentucky or southern Indiana despite past opinions (Patton, 1955, and Rexroad and others, 1978).

The present discussion of the Middle Silurian is concerned with the Laurel Dolomite-Waldron Shale paracontinuity, the Waldron Shale-Louisville Limestone disconformity, and the Louisville Limestone-Jeffersonville Limestone paraconformity. Detailed consideration is also given to the recent revision of the Louisville Limestone by Conkin, Conkin, Brown, Kubacko, and Fernane, 1992.

LAUREL-WALDRON PARACONTINUOUS BOUNDARY

A paracontinuity at the Laurel-Waldron contact is expressed as a wave-cut surface developed on the top of the Laurel Dolomite. The "oolitic" dolomite previously considered to mark the top of the Laurel Dolomite actually forms the basal bed of the overlying Waldron Shale, which paracontinuously overlies the Laurel Dolomite. This basal part of the Waldron is seen in eastern Jefferson County, Kentucky, at the Jefferson County quarry (Stop 5; pl. 5, figs. A-H; pl. 6, figs. D-G; and fig. 11) and near Utica in eastern Clark County, Indiana at the Nugent quarry (Stop 8; pl. 7, figs. B, C, E, G, I; fig. 12).

This "oolitic" base of the Waldron is present in Bullitt and Nelson Counties, Kentucky, as well. In addition, this "oolitic" base of the Waldron may bear a breccia of Laurel Dolomite fragments reworked into the basal Waldron, immediately above the paracontinuity, as seen in the Nugent quarry (Stop 8; pl. 7, figs. B, C; fig. 12). The so-called "oolites" are not true oolites, but are hollow ovoidal bodies composed of a thin coating of dolomite crystals surrounding a tectinous inner lining, and perhaps are organic in nature.

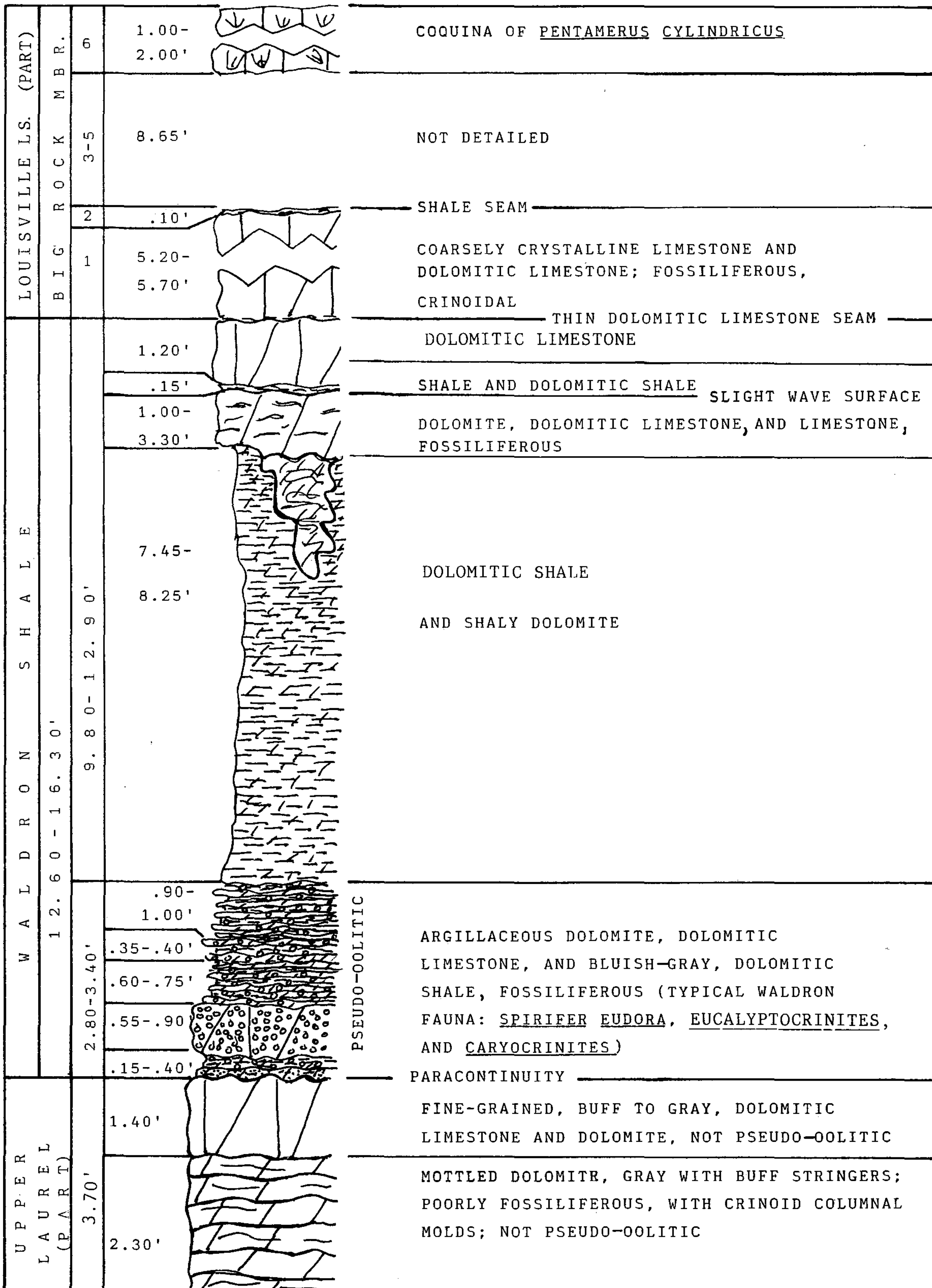


FIGURE 11.--Measured section at Stop 5, Jefferson County quarry (Rogers Group, Inc.), north of Middletown, Jefferson County, Kentucky.

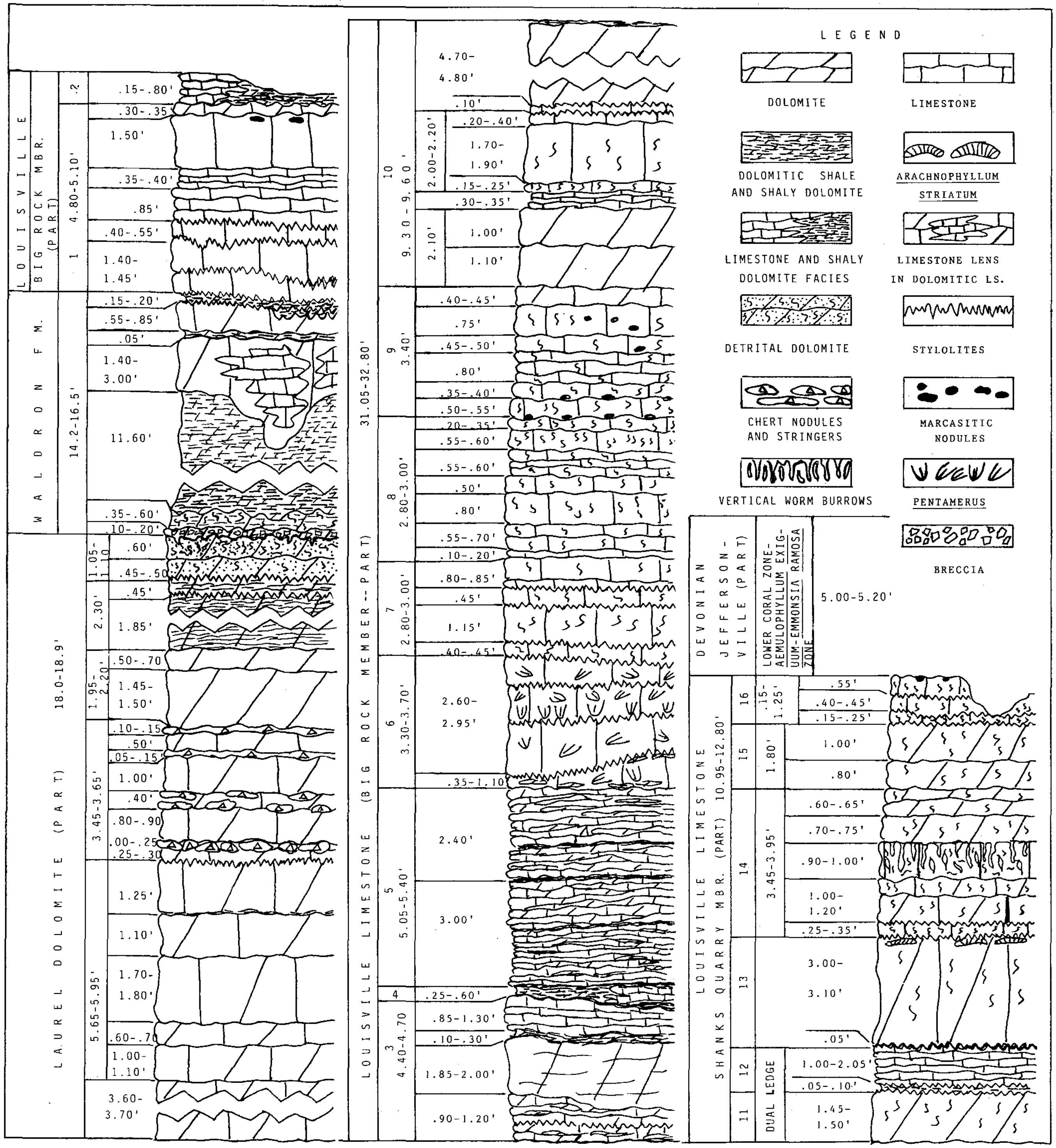


FIGURE 12.--Silurian section in the Nugent quarry (Stop 8), near Utica, Clark County, Indiana.

A significant faunal break is coincident with the physical surface of paracontinuity developed at the Laurel-Waldron contact. Typical Waldron Shale faunal elements (pl. 12, figs. K, M-P) occur above the paracontinuity.

WALDRON-LOUISVILLE DISCONFORMITY

There is a distinct disconformity between the Waldron and the Louisville which certainly is diastemic at least, for there is a distinct physical surface of erosion developed on the upper dolomitic limestone beds of the Waldron. This wave-cut surface truncates coralla of Favosites favosus in the Nugent quarry, (Stop 8; pl. 7, figs. D, F and G). Whether this break is diastemic or paracontinuous in nature must await more detailed paleontologic study of the faunas of both the Waldron and the Louisville tied to the stratigraphic revision of the Louisville by Conkin, Conkin, Brown, Kubacko, and Fernane (1992).

LOUISVILLE LIMESTONE

Foerste (1897) named the Louisville Limestone from the Beargrass Creek quarries in eastern Louisville, Jefferson County, Kentucky, but did not designate a type section. Butts (1915) presented a lithostratigraphic division of the Louisville consisting of 17 units based on the old quarrymen's ledge terminology developed in Shanks quarry (Stop 6A), one of the Beargrass Creek quarries. Figure 13 shows Butts' (1915) 17 units and these ledge names. His lowest two units are no longer exposed at Shanks quarry.

Butts (1915) well understood the concept of the unconformity which separates the Middle Silurian Louisville from the overlying late Early Devonian (Emsian)-Middle Devonian (Eifelian) Jeffersonville Limestone, but he did not coin a name for this kind of unconformity. Dunbar and Rodgers (1957) later proposed the term paraconformity. Field study of this paraconformity reveals that its nature is more complex than Dunbar and Rodgers realized, and confusion has continued concerning its nature.

Lithostratigraphy of the Louisville Limestone

Conkin, Conkin, Brown, Kubacko, and Fernane (1992) revised the lithostratigraphy of the Louisville Limestone, added seven more units to the lower part (fig. 13), and proposed a composite stratotype section in the Cherokee Park area of eastern Louisville, Jefferson County, Kentucky (fig. 14). They divided the Louisville Limestone into 24 units (fig. 13) allocated into three members, in ascending order: the Big Rock Member (units 1- 10), the Shanks Quarry Member (units 11-23), and the Cross Hill Member (units 24A and 24B).

Big Rock Member

The Big Rock Member (units 1-10) (pl. 8, figs. F, G; fig. 15) includes seven additional units not recognized by Butts (1915) below the section at Shanks Quarry. It is the lowest and most persistent member of the Louisville Limestone, ranging in thickness from 35 to about 42 feet in the type area, and is present throughout the areal extent of the Louisville Limestone. The stratotype of the Big Rock Member is seen at Stop 7. The best exposure of the Big Rock Member is in the Nugent quarry (Stop 8; pl. 7, figs. A, D, F, G; fig. 12).

		CONKIN, CONKIN, BROWN, KUBACKO, AND FERNANE (1992)			OLD QUARRYMEN'S LEDGE NAMES	BUTTS'1915 NUMBERED UNITS
LOUISVILLE LIMESTONE 67–100.65'	CROSS HILL MBR. 5.65–10.40'	IRON LEDGE	UPPER 24B	3.45–4.80'	IRON LEDGE	17
			LOWER 24A	2.20–5.60'		
	SHANKS QUARRY MEMBER 29.00–43.10'	TOP BLUE LEDGE	23	2.80–5.60'	TOP BLUE LEDGE	16
		GRAY LEDGE	22	2.80–5.60'	GRAY LEDGE	15
		OYSTER LEDGE	21	3.40–4.00'	OYSTER LEDGE	14
		7 FOOT LEDGE: FLINT FLAGGING	20	.80–1.55'	FLINT FLAGGING	13
		7 FOOT LEDGE: THREE TO FIVE FOOT LEDGE	19	2.90–5.15'	NO NAME	12
		BIG BLUE LEDGE	18	4.40–5.30'	BIG BLUE LEDGE	11
		HARD LEDGE	17	2.10–2.60'	HARD LEDGE	10
		HARD CURB LEDGE	16	2.25–2.95'	HARD CURB LEDGE	9
		22 INCH LEDGE	15	1.25–2.00'	22 INCH LEDGE	8
		BLUE CAPTAIN LEDGE	14	2.20–2.80'	BLUE CAPTAIN LEDGE	7
		PAVING LEDGE	13	2.60–3.00'	PAVING LEDGE	6
		LITTLE FLAG (DUAL LEDGE)	12	.50–1.05'	LITTLE FLAG	5
		BIG FLAG (DUAL LEDGE)	11	1.00–1.50'	BIG FLAG	4
	BIG ROCK MEMBER 32.35–47.15'	BOTTOM CURB LEDGE	10	6.00– 7.00– 9.65'	BOTTOM CURB LEDGE	3
		GRANDDAD LEDGE	9	2.50–3.00'	GRANDDAD LEDGE	2
		GREAT GRANDDAD LEDGE	8	3.35–8.20'	GREAT GRANDDAD LEDGE	1
		3 FOOT LS. LEDGE	7	2.80–3.45'		
		PENTAMERUS COQUINA	6	3.20–4.20'		
		ARGILLACEOUS LIMESTONE LEDGE	5	5.35–6.35'		
		SECOND SHALE	4	.20–.60'		
		SECOND ENCRINITAL LIMESTONE	3	4.50–5.20'		
		FIRST SHALE	2	.15–1.10'		
		FIRST ENCRINITAL LIMESTONE	1	4.30–5.50'		

FIGURE 13.--Units of Louisville Limestone of Butts (1915) and Conkin, Conkin, Brown, Kubacko, and Fernane (1992).

Several lithostratigraphic units are distinctive of the Big Rock Member. The First Shale ledge (unit 2) is a consistently present marker, containing interspersed glauconite in crinoidal and cystoidal limestone lenses. A glauconitic shale with crinoidal, crystalline limestone lenses constitutes the Second Shale ledge (unit 4). Unit 5 (the Argillaceous Limestone ledge) is an irregularly bedded, somewhat nodular and fossiliferous limestone with intercalated thin to very thin irregular lenses of dolomitic shale; it weathers to the most argillaceous appearing unit in the Louisville Limestone. Unit 6 is a marker zone of large Pentamerus cylindricus that constitutes a coquina and/or biocoenosis. The Great Granddad ledge (unit 8) is especially worm burrowed and rough textured on weathered surfaces, and the Bottom Curb ledge (unit 10) is a massive set of three dolomite layers. Scattered chert may occur in units 8-10.

Marcasite nodules that weather to orange-ocher (iron oxide and iron hydroxide) stains are present in limited numbers throughout many of the ledges of the Big Rock Member, but are especially noticeable in the Granddad ledge (unit 9). The

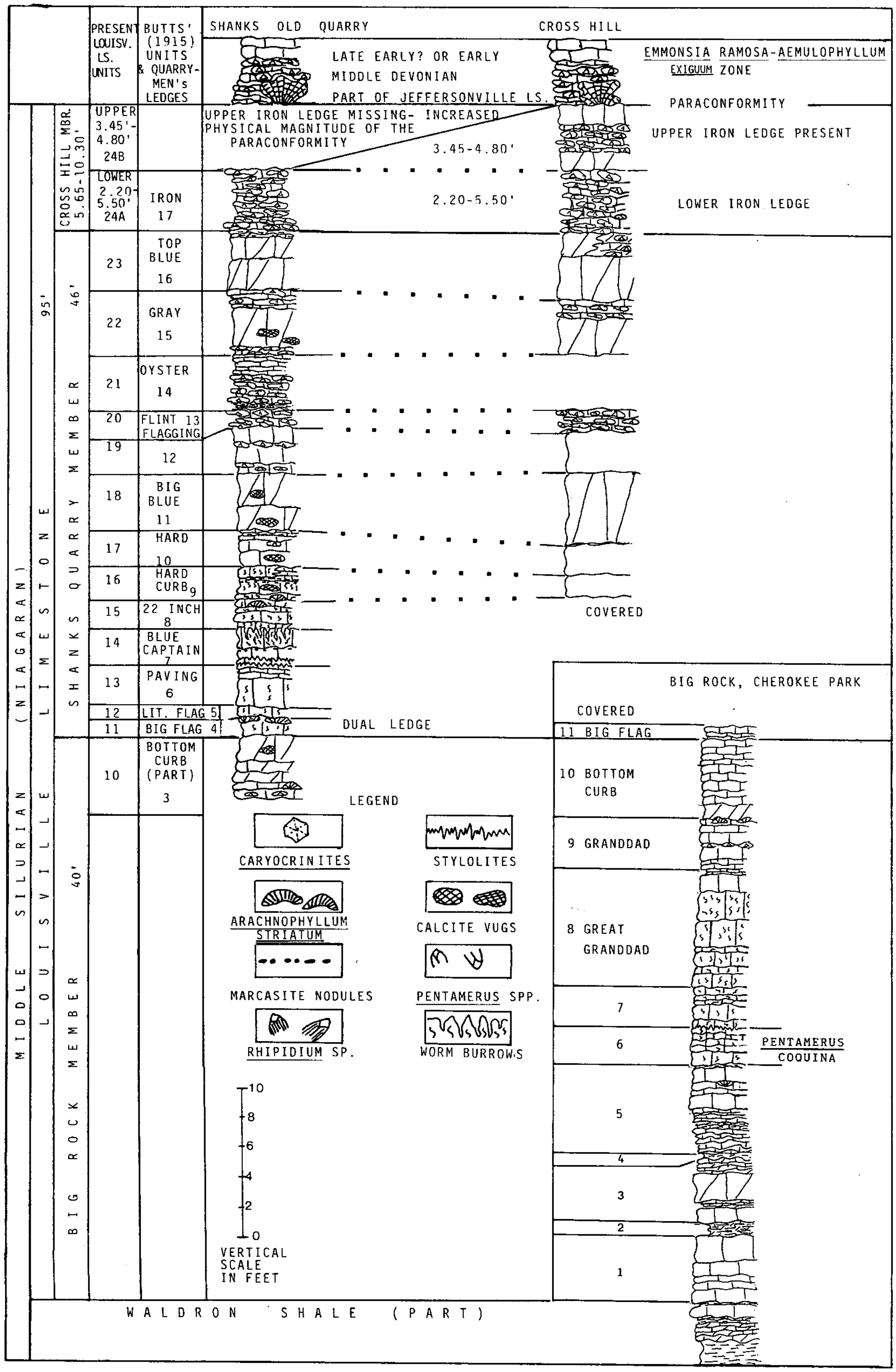


FIGURE 14.--Composite stratotype sectin of Louisville Limestone in the Cherokee Park area Stops 6 and 7), Louisville, Jefferson County, Kentucky.

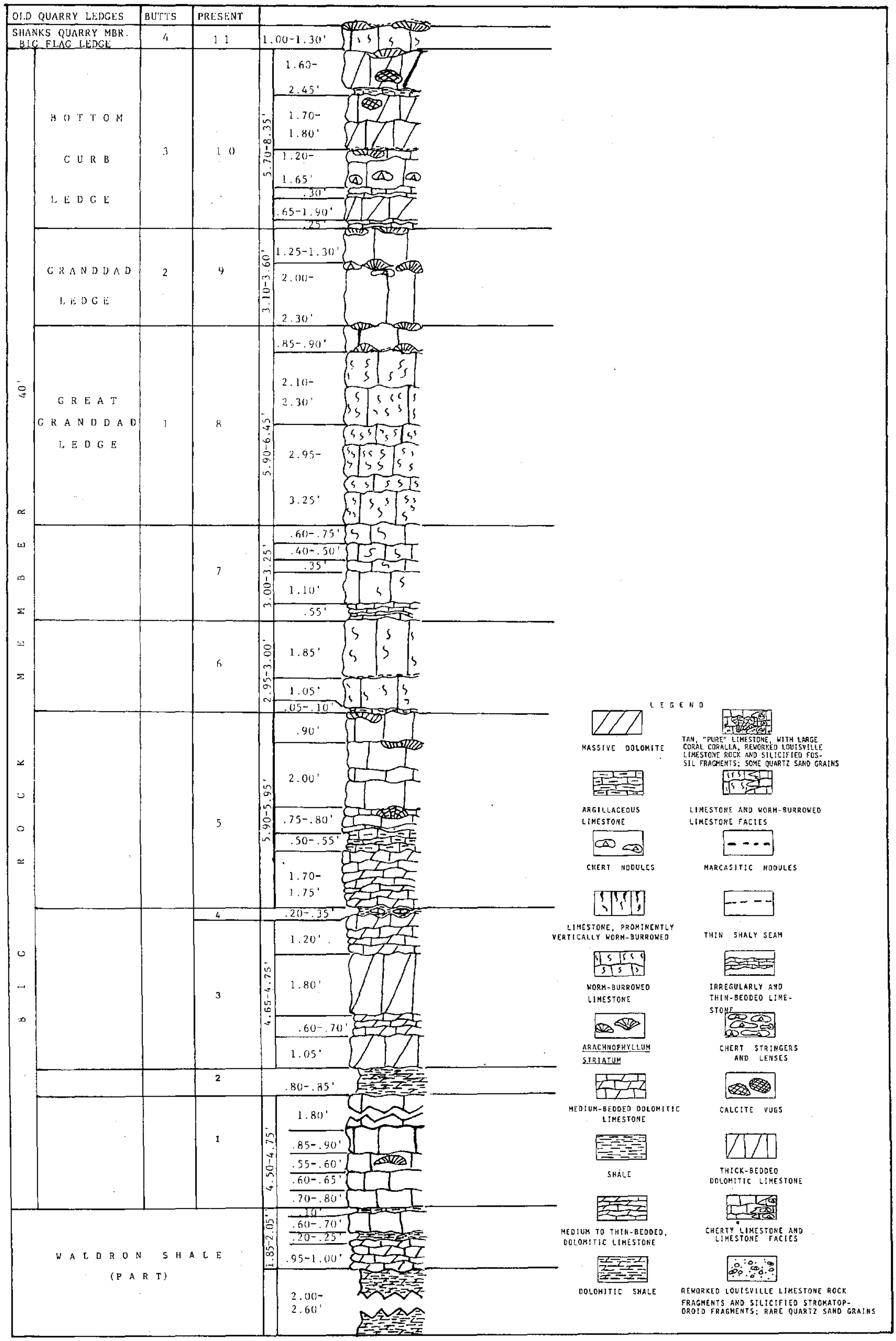


FIGURE 15.--Measured stratotype section of Big Rock Member of Louisville Limestone at Big Rock (Stop 7), Cherokee Park, Louisville, Jefferson County, Kentucky.

most conspicuous concentration is at the base of the Granddad ledge along its contact with the Great Granddad ledge (unit 8); "bleeding" of these oxides downward over the surface of the underlying beds is a distinctive mark of the Great Granddad-Granddad ledges contact.

Shanks Quarry Member

The Shanks Quarry Member (fig. 16) includes units 11-23. The stratotype of this middle member of the Louisville Limestone is at Shanks quarry, Louisville, Jefferson County, Kentucky (Stop 6A; pl. 8, figs. A, B, D). The thickness of the Shanks Quarry Member ranges from 29 to 48 feet (averaging 40 feet) in the Louisville area and northward along its strike in the Sellersburg area of Clark County, Indiana; however, this member thins rapidly from its top downward in a northeasterly direction from its type area. At Prospect Hill, in eastern Jefferson County (Stop 9; pl. 9, figs. B-F), the Jeffersonville Limestone rests paraconformably on the top (unit 10) of the Big Rock Member; in southern Indiana at the Nugent quarry (Stop 8; pl. 7, figs. A, F, G, pl. 10, figs. A, B, E, and pl. 11, figs. C-G), a diminished portion (units 11-16) of the Shanks Quarry Member persists.

The basal two thin beds (units 11 and 12, Little Flag and Big Flag ledges) of the Shanks Quarry Member form a distinctive pair of beds, termed the Dual ledge (fig. 13) by Conkin, Conkin, Brown, Kubacko, and Fernane (1992). The lower part of the Shanks Quarry Member is a medium-bedded, worm-burrowed limestone. The Blue Captain ledge (unit 14) is a conspicuous, prolifically vertically worm-burrowed bed. Small, scattered, marcasitic nodules are present in the upper part of unit 13, at the base of unit 14, in the middle of unit 16, in the lower part of unit 17, and throughout units 18 and 23. The upper parts of the Shanks Quarry Member are somewhat dolomitic, particularly the massive, bluish-gray unit 18 (the Big Blue ledge) and unit 23 (the Top Blue ledge). The Big Blue ledge is a marker for the Shanks Quarry Member. The Gray ledge (unit 22) is also a dolomitic limestone and is similar to the Top Blue ledge, but is more limy and has some chert near its base. Units 20 and 21 (Flint Flagging and Oyster ledges) are prolifically cherty. Reentrants are characteristically developed between these units and between the Top Blue ledge (unit 23) and the Lower Iron ledge (unit 24A) of the overlying Cross Hill Member. Unit 21 commonly weathers essentially to chert.

Cross Hill Member

The Cross Hill is the uppermost member of the Louisville Limestone and consists of unit 24A (Lower Iron ledge) and unit 24B (Upper Iron ledge). It ranges in thickness at its stratotype section (Stop 6B; fig. 17; pl. 8, figs. C, E) from 5.65 to about 10.30 feet. Units 24A and 24B are both cherty limestones (hence the name Iron ledge), but Unit 24B has a diagnostic thin dolomitic layer at its base which closely resembles the lithology of the Big Blue ledge (unit 18) of the Shanks Quarry Member. The Cross Hill Member is only spottily present even in the Louisville composite stratotype area and is the least persistent member of the Louisville. Unit 24B, which is present along its strike in Liter's quarry in the Sellersburg area of Clark County, Indiana, is absent in Shanks quarry adjacent to the Cross Hill stratotype. In the Bickel Lane quarry (fig. 18), only 2,000 feet north of Shanks quarry, both units 24A and 24B are absent.

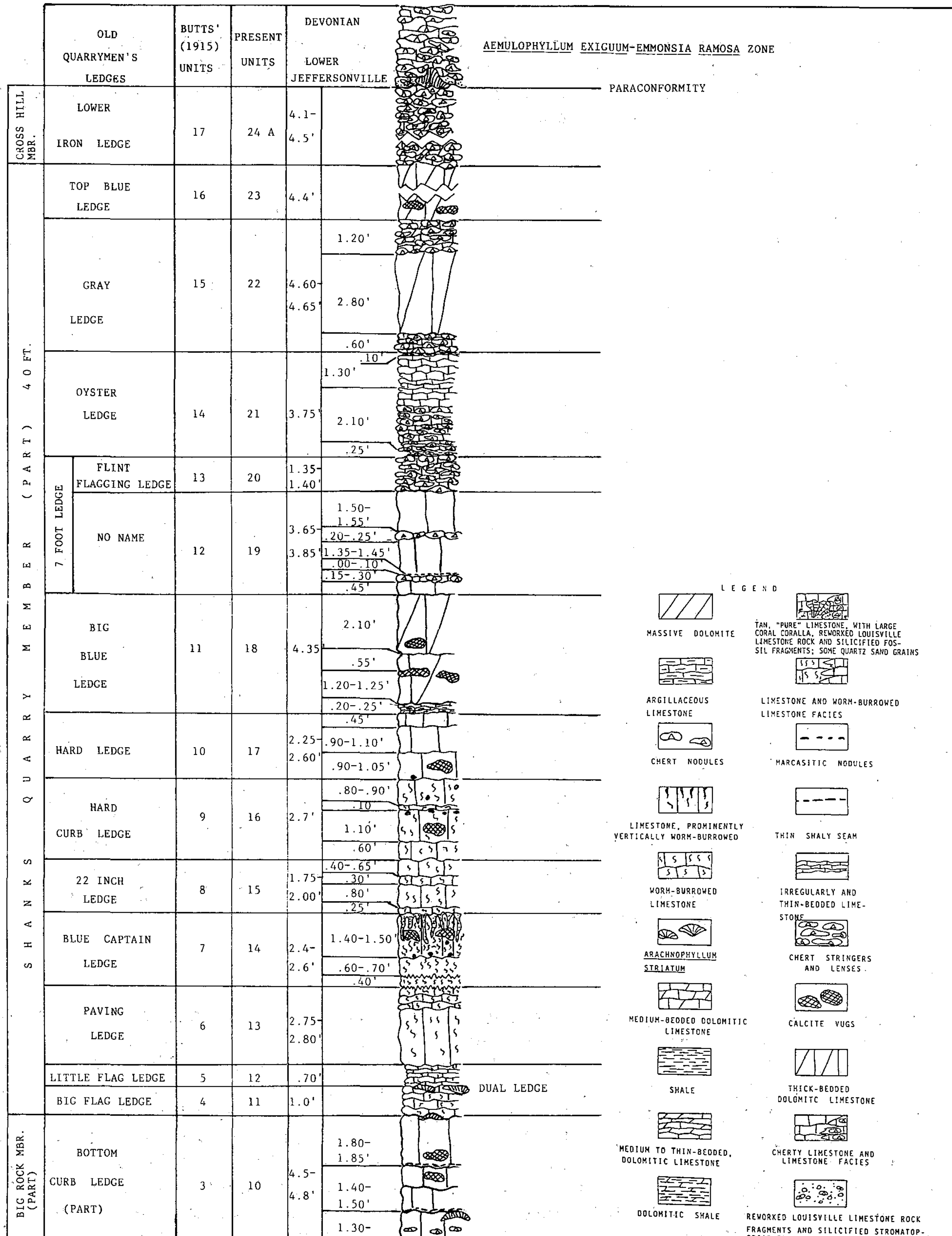


FIGURE 16.--Measured stratotype section of Shanks Quarry Member of Louisville Limestone, Grinstead Drive and I-64W (Stop 6A), Louisville, Jefferson County, Kentucky.

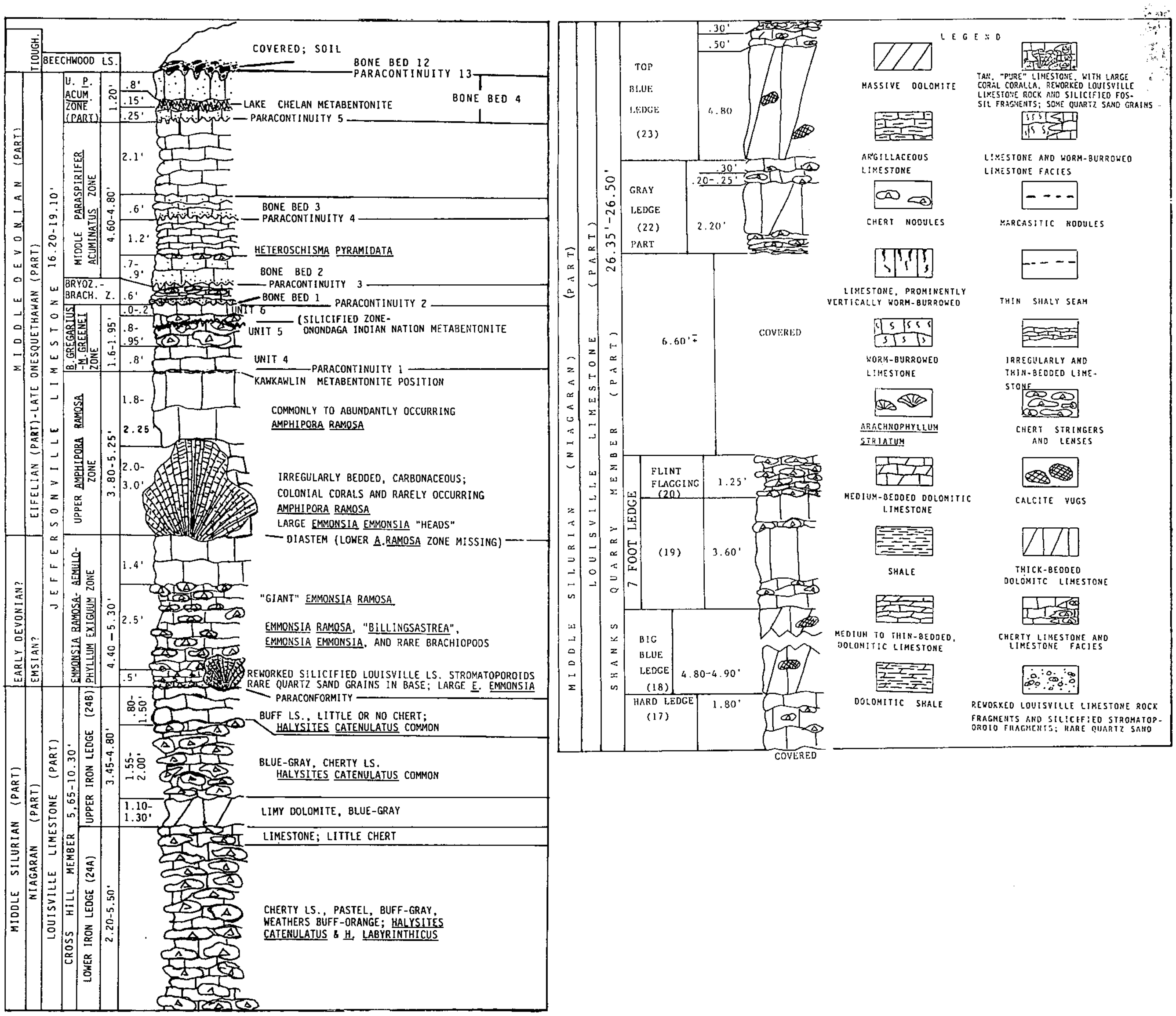


FIGURE 17.--Measured stratotype section of Cross Hill Member of Louisville Limestone at Cross Hill and Lexington Roads (Stop 6B), Louisville, Jefferson County, Kentucky.

The variation in magnitude of the lithostratigraphic gap of the paraconformity was not recognized by Butts (1915) nor by Dunbar and Rodgers (1957). In fact, at Shanks quarry, the cherty lower 3 feet of the Aemulophyllum exiguum-Emmonsia ramosa Zone of the Jeffersonville Limestone, which there paraconformably overlies the cherty unit 24A of the Louisville, was included in the upper part of Butts' (1915) Louisville unit 17 (Iron ledge). We may consider that Butts would have misplaced the paraconformity upward outside the Shanks quarry

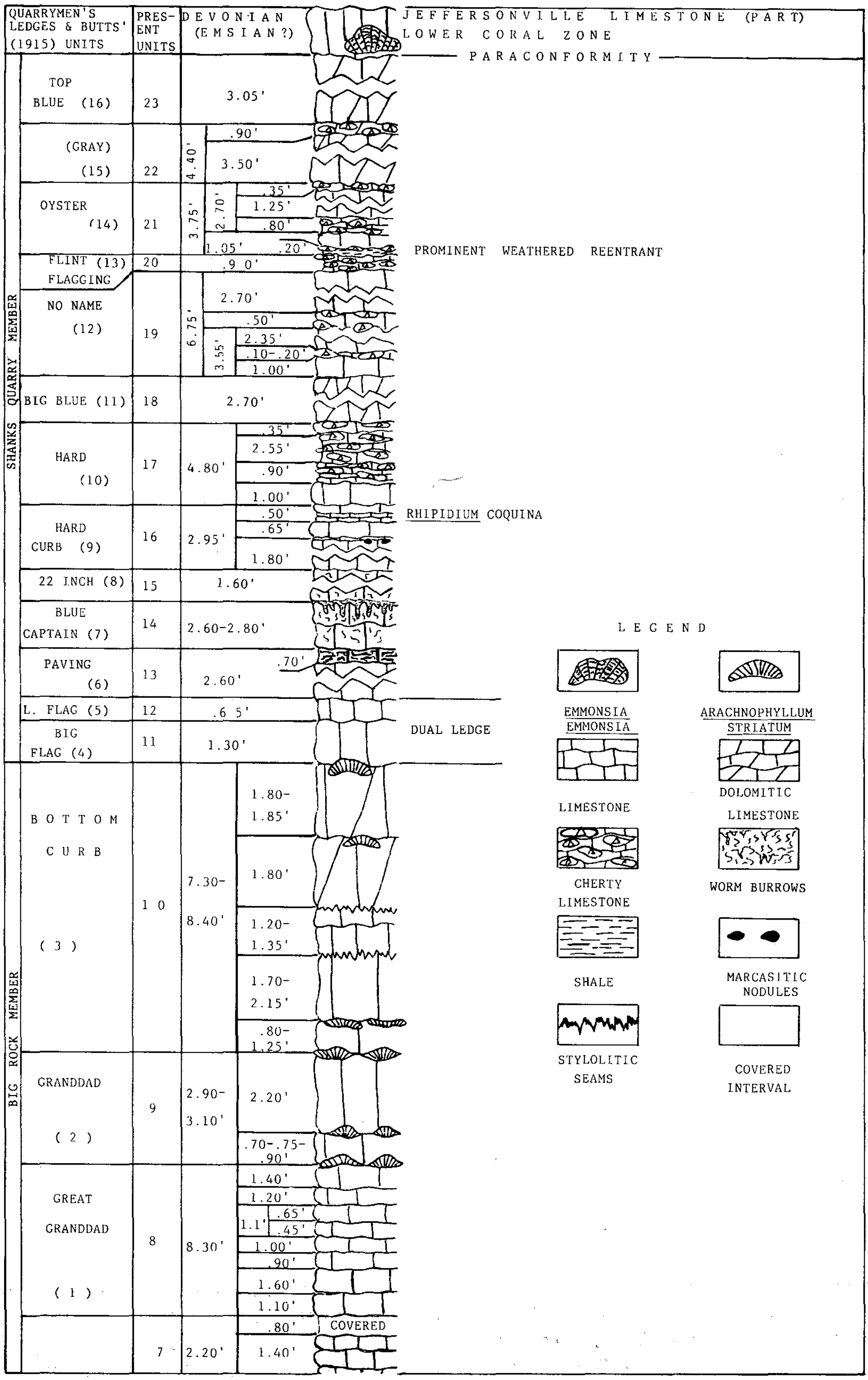


FIGURE 18.--Measured section at Bickel Lane quarry, between Bickel Lane and I-64W, Loiusville, Jefferson County, Kentucky.

locality as well, for he stated that the basal Jeffersonville was without chert. However, it is prolifically cherty both at Shanks quarry and at the Cross Hill stratotype, so that the type paraconformity is between two cherty limestones, causing Butts to place part of the Jeffersonville into his Louisville Limestone Iron ledge. Farther east in Jefferson County, Kentucky, and in extreme eastern Clark and Scott Counties, Indiana, the cherty Shanks Quarry and Cross Hill Members of the Louisville are absent because of increase in magnitude of the Louisville-Jeffersonville paraconformity.

Macrofossils of the Louisville Limestone

Big Rock Member

The macrofossils (Pentamerus cylindricus, Caryocrinites spp., Omphyma verrucosa, Arachnophyllum striatum, and Eucalyptocrinites crassus) which we believe to be of value in recognition of the Big Rock Member are illustrated in plate 12. Dolomitic, glauconitic, crinoidal limestones in the lower part of the member (units 1-5) are particularly rich in the cystoid Caryocrinites and crinoid heads. Caryocrinites occurs in any numbers only in the Big Rock Member and in the uppermost dolomitic limestone of the Waldron Shale.

The coral Omphyma verrucosa has been recorded only from the lower part of the Louisville; it is not a common fossil. The coral Arachnophyllum striatum occurs more or less throughout the Louisville Limestone, particularly along bedding planes in the Paving ledge (unit 13), especially in eastern Clark County, Indiana, just below the Blue Captain ledge (unit 14). However, it is most common in the Big Rock Member, especially along bedding planes in unit 9 (Granddad ledge) and somewhat less so in unit 8 (Great Granddad ledge). The corals Thecia and Coenites reticularia are rather abundant in the Big Rock Member; both, however, occur more or less throughout the Louisville.

Interambulacral plates of the crinoid Eucalyptocrinites crassus, which are characteristically encountered in the Waldron Shale, are common in the Big Rock Member.

The large, smooth-valved brachiopod Pentamerus cylindricus occurs in any numbers only in the Big Rock Member; these brachiopods form a coquina biocoenosis in the upper part of unit 6 (pl. 12, figs. C-E). Stropheodontid brachiopods and smaller striated brachiopods (not, however, Rhipidium or Conchidium) are more or less common in the Big Rock Member, particularly in units 1-5.

Bioturbation in the form of worm burrows is present throughout the Big Rock Member, but is most conspicuous in the massive unit 8 (the Great Granddad ledge) which serves as a marker for the Big Rock Member.

Shanks Quarry Member

The Shanks Quarry Member is somewhat less fossiliferous than the lower units (1-5) of the Big Rock Member. Fossils are more common in the limy units above the Big Blue ledge (unit 18). The striated pentamerid Rhipidium (pl. 12, figs. A and B) is first noted in unit 16 (Hard Curb ledge) of the Shanks Quarry Member, where it is common. Rhipidium is present more or less throughout the

Shanks Quarry Member above unit 16, but is more noticeable in unit 22 (Gray ledge).

Large, ribbed pentamerids, possibly Conchidium, having somewhat more incurved beaks than those of Pentamerus, are present in the upper beds of the Shanks Quarry Member. The large blastoid Troostocrinus has been seen only in the Shanks Quarry Member. Stromatoporoids are common in this member.

The most conspicuous vertically worm-burrowed zone (pl. 11, fig. G) in the entire Louisville Limestone is consistently present in the upper part of unit 14 (Blue Captain ledge) and is a marker for this middle part of the Shanks Quarry Member. It is well displayed in all areas of outcrop of the member.

Cross Hill Member

The Cross Hill Member is very fossiliferous. Stromatoporoids and corals, including Halysites catenularia and Coenites reticularia, are notable (pl. 12). Other fossils are essentially the same as those in the Shanks Quarry Member. Rhipidium is the dominant ribbed pentamerid in the Cross Hill Member.

Microfossils of the Louisville Limestone

Agglutinate foraminiferans, although abundant only in the limier portions, are the most notable and common microfossils in the Louisville Limestone. The Foraminifera are characteristically represented by genera which range from the Ordovician or Silurian into the Devonian, but a few that extend into the Early Mississippian. However, there is an absence of any typical Early Silurian forms such as species of Amphicervicis and Amphitremoida citrona, or typical Late Silurian-Early Devonian forms such as Hemisphaerammina geometrica. Webbinelloidea similis is the most common foraminiferan in the Louisville Limestone, but this species is also the dominant agglutinate in the Jeffersonville Limestone, as it is in the Devonian throughout the world. Conkin and Conkin (1960) gave a preliminary account of the Silurian Foraminifera of Kentucky; the most recent general summary of North American Paleozoic agglutinate Foraminifera was presented by Conkin and Conkin (1982).

Isolated scolecodonts and silicified spicules of the sponge Astraeospongia are common in acidized and washed residues of the Louisville Limestone.

Conodont studies by Rexroad and others (1978) presented no definitive evidence as to the age of the Louisville Limestone other than Middle Silurian, but indicated an age range from Middle to Late Silurian. Their opinion that the Louisville might contain in its upper part some Late Silurian was based not on conodonts, but on the belief that this part of the Louisville was the correlative of the Mississinewa Shale (Lower Wabash), and even more on the report of a specimen of "Kirkidium" from an undetermined stratigraphic position at an unspecified locality "near the Falls" (Dutro, in Berry and Boucot, 1970). This reference may actually be to the typical Middle Silurian striated brachiopod Rhipidium, which is common in the Shanks Quarry and Cross Hill Members, or even to Conchidium, but doubtfully to Kirkidium. Even if it were a single specimen of Kirkidium, we suggest that this is a lower occurrence of an unidentified species of Kirkidium in the Middle Silurian, rather than fly in the face of all other paleontologic data and suggest it implies a Late

Silurian age. In fact, no Upper Silurian beds are present in the Louisville Limestone, either in southern Indiana or northwestern Kentucky, for the strata in southern Indiana considered to be the correlative of the Wabash of northern and northeastern Indiana are part of the Louisville and correlate ledge for ledge from southern Indiana to Jefferson County, Kentucky. Louisville Limestone units in extreme eastern Clark County and in Scott and Jennings Counties in southeastern Indiana are restricted to the Big Rock Member, which by all macrofossils and microfossils is strictly Middle Silurian. Furthermore, no part of the Louisville Limestone in Indiana or Kentucky is lithologically like the Mississinewa Shale.

THE NATURE OF THE LOUISVILLE-JEFFERSONVILLE PARACONFORMITY

Conkin and Conkin (1973, 1979a, 1979b, 1980, and 1984a, 1984b) and Conkin, Layton, and Conkin (1983) previously considered the nature of this paraconformity. In its original concept (Dunbar and Rogers, 1957), a paraconformity was defined as a disconformity in which the beds are parallel and the contact is a simple bedding plane, but which exhibits a large time gap, as ascertained by a large faunal and/or floral discontinuity (evolutionary gap). Detailed study of the physical surface of the paraconformity in the Louisville area, given by Dunbar and Rodgers (1957) as their first example of a paraconformity, shows that it varies from an almost horizontal plane to a surface with irregularities of up to a few feet. The previous discussion of the Cross Hill Member presents an example of this unevenness, as does the section seen on Poplar Level Road at Trevilian Way in southern Louisville (fig. 19), where in places along the outcrop the Brevispirifer gregarius Zone of the Jeffersonville Limestone lies on unit 24A of the Louisville Limestone owing to the irregularity of the erosion surface on the Louisville Limestone. At the Nugent quarry in Clark County, Indiana (Stop 8; fig. 12), the Jeffersonville rests on a remnant of the Hard Curb ledge (unit 16) of the Shanks Quarry Member (pl. 10, figs. A, B, E; pl. 11, figs. C-G). In extreme northeastern Jefferson County, at Prospect Hill (Stop 9; fig. 20), the Aemulophyllum exiguum-Emmonsia ramosa Zone rests on the Bottom Curb ledge (unit 10), the top of the Big Rock Member (pl. 9, figs. B-F). Within its area of occurrence, the Geneva dolomitic phase of the lower Jeffersonville (A. exiguum-E. ramosa Zone) overlies different parts of the Big Rock Member at different localities, and there is an increase in the magnitude of the paraconformity between these members northward, as shown in the Scott County quarry, north of Lexington, Indiana (fig. 21), where the Big Rock Member of the Louisville has been reduced and is only 13 to 15 feet thick. The loss of section is from the upper part of that member. Thus, the stratal gap along the Louisville-Jeffersonville paraconformity exceeds 60 feet in eastern Jefferson County and 80 feet in Scott County, southern Indiana.

Basal rocks of the Jeffersonville overlying the physical surface of the type paraconformity exhibit various combinations of physical features and stratigraphic relationships characteristic of unconformities in general. A breccia in the base of the Jeffersonville bears reworked chert and silicified fossils (mostly stromatoporoid fragments, with some Halysites catenularia), all derived from the underlying Louisville Limestone in places where unit 24, the cherty Iron ledge, immediately underlies the paraconformity, as seen at the Cross Hill stratotype (fig. 17 and pl. 8, fig. E). In addition, glauconite, quartz sand grains, and phosphatic nodules, all characteristic of classic unconformities, are variously present in the Jeffersonville just above the

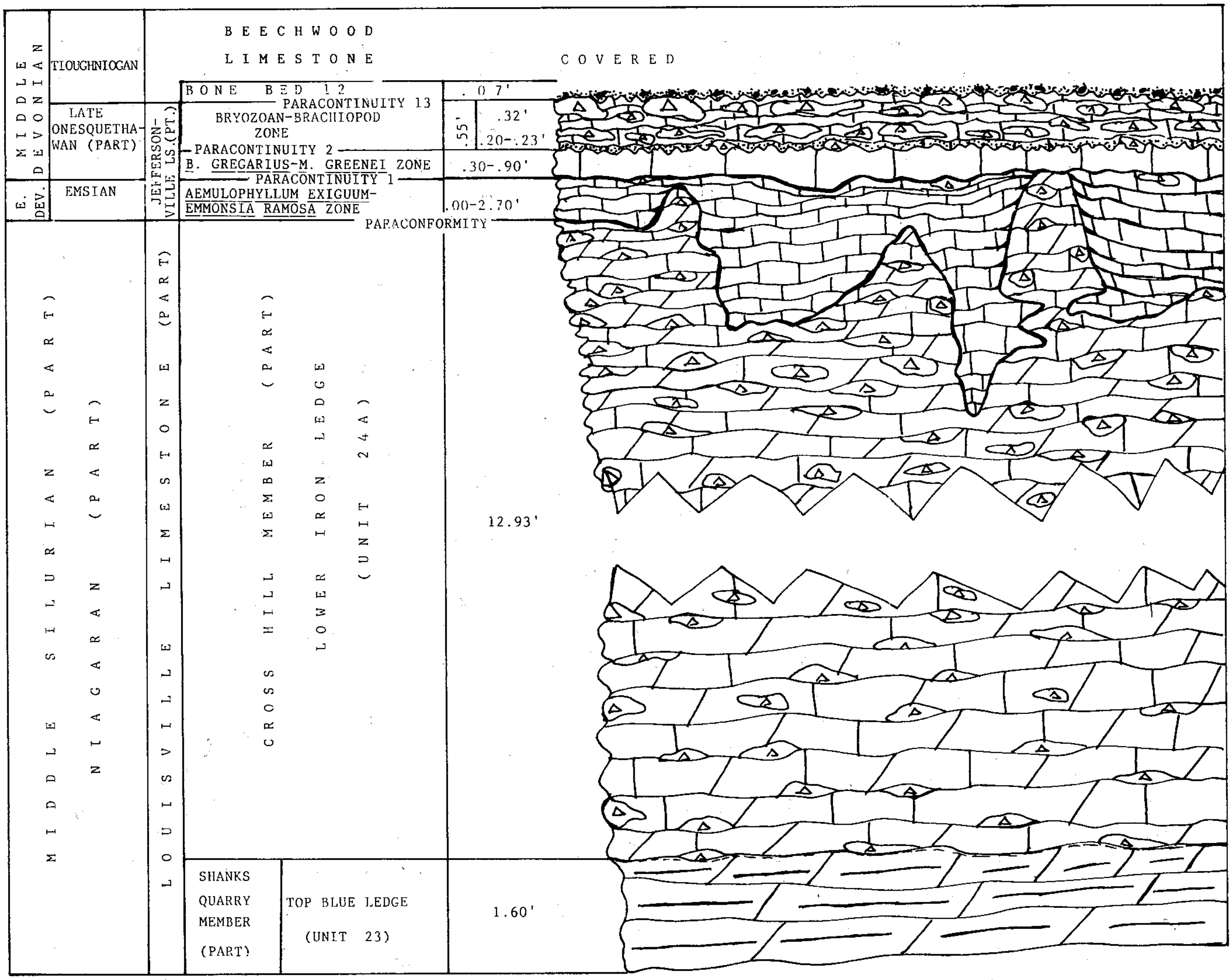


FIGURE 19.--Measured section at Poplar Level Road and Trevilian Way, Louisville, Jefferson County, Kentucky.

paraconformity. Corrosion of the paraconformable surface may be seen in places. At localities where the Louisville-Jeffersonville paraconformity overlies noncherty ledges within the Louisville, no appreciable amounts of chert are present in the Jeffersonville; however, the other distinctive features of unconformities listed above are present.

A lithologic feature that is definitive for determining the position of the Louisville-Jeffersonville paraconformity in localities where the Shanks Quarry Member and/or Cross Hill Member are present is the dark-tan color of the basal Jeffersonville, in contrast to the lighter gray color of the underlying Louisville Limestone. As a result of the long subaerial weathering of the Louisville Limestone during the Late Silurian and most of the Early Devonian, a regolith was developed. The component colloidal fractions of the regolith were reworked and disseminated into the deposits formed during the Jeffersonville

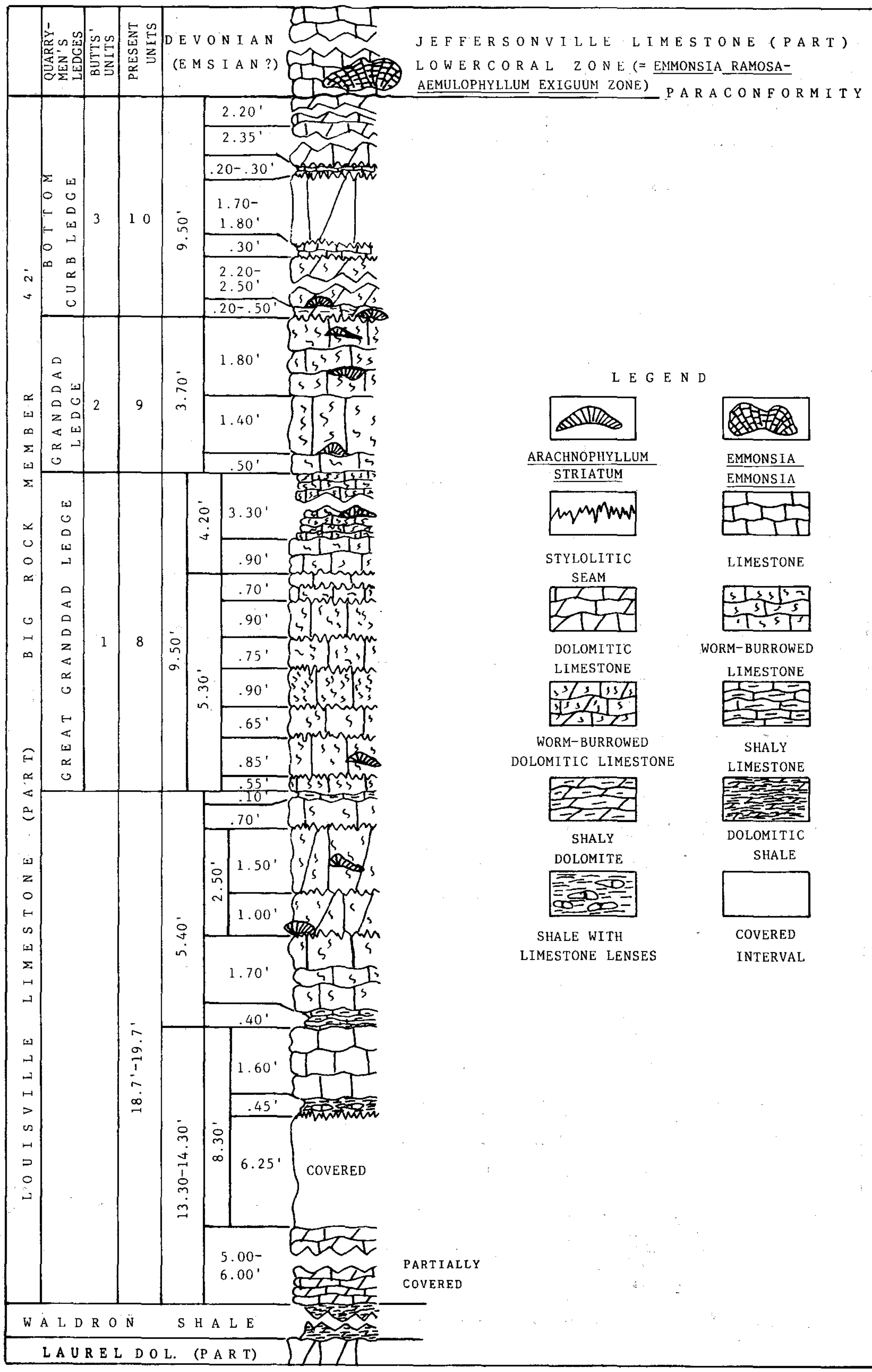


FIGURE 20.--Measured section at Stop 9, Prospect Hill, on Hwy 42 and Gene Snyder Freeway, Jefferson County, Kentucky.

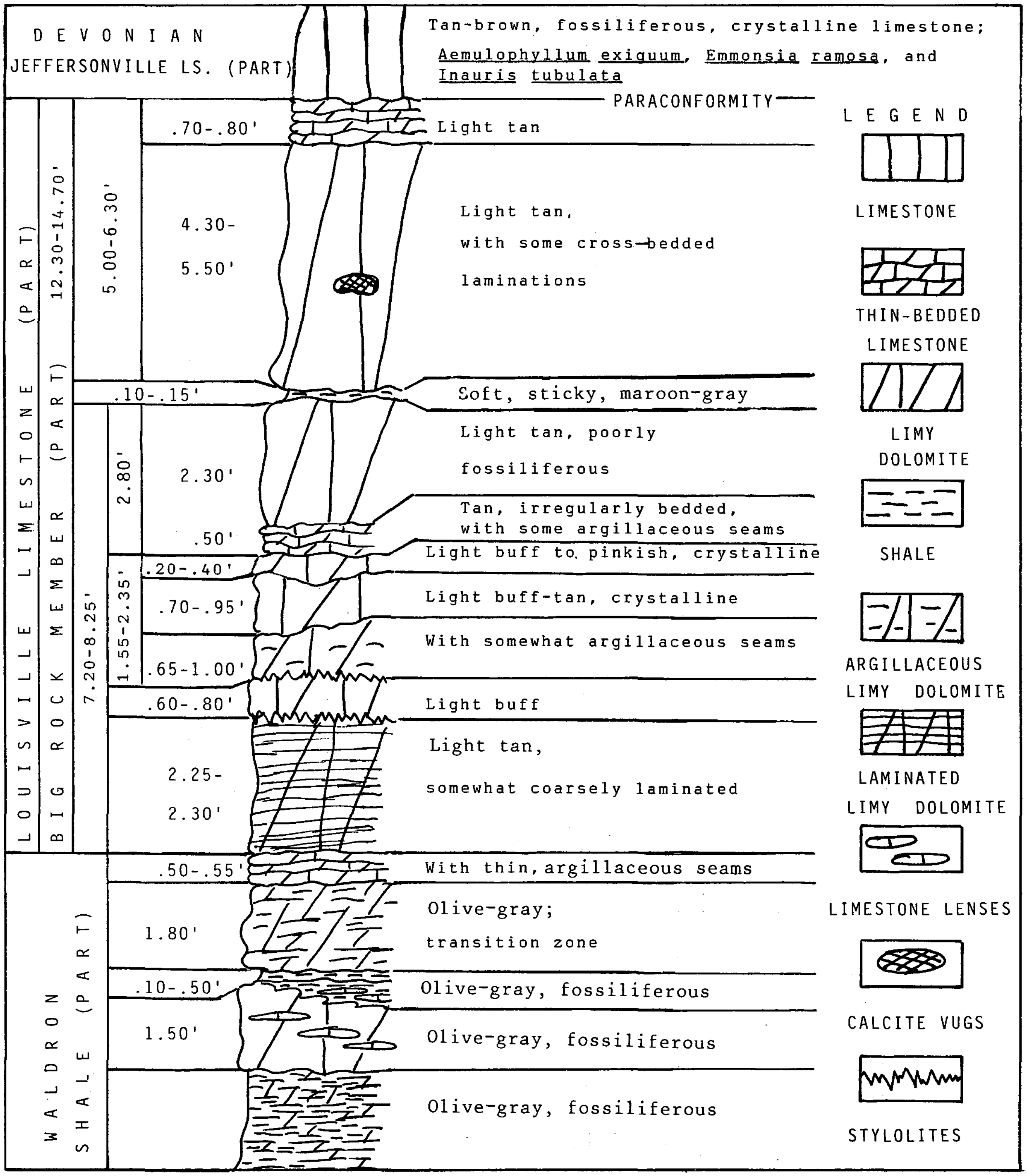


FIGURE 21.--Measured section in Scott County quarry, north of Lexington, Scott County, Indiana.

transgression. In areas somewhat higher on the flank of the Cincinnati Arch, east and northeast of the type Louisville Limestone, where the dominantly dolomitic Big Rock Member is secondarily dolomitized further and is in contact with the Geneva Dolomite, the position of the Louisville-Jeffersonville paraconformity has been in doubt, especially in the subsurface. However, if the full complement of 24 units of the Louisville Limestone are known (thus allowing determination of the portion of the Louisville Limestone that is missing), the precise position of the paraconformity can be recognized in the field with only moderate effort.

Paraconformities are of great value in structural and historical geology in reconstructing the sequence of events. They are, of course, of no value in determination of chronostratigraphic boundaries, nor in subsequent attempts at close correlation, for the time gaps along them are too great and too variable from place to place. In contrast, paracontinuities (fig. 3) are practical tools for chronostratigraphy, for their significant evolutionary time gaps are small and their associated physical surfaces allow field determination of their precise stratigraphic positions.

DETERMINATION OF THE LOUISVILLE-JEFFERSONVILLE BOUNDARY BY MEANS OF AGGLUTINATE FORAMINIFERA

It is now possible to clearly define the precise position of the Louisville-Jeffersonville boundary in the surface and subsurface sections on both physical and faunal evidence in areas where the contact had been in doubt owing to incomplete knowledge of the full Louisville Limestone stratigraphic complement, the subtle expression of the paraconformity, the dolomitic nature of both the Big Rock Member of the Louisville and the Geneva phase of the Jeffersonville, and the lack of realization that the Shanks Quarry and Cross Hill Members of the Louisville are missing in the area of the Geneva occurrence. These factors all make the position of the Louisville-Jeffersonville paraconformity less obvious.

Even though the Louisville-Jeffersonville paraconformity can be determined by the careful field observer aware of the full stratigraphic complement of the Louisville Limestone, as presented by Conkin, Conkin, Brown, Kubacko, and Fernane (1992), it is now possible, paleontologically, to determine with facility its precise position. The agglutinate foraminiferan _Inauris tubulata_ Conkin, Conkin, and Thurman, 1979 (pl. 13, fig. K) has its first occurrence (and greatest abundance) in the _Aemulophyllum exiguum-Emmonsia ramosa_ Zone of the Jeffersonville Limestone (including its dolomitic facies, the Geneva) and ranges only into the upper part of the _Amphipora ramosa_ Zone of the Jeffersonville. In fact, _I. tubulata_ has the same range in the Columbus Limestone of Ohio (B and C Zones = Schoharie Formation to Edgecliff Member of the Onondaga Limestone of New York and southern Ontario). Thus, _I. tubulata_ allows precise correlation far afield. The stratigraphic value of _I. tubulata_ is enhanced by the presence of the Kawkawlin Metabentonite in the upper part of the range zone of _I. tubulata_ (Upper _A. ramosa_ Zone) in southern Indiana and in the upper part of the Lucas Member of the Detroit River Formation of southern Ontario (Conkin and Conkin, 1984a). Plate 13 shows an example of _I. tubulata_, as well as the two diagnostic fossils of the _A. exiguum-E. ramosa_ Zone, _Favosites hemisphericus cornutiformis_, diagnostic of the Lower _A. ramosa_ Zone (Upper Coral Zone), and two foraminiferans, _Earlandia_ and _Semitextularia_, diagnostic of the Upper _A. ramosa_ Zone, as well as _A. ramosa_ itself.

LOWER AND MIDDLE DEVONIAN OF THE FIELD-TRIP AREA

The paracontinuous stratigraphy of the Devonian has been treated in detail in our several papers; representative references are Conkin and Conkin (1979a, 1979b, 1980, 1984a, 1984b) and Conkin and others (1981). Guide fossils and other fossils characteristic of the Lower and Middle Devonian formations of the field-trip area are shown in plates 13-16. Brevispirifer gregarius and Moellerina greenei constitute an Oppel Zone and allow differentiation of the late Onesquethawan Onondaga Indian Nation Metabentonite from the early Cazenovian Tioga Metabentonite throughout eastern North America (Conkin and Conkin, 1979a, figs. 3 and 4). Representative, definitive pyroclastic euhedra present in the Middle Devonian metabentonites are shown in plate 17. Details of stratigraphic units, paracontinuities, bone beds, and metabentonitic intervals within the Lower and Middle Devonian are presented in figure 22.

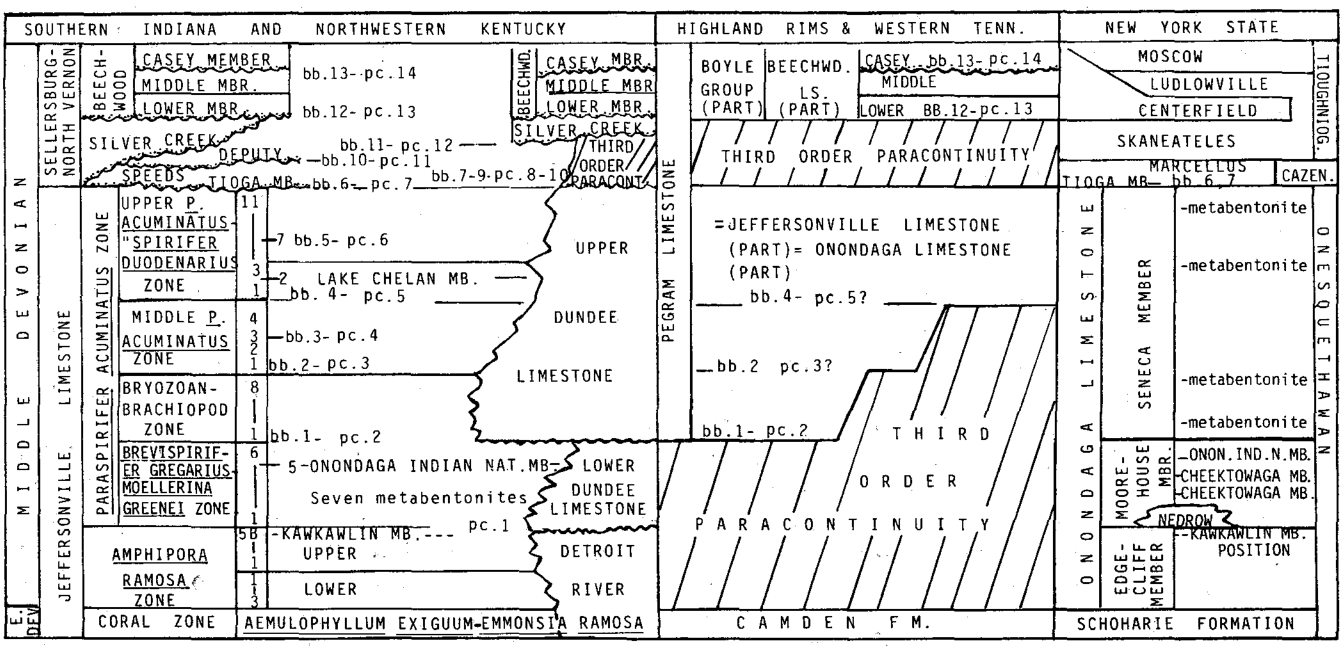


FIGURE 22.--Paracontinuous stratigraphic correlation of late Early Devonian (Emsian) and Middle Devonian of southern Indiana-northwestern Kentucky with Tennessee and New York.

PARACONTINUITIES AND BONE BEDS

The Lower and Middle Devonian units viewed during the field trip include the Jeffersonville, Speeds, and Silver Creek limestones. The Onesquethawan Jeffersonville and the Cazenovian Speeds are separated by paracontinuity 7 overlain by bone bed 6. The Speeds Limestone (Marcellus correlative) and the Silver Creek Limestone (Skaneateles correlative) are separated by paracontinuity 12 overlain by bone bed 11 (fig. 22). Individual biozones of the Jeffersonville are separated by paracontinuities, each of which, except that separating the Aemulophyllum exiguum-Emmonsia ramosa and Amphipora ramosa Zones, is overlain by a bone bed as shown in figure 22. Figure 22 compares paracontinuous stratigraphic correlation of the late Early Devonian (Emsian) and Middle Devonian of the southern Indiana-northwestern Kentucky area with that of Tennessee and New York.

METABENTONITES

Three metabentonites, the Kawkawlin, Onondaga Indian Nation, and Lake Chelan, function as a time framework within the Jeffersonville Limestone, along with a fourth metabentonite, the Tioga (restricted), at the base of the Speeds Limestone. The precise paracontinuous stratigraphy of the Jeffersonville is considered at Stops 6B, 8, and 9, and that of the Speeds and Silver Creek at Stops 8 and 9.

The above four metabentonites are the most prominent ones in the Middle Devonian of eastern North America, but Conkin and Conkin (1979a, 1979b) have reported more than 33 from the Devonian (fig. 23). Eight separate metabentonites are known from the Brevispirifer gregarius Zone alone; the uppermost one, the Onondaga Indian Nation Metabentonite, is well shown in the Sellersburg Stone Company quarry, Sellersburg, Clark County, Indiana (Conkin and others, 1981, pl. 2, figs. A, B, E-G, and Conkin and Conkin, 1984a, pl. 5, figs. D-I). All four metabentonites are present in the Devonian section at the Nugent quarry (Stop 8), near Utica, Clark County, Indiana (pl. 10, figs. A-E; pl. 11, figs. A-C; pl. 18, figs. A-E; and pl. 19, figs. A-G; fig. 24). The Kawkawlin, Onondaga Indian Nation, and Lake Chelan Metabentonites are seen at Prospect Hill, Jefferson County, Kentucky (Stop 9; pl. 9, fig. A; fig. 20) as well.

There are many thin, weathered pyroclastic intervals in the Ordovician and Devonian which cannot be detected by X-ray diffraction, for their smectitic (mixed-layer) clays commonly have been winnowed away by wave action along the shorelines (the sites of preservation of most Paleozoic weathered ash falls). However, their ash fall nature can be recognized by the presence of definitive pyroclastic mineral euhedra which accumulated and were preserved along these shorelines; this is the general mode of occurrence of metabentonites in the Devonian rocks of the field-trip area. In many cases, the weathered ash fall pyroclastic horizons are represented only as chert lenses. In some cases, pyroclastics are represented only in stylolitic seams (generally magenta stained) or are disseminated in the strata; in the latter case, acidization may reveal good representatives of definitive pyroclastic mineral euhedra. Some definitive pyroclastic mineral euhedra obtained from the Middle Devonian metabentonites (Kawkawlin, Onondaga Indian Nation, Lake Chelan, and Tioga restricted) are shown in plate 17. The euhedra from the Onondaga Indian Nation Metabentonite in the Sandusky Crushed Stone Company quarry (Rogers Group, Inc.)

CENTRAL OHIO
DELAWARE FORMATION
J ZONE
Two unnamed pyroclastics
I ZONE (WELLS' 1947 DUBLIN SHALE)
TIOGA METABENTONITE (RESTRICTED) NEAR BASE
ONESQUETHAWAN
COLUMBUS LIMESTONE
VENICE MEMBER - LAKE CHELAN METABENTONITE (MB13)
MARBLEHEAD MEMBER
G ZONE
pyroclastics 5-12 (MB12 = ONONDAGA INDIAN NATION METABENTONITE)
F ZONE
pyroclastics 3 and 4
E ZONE
pyroclastics 1 and 2
DETROIT RIVER MEMBER
D ZONE
possible Kawkawlin Metabentonite
EASTERN KENTUCKY
OHIO SHALE (PART)
HURON SHALE MEMBER (MORGAN TRAIL CORRELATIVE)
CENTER HILL METABENTONITE
OLENTANGY SHALE
UPPER OLENTANGY (SELMIER CORRELATIVE)
BELPRE METABENTONITE
LOWER OLENTANGY (BLOCHER CORRELATIVE)
Unnamed metabentonite
SOUTHERN INDIANA--NORTHWESTERN KENTUCKY
NEW ALBANY SHALE
MORGAN TRAIL (HURON CORRELATIVE)
CENTER HILL METABENTONITE
BLACKISTON FORMATION (OLENTANGY CORRELATIVE)
SELMIER FORMATION (UPPER OLENTANGY CORRELATIVE)
BELPRE METABENTONITE
BLOCHER FORMATION (LOWER OLENTANGY CORRELATIVE)
Unnamed pyroclastic
CAZENOVIAN
SPEEDS FORMATION
TIOGA METABENTONITE (RESTRICTED) NEAR THE BASE
ONESQUETHAWAN
JEFFERSONVILLE LIMESTONE (COLUMBUS—ONONDAGA CORRELATIVE)
UPPER *PARASPIRIFER ACUMINATUS* ZONE (correlative of the upper 2/3 of the Seneca Member of New York)
UNIT 1—LAKE CHELAN METABENTONITE
BREVISPIRIFER GREGARIUS-MOELLERINA GREENEI-LOWER *P. ACUMINATUS* ZONE (Marblehead-Moorehouse correlative)
8 METABENTONITES
UNIT 5—ONONDAGA INDIAN NATION METABENTONITE
UNITS 1-4 — 7 METABENTONITES
AMPHIPORA RAMOSA ZONE
UPPER *AMPHIPORA RAMOSA* ZONE (upper Edgecliff correlative in New York)
UNIT 5B—KAWKAWLIN METABENTONITE
TENNESSEE (Eastern Highland Rim)
CHATTANOOGA SHALE
GASSAWAY FORMATION
LOWER GASSAWAY
CENTER HILL METABENTONITE *
DOWELLTOWN FORMATION
UPPER DOWELLTOWN (UPPER OLENTANGY—SELMIER CORRELATIVE)
CENTER HILL METABENTONITE *
BELPRE METABENTONITE
LOWER DOWELLTOWN (LOWER OLENTANGY—BLOCHER CORRELATIVE)
Unnamed pyroclastic
TENNESSEE (Northern Highland Rim)
CHATTANOOGA SHALE
GASSAWAY FORMATION (HURON CORRELATIVE)
LOWER GASSAWAY
BRANSFORD SANDSTONE (BONE BED 18)
CENTER HILL METABENTONITE
DOWELLTOWN FORMATION
UPPER DOWELLTOWN (SELMIER=UPPER OLENTANGY CORRELATIVE)
BELPRE METABENTONITE PROBABLE POSITION
LOWER DOWELLTOWN (BLOCHER=LOWER OLENTANGY CORRELATIVE)
Unnamed pyroclastic

VIRGINIA
CAZENOVIAN (PART)
MILLBORO SHALE (MARCELLUS PART)
TIOGA METABENTONITE (RESTRICTED) AT BASE AND SEVERAL PYROCLASTICS ABOVE
ONESQUETHAWAN
NEEDMORE SHALE
ONONDAGA INDIAN NATION METABENTONITE
SCHOHARIE FORMATION
Two unnamed pyroclastics
NEW YORK STATE
CAZENOVIAN (PART)
MARCELLUS SHALE
OATKA-UNION SPRINGS-BAKEOVEN MEMBER
TIOGA METABENTONITE NEAR OR AT BASE
ONESQUETHAWAN
ONONDAGA FORMATION
SENECA MEMBER—SEVERAL PYROCLASTICS
MOOREHOUSE MEMBER
ONONDAGA INDIAN NATION METABENTONITE
SECOND CHEEKTOWAGA METABENTONITE
FIRST CHEEKTOWAGA METABENTONITE
HELDERBERGIAN
KALKBERG FORMATION
JUDD FALLS METABENTONITE
PENNSYLVANIA
CAZENOVIAN (PART)
MARCELLUS CORRELATIVE
TIOGA METABENTONITE (RESTRICTED)
ONESQUETHAWAN
BUTTERMILK FALLS FORMATION
SENECA MEMBER CORRELATIVE
Unnamed pyroclastic
MOOREHOUSE MEMBER CORRELATIVE
ONONDAGA INDIAN NATION METABENTONITE
HAZZARD PAINT ORE
SECOND CHEEKTOWAGA METABENTONITE POSSIBLY PRESENT
SOUTHERN ONTARIO — MICHIGAN BASIN
CAZENOVIAN (PART)
DELAWARE FORMATION (MARCELLUS CORRELATIVE)
I ZONE
TIOGA METABENTONITE (RESTRICTED)
ONESQUETHAWAN
COLUMBUS LIMESTONE
LOWER DUNDEE (MARBLEHEAD—MOOREHOUSE CORRELATIVE)
ONONDAGA INDIAN NATION METABENTONITE (=BALTRUSAITIS' 1974)
UPPER ASH
UPPER DETROIT RIVER (LUCAS MEMBER)
KAWKAWLIN METABENTONITE = ?K-MARKER METABENTONITE
NORTHERN OHIO
CAZENOVIAN (PART)
SILICA FORMATION (PART)
BLUE LIMESTONE—MARCELLUS—SPEEDS CORRELATIVE
TIOGA METABENTONITE (RESTRICTED) near base; two pyroclastics above.
ONESQUETHAWAN
COLUMBUS LIMESTONE
UPPER DUNDEE—VENICE (SENECA CORRELATIVE) — Two pyroclastics
LOWER DUNDEE—MARBLEHEAD (MOOREHOUSE CORRELATIVE)
ONONDAGA INDIAN NATION METABENTONITE

* THE CENTER HILL METABENTONITE IS AT THE TOP OF THE UPPER DOWELLTOWN IN THE EASTERN HIGHLAND RIM; HOWEVER, IN CANNON COUNTY, PARACONTINUITY 17 (AND BONE BED 16) AT THE BASE OF THE UPPER GASSAWAY CUTS INTO THE CENTER HILL. IN THE NORTHERN HIGHLAND RIM, CENTER HILL PYROCLASTIC EUHEDRA ARE REWORKED INTO THE BASE OF THE UPPER GASSAWAY (MORGAN TRAIL OF KENTUCKY AND SOUTHERN INDIANA) AND THUS THE CENTER HILL METABENTONITE COINCIDES WITH BONE BED 16 IN THE NORTHERN HIGHLAND RIM AND NORTHWARD IN KENTUCKY AND INDIANA.

FIGURE 23.--Stratigraphic positions and identities of Devonian metabentonites in eastern North America.

at Parkertown, Ohio (pl. 17, figs. S-U), were obtained by acidization of a very thin stylolitic seam in the G Zone of the Marblehead Member of the Columbus Limestone.

Kawkawlin Metabentonite

Baltrusaitis (1974) named the Kawkawlin Metabentonite from the subsurface Detroit River Group of the Michigan Basin. Conkin and Conkin (1984a) recognized the Kawkawlin at the surface in the Lucas Member of the Detroit

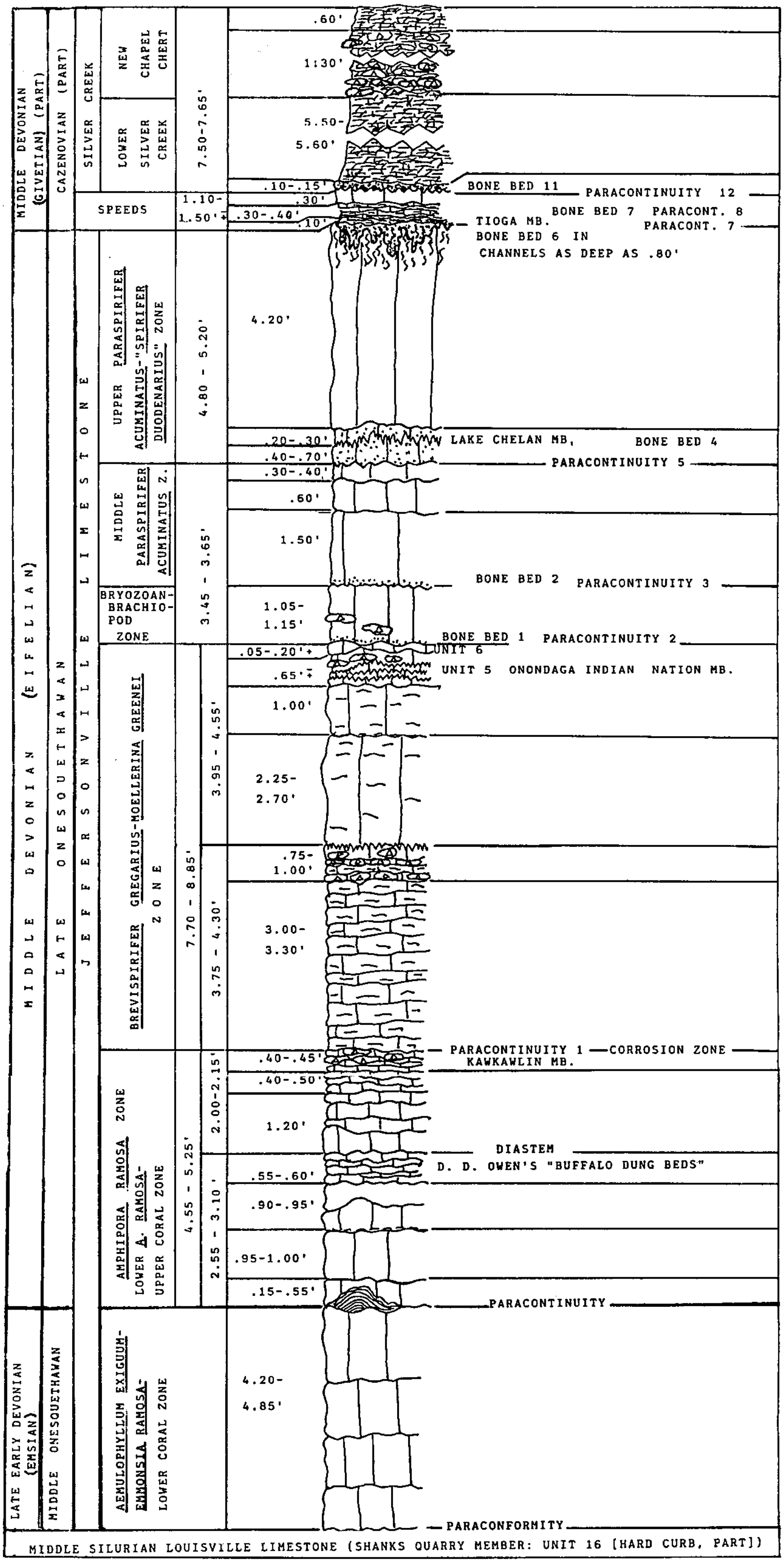


FIGURE 24.--Measured Devonian section in the Nugent quarry (Stop 8), near Utica, Clark County, Indiana.

River Group in Ontario and in unit 6 of the Amphipora ramosa Zone of the Jeffersonville Limestone of Indiana and Kentucky. Conkin (1989) identified the Kawkawlin in the unfossiliferous middle of the Grand Tower Limestone in the Tuscola Stone Company quarry, Tuscola, Douglas County, central Illinois (fig. 25). The Kawkawlin Metabentonite is late Onesquethawan and is a marker for correlation of the Upper A. ramosa Zone of the Jeffersonville Limestone of Indiana and Kentucky with the middle Grand Tower Limestone of Illinois, the D Zone of the Columbus Limestone of Ohio, the Lucas Member of the Detroit River

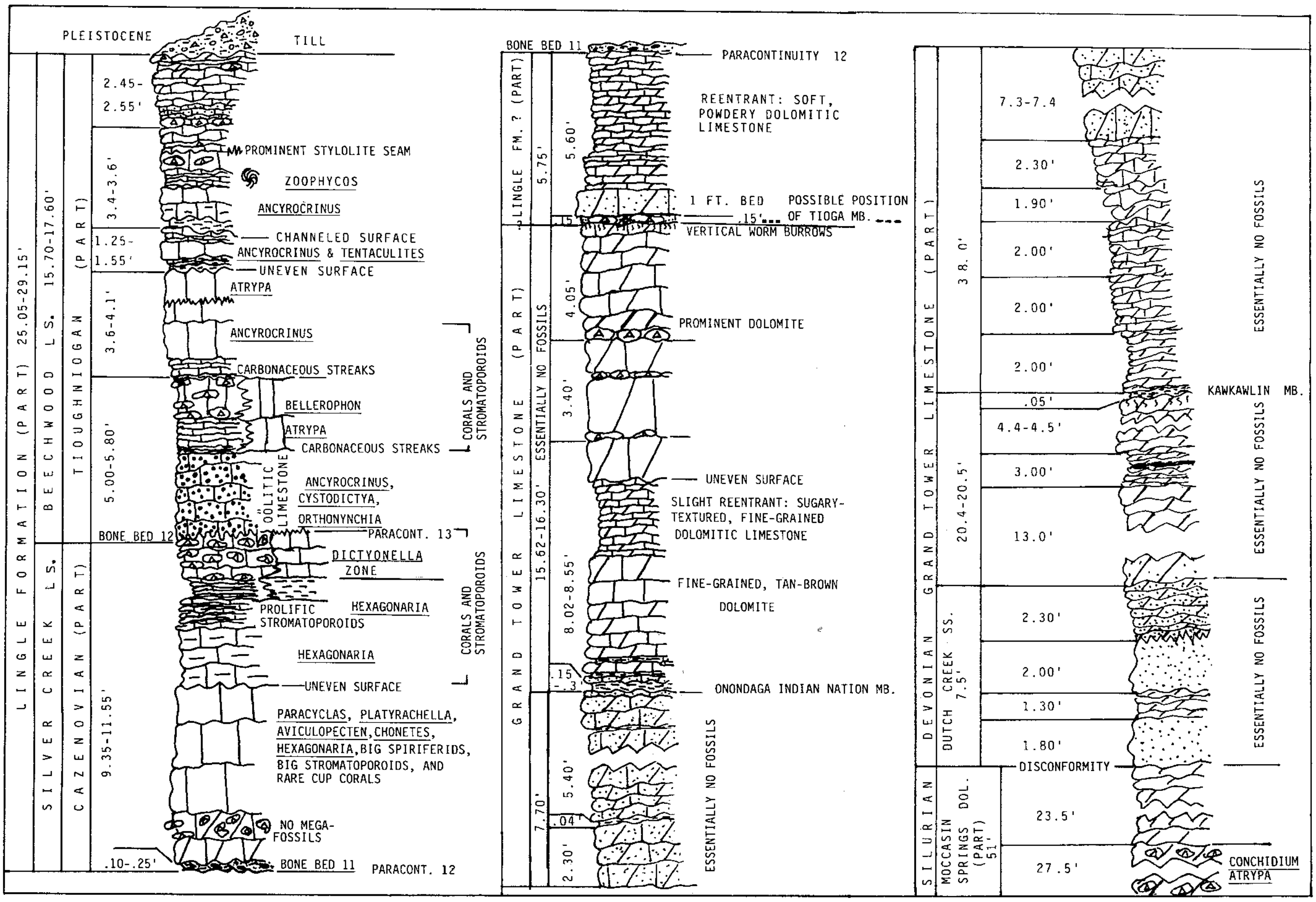


FIGURE 25.--Measured Devonian section in the Tuscola Stone Company quarry, Tuscola, Douglas County, Illinois (after Conkin, 1987).

Group of Michigan and southern Ontario, and the upper Edgecliff Member of the Onondaga Limestone of New York (fig. 22). This correlation is substantiated by the association of the Kawkawlin with the stromatoporoid A. ramosa, the foraminiferans Earlandia and Semitextularia, the brachiopod Prosserella lucasensis, and the mollusks Murchisonia and Conocardium.

The position of the Kawkawlin Metabentonite in the field-trip area is shown in plate 9, figure A; plate 10, figures A, B and E; plate 11, figures C and F; and plate 18, figures D and E. Definitive pyroclastic euhedra from the Kawkawlin Metabentonite are shown in plate 17, figures LL-OO.

Onondaga Indian Nation Metabentonite

The Onondaga Indian Nation Metabentonite was named by Conkin and Conkin (1979a) from the uppermost part of the Moorehouse Member of the Onondaga Limestone, about 2 feet below the paracontinuous contact of the Moorehouse and Seneca Members of the Onondaga Limestone, on the lands of the Onondaga Indian Nation near Nedrow, New York. It is late Onesquethawan in age, but has been almost universally misidentified as the early Cazenovian Tioga Metabentonite (restricted), beginning with Oliver (1954) and continuing even to the present. The Tioga Metabentonite occurs about 25 feet above the Onondaga Indian Nation Metabentonite throughout New York State from Erie to Otsego Counties (Conkin and Conkin, 1979a). Conkin and Conkin (1979a, 1984a, 1984b) and Conkin and others (1981) have demonstrated by paracontinuous stratigraphy that the stratigraphic position of the Onondaga Indian Nation Metabentonite (fig. 22) is restricted to the Moorehouse Member of the Onondaga Limestone of New York, the G Zone of the Marblehead Member of the Columbus Limestone of Ohio, the upper Dundee Formation of Michigan and southern Ontario, unit 5 of the *Brevispirifer gregarius* Zone of the Jeffersonville Limestone of southern Indiana and Kentucky, and the upper Grand Tower Limestone of Illinois (Conkin, 1987 and 1988). Figure 25 shows the position of the Onondaga Indian Nation Metabentonite as displayed in the Tuscola Stone Company quarry, Tuscola, Douglas County, Illinois. The charophyte (stonewort alga) species *Moellerina greenei* Ulrich, 1886 emend. Conkin, Conkin, Gregory, and Hotchkiss, 1974 is an extremely valuable fossil for correlation (Conkin and Conkin, 1979a, figs. 3 and 4), as it is restricted to the late Onesquethawan throughout eastern North America, and, with *B. gregarius*, constitutes an Oppel Zone, within which the Onondaga Indian Nation Metabentonite is stratigraphically confined. Neither species extends into the early Cazenovian (Marcellus Shale and its correlatives such as the Speeds Limestone of southern Indiana and the Dublin Shale of central Ohio), which is the age of the Tioga Metabentonite.

The position of the Onondaga Indian Nation Metabentonite in the field-trip area is shown in plate 9, figure A; plate 10, figures A, C and E; plate 11, figure C; and plate 18, figures C and D. Definitive pyroclastic euhedra from the Onondaga Indian Nation Metabentonite are shown in plate 17, figures S-Z and AA-EE.

Lake Chelan Metabentonite

The Lake Chelan Metabentonite was named by Conkin and Conkin (1984a) from the base of the Upper *Paraspirifer acuminatus*-"*Spirifer duodenarius*" subzone of the *P. acuminatus* Zone of the Jeffersonville Limestone in the Sellersburg Stone quarry, Sellersburg, Clark County, Indiana. It is late Onesquethawan. It is associated with bone bed 4 and paracontinuity 5 and is a marker for the base of the Upper *P. acuminatus*-"*S. duodenarius*" Zone of the Jeffersonville Limestone of southern Indiana and Kentucky. This metabentonite is present at the same stratigraphic position (fig. 22) in Ohio, at the base of the upper part of the H Zone (Venice Member) of the Columbus Limestone (as seen in the Scioto River quarries in Columbus, Franklin County, and in the National Lime & Stone Company quarry at Delaware, Delaware County) and in New York in the upper part of the Seneca Member of the Onondaga Limestone (as seen in the Warren Brothers quarry, Canoga, Seneca County). The occurrences of the Lake Chelan Metabentonite have been considered in additional papers (Conkin and Conkin, 1979b, and Conkin and DeChurch, 1992).

The position of the Lake Chelan Metabentonite in the field-trip area is shown in plate 9, figure A; plate 10, figures A, B, and E; plate 11, figure C; and plate 18, figures A and D. Definitive pyroclastic euhedra from the Lake Chelan Metabentonite are shown in plate 17, figures L-R.

Tioga Metabentonite (restricted)

The Tioga Metabentonite (restricted) is universally present at the base of the earliest Cazenovian in the northeastern United States and southern Ontario (fig. 22), as has been demonstrated by paracontinuous stratigraphy (Conkin and Conkin, 1979a, 1979b, 1984a, 1984b; Conkin and others, 1981). The stratigraphic position of the Tioga Metabentonite is at the base of the Union Springs Member of the Marcellus Shale of New York, which correlates with the basal I Zone (basal Dublin Shale) of the Delaware Limestone of Ohio and southern Ontario and the basal Speeds Limestone of southern Indiana.

The Tioga Metabentonite (restricted) does not occur in Kentucky because the Speeds Limestone is cut out by paracontinuity 11 at the base of the lower part of the Silver Creek Limestone. The farthest south the Tioga Metabentonite (restricted) has been seen in Indiana is at the Nugent quarry in Clark County (Stop 8; fig. 24; pl. 10, figs. A, B, E; pl. 11, figs. A-C; pl. 18, figs. B, D; pl. 19, figs. A-G). About 1.5 feet of Speeds Limestone is present in the north part of the quarry, but it thins rapidly to less than an inch in the south wall of the quarry adjacent to the Ohio River, and disappears before the first outcrops of the Devonian strata in Kentucky, directly across the Ohio River. However, some zircons (pl. 17, figs. H, I) derived by erosion of the Tioga Metabentonite at the base of the Speeds Limestone have been found reworked into bone bed 11 (associated with paracontinuity 12) at the base of the lower Silver Creek at the Prospect Hill section (Stop 9; pl. 9, fig. A). Definitive pyroclastic euhedra from the Tioga Metabentonite are shown in plate 17, figures A-G and J-L.

The late Onesquethawan-early Cazenovian paracontinuous boundary is marked in southern Indiana by bone bed 6 directly overlying paracontinuity 7, the surface of which exhibits specimens of an as yet undescribed new species of the crinoid holdfast Parapodolithus Conkin, Conkin, and Davidson, 1992 (pl. 19, figs. A, B, E-G).

SUMMARY

Paracontinuities mark the positions of the boundaries between the Middle and Upper Ordovician, the Middle Silurian Laurel Dolomite and Waldron Shale, and the Middle Devonian Jeffersonville Limestone and Speeds Limestone, as well as boundaries between internal units within the Jeffersonville and the Sellersburg Group in Kentucky and southern Indiana. The Waldron Shale-Louisville Limestone boundary is certainly diastemic at least, and it may be paracontinuous. The paracontinuity marking the position of the Late Ordovician (Edenian) marine transgression truncates the uppermost strata of the various lithostratigraphic members of the Middle Ordovician (Mohawkian) Cynthiana Formation. It is recognized in the field by the presence of crinoid holdfasts, Parapodolithus sardesoni Conkin, Conkin, and Davidson, 1992, attached to the paracontinuous surface, as well as by a Shermanian fauna below and a Cincinnatian (Edenian) fauna above.

Stratigraphically significant Middle Ordovician (Mohawkian) metabentonites in Kentucky are the late Blackriverian Pencil Cave and Mud Cave in the upper part of the Tyrone Limestone and the Rocklandian Capitol Metabentonite in the Curdsville Limestone. The recently recognized late Blackriverian Dead Horse Road Quarry Metabentonite occurs in the Tyrone Limestone approximately 3 feet below the Pencil Cave Metabentonite; the Shermanian Sleepy Hollow Branch Metabentonite occurs in the lower Woodburn Limestone.

The Tyrone-Curdsville contact in Kentucky and Tennessee correlates with the Blackriverian-Rocklandian boundary at the Lowville Limestone-Watertown Limestone contact in New York and southern Ontario. The upper part of the Tyrone Limestone and the upper part of the Carters Limestone of Tennessee (above the Pencil Cave Metabentonite) are correlatives of the late Blackriverian upper Lowville Limestone (which bears the Pencil Cave Metabentonite at its base) of New York and southern Ontario.

Paracontinuous stratigraphy indicates that the early Rocklandian "Deicke" Metabentonite of the upper Mississippi Valley is not a correlative of the late Blackriverian type Deicke Metabentonite of the Missouri area, nor the late Blackriverian Pencil Cave of Kentucky and Tennessee, but that the type Deicke of Missouri is correlative to the Pencil Cave Metabentonite of Kentucky and Tennessee. Recently, Cerrito, Conkin, Kubacko, and Fernane (1992) indicated that miscorrelation of important Mohawkian metabentonites resulted from discriminant analysis of trace elements, and continuing, but unpublished, work by Cerrito, Conkin, and Fernane, by means of the statistical method of kernel density estimation of trace elements, have substantiated the correlation previously determined by paracontinuous stratigraphy (Conkin and Conkin, 1983; Conkin and Kubacko, 1987; and Conkin, 1991).

A paracontinuity at the Laurel-Waldron contact is expressed as a wave-cut surface developed on the top of the Laurel Dolomite. The "oolitic" dolomite previously considered to mark the top of the Laurel Dolomite actually forms the basal bed of the paracontinuously overlying Waldron Shale. The so-called "oolites" are hollow ovoidal bodies composed of a thin coating of dolomite crystals surrounding a tectinous inner lining, and perhaps are organic in nature.

There is a distinct disconformity between the Waldron and the Louisville which is diastemic at least and may be paracontinuous.

The Louisville Limestone has been divided into three members, in ascending order: the Big Rock, Shanks Quarry, and Cross Hill (Conkin, Conkin, Brown, Kubacko, and Fernane, 1992). In Jefferson County, Kentucky, east of the type section of the Louisville Limestone, the Louisville-Jeffersonville paraconformity shows an increase in magnitude such that the Jeffersonville Limestone rests directly on the Big Rock Member, a stratigraphic loss of 50-60 feet. In Scott County, Indiana, the thickness of the Big Rock Member is further reduced so that the stratigraphic gap of the Louisville-Jeffersonville paraconformity increases to 80 feet. No part of the Louisville Limestone represents any part of the Upper Silurian Wabash Formation of Indiana; thus, the Louisville is all Middle Silurian (Niagaran). The Aemulophyllum exiguum-Emmonsia ramosa Zone (the correlative of the Schoharie of New York) is consistently present at the base of the Jeffersonville Limestone in the field-trip area; stratal loss along the paraconformity occurs at the expense of the

Silurian.

In areas in southeastern Indiana where the Geneva Dolomite directly overlies the dolomitic Big Rock Member of the Louisville, it has been difficult in the past to determine the position of the Louisville-Jeffersonville paraconformity. However, the precise position of this paraconformity in outcrops and in the subsurface can be ascertained by the presence of the distinctive agglutinate foraminiferan Inauris tubulata Conkin, Conkin, and Thurman, 1979, whose total stratigraphic range is from the Aemulophyllum exiguum-Emmonsia ramosa Zone to the Amphipora ramosa Zone of the Jeffersonville; I. tubulata has the same range in the Columbus Limestone of Ohio.

Three metabentonites (Kawkawlin, Onondaga Indian Nation, and Lake Chelan) function as a time framework within the Onesquethawan part of the Jeffersonville Limestone. A fourth metabentonite, the Tioga (restricted), is at the base of the early Cazenovian Speeds Limestone. These four Devonian metabentonites occur in equivalent paracontinuous stratigraphic positions over the eastern United States and southern Ontario. The late Onesquethawan-early Cazenovian paracontinuous boundary in southern Indiana is marked by examples of an as yet undescribed species of the crinoid holdfast Parapodolithus.

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PLATE 1.--Exposures in Liter's quarry (Stop 1) (B, C, F-H), and specimens of *Parapodolithus sardesoni* (A, D, E) from just west of Little Benson Creek, at Bridgeport, Franklin County, Kentucky

A, D, E. Single specimens and clusters of the crinoid holdfast *Parapodolithus sardesoni* Conkin, Conkin and Davidson, 1992 attached to the paracontinuous surface at the Middle Ordovician Cynthiana-Late Ordovician Eden boundary; X1.
B. View of quarry wall showing the position of the Middle Ordovician Cynthiana-Late Ordovician Eden paracontinuous boundary.
C, G, H. Closer views of the Cynthiana-Eden paracontinuous boundary; position marked by hammer.
F. Close-up view of the paracontinuous surface of the Cynthiana to which a specimen of *Parapodolithus sardesoni* is attached.

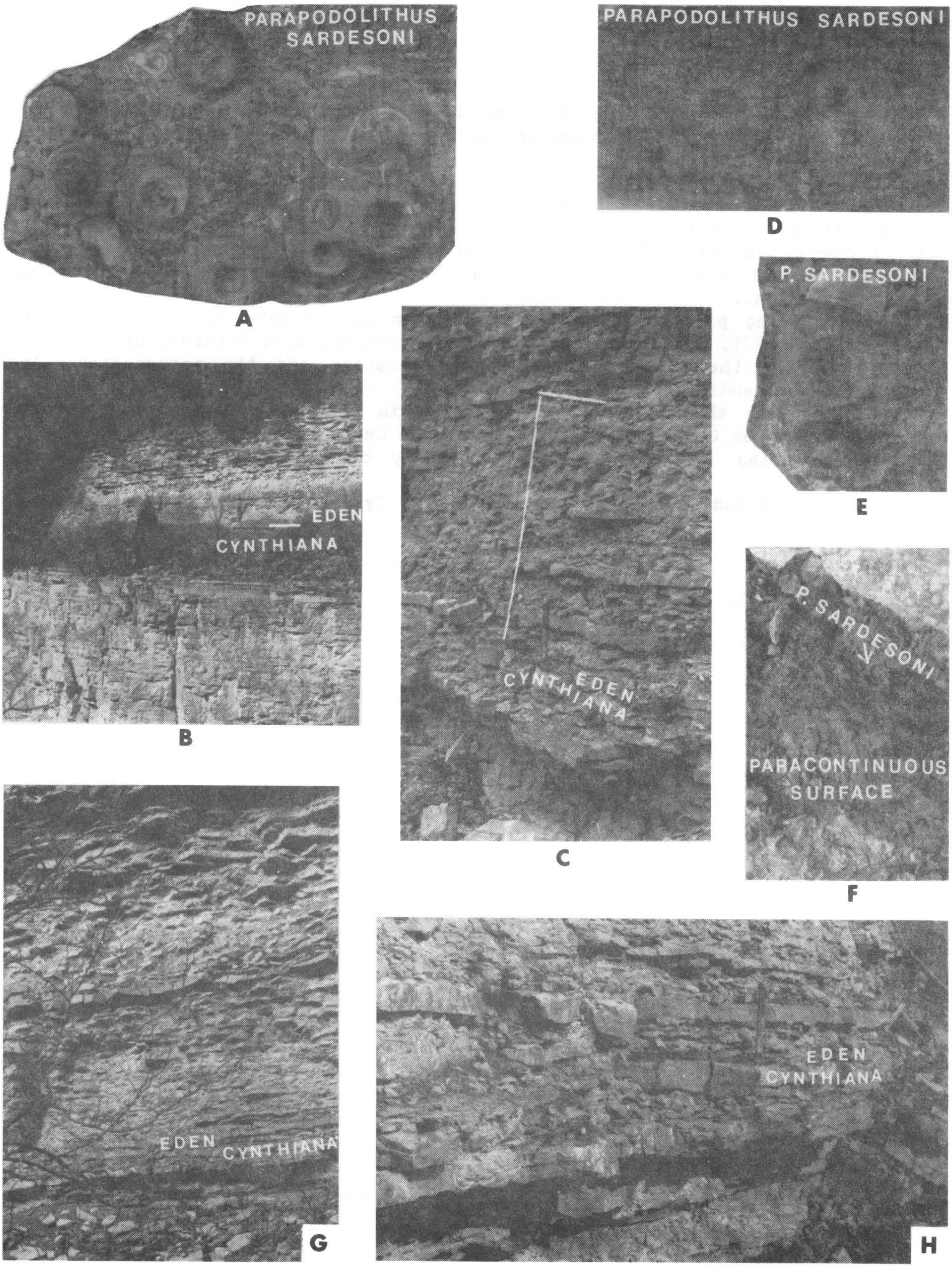
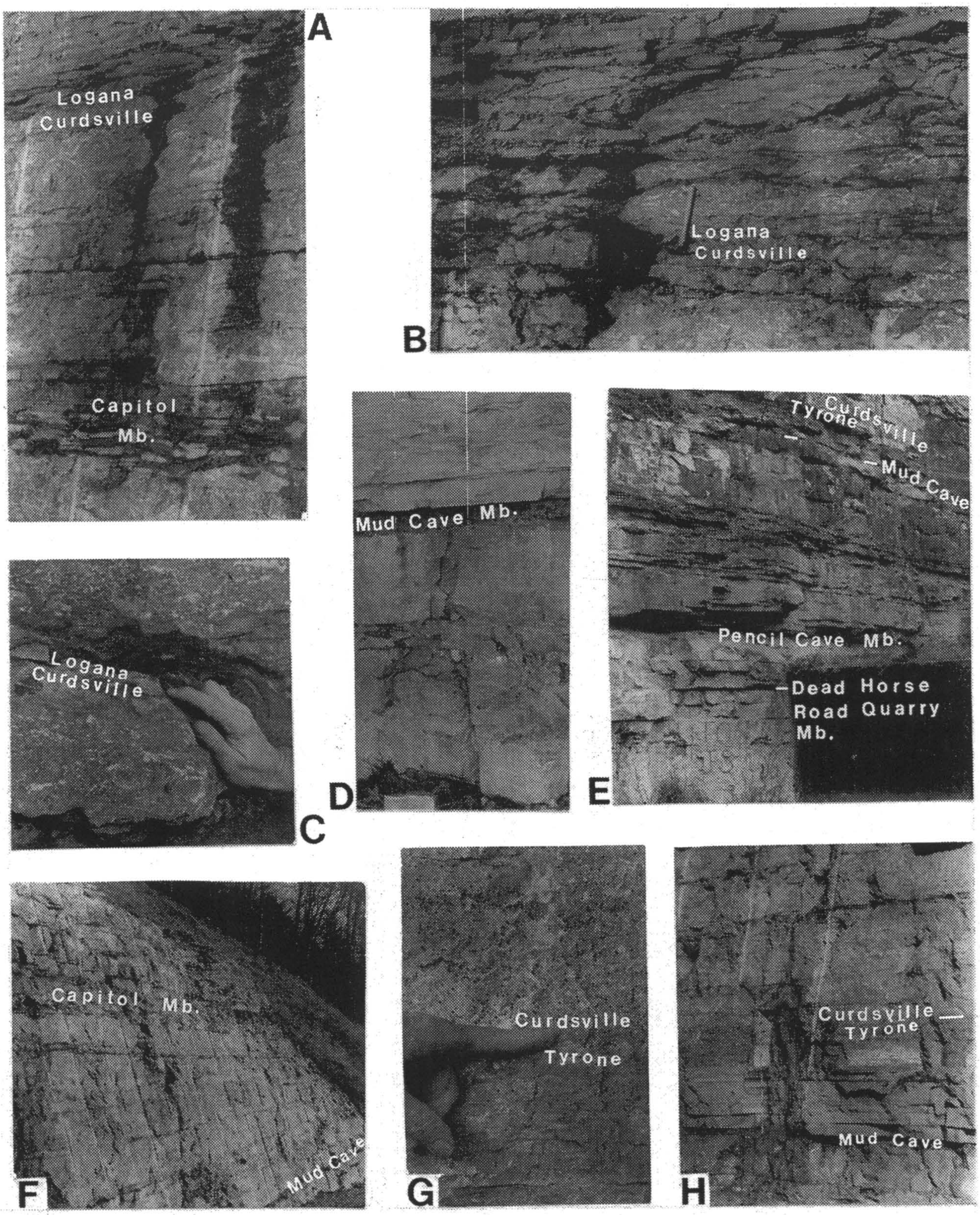

PARAPODOLITHUS SARDESONI
A
PARAPODOLITHUS SARDESONI
D
P. SARDESONI
E
EDEN
CYNTHIANA
B
CYNTHIANA
EDEN
C
P. SARDESONI
PARACONTINUOUS SURFACE
F
EDEN
CYNTHIANA
G
EDEN
CYNTHIANA
H

PLATE 2.--Exposures at Stop 2 along U.S. Hwy 127N (A-D and F-H) and at abandoned quarry at intersection of Dead Horse Road and Cove Spring Road (E), Franklin County, Kentucky

A, B. Views of Capitol Metabentonite of Conkin and Dasari (1986) and the Curdsville-Logana paracontinuity.
C. Close-up view of Curdsville-Logana paracontinuity.
D. View of Mud Cave Metabentonite in the upper part of the Blackriverian Tyrone Limestone.
E. View showing positions of Dead Horse Road Quarry Metabentonite of Conkin and Conkin (1992), Pencil Cave Metabentonite, and Mud Cave Metabentonite in the upper part of the Blackriverian Tyrone Limestone and the paracontinuously overlying Rocklandian Curdsville Limestone.
F. View showing the Mud Cave Metabentonite in the upper part of the Tyrone Limestone and the Capitol Metabentonite in the Curdsville Limestone.
G. View showing the paracontinuous boundary of the Tyrone and Curdsville Limestones.
H. View of the Mud Cave Metabentonite and the Tyrone-Curdsville paracontinuous boundary.

ERRATUM

The halftone image of plate 2 reproduced poorly when this guidebook was printed. This xerographic copy from the original photographic plate shows more contrast. We apologize for any inconvenience.



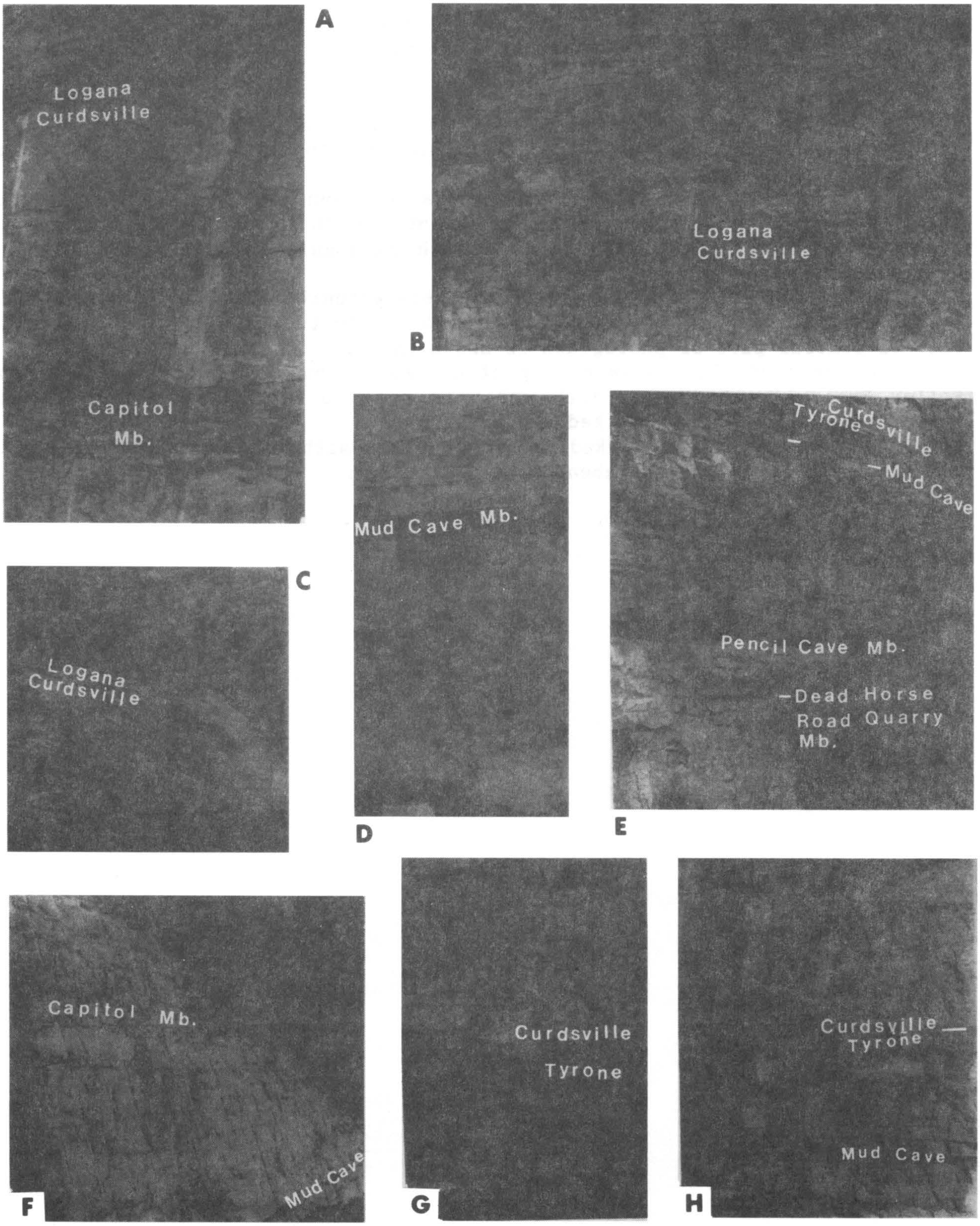
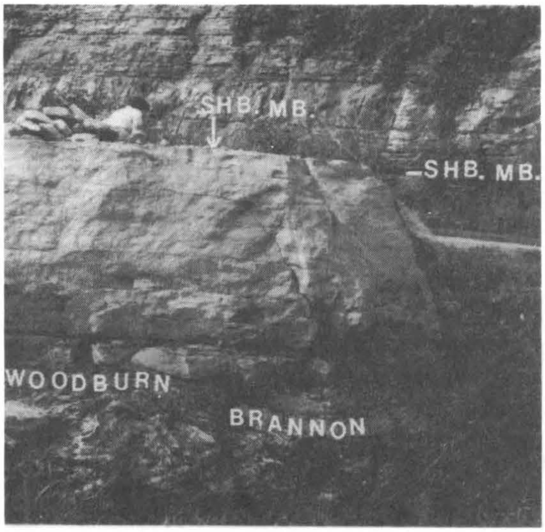
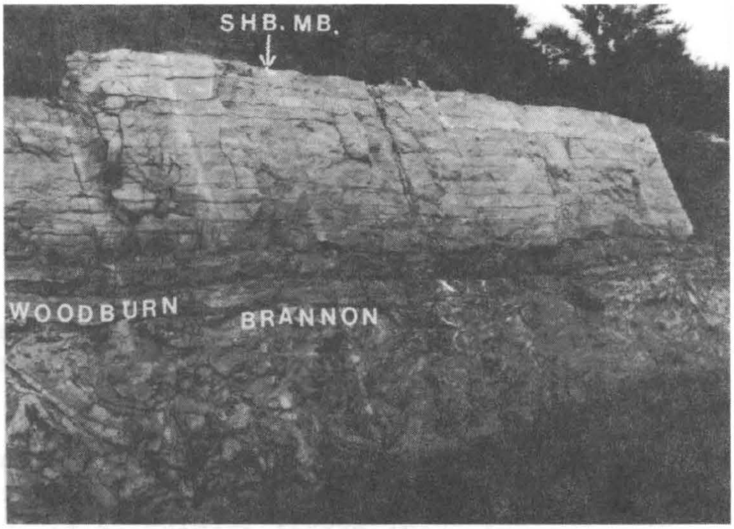

A
Logana
Curdsville
Capitol
Mb.
B
Logana
Curdsville
C
Logana
Curdsville
D
Mud Cave Mb.
E
Curdsville
Tyrone
Mud Cave
Pencil Cave Mb.
Dead Horse
Road Quarry
Mb.
F
Capitol Mb.
Mud Cave
G
Curdsville
Tyrone
H
Curdsville
Tyrone
Mud Cave

PLATE 3.--Exposures of Middle Ordovician (Shermanian) Brannon and Woodburn limestones at Stop 4, the stratotype section of the Sleepy Hollow Branch Metabentonite of Conkin and Conkin (1992)

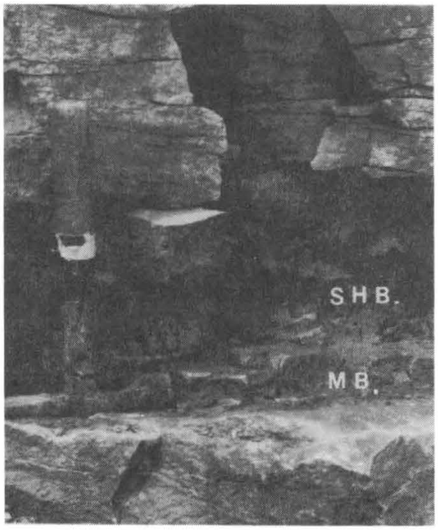
A. View on south side of Hwy 767 (at Collins Lane), the stratotype of the Sleepy Hollow Branch Metabentonite (SHB. MB.), showing in addition the Brannon-Woodburn contact.
B. View, continuing eastward along exposure shown in 3A. The prominently contorted beds of the Brannon are shown as well as Brannon-Woodburn contact and the position of the Sleepy Hollow Branch Metabentonite (SHB. MB.) on top surface of exposure.
C. Close-up view of Sleepy Hollow Branch Metabentonite (SHB. MB.); part of 3D.
D. Stereo-pair view of Sleepy Hollow Branch Metabentonite (SHB. MB.); close-up view of central part of photograph is shown in 3C.
E. Stereo-pair of plane view of top of exposure shown in 3A and B. The Sleepy Hollow Branch Metabentonite (SHB. MB.) is seen to overlie ripple-marked and silicified (cherty), wave-marked surfaces.
F. Close-up view of wave-marked, cherty surface with wave troughs filled with the Sleepy Hollow Branch Metabentonite (SHB. MB.).


SHB. MB.
SHB. MB.
WOODBURN
BRANNON

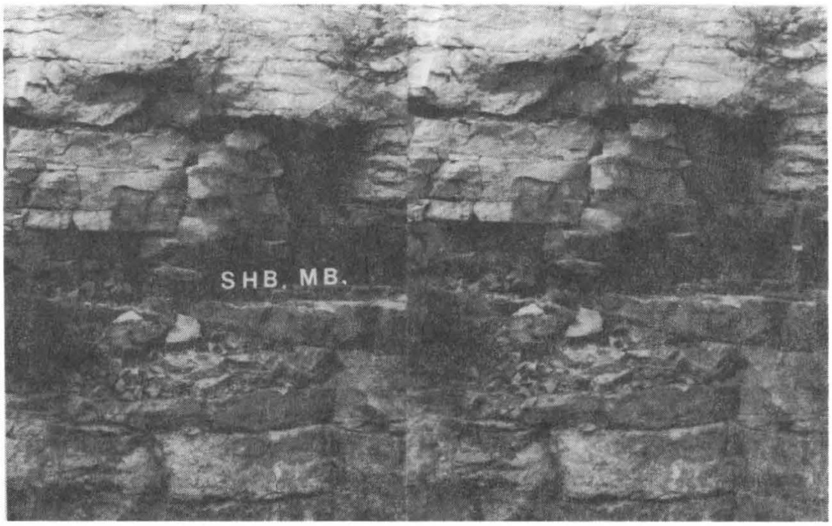
A


SHB. MB.
WOODBURN
BRANNON

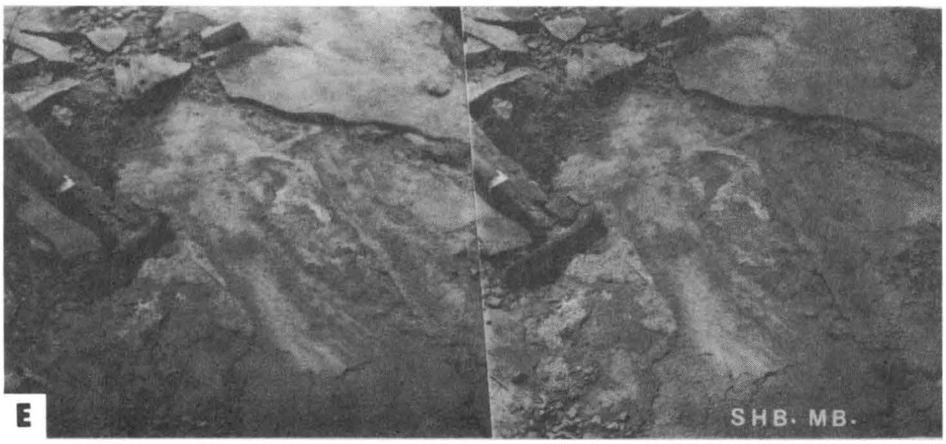
B


SHB.
MB.

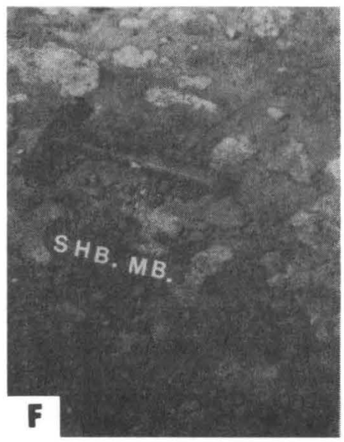
C


SHB. MB.

D


SHB. MB.

E


SHB. MB.

F

PLATE 4.--Pyroclastic mineral euhedra from the Middle Ordovician Sleepy Hollow Branch Metabentonite at Stop 4 and the Capitol, Mud Cave, Dead Horse Road Quarry, and Pencil Cave Metabentonites at Stop 2; all X143

A. K. Broken zircon euhedra.
B, P, T, V. Doubly terminated zircon euhedra.
C, D, E, Q. Doubly terminated apatite euhedra.
F, I. Some worn apatite euhedra.
G. Broken bipyramidal quartz euhedron.
H. Bipyramidal quartz rounded to nearly a sphere.
J, O, S, W. Fragmental black biotite euhedron.
L. Somewhat worn, doubly terminated zircon euhedron.
M. Glass shard displaying conchoidal fracture.
N, U, X. Doubly terminated bipyramidal quartz euhedra.
R, Y. Titanium oxide euhedra.

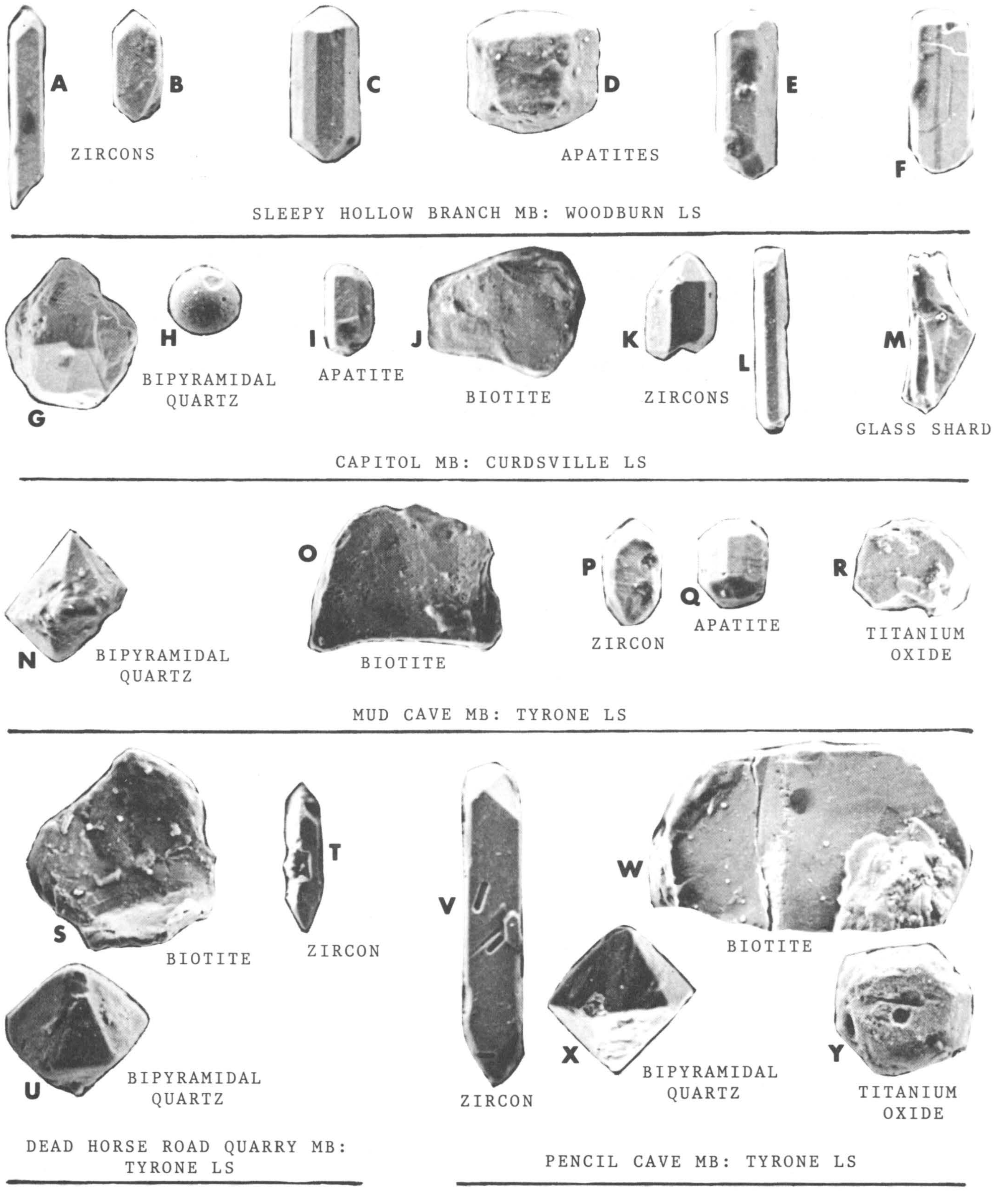

A
B
ZIRCONS
C
D
APATITES
E
F
SLEEPY HOLLOW BRANCH MB: WOODBURN LS
G
H
BIPYRAMIDAL QUARTZ
I
APATITE
J
BIOTITE
K
ZIRCONS
L
M
GLASS SHARD
CAPITOL MB: CURDSVILLE LS
N
BIPYRAMIDAL QUARTZ
O
BIOTITE
P
ZIRCON
Q
APATITE
R
TITANIUM OXIDE
MUD CAVE MB: TYRONE LS
S
BIOTITE
T
ZIRCON
U
BIPYRAMIDAL QUARTZ
DEAD HORSE ROAD QUARRY MB: TYRONE LS
V
ZIRCON
W
BIOTITE
X
BIPYRAMIDAL QUARTZ
Y
TITANIUM OXIDE
PENCIL CAVE MB: TYRONE LS

PLATE 5.--Exposures in and fossils from the Jefferson County quarry (Stop 5)

A. View showing part of the lower part and the upper part of the Laurel Dolomite, the Waldron Shale, and lower part of the Big Rock Member of the Louisville Limestone.

B. View of the Laurel Dolomite-Waldron Shale paracontinuity.

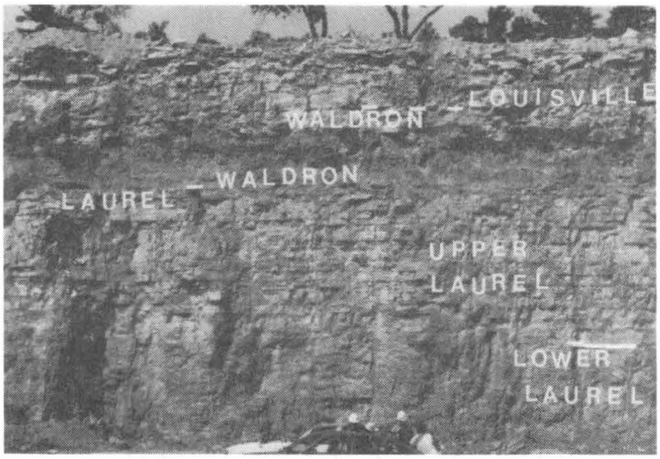
C. Close-up view of Laurel Dolomite-Waldron Shale paracontinuity.

D, F. Specimens of Eucalyptocrinites from the shaly dolomitic "oolitic" basal bed of the Waldron Shale; X.7.

E. Basal "oolitic" shaly dolomite of the Waldron Shale directly overlying the paracontinuous surface of the Laurel Dolomite.

G. Cyrtocone cephalopod, showing the living chamber, in the basal "oolitic" shaly dolomite of the Waldron Shale; X.5.

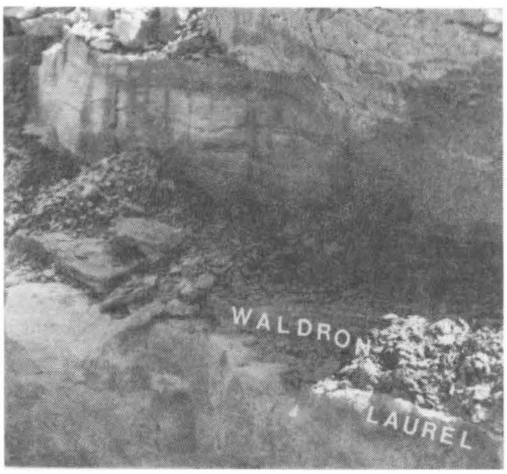
H. Close-up view of "oolites" in basal shaly dolomite of the Waldron; X.8.


WALDRON
LOUISVILLE
LAUREL
WALDRON
UPPER LAUREL
LOWER LAUREL

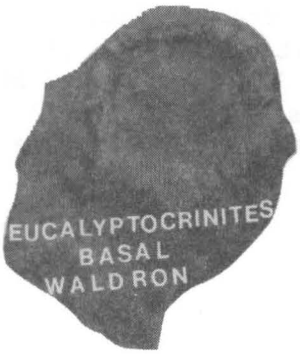
A


WALDRON
LAUREL
S

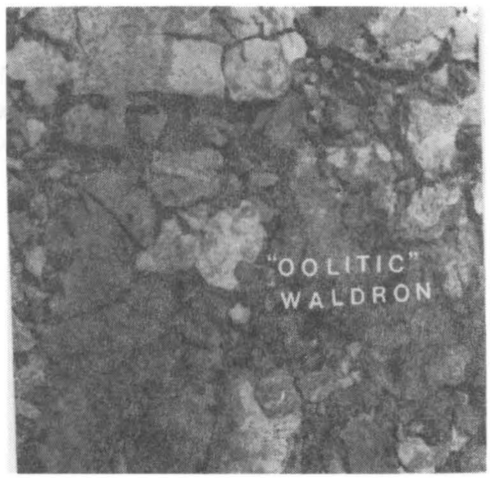
B


WALDRON
LAUREL

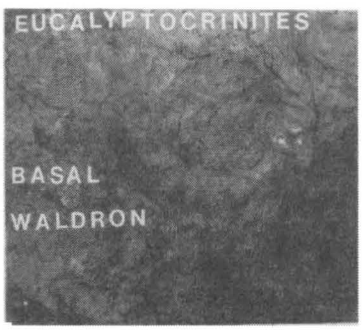
C


EUCALYPTOCRINITES
BASAL
WALDRON

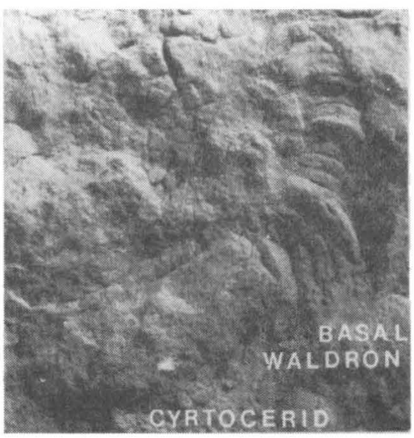
D


"OOLITIC"
WALDRON

E


EUCALYPTOCRINITES
BASAL
WALDRON

F


BASAL
WALDRON
CYRTOCERID

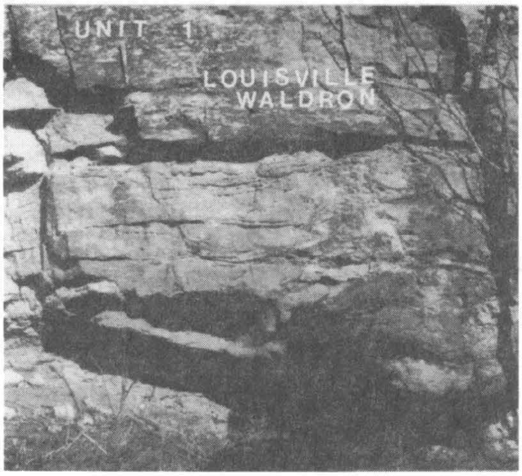
G


"OOLITIC"
WALDRON

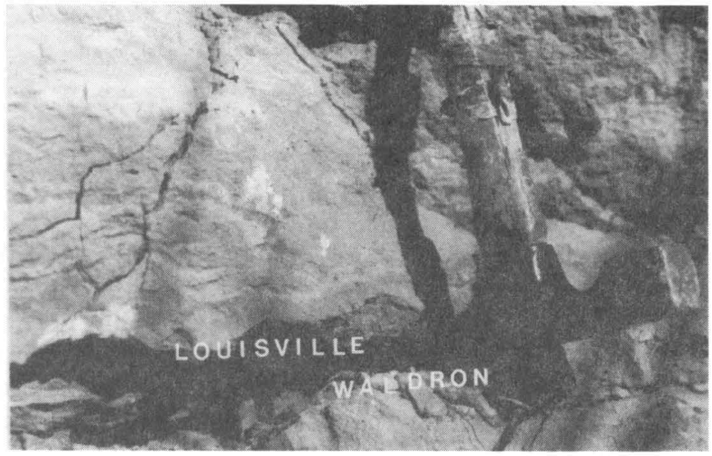
H

PLATE 6.--Exposures in the Jefferson County quarry (Stop 5)

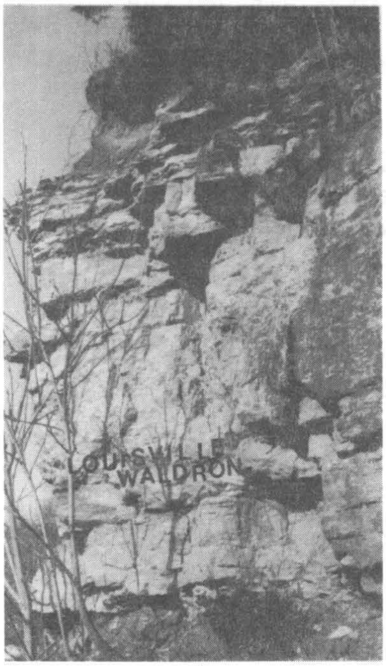
A. Diastemic or possibly paracontinuous surface between the dolomitic limestone and shale of the Waldron Shale and the Big Rock Member of the Louisville Limestone.
B. Close-up view of contact of Waldron Shale and Big Rock Member of Louisville Limestone.
C. View of upper part of the Waldron Shale and the lower part of the Big Rock Member of the Louisville Limestone.
D. Close-up view of paracontinuous contact of the massive dolomitic limestone of the Laurel Dolomite and the overlying basal "oolitic" dolomitic shale and dolomite of the Waldron Shale.
E. Basal "oolitic" shaly dolomite of the Waldron Shale.
F. View of the upper Laurel Dolomite, the paracontinuous contact with the overlying Waldron Shale, the Waldron Shale, the diastemic to possibly paracontinuous contact of the Waldron Shale and Louisville Limestone, and the overlying lower part of the Big Rock Member of the Louisville Limestone.
G. View of uppermost beds of the Laurel Dolomite and the paracontinuous contact of the Laurel Dolomite and Louisville Limestone.


UNIT 1
LOUISVILLE
WALDRON

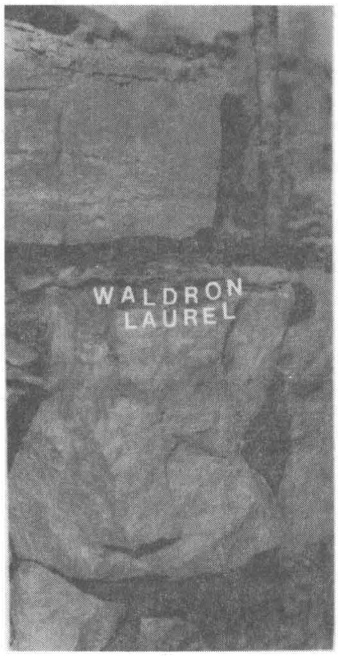
A


LOUISVILLE
WALDRON

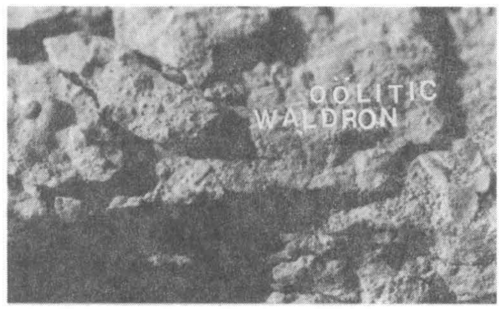
B


LOUISVILLE
WALDRON

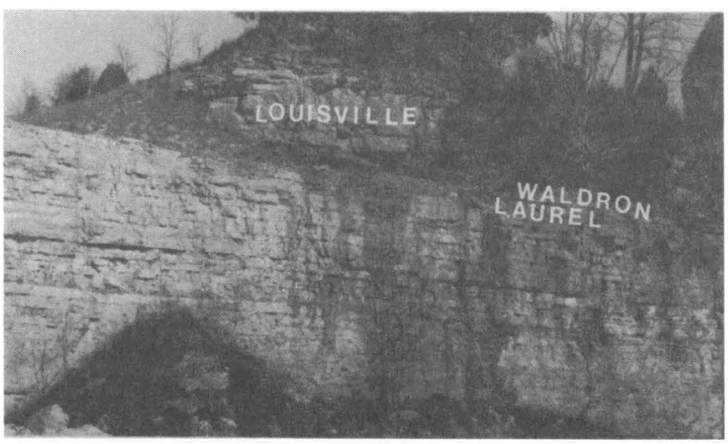
C


WALDRON
LAUREL

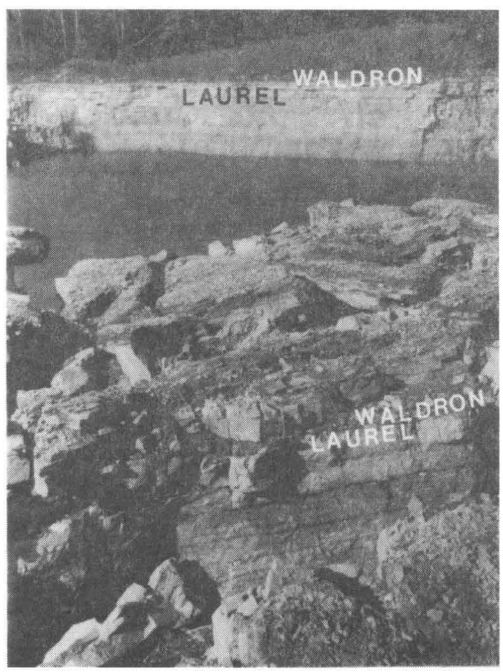
D


OÖLITIC
WALDRON

E


LOUISVILLE
WALDRON
LAUREL

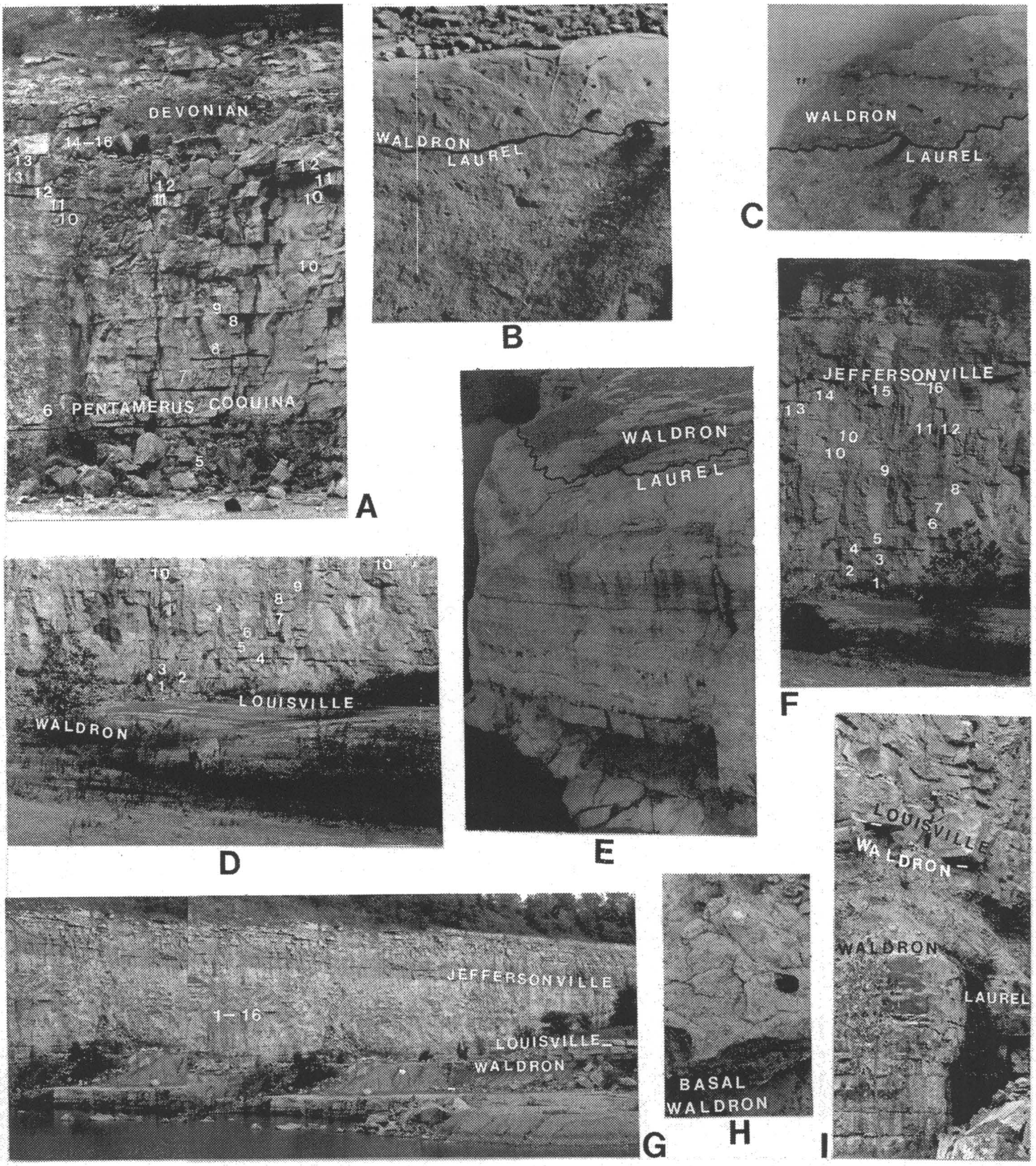
F


LAUREL
WALDRON
WALDRON
LAUREL

G

PLATE 7.--Exposures of the Middle Silurian section and the Louisville-Jeffersonville paraconformity in the Nugent quarry (Stop 8)

A. Quarry wall showing Louisville Limestone (units 5-10 of the Big Rock Member and units 11-lower part of 16 of the Shanks Quarry Member) paraconformably overlain by the Devonian Jeffersonville Limestone.
B, C. Close-up views of the paracontinuity between the Laurel Dolomite and the Waldron Shale showing brecciated fragments of Laurel reworked into the basal "oolitic" dolomite of the Waldron and the bioturated nature of the upper bed of the Laurel.
D. View of the wave-cut diastemic or possibly paracontinuous surface developed on the uppermost dolomitic limestone bed of the Waldron overlain by the Big Rock Member of the Louisville.
E. View of the upper part of the Laurel and the channeled paracontinuous surface between the Laurel and Waldron.
F. View of wave-cut diastemic to possibly paracontinuous surface developed on the top of the Laurel, overlain by the Big Rock Member (units 1-10) and part of the Shanks Quarry Member (units 11-lower part of 16) of the Louisville, as well as the paraconformable contact of the Louisville-Jeffersonville.
G. View of top of the Laurel, and the Waldron, Louisville, Jeffersonville, Speeds, and Silver Creek (at top of quarry).
H. Close-up view of the basal "oolitic" shaly dolomite of the Waldron.
I. View in entrance ramp to quarry showing the upper part of the Laurel, the Waldron, and lower part of the Big Rock Member of the Louisville.



ERRATUM

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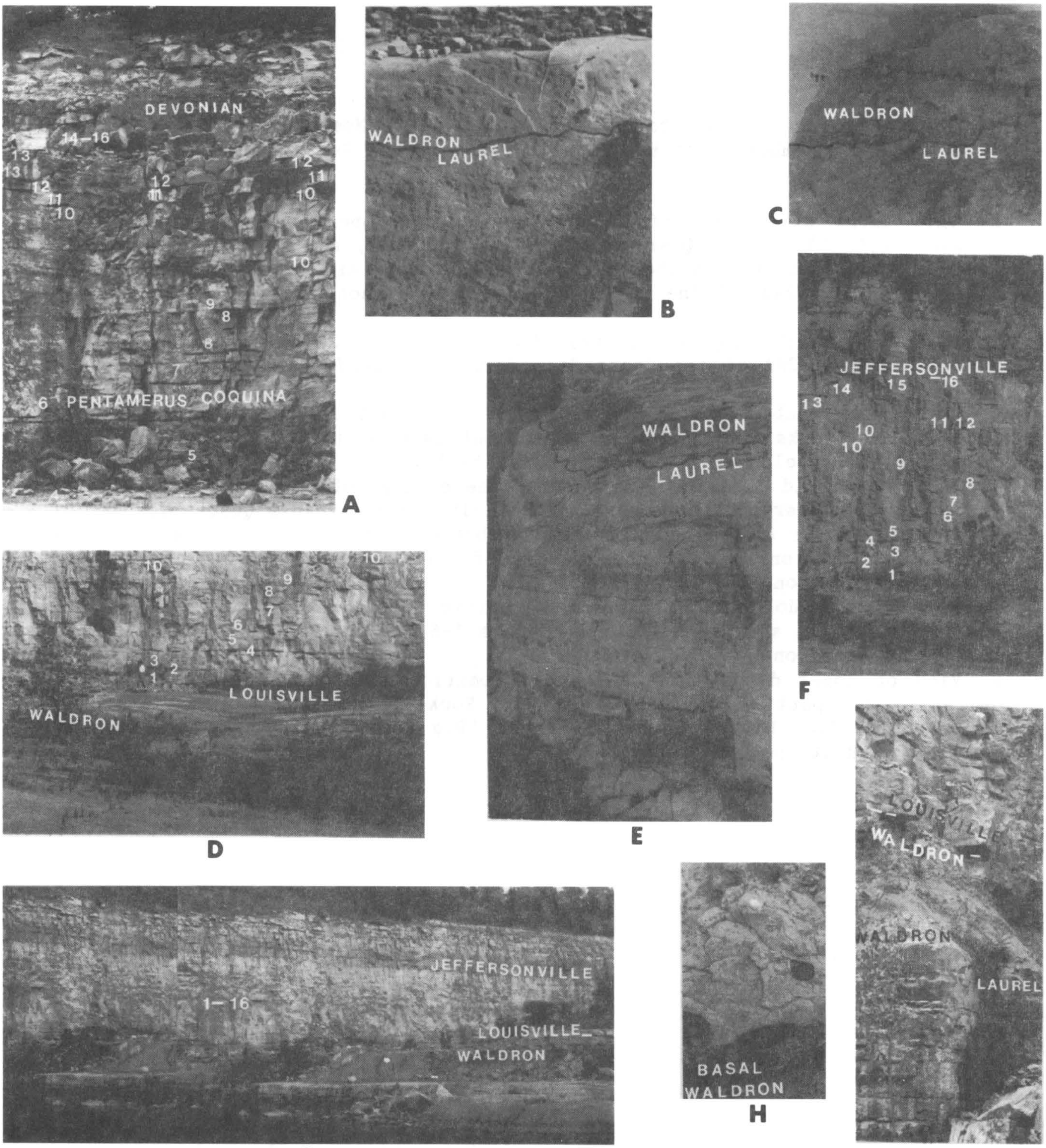

DEVONIAN
14–16
13
13
12
11
10
12
11
12
11
10
10
9
8
8
7
6 PENTAMERUS COQUINA
5
A
WALDRON
LAUREL
B
WALDRON
LAUREL
C
JEFFERSONVILLE
14
15
16
13
10
10
11 12
9
8
7
6
5
4
3
2
1
F
10
10
9
8
7
6
5
4
3
2
1
LOUISVILLE
WALDRON
D
WALDRON
LAUREL
E
JEFFERSONVILLE
1–16
LOUISVILLE
WALDRON
G
BASAL
WALDRON
H
LOUISVILLE
WALDRON
WALDRON
LAUREL
I

PLATE 8.--Exposures at stratotypes of Shanks Quarry Member (Stop 6A) (A, B, D, E), Cross Hill Member (Stop 6B) (C, E), and Big Rock Member (Stop 7) (F, G) of Louisville Limestone.

A. View along exit ramp off I-64W, showing the upper part of the Big Rock Member (unit 10), Shanks Quarry Member (units 11-23), and the lower part (unit 24A) of the Cross Hill Member paraconformably overlain by the Jeffersonville Limestone. Unit 24B of the Cross Hill Member is not present at the Shanks quarry.

B. View along exit ramp off I-64W, showing units 13-23 of the Shanks Quarry Member and Unit 24A of the Cross Hill Member paraconformably overlain by the Jeffersonville.

C. Cross Hill Member (units 24A and 24B) in contact below with the top unit (23) of the Shanks Quarry Member; the basal part of unit 24B is marked by a thin, locally developed, bluish-gray dolomite layer.

D. View inside old Shanks quarry showing the contact of the upper unit (10) of the Big Rock Member and the lower units (11-15) of the Shanks Quarry Member.

E. Close-up view of the paraconformity between the top unit (24B) of the Louisville Limestone and the basal unit of the Jeffersonville Limestone with chert reworked from the Louisville.

F. View showing dolomitic shale and dolomitic limestone in the upper part of the Waldron Shale and the lower part (units 1-6) of the Big Rock Member of the Louisville Limestone.

G. View of upper dolomitic shale and dolomitic limestone of the Waldron and units 1-9 and part of unit 10 of the Big Rock Member of the Louisville. The large upside-down block of unit 8 is the "Big Rock" that gives this area of Cherokee Park its popular name.

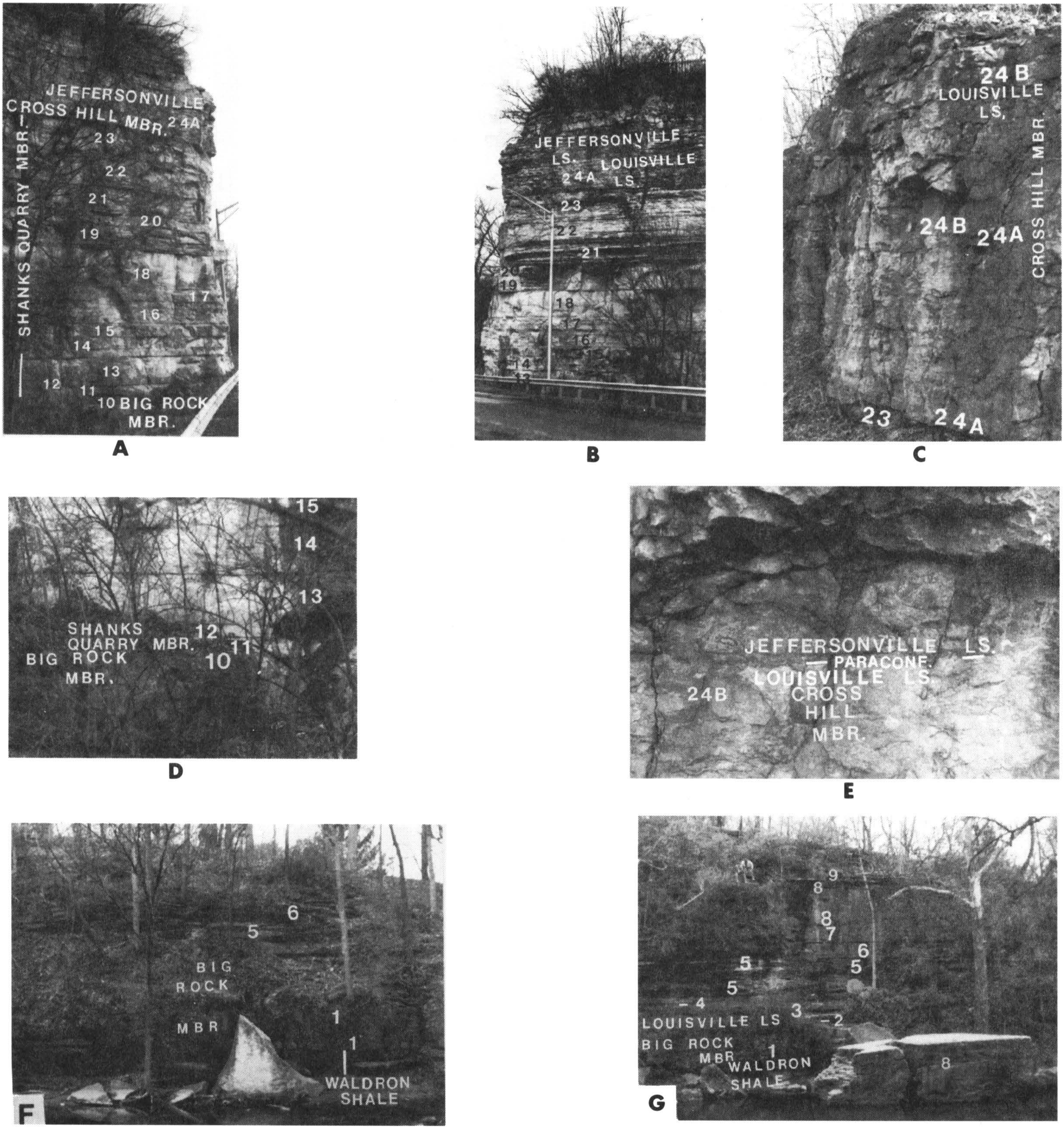

JEFFERSONVILLE
CROSS HILL MBR.
24A
SHANKS QUARRY MBR.
23
22
21
20
19
18
17
16
15
14
13
12
11
10 BIG ROCK
MBR.
A
JEFFERSONVILLE
LS.
LOUISVILLE
LS.
24A
23
22
21
20
19
18
17
16
15
14
B
24 B
LOUISVILLE
LS.
CROSS HILL MBR.
24B
24A
23
24A
C
15
14
13
SHANKS
QUARRY MBR.
12
11
BIG ROCK
MBR.
10
D
JEFFERSONVILLE LS.
PARACONF.
LOUISVILLE LS.
24B
CROSS
HILL
MBR.
E
6
5
BIG
ROCK
MBR
1
1
WALDRON
SHALE
F
9
8
8
7
6
5
5
5
4
3
2
LOUISVILLE LS
BIG ROCK
MBR
1
WALDRON
SHALE
8
G

PLATE 9.--Exposures in roadcut on U.S. Hwy 42 at Prospect Hill, just east of intersection with Gene Snyder Freeway (Stop 9)

A. View of south side of road showing the top of the *Aemulophyllum exiguum*-*Emmonsia ramosa* Zone through Upper *Paraspirifer acuminatus* Zone of the Jeffersonville Limestone overlain paracontinuously by the lower part of the Silver Creek Limestone. The positions of the Kawkawlin, Onondaga Indian Nation (O.I.N.), and Lake Chelan Metabentonites are marked, as are bone beds 2, 4, and 11.

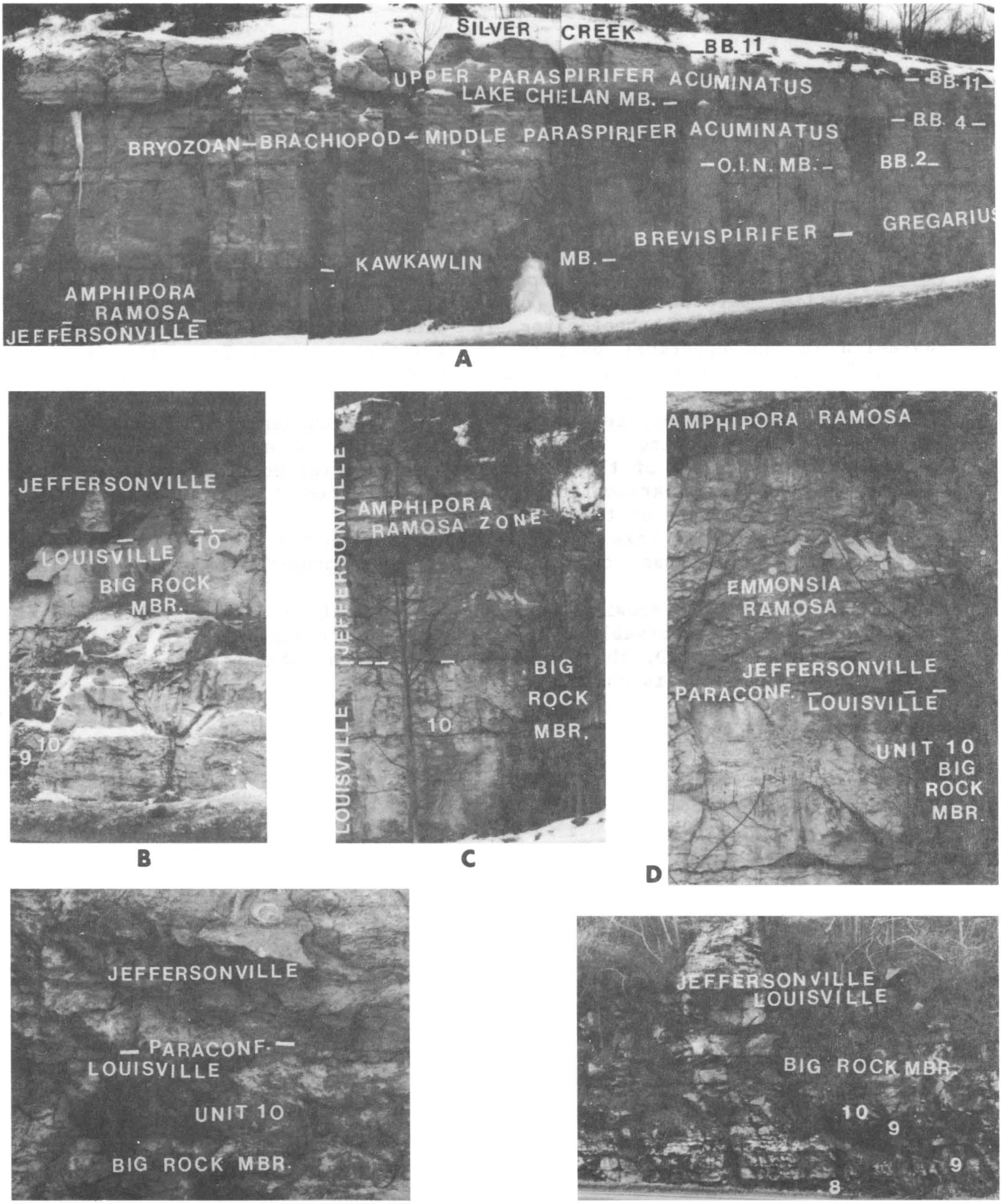
B. View showing the upper part of unit 9 and unit 10 of the Big Rock Member of the Louisville Limestone paraconformably overlain by the Jeffersonville Limestone.

C. Closer view of the upper part (unit 10) of the Big Rock Member of the Louisville Limestone overlain by the lower part of the Jeffersonville Limestone.

D. Close-up view of part of view in 9C showing the position of the Louisville-Jeffersonville paraconformity and showing in more detail the colonial tabulate coral *Emmonsia ramosa*.

E. Close-up view of the Louisville-Jeffersonville paraconformity and the cup coral *Aemulophyllum exiguum*, which with *Emmonsia ramosa* constitutes a fossil zone which allows correlation of the lowest part of the Jeffersonville (and the Geneva Dolomite facies of southeastern Indiana) with the Schoharie of New York.

F. View of exposure on north side of Hwy 42 showing upper part of unit 8 through unit 10 of the Big Rock Member paraconformably overlain by the Jeffersonville Limestone.



SILVER CREEK
BB.11
UPPER PARASPIRIFER ACUMINATUS
BB.11
LAKE CHELAN MB.
BRYOZOAN–BRACHIOPOD
MIDDLE PARASPIRIFER ACUMINATUS
B.B. 4
O.I.N. MB.
BB.2
BREVISPIRIFER
GREGARIUS
KAWKAWLIN
MB.
AMPHIPORA
RAMOSA
JEFFERSONVILLE
A
JEFFERSONVILLE
LOUISVILLE
10
BIG ROCK
MBR.
9
10
B
JEFFERSONVILLE
LOUISVILLE
AMPHIPORA
RAMOSA ZONE
BIG
ROCK
MBR.
10
C
AMPHIPORA RAMOSA
EMMONSIA
RAMOSA
JEFFERSONVILLE
PARACONF.
LOUISVILLE
UNIT 10
BIG
ROCK
MBR.
D
JEFFERSONVILLE
PARACONF.
LOUISVILLE
UNIT 10
BIG ROCK MBR.
E
JEFFERSONVILLE
LOUISVILLE
BIG ROCK MBR.
10
9
9
8
F

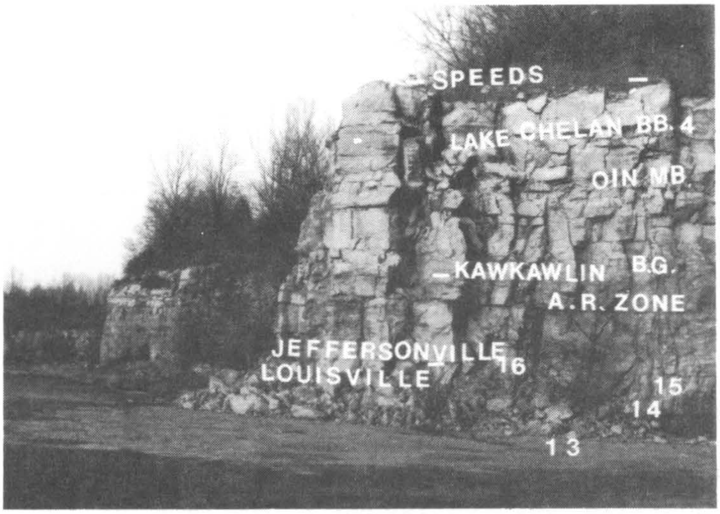
PLATE 10.--Exposures of Louisville, Jeffersonville, and Speeds Limestones in the Nugent quarry (Stop 8), near Utica, Clark County, Indiana

A, B. Views of the upper level of the quarry showing the floor formed by the top of unit 13 of the Shanks Quarry Member of the Louisville Limestone. The wall of the quarry shows units 14, 15, and the lower part of 16 of the Shanks Quarry Member, paraconformably overlain by the *Aemulophyllum exiguum*-*Emmonsia ramosa* (A.R.) Zone of the Jeffersonville Limestone, and the remainder of the Jeffersonville paracontinuously overlain by the Speeds Limestone. The positions of three metabentonites in the Jeffersonville are shown: the Kawkawlin in the uppermost part of the *Amphipora ramosa* Zone, the Onondaga Indian Nation (O.I.N.) in unit 5 of the *Brevispirifer gregarius*-*Moellerina greenei* (B.G.) Zone, and the Lake Chelan, associated with bone bed 4 in the base of the Upper *Paraspirifer acuminatus*-"*Spirifer duodenarius*" Zone.

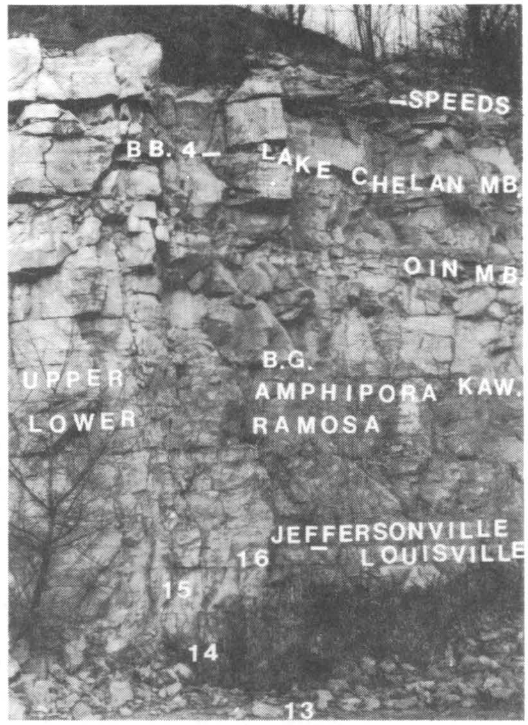
C. Stereo view showing the position of the Onondaga Indian Nation Metabentonite in unit 5 of the *Brevispirifer gregarius*-*Moellerina greenei* Zone overlain directly by paracontinuity 2 and bone bed 1 at the base of the Bryozoan-Brachiopod Zone of the *P. acuminatus* Zone.

D. Close-up view of the Lake Chelan Metabentonite in the middle of bone bed 4, which constitutes the base of the Upper *P. acuminatus*-"*Spirifer duodenarius*" Zone.

E. View of quarry wall showing the lower part of the Shanks Quarry Member of the Louisville paraconformably overlain by the Jeffersonville. In addition to the units shown in 10A-D, the position of the Tioga Metabentonite at the base of the Speeds Limestone is shown.


SPEEDS
LAKE CHELAN BB. 4
OIN MB.
KAWKAWLIN B.G.
A. R. ZONE
JEFFERSONVILLE
LOUISVILLE
16
15
14
13

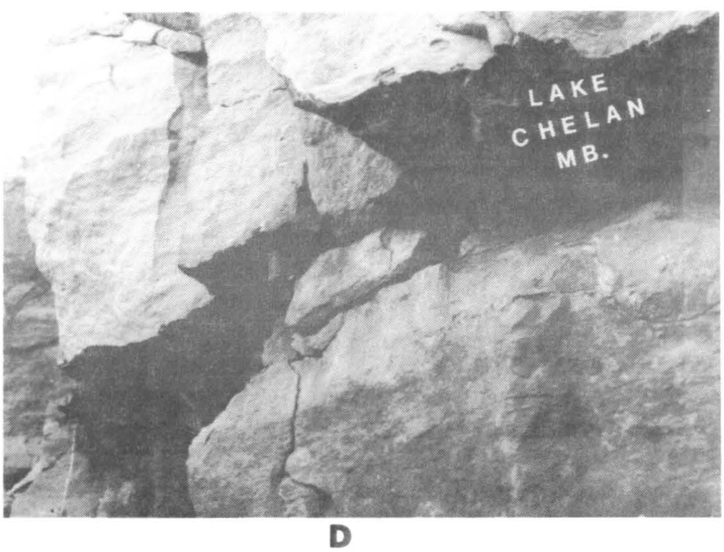
A


SPEEDS
BB. 4
LAKE CHELAN MB.
OIN MB.
B.G.
UPPER
LOWER
AMPHIPORA KAW.
RAMOSA
JEFFERSONVILLE
LOUISVILLE
16
15
14
13

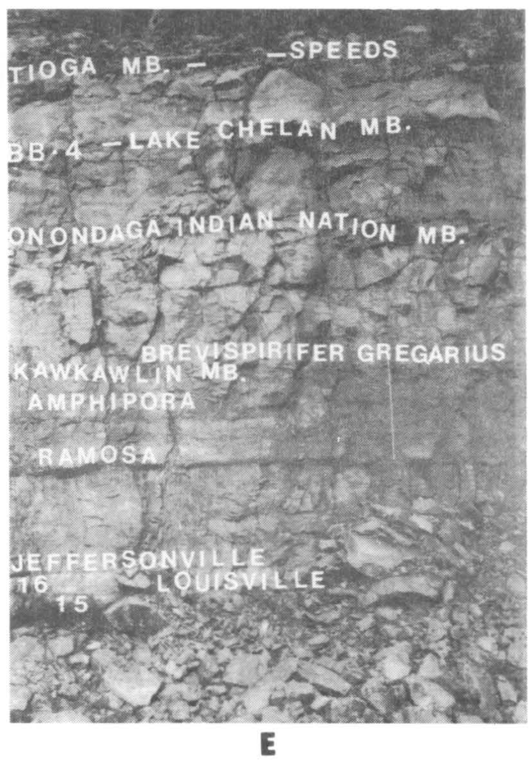
B


BB.1
6
5
ONONDAGA
INDIAN NATION
MB.
5

C


LAKE
CHELAN
MB.

D


TIOGA MB.
SPEEDS
BB 4 LAKE CHELAN MB.
ONONDAGA INDIAN NATION MB.
BREVISPIRIFER GREGARIUS
KAWKAWLIN MB.
AMPHIPORA
RAMOSA
JEFFERSONVILLE
16
LOUISVILLE
15

E

PLATE 11.--Exposures of Louisville, Jeffersonville, and Speeds Limestones in the Nugent quarry (Stop 8), near Utica, Clark County, Indiana

A, B. View showing the paracontinuous contact between the Upper *Paraspirifer acuminatus*-"*Spirifer duodenarius*" Zone of the Jeffersonville Limestone and the Speeds Limestone; the Tioga Metabentonite is associated with bone beds 6 and 7, at the base of the Speeds Limestone.

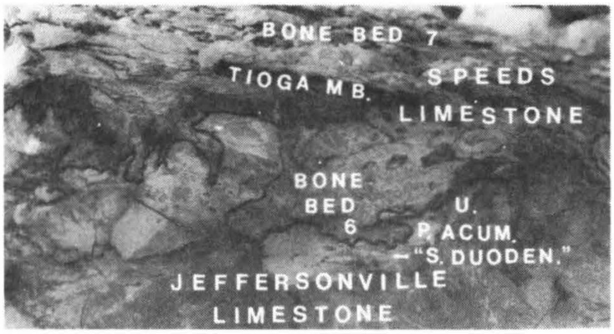
C. View of quarry wall showing the paraconformity between unit 16 in the lower part of the Shanks Quarry Member of the Louisville Limestone and the *Aemulophyllum exiguum*-*Emmonsia ramosa* Zone of the Jeffersonville Limestone and the succeeding units of the Jeffersonville paracontinuously overlain by the Speeds Limestone. The positions of the Kawkawlin, Onondaga Indian Nation, and Lake Chelan Metabentonites in the Jeffersonville are shown, as well as the Tioga Metabentonite at the base of the Speeds Limestone.

D. Closer view showing the paraconformable contact of unit 16 of the Shanks Quarry Member of the Louisville Limestone and the overlying *A. exiguum*-*E. ramosa* Zone of the Jeffersonville Limestone.

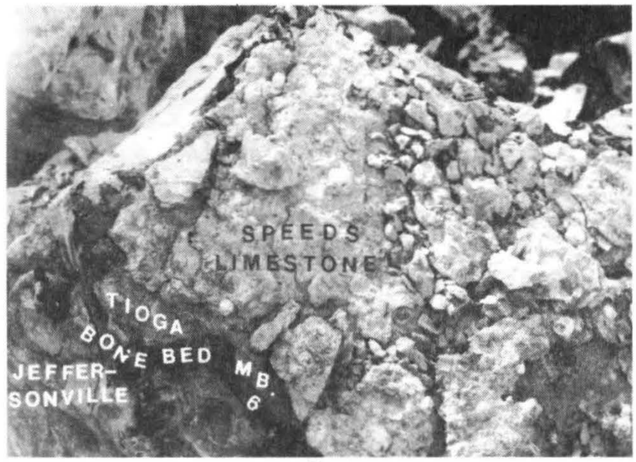
E. Close-up view of the Louisville-Jeffersonville paraconformity showing unit 16 of the Shanks Quarry Member overlain by the *A. exiguum*-*E. ramosa* Zone of the Jeffersonville.

F. View of wall at lower part of upper level of the quarry showing the lower part of the Shanks Quarry Member paraconformably overlain by the *A. exiguum*-*E. ramosa* Zone of the Jeffersonville and the succeeding Jeffersonville, extending into the *Brevispirifer gregarius*-*Moellerina greenei* Zone. The position of the Kawkawlin Metabentonite in the uppermost part of the *Amphipora ramosa* Zone is shown.

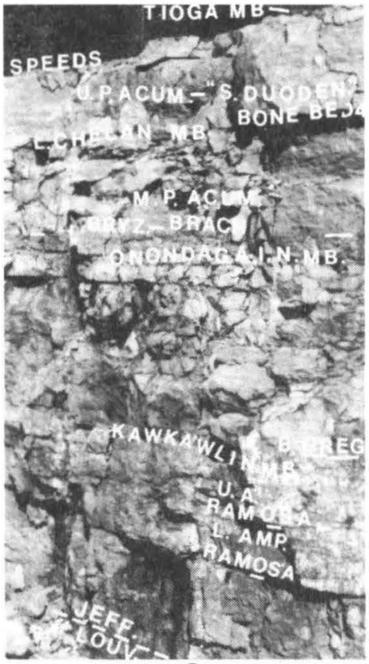
G. Closer view of the lower part of 11F showing the vertically worm-burrowed zone in unit 14 (Blue Captain ledge), a marker bed in the Shanks Quarry Member of the Louisville.


BONE BED 7
TIOGA MB.
SPEEDS
LIMESTONE
BONE
BED
6
U.
P. ACUM.
— "S. DUODEN."
JEFFERSONVILLE
LIMESTONE

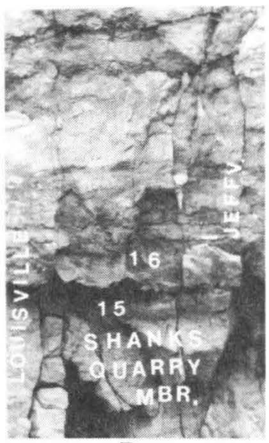
A


SPEEDS
LIMESTONE
TIOGA
BONE BED
MB.
6
JEFFER-
SONVILLE

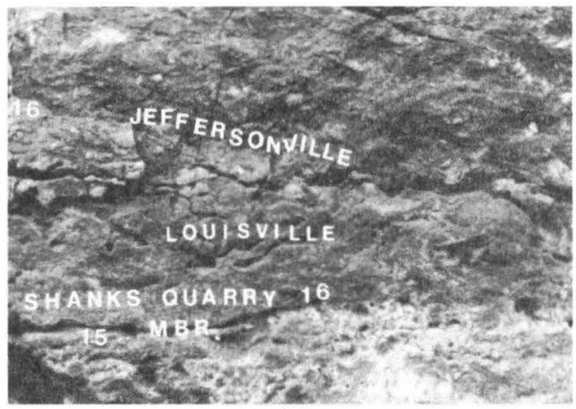
B


TIOGA MB
SPEEDS
M. P. ACUM.
ONONDAGA I.N. MB.
KAWKAWLIN MB.
U. A.
L. AMP.
RAMOSA
JEFF.
LOUV.

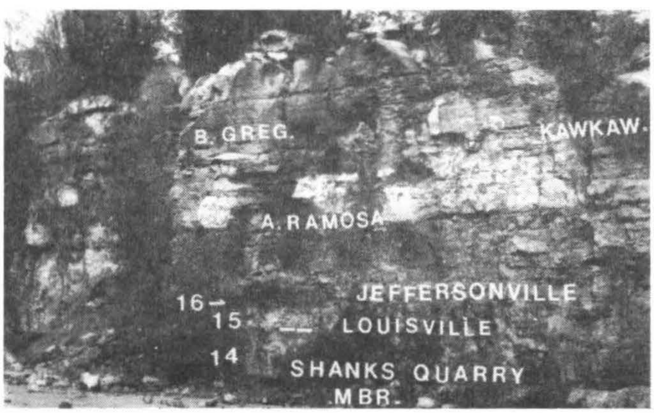
C


LOUISVILLE
JEFFV.
16
15
SHANKS
QUARRY
MBR.

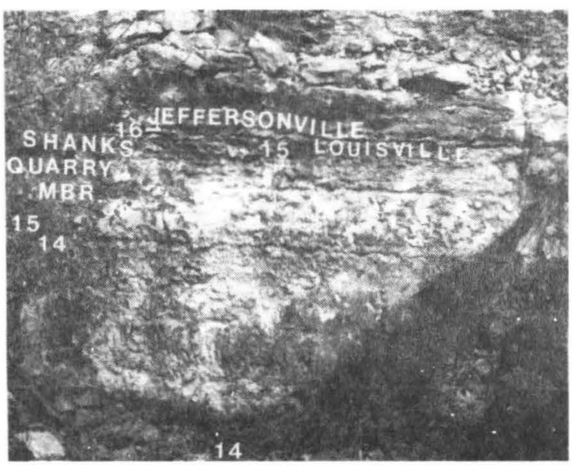
D


16
JEFFERSONVILLE
LOUISVILLE
SHANKS QUARRY 16
15 MBR.

E


B. GREG.
KAWKAW.
A. RAMOSA
JEFFERSONVILLE
16
15
LOUISVILLE
14
SHANKS QUARRY
MBR.

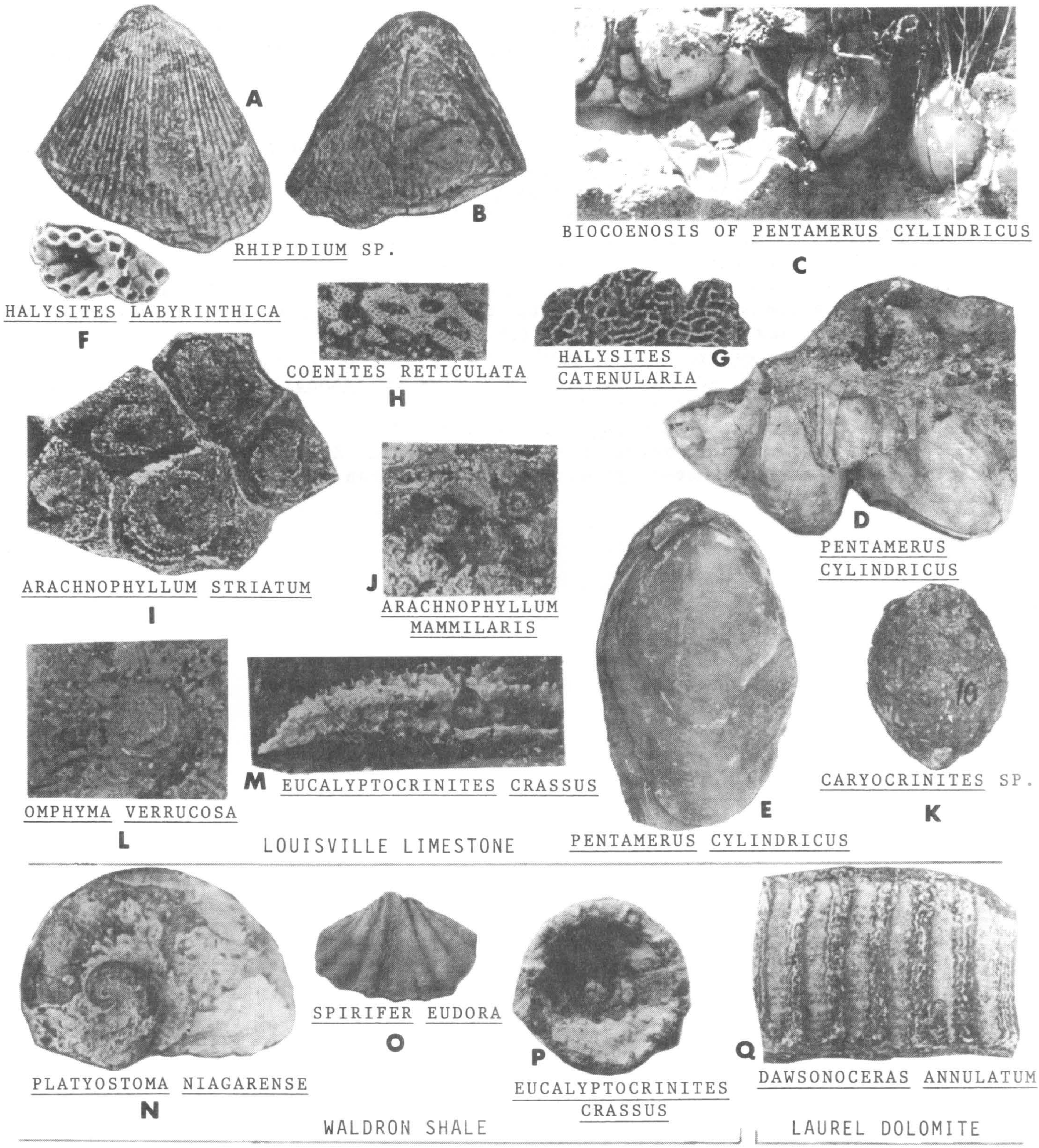
F


16
JEFFERSONVILLE
SHANKS
QUARRY
MBR
15 LOUISVILLE
15
14
14

G

PLATE 12.--Fossils characteristic of the Middle Silurian Laurel Dolomite, Waldron Shale, and Louisville Limestone

A, B. Pedicle and brachial views of the pentamerid brachiopod Rhipidium sp., which ranges from unit 16 of the Shanks Quarry Member through unit 24B of the Cross Hill Member of the Louisville Limestone, X.5.
C, D. Specimens from the biocoenosis of Pentamerus cylindricus in unit 6 of the Big Rock Member of the Louisville; X.5.
E. Pentamerus cylindricus from unit 6 of the Big Rock Member; X.5.
F. Halysites labyrinthica, a rare coral in various parts of the Louisville Limestone; X.8.
G. Halysites catenularia, which occurs throughout the Louisville Limestone, but is abundant in the Shanks Quarry and Cross Hill Members; X.7.
H. Coenites reticulata, a colonial coral present throughout the Louisville Limestone; X.7.
I. Arachnophyllum striatum, a common coral in the Louisville Limestone, but particularly abundant in unit 9 of the Big Rock Member; X.3.
J. Arachnophyllum mammilaris, a coral of rare occurrence in the Louisville Limestone; X.7.
K. Caryocrinites sp., a cystoid particularly common in the Waldron Shale and in the Big Rock Member of the Louisville Limestone; X.1.
L. Omphyma verrucosa, a cup coral restricted to the Big Rock Member of the Louisville Limestone; X.7.
M. Interambulacral plate of Eucalyptocrinites crassus, a crinoid occurring in the Waldron Shale and throughout the Louisville Limestone, but especially in the Big Rock Member; X1.5.
N. Platyostoma niagarense, a rare but characteristic snail in the Waldron Shale; X.7.
O. Spirifer eudora, a brachiopod characteristic of the Waldron Shale; X1.5.
P. View of the interior of the base of Eucalyptocrinites sp. from the basal "oolitic" beds of the Waldron Shale; X.7.
Q. Fragment of the orthocone cephalopod Dawsonoceras annulatum, characteristic of the Laurel Dolomite; X.8.



A, B — RHIPIDIUM SP.

C — BIOCOENOSIS OF PENTAMERUS CYLINDRICUS

F — HALYSITES LABYRINTHICA

H — COENITES RETICULATA

G — HALYSITES CATENULARIA

D — PENTAMERUS CYLINDRICUS

I — ARACHNOPHYLLUM STRIATUM

J — ARACHNOPHYLLUM MAMMILARIS

E — PENTAMERUS CYLINDRICUS

K — CARYOCRINITES SP.

L — OMPHYMA VERRUCOSA

M — EUCALYPTOCRINITES CRASSUS

LOUISVILLE LIMESTONE

N — PLATYOSTOMA NIAGARENSE

O — SPIRIFER EUDORA

P — EUCALYPTOCRINITES CRASSUS

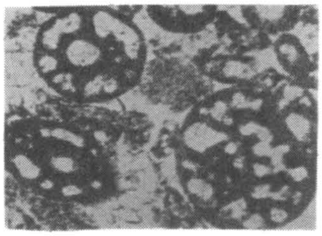
WALDRON SHALE

Q — DAWSONOCERAS ANNULATUM

LAUREL DOLOMITE

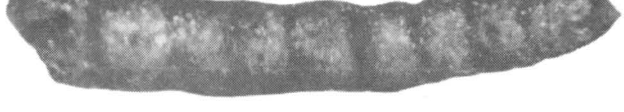
PLATE 13.--Fossils characteristic of the late Early Devonian (Emsian) Aemulophyllum exiguum-Emmonsia ramosa Zone and Middle Devonian (middle Onesquethawan) lower and upper Amphipora ramosa zones of the Jeffersonville Limestone

A. Cross-sectional views of the small, cylindrical, "spaghetti"-like stromatoporoid Amphipora ramosa; X18.
B. Agglutinate foraminiferan Earlandia sp.; X44.
C. Agglutinate foraminiferan Semitextularia sp.; X44.
D. Colonial "finger" corals in carbonaceous "Buffalo Dung Beds" of David Dale Owen, 1857, representing tidal pool environment; X.9.
E. The ham-shaped colonial coral Favosites hemisphericus cornutiformis; X.4.
F. Five specimens of the small cup coral Aemulophyllum exiguum, an Emsian (Schoharie of New York) key fossil; X.5.
G. Billingsastraea sp., a heliophylloid colonial coral; X.6.
H. External and oblique cross-sectional view of Emmonsia ramosa, a favositid coral with degenerate tabulae; X.5.
I. Saggital section of Emmonsia ramosa; X.5.
J. Interior of pedicle valve of Meristella nasuta; X1.
K. Classic earring-shaped agglutinate foraminiferan Inauris tubulata; X34.



AMPHIPORA RAMOSA

A



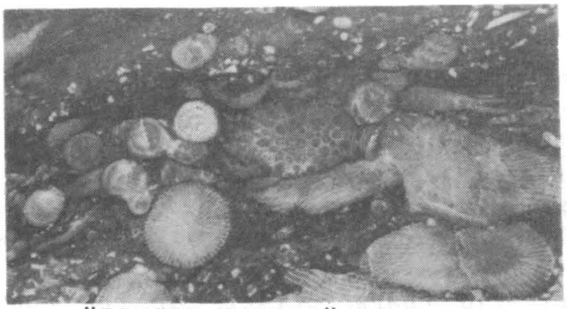
EARLANDIA SP.

B

C

SEMITEXTULARIA SP.

UPPER AMPHIPORA RAMOSA ZONE



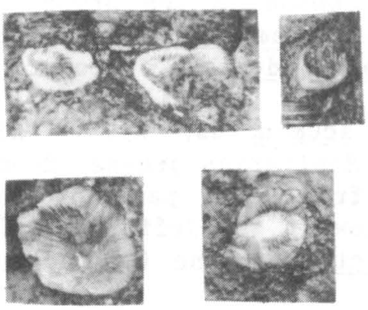
"FINGER CORALS" IN D. D. OWEN'S BUFFALO DUNG BEDS

D

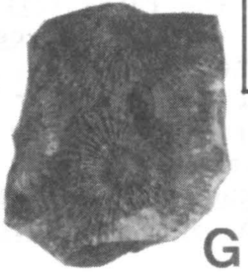
LOWER AMPHIPORA RAMOSA ZONE

E

FAVOSITES HEMISPHERICUS CORNUTIFORMIS

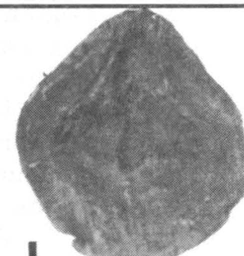


F AEMULOPHYLLUM EXIGUUM

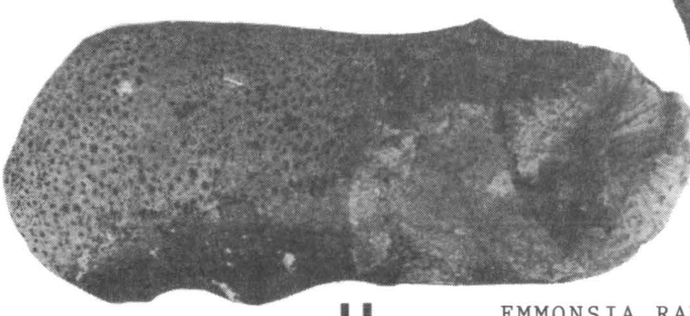


G

BILLINGSASTREA SP.



J MERISTELLA NASUTA



H EMMONSIA RAMOSA I

K INAURIS TUBULATA

AEMULOPHYLLUM EXIGUUM-EMMONSIA RAMOSA ZONE

PLATE 14.--Fossils characteristic of the Middle Devonian (middle Onesquethawan) *Brevispirifer gregarius*-*Moellerina greenei* Zone and *Paraspirifer acuminatus* Zone of the Jeffersonville Limestone.

A, B. Side and ambulacral views of the blastoid *Heteroschisma pyramidata*; X.3.
C, D. Apical and basal views of the blastoid *Elaeacrinus verneuili*; X1.3.
E. Posterior view of *Paraspirifer acuminatus*; X.9.
F. Phaceloid colonial coral *Eridophyllum seriale*; X.4.
G. Worm burrows, which are common beginning in the middle *Paraspirifer acuminatus* Zone and ranging through the top of the upper *Paraspirifer acuminatus*-"*Spirifer duodenarius*" Zone; X.5.
H. "*Spirifer duodenarius*", a marker spiriferid characteristic of the upper *Paraspirifer acuminatus* Zone of the Jeffersonville and the H Zone of the Columbus Limestone; X1.2.
I. Several specimens of fenestrate bryozoans, occurring in special abundance in the Jeffersonville above the *Brevispirifer gregarius*-*Moellerina greenei* Zone; X.9.
J. Columnal of the small *Dolatocrinus* sp., which is common in the Bryozoan-Brachiopod Zone, but ranges throughout the *Paraspirifer acuminatus* Zone; X.3.
K. View of fragment of the spiny snail *Platyceras dumosum*, occurring throughout the *Paraspirifer acuminatus* Zone; X1.
L. Fragment of the pedicle valve of *Paraspirifer acuminatus*; X1.2. This specimen is from Unit 1 of the *Brevispirifer gregarius*-*Moellerina greenei* Zone. Only five specimens have been recovered to date from this part of the Jeffersonville. The occurrence of *P. acuminatus* this low in the Jeffersonville allows correlation of this unit with the *Spirifer macrothyris* Zone (E Zone) of the Columbus Limestone.
M, N. Side view (M; X13) of gyrogonite of the primitive charophyte *Moellerina greenei* and rock-section view (N; X3) showing several cross sections of *M. greenei*.
O. *Turbonopsis shumardi*, a common large gastropod in the upper parts (units 4 and 5) of the *Brevispirifer gregarius*-*Moellerina greenei* Zone; X.3.
P. *Zaphrentis phrygia*, a cup coral of abundant occurrence in the *B. gregarius*-*M. greenei* Zone; X.65.
Q. *Favosites hemisphericus turbinatus*, a colonial coral generally found as fragments consisting mostly of the "knee cap"-like basal attached portion; X.36.


A

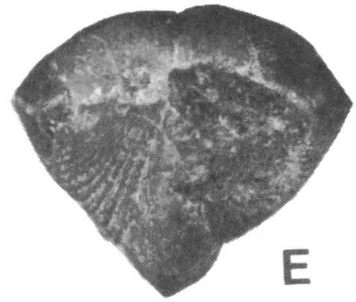
B

HETEROSCHISMA PYRAMIDATA

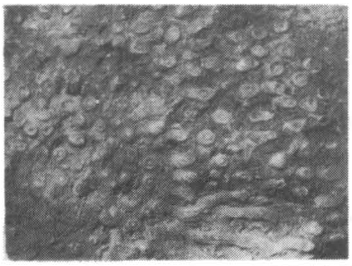

C

D

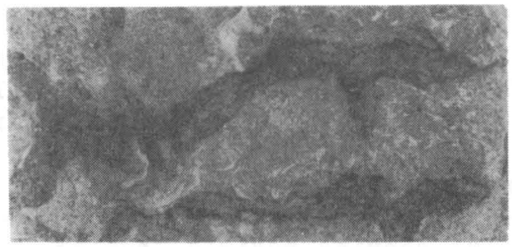
ELAEACRINUS VERNEUILI


E

PARASPIRIFER ACUMINATUS


F

ERIDOPHYLLUM SERIALE


G

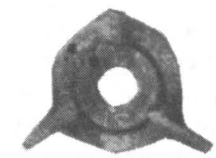
WORM BURROWS


H

"SPIRIFER DUODENARIUS"


I

FENESTRATE BRYOZOANS


J

SMALL DOLATOCRINUS SP.


K

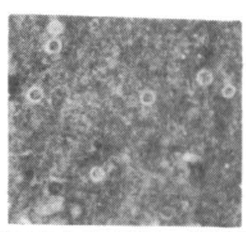
PLATYCERAS DUMOSUM

PARASPIRIFER ACUMINATUS ZONE (H ZONE OF COLUMBUS LIMESTONE)


PARASPIRIFER ACUMINATUS
L

M

MOELLERINA GREENEI

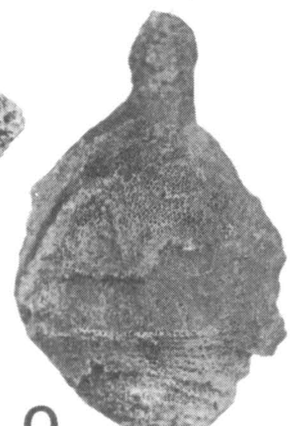

MOELLERINA GREENEI
N


O

TURBONOPSIS SHUMARDI


P

ZAPHRENTIS PHRYGIA

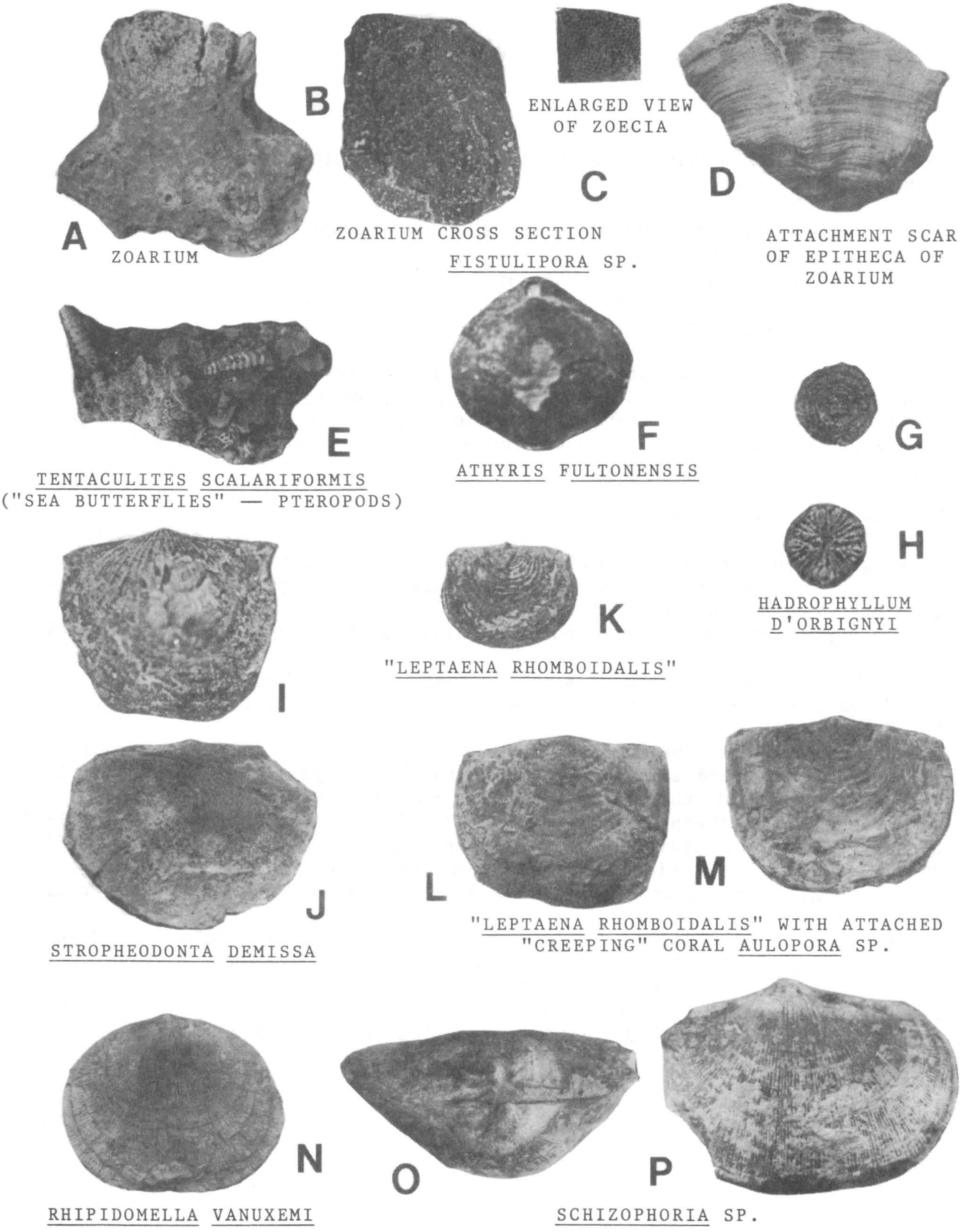

Q

FAVOSITES HEMISPHERICUS TURBINATUS

BREVISPIRIFER GREGARIUS - MOELLERINA GREENEI ZONE
(COLUMBUS LIMESTONE E-G ZONES)

PLATE 15.--Fossils characteristic of the Middle Devonian (early Cazenovian) Speeds Limestone in the Nugent quarry (Stop 8), near Utica, Clark County, Indiana

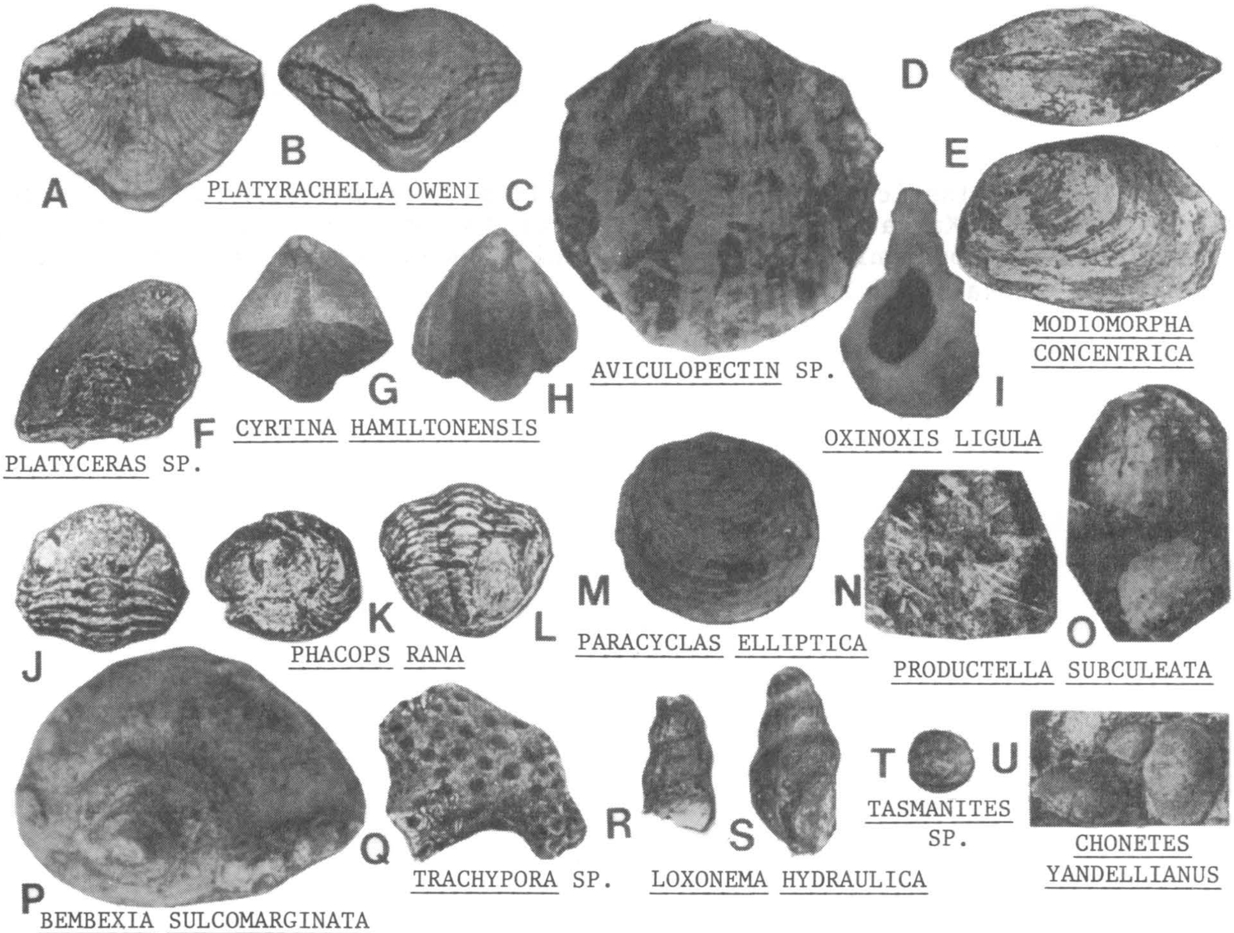
A-D. Fistulipora sp. a common bryozoan in the Speeds Limestone. (A) External view of zoarium; X.85. (B) cross-sectional view; X1.1 (C) Enlarged view of zoecial surface; X2. (D) Impression of epithecal wrinkling of attachment scar of zoarium; X.9.
E. Tentaculites scalariformis, a pteropod common in the Speeds, but abundant in and marking Stauffer's (1909) K Zone of the Delaware Limestone of Ohio; X3.
F. View of brachial valve showing pedicle opening on pedicle valve of Athyris fultonensis, a diagnostic Speeds Limestone fossil; X1.4.
G, H. Basal and top views of Hadrophyllum d'Orbignyi, a "button coral" restricted to the Speeds Limestone of southern Indiana and characteristic of Stauffer's (1909) L Zone of the Delaware Limestone of Ohio; X.85.
I, J. Pedicle and dorsal views of Stropheodonta demissa; X.85.
K-M. "Leptaena rhomboidalis", a brachiopod abundant in the Tioga Metabentonite (restricted) and associated with bone beds 6 and 7 of the Speeds. (K) Brachial valve view; X.8. Pedicle view (L) and brachial view (M) showing the creeping coral Aulopora sp. attached to the valves; X1.3.
N. Rhipidomella vanuxemi, a bioconvex brachiopod common in the Speeds but ranging downward into the upper part of the Jeffersonville; X1.8.
O, P. Posterior and brachial valve views of Schizophoria sp.; X1.



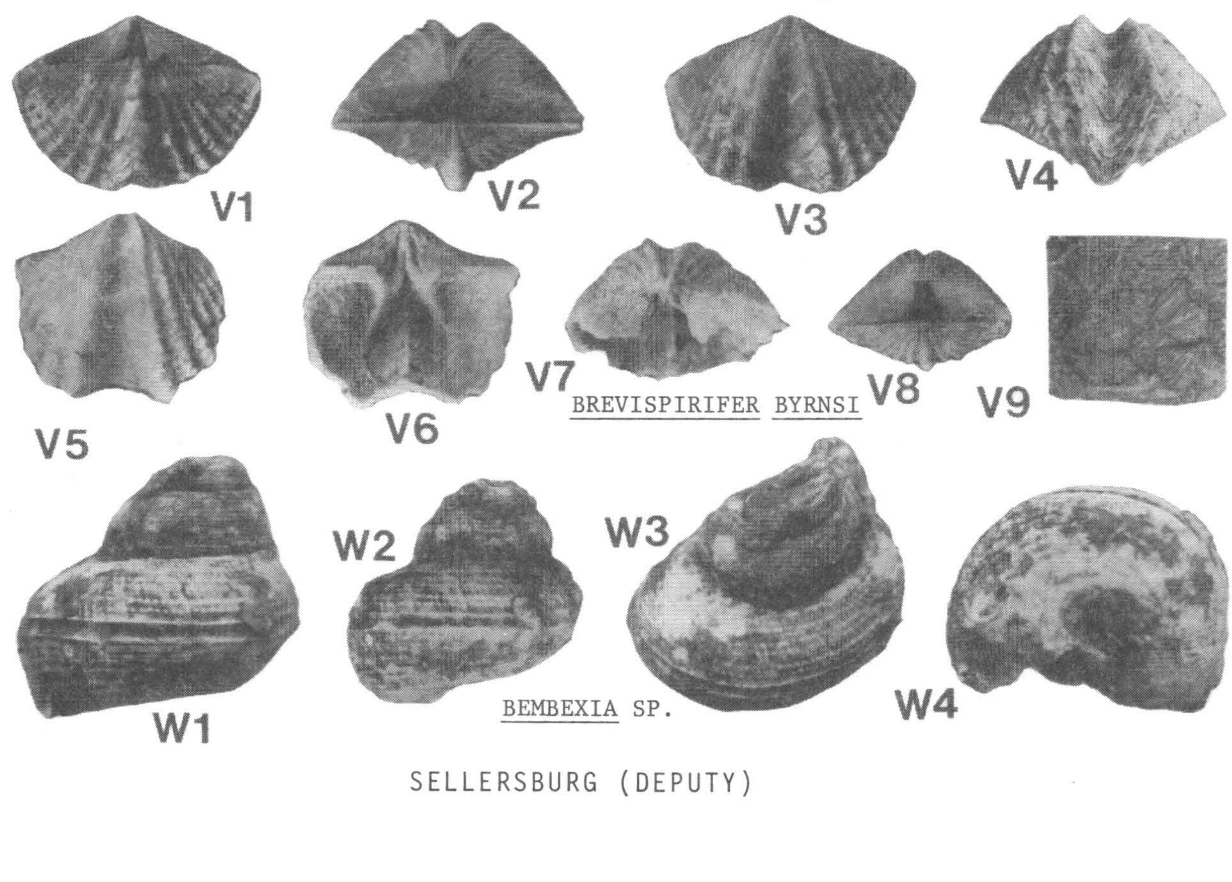
SPEEDS LIMESTONE

PLATE 16.--Fossils characteristic of the Sellersburg Group (Silver Creek and Deputy Limestones)

A, B. Oblique brachial-valve posterior view and anterior view of spiriferid brachiopod Platyrachella oweni; X.7.
C. Cast of the clam, Aviculopectin sp.; X.65.
D, E. Dorsal view showing hinge line and side view of left valve of the clam Modiomorpha concentrica; X.6.
F. The snail Platyceras sp.; X.6.
G, H. View of characteristic extremely high cardinal area and somewhat curved beak, and pedicle view of the brachiopod Cyrtina hamiltonensis; X.5.
I. View of attachment surface of the agglutinate foraminiferan Oxinoxis ligula, which ranges from early Cazenovian to late Kinderhookian, X43.
J-L. Cephalon, side, and pygidial views of the "frog-faced" trilobite, Phacops rana; X.6.
M. The clam, Paracyclas elliptica; X.67.
N, O. Examples of the primitive productid brachiopod Productella subculeata showing long spines (N) and broken spine bases (O); X1.5.
P. Poorly preserved specimen of Bembexia sulcomarginata, a snail genus characterized by a selenizone; X1.4.
Q. Trachypora sp., a colonial coral usually found silicified and with beekite ring structures; X1.
R, S. Two fragmentary specimens of the snail Loxonema hydraulica; X1.4.
T. Tasmanites sp., often referred to under the older name, Sporangites huronense; X25.
U. Specimens of the brachiopod Chonetes yandellianus, which is prolifically present in, and used as a guide fossil to, the Silver Creek Limestone; X1.5.
V1-V9. Examples of the spiriferid Brevispirifer byrnsi, restricted in its occurrence in southern Indiana to the Speeds and Deputy Limestones. V1-V4, dorsal, posterior, pedicle, and anterior views of a single specimen; X1.3. V5-V7, exterior, interior, and posterior views of pedicle valve of single specimen; X1.6. V8, posterior view; X.8. V9, view of four fragmentary pedicle valves; X.6.
W1-W4. Four views of a single specimen of an undescribed species of Bembexia which has affinities to the Mississippian (Osagean) Bembexia ellenae Conkin, 1957, from the New Providence Shale of Jefferson and Bullitt Counties, Kentucky. W1 and W2, two side views taken at somewhat different angles; X.8 and X.6, respectively. W3, oblique apical-side view; X.8. W4, basal view; X.8.



SELLERSBURG (SILVER CREEK)



SELLERSBURG (DEPUTY)

PLATE 17.--Pyroclastic euhedral crystals from five Devonian metabentonites: Middle Devonian Kawkawlin, Onondaga Indian Nation, Lake Chelan, and Tioga (restricted) Metabentonites and Lower Devonian Judds Fall Metabentonite (Conkin and Conkin, 1984a); all X102.

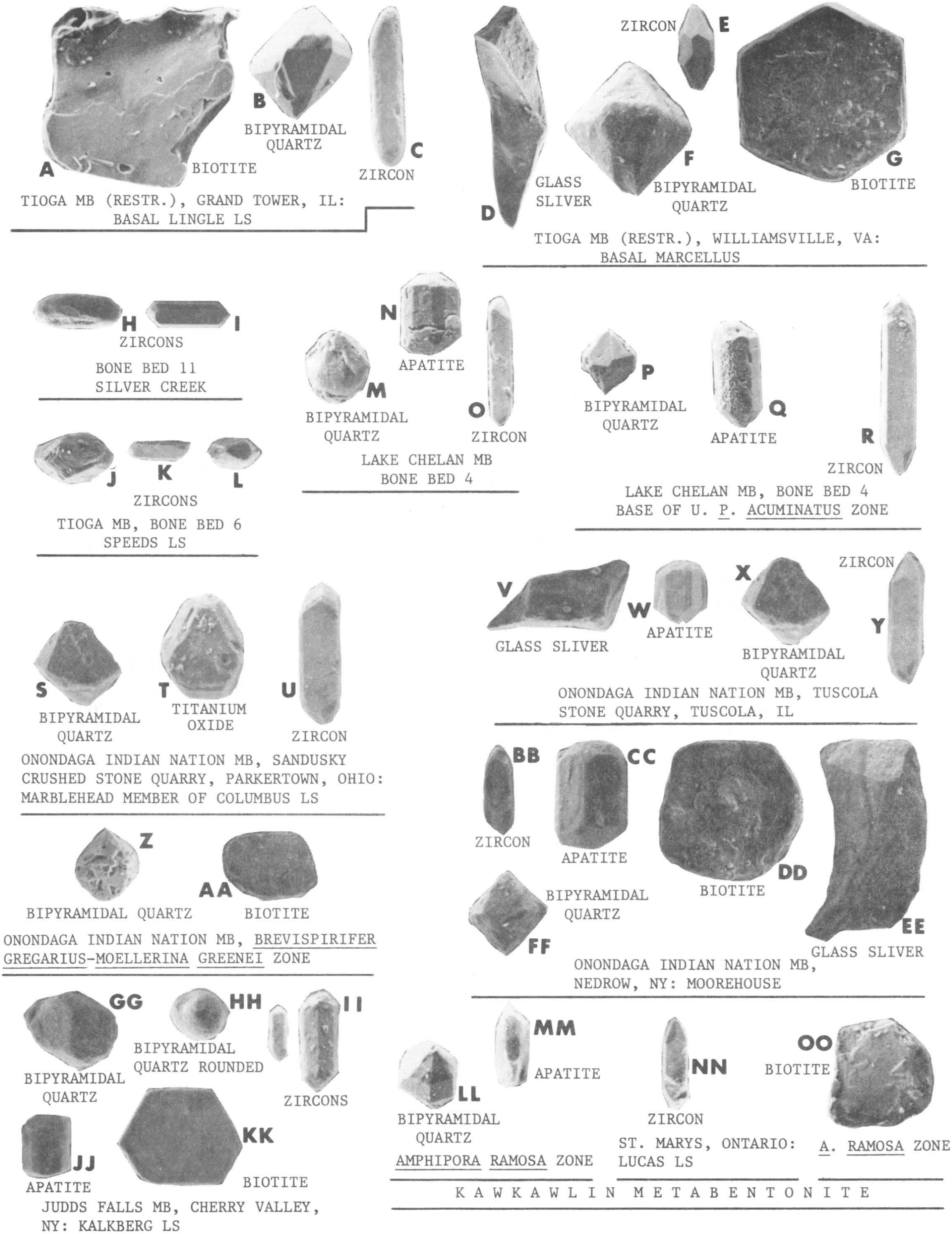
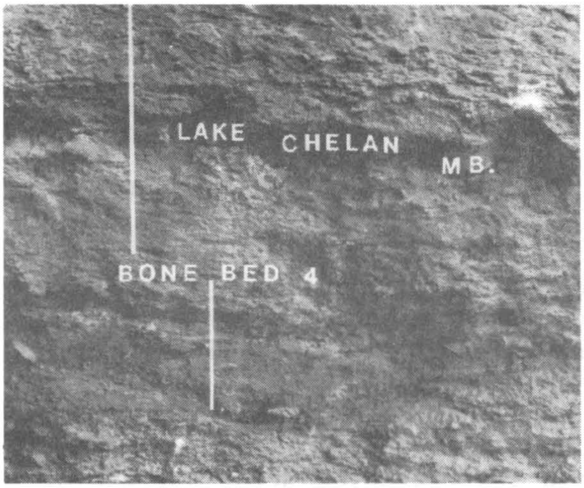
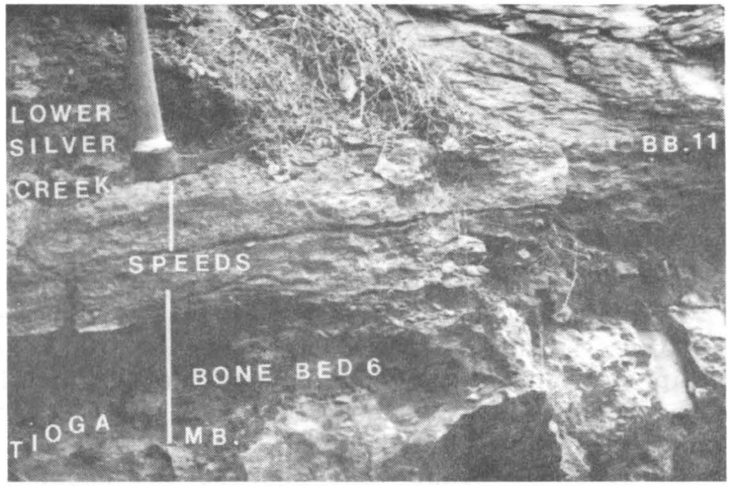

A
BIOTITE
B
BIPYRAMIDAL QUARTZ
C
ZIRCON
TIOGA MB (RESTR.), GRAND TOWER, IL: BASAL LINGLE LS
D
GLASS SLIVER
ZIRCON
E
F
BIPYRAMIDAL QUARTZ
G
BIOTITE
TIOGA MB (RESTR.), WILLIAMSVILLE, VA: BASAL MARCELLUS
H
I
ZIRCONS
BONE BED 11 SILVER CREEK
J
K
L
ZIRCONS
TIOGA MB, BONE BED 6 SPEEDS LS
M
BIPYRAMIDAL QUARTZ
N
APATITE
O
ZIRCON
LAKE CHELAN MB BONE BED 4
P
BIPYRAMIDAL QUARTZ
Q
APATITE
R
ZIRCON
LAKE CHELAN MB, BONE BED 4 BASE OF U. P. ACUMINATUS ZONE
S
BIPYRAMIDAL QUARTZ
T
TITANIUM OXIDE
U
ZIRCON
ONONDAGA INDIAN NATION MB, SANDUSKY CRUSHED STONE QUARRY, PARKERTOWN, OHIO: MARBLEHEAD MEMBER OF COLUMBUS LS
V
GLASS SLIVER
W
APATITE
X
BIPYRAMIDAL QUARTZ
ZIRCON
Y
ONONDAGA INDIAN NATION MB, TUSCOLA STONE QUARRY, TUSCOLA, IL
Z
BIPYRAMIDAL QUARTZ
AA
BIOTITE
ONONDAGA INDIAN NATION MB, BREVISPIRIFER GREGARIUS-MOELLERINA GREENEI ZONE
BB
ZIRCON
CC
APATITE
DD
BIOTITE
EE
GLASS SLIVER
FF
BIPYRAMIDAL QUARTZ
ONONDAGA INDIAN NATION MB, NEDROW, NY: MOOREHOUSE
GG
BIPYRAMIDAL QUARTZ
HH
BIPYRAMIDAL QUARTZ ROUNDED
II
ZIRCONS
JJ
APATITE
KK
BIOTITE
JUDDS FALLS MB, CHERRY VALLEY, NY: KALKBERG LS
LL
BIPYRAMIDAL QUARTZ
MM
APATITE
AMPHIPORA RAMOSA ZONE
NN
ZIRCON
ST. MARYS, ONTARIO: LUCAS LS
OO
BIOTITE
A. RAMOSA ZONE
K A W K A W L I N M E T A B E N T O N I T E

PLATE 18.--Exposures of the Devonian section in the Nugent quarry (Stop 8); figures A-C and E are close-up views of section shown in figure D

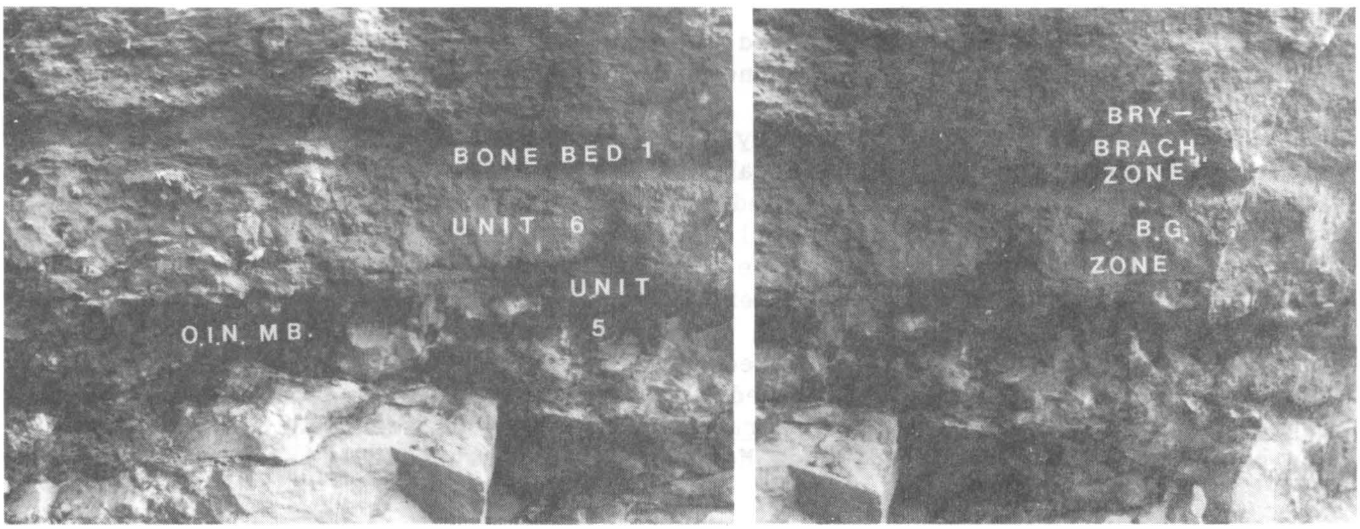
A. Bone bed 4 at the base of Upper Paraspirifer acuminatus-"Spirifer duodenarius" Zone of the Jeffersonville Limestone with Lake Chelan Metabentonite in stylolitic seam in middle of bone bed 4.
B. Top of Jeffersonville Limestone paracontinuously overlain by bone bed 6 and associated Tioga Metabentonite (restricted) at the base of the much-thinned early Cazenovian Speeds Limestone. Most of the Speeds Limestone is missing here because of the increased magnitude of paracontinuity 12, directly overlain by bone bed 11 at the base of the lower Silver Creek dolomitic hydraulic limestone.
C. Stereopair showing the position of the Onondaga Indian Nation Metabentonite (O.I.N.) in a stylolitic seam within unit 5 of the Brevispirifer gregarius-Moellerina greenei Zone (B.G.). Paracontinuity 2 is developed on unit 6 of B. gregarius-M. greenei Zone and overlain directly by bone bed 1, forming the base of the Bryozoan-Brachiopod Zone of the Jeffersonville (=base of Seneca member of the Onondaga Limestone of New York, base of Venice Member of the Columbus Limestone of Ohio, and base of upper Dundee Limestone of Michigan).
D. Wall of upper lift of quarry showing the Devonian section ranging from the Emsian Aemulophyllum exiguum-Emmonsia ramosa Zone (=Schoharie of New York) into the Silver Creek Limestone (Cazenonian Skaneateles of New York). The positions of three important metabentonites are shown.
E. Paracontinuity 1 developed on top of the upper Amphipora ramosa (A.R.) Zone and immediately overlain by the Brevispirifer gregarius-Moellerina greenei (B.G.Z.) Zone. The position of the Kawkawlin Metabentonite is localized along a stylolitic seam in the uppermost A. ramosa Zone.


LAKE CHELAN
MB.
BONE BED 4

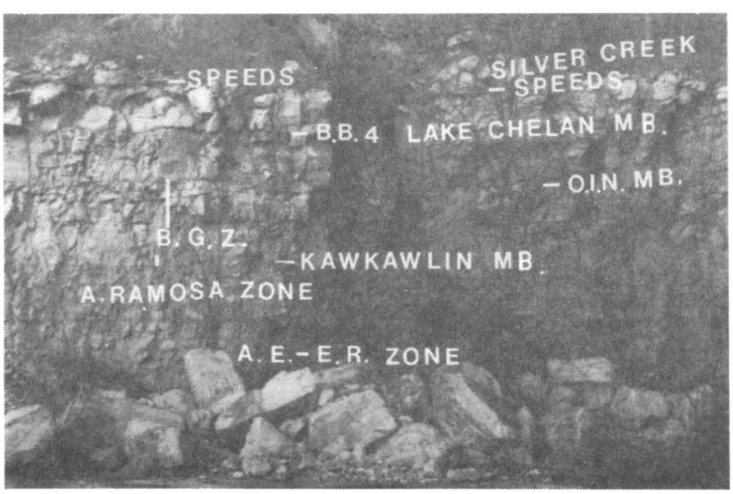
A


LOWER
SILVER
CREEK
BB.11
SPEEDS
BONE BED 6
TIOGA
MB.

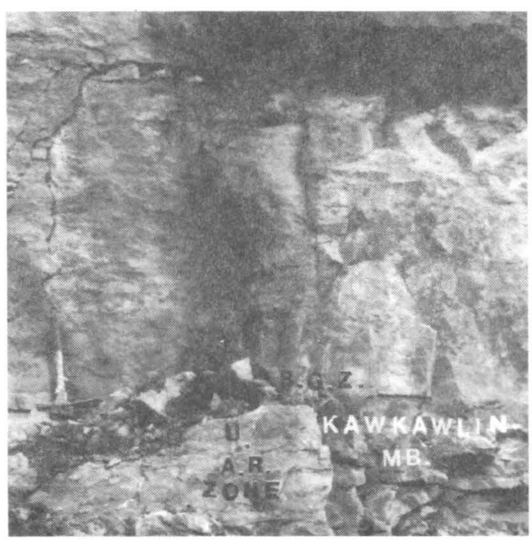
B


BONE BED 1
UNIT 6
UNIT
5
O.I.N. MB.
BRY.-
BRACH.
ZONE
B.G.
ZONE

C


-SPEEDS
SILVER CREEK
- SPEEDS
-B.B.4
LAKE CHELAN MB.
-O.I.N. MB.
B.G.Z.
-KAWKAWLIN MB.
A.RAMOSA ZONE
A.E.-E.R. ZONE

D


B.G.Z.
KAWKAWLIN-
MB.
U.
A.R.
ZONE

E

PLATE 19.--Exposures of the Middle Devonian in the upper level of the Nugent quarry (Stop 8), near Utica, Indiana

A. Paracontinuous contact of Upper *Paraspirifer acuminatus* Zone (U.P.Acum.) with overlying bone bed 6 (B.B.6) in base of Speeds Limestone and associated Tioga Metabentonite (restricted). The darkened, phosphatized, and channeled upper surface of the upper Jeffersonville marks the physical surface of paracontinuity 7, which is filled in with bone bed 6 and associated Tioga Metabentonite (restricted).

B. Close-up plane view showing the phosphatized and channeled upper surface of the Jeffersonville paracontinuously overlain by the Tioga Metabentonite and associated bone bed 6, filling bioturbated channels in the Upper *P. acuminatus*-"*S. duodenarius*" Zone. A specimen of an undescribed species of *Parapodolithus* is marked by point of knife.

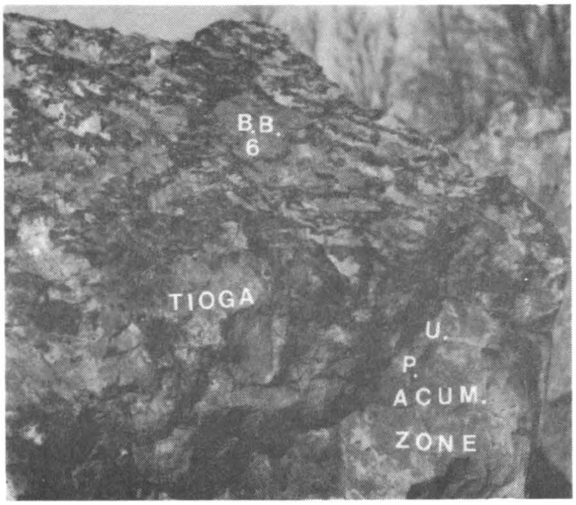
C. Close-up side view of channeled and irregularly worm-burrowed surface of paracontinuity 7 filled in with bone bed 6 and associated Tioga Metabentonite (restricted).

D. Side view showing paracontinuity 7, with channeled surface filled in with bone bed 6 and associated Tioga Metabentonite (restricted).

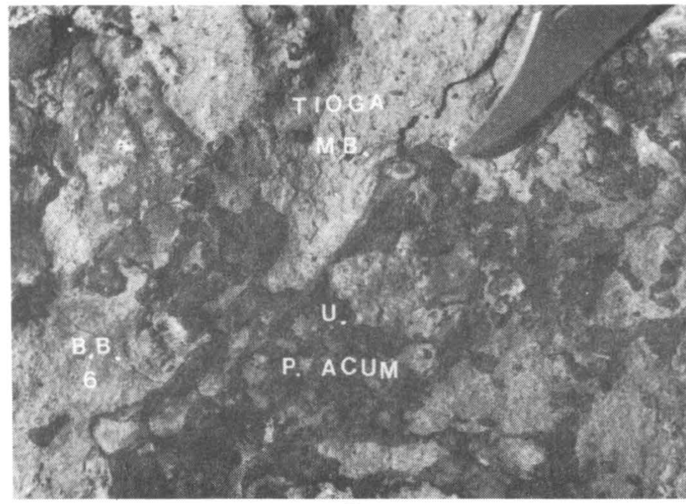
E. Plane view showing the channeled surface of paracontinuity 7 developed on top of the underlying Jeffersonville and overlain by bone bed 6 and Tioga Metabentonite (restricted). The phosphatized physical surface of paracontinuity 7 has several specimens of *Parapodolithus* attached to it.

F. Plane views of the phosphatized, channeled surface of paracontinuity 7 with a specimen of *Parapodolithus* attached.

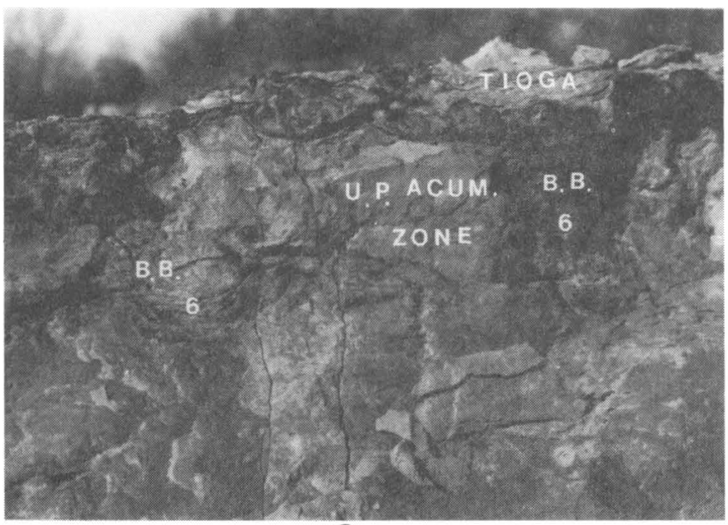
G. Close-up view of the phosphatized physical surface of paracontinuity 7 onto which is attached a specimen of *Parapodolithus*; the paracontinuity is overlain by bone bed 6 and associated Tioga Metabentonite (restricted).


B.B.
6
TIOGA
U.
P.
ACUM.
ZONE

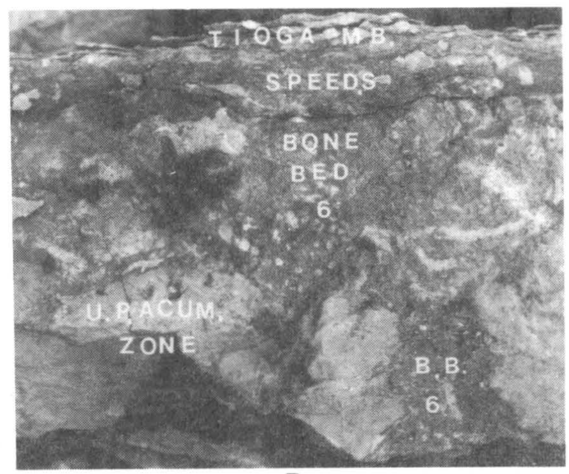
A


TIOGA
MB.
B.B.
6
U.
P. ACUM

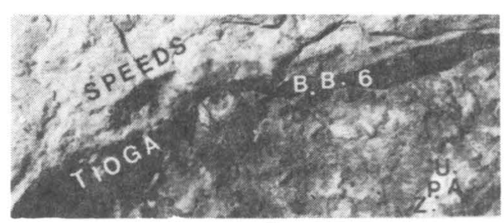
B


TIOGA
U.P. ACUM.
ZONE
B.B.
6
B.B.
6

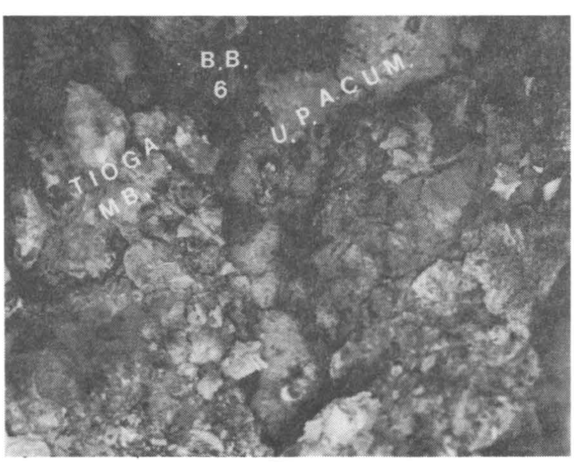
C


TIOGA MB.
SPEEDS
BONE
BED
6
U.P. ACUM.
ZONE
B.B.
6

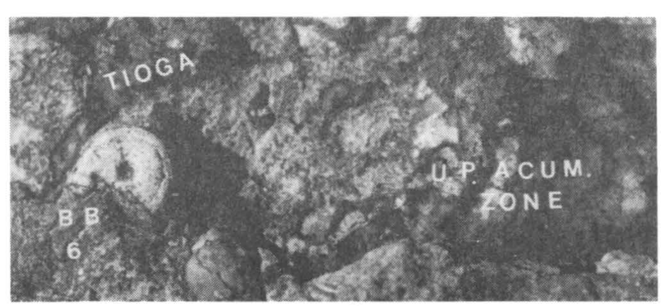
D


SPEEDS
B.B. 6
TIOGA
U.
P.A.
Z.

F


B.B.
6
U.P. ACUM.
TIOGA
MB.

E


TIOGA
B.B.
6
U.P. ACUM.
ZONE

G