Lithostratigraphy and Depositional Environments of the Lexington Limestone (Ordovician) of Central Kentucky

By EARLE R. CRESSMAN

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Prepared in cooperation with the Kentucky Geological Survey

A description of a Middle and Upper Ordovician limestone formation and its constituent members with a discussion of facies relations, environments of deposition, and paleogeography

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LITHOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF THE LEXINGTON LIMESTONE (ORDOVICIAN) OF CENTRAL KENTUCKY

By Earle R. Cressman

ABSTRACT

The fossiliferous and bioclastic Lexington Limestone underlies the inner Blue Grass region of central Kentucky. The formation is mostly of late Middle Ordovician age, but the upper part is equivalent to the basal beds of the type Cincinnatian Series (Late Ordovician) of southwestern Ohio. The Lexington rests disconformably on the Tyrone Limestone of Wilderness Age and is overlain conformably by interbedded limestone and shale of the Clays Ferry Formation. In the east-central part of the outcrop area, the Lexington is more than 320 feet thick, but it thins to the north, west, and southwest by the intertonguing of the upper part with the Clays Ferry Formation. The Lexington Limestone is abundantly fossiliferous, and both the calcarenites and calcisiltites are composed largely of fossil fragments. Bryozoans, crinoid debris, brachiopods, mollusks, and stromatoporoids are all common.

The Lexington is unusually phosphatic. Calcarenites average 2.4 percent P_2O_5. The phosphate, present as cryptocrystalline carbonate-fluorapatite, occurs as fillings and replacements of small fossils.

The Lexington Limestone has been divided into 11 members. These are the Curdsville Limestone Member (mostly calcarenite), the Logana Member (calcisiltite and shale), the Grier Limestone Member (fossiliferous limestone), the Perryville Limestone Member (calcilutite), the Brannon Member (calcisiltite and shale), the Sulphur Well Member (bryozoan limestone), the Tanglewood Limestone Member (calcarenite), the Devils Hollow Member (gastropodal calcirudite and calcilutite), and the Greendale Lentil, the Stamping Ground Member, and the Millersburg Member (nodular fossiliferous limestone and shale). The members are complexly intertongued.

The fossiliferous limestone and nodular fossiliferous limestone and shale units formed in marine water of the infralittoral zone where conditions were most favorable for growth of the fauna. Calcareous skeletal material that formed in the infralittoral zone was broken and sorted and deposited in shallow water by tidal currents to produce crossbedded calcarenite; calcareous fines were transported from shallow water and deposited in deeper water of the circalittoral zone along with terrigenous silt and clay from a distant source to produce interbedded calcisiltite and shale. Shallow subtidal and intertidal calcilutite was deposited as pelleted lime mud in lagoons behind calcarenite bars. Terrigenous clay and silt derived from distant tectonic lands in and bordering the Appalachian geosyncline were deposited below wave base and in shallower water where they were trapped by the baffling effect of the epifauna and flora. Transgression and regression of the rock types resulted from varying rates of subsidence.

During the time of deposition of the lower half of the Lexington Limestone, the sea floor sloped northward; calcarenite, formed above surf base in the south, grades successively northward to fossiliferous limestone, nodular fossiliferous limestone and shale, and interbedded limestone and shale. During deposition of the upper part of the Lexington, the southern part of the area subsided; calcarenite, deposited on a northwest-trending topographic high, grades southward into interbedded calcisiltite and shale and successively northward to nodular fossiliferous limestone and shale, interbedded calcisiltite and shale, and shale.

Facies and thickness trends are unrelated to the present Cincinnati arch or Jessamine dome. Subsidence of the southern part of the area in the later part of Lexington time may have resulted from movements along the Kentucky River and Irvine-Paint Creek fault zones.

Most of the Eastern and Central United States was the site of shallow-water carbonate deposition during the late Middle Ordovician, but a deeper water channel that received deposits of terrigenous mud and carbonate fines extended from western Tennessee through western Kentucky into central Ohio. Inasmuch as a fairly direct connection between central Kentucky and water of the open ocean was probably required to supply phosphate to the area of limestone deposition, the channel of western Kentucky may have connected with open oceanic waters to the south.

INTRODUCTION

Most of the inner Blue Grass region of central Kentucky is underlain by fossiliferous and bioclastic limestones, largely of Middle Ordovician age, which make up the Lexington Limestone. These rocks have been studied for many years, but because of limited exposures, perplexing facies changes, the abundance of fossils, and the predilections of the investigators, most earlier work had a strong paleontologic emphasis, and only the broad outlines of the lithostratigraphy were determined. Recent geologic mapping at a scale of 1:24,000 conducted by the U.S. Geological Survey in cooperation with the Kentucky Geological Survey has revealed much new information about the lithology of the Lexington

Limestone, the extent and interrelations of its subdivisions, and relations of these rocks to those of adjacent areas. Preliminary results of these investigations have been published by Black, Cressman, and MacQuown (1965), Black and MacQuown (1965), and Cressman and Karklins (1970). This report is a comprehensive summary of the new information obtained during the mapping program and examines the resulting implications as to paleoenvironments and paleogeography. The area of the report (fig. 1) includes most of the outcropping Middle Ordovician rocks of Kentucky.

This report is based primarily on information gained in the mapping of twenty-three 7½-minute quadrangles. The mapping was supplemented by measured sections and by diamond-drill cores (on file at the core library of the Kentucky Geological Survey). The locations of the quadrangles, the measured sections, and the diamond-drill holes are shown in figure 2; the measured sections are listed in table 1. Correlations within mapped areas are based largely on tracing of contacts in the field. Elsewhere they are based on interpolation between measured sections.

Fossils were collected by R. J. Ross, Jr., John Pojeta, Jr., R. B. Neuman, O. L. Karklins, and E. L. Yochelson. Trilobites were identified by Ross, pelecypods by Pojeta, brachiopods by Neuman, bryozoans by Karklins, monoplacophorans and gastropods by Yochelson, corals by W. A. Oliver, Jr., and ostracodes by J. M. Berdan. These paleontologists posted the fossil identifications on the stratigraphic sections and prepared the faunal lists presented herein.

Megascopic descriptions of the rocks were supplemented by the examination of thin sections. No systematic attempt was made to study the microscopic petrography, but thin sections from most of the common rock types are described.

Twenty-five samples from the upper part of the Lexington Limestone and included tongues of the Clays Ferry Formation were analyzed in U.S. Geological Survey laboratories (table 2). The samples, taken from 14 of the shallow bore holes drilled near Lexington, consisted of 6-inch lengths of core, five each from the Millersburg, Tanglewood, Brannon, and Grier Members of the Lexington and five from tongues of the Clays Ferry Formation. The five samples from each unit were selected at random from the total length of the unit exposed in all 14 cores. Only the upper part of the Grier Limestone Member was present in the cores sampled, but the samples should give an unbiased estimate of the composition of the other units in the Lexington area. The mineralogic compositions of the samples as calculated from the analyses, are shown in figure 3.

Terms used in megascopic descriptions of limestones are:

Bioclastic—Consists of fragmental skeletal remains of organisms.

Calcirudite—Mechanically deposited limestone in which the constituent grains are mostly larger than 2 mm (millimeters).

Calcarenite—Mechanically deposited limestone in which the constituent grains are mostly of sand size (1/16 to 2 mm). Modifying grade terms (very fine, fine, etc.) are those of the Wentworth (1922) scale. Nearly all calcarenites of the Lexington Limestone are bioclastic.

Calcisiltite—Limestone in which the constituent grains are mostly of silt size.

Calcilutite—Limestone in which the constituent grains are mostly of clay size. In practice, calcisiltite and calcilutite were differentiated on the basis of whether granularity was observed using a hand lens.

Fossiliferous—Contains abundant whole fossils and large fossil fragments; does not apply to rocks containing comminuted fossils.

Coquina—Limestone in which the framework consists of packed, mechanically sorted, whole fossils or large fossil fragments.

Color terms are those of the Munsell color system (Goddard, 1948).

The terminology used in the description of thin sections is that of Folk (1962).

Infralittoral and **circalittoral** refer respectively to shelf environments shallower and deeper than the maximum depth of effective photosynthesis.

The basic lithologic and faunal data and correlations are shown along six lines of section (pls. 1–6). The vertical scale of the lithologic columns is 1 inch equals 20 feet; the horizontal spacing is not to scale. The locations of the lines of section are shown in figure 2. Conodonts were identified by Walter C. Sweet but are not shown on the illustrations because of lack of space; information on the conodonts and an analysis of the conodont biostratigraphy has been published by Bergström and Sweet (1966). To emphasize lithologic relations, the same lines of section are plotted on plate 7 at 1 inch equals 100 feet and with the horizontal dimension to scale.

Unless stated otherwise, all isopach and facies maps are of the same area shown in figure 2.

In addition to the author, the following members of the U.S. Geological Survey participated in the mapping and the measuring of sections that led to this report: D. F. B. Black, Ernest Dobrovolny, R. C. Green, S. P. Kanizay, R. D. Miller, J. S.

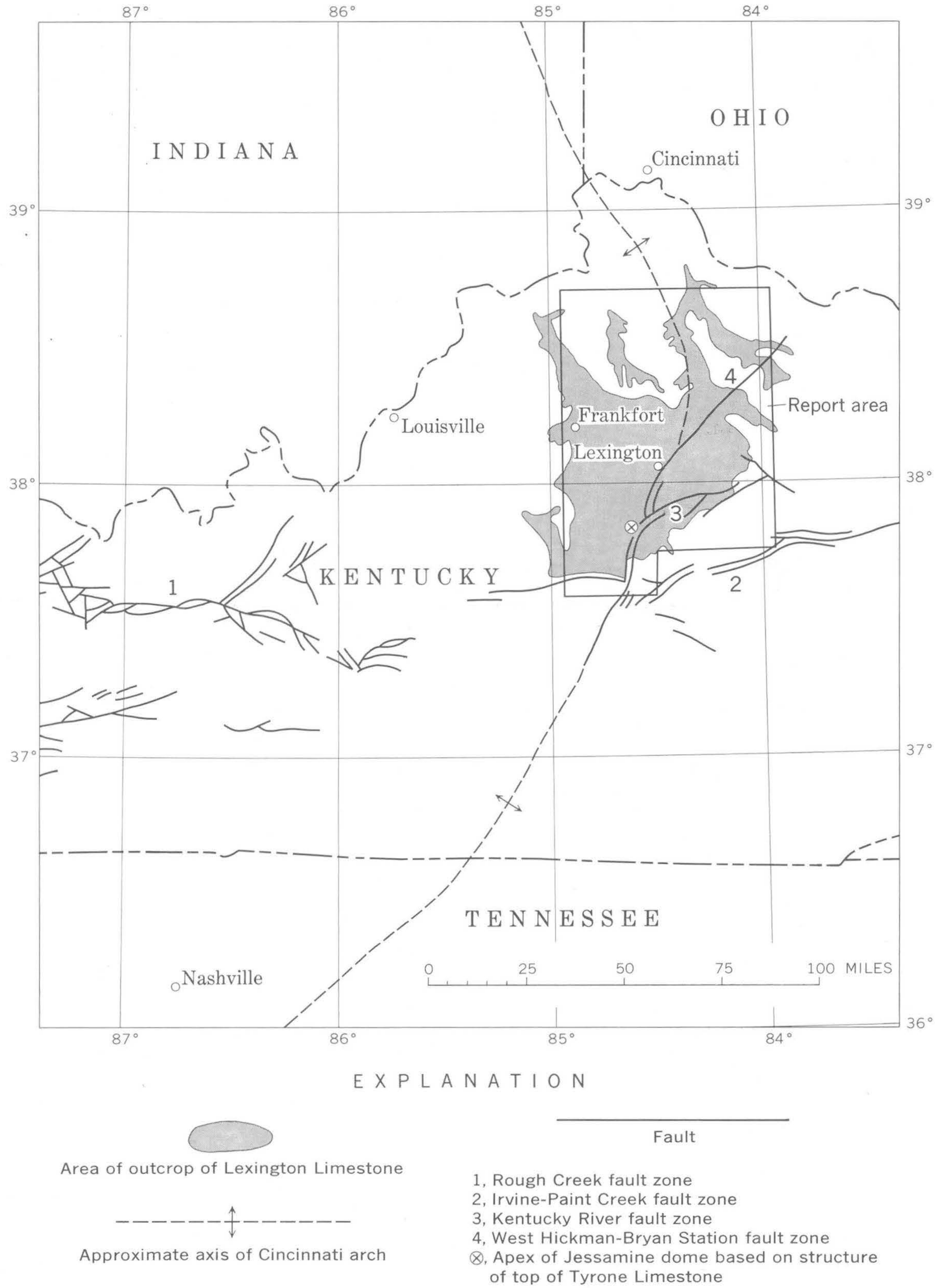


FIGURE 1.—Index map showing location of area studied, the surface extent of the Lexington Limestone, and major structural features. Faults are from the U.S. Geological Survey and American Association of Petroleum Geologists (1961); the area of outcrop of the Lexington Limestone is modified slightly from U.S. Geological Survey (1932).

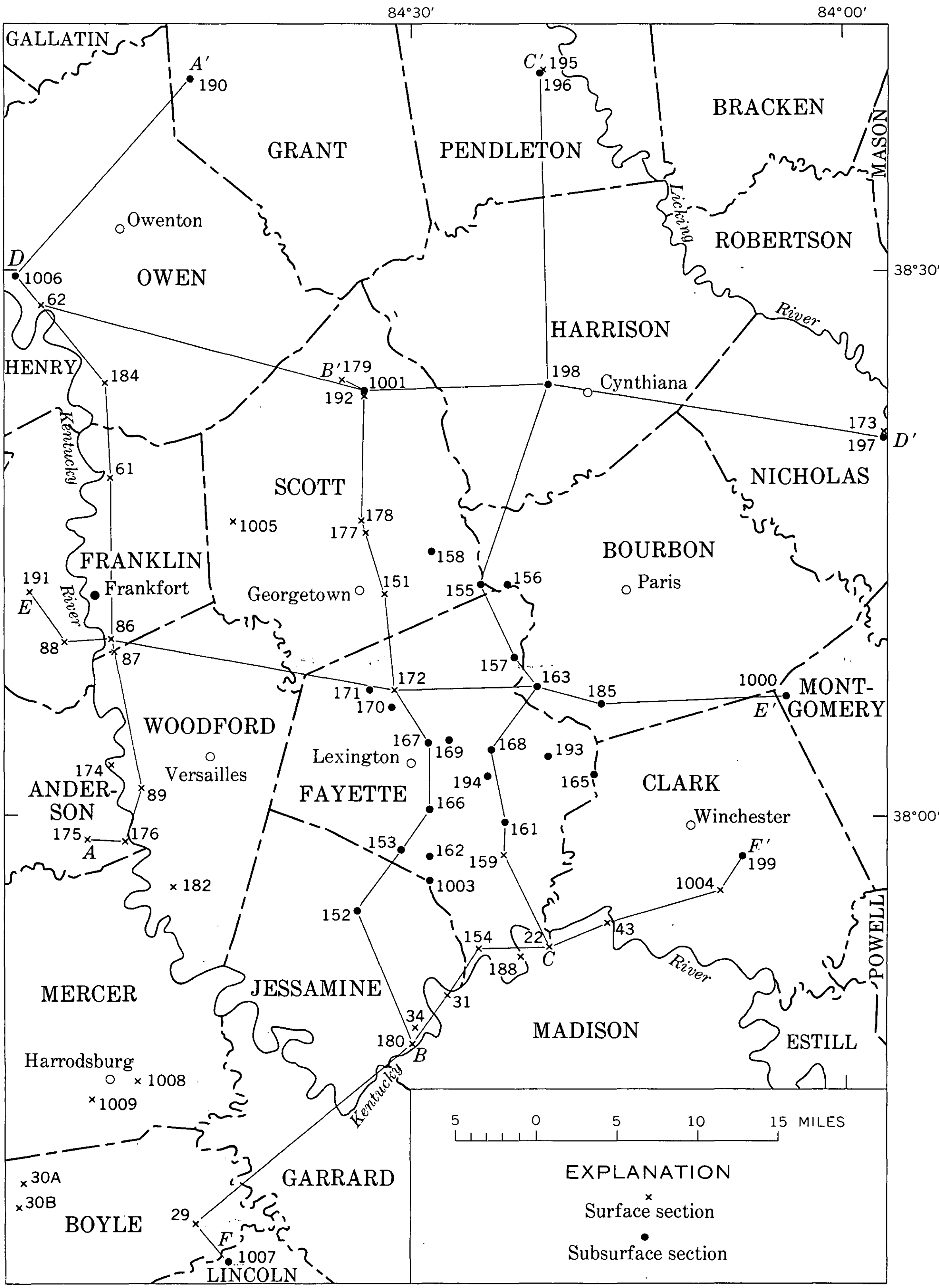


FIGURE 2 (above and right).—Index maps of central Kentucky. *Above:* counties, location of measured sections, and lines of section. *Right:* 7½-minute quadrangles and location of measured sections. Measured-section data are listed in table 1.

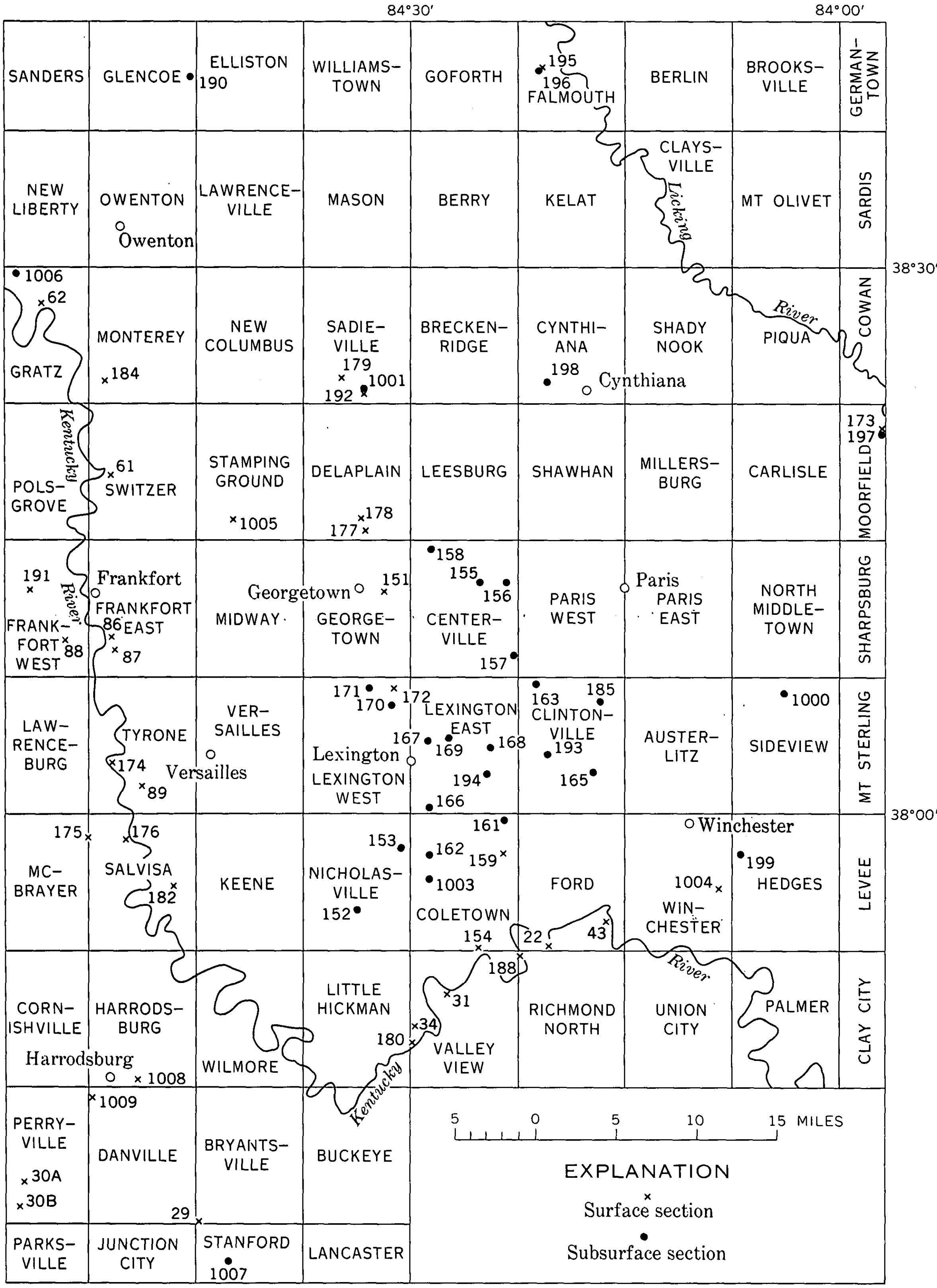


FIGURE 2.—Continued.

TABLE 1.—*Measured sections of the Lexington Limestone and related formations of central Kentucky*

[Section designation: 7½-minute quadrangle followed by a letter for surface sections or a number for subsurface section; name or location shown in parentheses. All coordinates are in north zone of Kentucky 10,000-foot grid system except sections 29, 30A, 30B, 1007, and 1009, which are in south zone. Location of sections shown in fig. 2]

Section No.	Section Designation	County	Coordinates at base of measured section	Unit exposed	Measurement of section	Remarks
22	Ford A	Madison	E. 1,974,900; N. 140,500	Middle and upper Lexington Limestone and Clays Ferry Formation.	G. W. Weir and R. C. Greene.	Type section of Clays Ferry Formation (Weir and Greene, (1965).
29	Bryantsville A	Boyle	E. 2,290,500; N. 472,500	Middle and upper Lexington Limestone and basal Clays Ferry Formation.	G. W. Weir and R. C. Greene; modified by E. R. Cressman.	Caldwell Stone quarry.
30A	Perryville A (Perryville North).	do	E. 2,234,100; N. 485,100	Middle Lexington Limestone.	E. R. Cressman	Quarry operated by Boyle County Fiscal Court.
30B	Perryville B (Perryville South).	do	E. 2,222,200; N. 478,500	Upper Lexington Limestone.	G. W. Weir and R. C. Greene.	Abandoned quarry.
31	Valley View A (Cuzick).	Madison	E. 1,940,700; N. 123,500	Lexington Limestone	R. C. Greene and P. L. Cassity.	Stream exposure.
34	Valley View B (Hunters Ferry Road).	Jessamine	E. 1,931,200; N. 112,400	Middle and upper Lexington Limestone.	R. C. Greene and P. L. Cassity; modified by D. E. Wolcott.	Roadcuts.
43	Ford B (Boonesboro Beach).	Madison	E. 1,994,000; N. 145,500	do	G. W. Weir, G. C. Simmons, and R. C. Greene; modified by D. F. B. Black.	Do.
61	Switzer A	Franklin	E. 1,829,650; N. 295,800	do	E. R. Cressman and D. F. B. Black.	Do.
62	Gratz A	Owen	E. 1,807,100; N. 352,200	Middle and upper Lexington Limestone; Clays Ferry and Kope Formations.	do	Do.
86	Frankfort East A	Franklin	E. 1,827,150; N. 241,350	Lexington Limestone	do	Reference section of Lexington Limestone (Black and others, 1965, p. 11).
87	Frankfort East B	Woodford	E. 1,831,250; N. 236,950	Lower Lexington Limestone.	do	Gully exposure.
88	Frankfort West A	Franklin	E. 1,816,150; N. 240,230	Middle and upper Lexington Limestone.	do	Type section of Tanglewood Limestone Member of Lexington Limestone (Black and others, 1965, p. 22).
89	Tyrone A	Woodford	E. 1,838,500; N. 189,650	Lower and middle Lexington Limestone.	E. R. Cressman	Type section of Grier Limestone Member of Lexington Limestone (Black and others, 1965, p. 18).
151	Georgetown A	Scott	E. 1,921,100; N. 253,500	Middle Lexington Limestone.	E. R. Cressman, S. P. Kanizay, and Ernest Dobrovolny.	Roadcuts.
152	Nicholasville 1 (Denny Heirs).	Jessamine	E, 1,910,750; N. 151,300	Lower and middle Lexington Limestone.	W. C. MacQuown, Jr.	
153	Nicholasville 2 (Emmett Coons 1).	Fayette	E. 1,925,480; N. 171,700	Middle and upper Lexington Limestone and Clays Ferry Formation.	do	
154	Coletown A (Spears Road).	do	E. 1,950,000; N. 137,700	Lexington Limestone	D. F. B. Black and Ernest Dobrovolny.	Creek exposure.
155	Centerville 1	Scott	E. 1,951,420; N. 260,140	Middle Lexington Limestone.	S. P. Kanizay	
156	Centerville 2	Bourbon	E. 1,960,100; N. 259,750	do	do	
157	Centerville 3	Fayette	E, 1,963,400; N. 234,250	do	do	
158	Centervile 4	Scott	E. 1,934,600; N. 270,950	Middle and upper Lexington Limestone.	do	
159	Coletown B (Athens-Boonesboro Road).	Fayette	E. 1,958,650; N. 169,100	Upper Lexington Limestone.	D. F. B. Black and E. R. Cressman.	Reference section Millersburg Member of Lexington Limestone (Black and others, 1965, p. 25).
161	Coletown 1	do	E. 1,959,950; N. 181,020	Middle and upper Lexington Limestone.	D. F. B. Black	
162	Coletown 2	do	E. 1,936,000; N. 169,150	do	do	
163	Clintonville 1 (Beatty 1).	Bourbon	E. 1,969,750; N. 224,900	do	W. C. MacQuown, Jr.	
165	Clintonville 3 (Graves Farm).	Fayette	E. 1,989,200; N. 184,300	do	do	
166	Lexington East 1	do	E. 1,934,000; N. 184,650	Middle and upper Lexington Limestone and Clays Ferry Limestone.	Ernest Dobrovolny	
167	Lexington East 2	do	E. 1,934,100; N. 206,250	Middle Lexington Limestone.	do	
168	Lexington East 3	do	E. 1,954,400; N. 204,600	Middle and upper Lexington Limestone.	do	
169	Lexington East 5	do	E. 1,942,750; N. 208,300	Middle Lexington Limestone.	do	
170	Lexington West 1	do	E. 1,922,600; N. 217,950	do	R. D. Miller	
171	Lexington West 2	do	E. 1,915,300; N. 225,500	do	do	

TABLE 1.—*Measured sections of the Lexington Limestone and related formations of central Kentucky*—Continued

Section No.	Section Designation	County	Coordinates at base of measured section	Unit exposed	Measurement of section	Remarks
172	Lexington West A	Fayette	E. 1,922,500; N. 224,600	Middle Lexington Limestone.	R. D. Miller and E. R. Cressman.	Bluegrass quarry.
173	Moorefield A	Nicholas	E. 2,087,050; N. 312,650. Top of section at E. 2,085,550; N. 313,950.	Upper Lexington Limestone.	D. F. B. Black and J. S. Pomeroy.	Reference section at Nicholas Bed of Tanglewood Limestone Member of Lexington Limestone (Black and others, 1965, p. 27).
174	Tyrone C	Woodford	E. 1,828,840; N. 198,350	Logana Member of Lexington Limestone.	E. R. Cressman	Reference section of Logana Member of Lexington Limestone (Black and others, 1965, p. 15–17).
175	Salvisa A	Anderson	E. 1,821,500; N. 174,550	Upper Lexington Limestone.	E. R. Cressman and D. F. B. Black.	Roadcuts.
176	Salvisa B	do	E. 1,835,050; N. 173,600	Lower and middle Lexington Limestone.	do	Do.
177	Delaplain A	Scott	E. 1,913,500; N. 276,600	Part of upper Lexington Limestone.	E. R. Cressman	Do.
178	Delaplain B	do	E. 1,912,200; N. 280,900	do	do	Do.
179	Sadieville A	do	E. 1,906,400; N. 328,200	Upper Lexington Limestone and lower Clays Ferry Formation.	do	Do.
180	Valley View C (Antioch Church Road).	Jessamine	E. 1,929,350; N. 105,200	Middle and upper Lexington Limestone and Clays Ferry Formation.	D. E. Wolcott, E. R. Cressman, and D. F. B. Black.	Do.
182	Salvisa C	Woodford	E. 1,850,500; N. 158,800	Curdsville Limestone Member of Lexington Limestone.	E. R. Cressman	Do.
184	Monterey A	Owen	E. 1,828,000; N. 326,750	Upper Lexington Limestone.	do	Do.
185	Clintonville 2	Bourbon	E. 1,992,100; N. 219,850	Middle Lexington Limestone.	W. C. MacQuown, Jr.	
188	Richmond North A.	Fayette	E. 1,965,200; N. 134,850	Lexington Limestone	R. C. Greene and P. L. Cassity.	Creek exposure.
190	Glencoe 1 (Cincinnati Gas and Electric test well 3).	Grant	E. 1,856,600; N. 428,000	do	E. R. Cressman and D. F. B. Black.	
191	Frankfort West B	Franklin	E. 1,802,400; N. 258,050	Middle Lexington Limestone.	E. R. Cressman	Roadcuts.
192	Sadieville C	Scott	E. 1,915,500; N. 323,650	Upper Lexington Limestone and lower Clays Ferry Formation.	do	Do.
193	Clintonville 4 (Ferguson-Bosworth Asbury 1).	Fayette	E. 1,974,650; N. 202,200	Lower and middle Lexington Limestone.	W. C. MacQuown, Jr.	
194	Lexington East 6 (Lexington-Winchester Road).	do	E. 1,953,400; N. 196,600	do	do	Ferguson-Bosworth core hole.
195	Falmouth A	Pendleton	E. 1,971,850; N. 430,350	Point Pleasant Formation and basal Kope Formation.	E. R. Cressman and D. F. B. Black.	Roadcuts.
196	Falmouth 1 (Carl Stampp 1).	do	E. 1,970,550; N. 429,100	Lexington Limestone and lower Point Pleasant Formation.	do	
197	Moorefield 1 (A. Cox 1).	Nicholas	E. 2,087,400; N. 312,750	Lower and middle Lexington Limestone.	do	
198	Cynthiana 1 (Turner Farm).	Harrison	E. 1,974,000; N. 326,700	Lexington Limestone.	D. F. B. Black	
199	Hedges 1 (Troy Sams 1).	Clark	E. 2,037,450; N. 165,700	do	E. R. Cressman	
1000	Sideview 1	Montgomery	E. 2,051,400; N. 222,550	do	E. R. Cressman and D. F. B. Black.	
1001	Sadieville 1	Scott	E. 1,915,800; N. 324,700	Lower and middle Lexington Limestone.	do	
1003	Coletown 3 (Ferguson-Bosworth Teater 1).	Fayette	E. 1,935,300; N. 159,900	do	W. C. MacQuown, Jr.	
1004	Winchester A (Dry Fork Road).	Clark	E. 2,031,000; N. 158,200	Upper Lexington Limestone.	D. F. B. Black	Roadcuts.
1005	Samping Ground A	Scott	E. 1,868,950; N. 281,700	Stamping Ground Member of Lexington Limestone.	E. R. Cressman	Abandoned quarry; type section of Stamping Ground Member.
1006	Gratz 1 (City Service BT–7).	Owen		Lexington Limestone	do	
1007	Stanford 1 (Humble CH–5).	Lincoln	E. 2,300,300; N. 457,000	do	do	
1008	Harrodsburg A	Mercer	E. 1,837,300; N. 94,300	Middle Lexington Limestone.	do	Mercer Stone quarry.
1009	Danville A	do	E. 2,256,850; N. 513,150	Salvisa Bed of Perryville Limestone Member of Lexington Limestone.	do	Abandoned quarry.

TABLE 2.—*Chemical analyses of samples of the*

[Chemical analysis in percent. Analysts: Paul Elmore, S. D. Botts, Lowell spectrographic analyses in parts per million. <, less than number shown Analyst: W. B. Crandell, U.S. Geological Survey]

	Lexington Limestone									
	Grier Limestone Member					Brannon Member				
Field no	LC–2	LC–18	LC–21	LC–25	LC–10	LC–1	LC–9	LC–19	LC–4	LC–23
Chemical analysis										
SiO_2	4.2	3.3	15.6	1.5	2.0	28.1	24.7	28.6	27.4	26.9
Al_2O_3	.46	1.1	4.5	.76	.46	4.8	5.4	4.2	3.8	7.5
Fe_2O_3	.37	.37	1.0	.17	.26	1.2	1.2	.76	.83	1.1
FeO	.10	.10	.60	.14	.20	.58	.88	.76	.70	1.2
MgO	1.1	1.1	2.9	.02	3.6	2.8	3.7	3.4	5.4	7.8
CaO	50.7	50.3	38.9	53.6	49.2	31.3	31.7	31.2	29.4	24.3
Na_2O	.13	.16	.16	.13	.14	.23	.24	.08	.27	.30
K_2O	.21	.30	1.4	.22	.22	1.5	1.8	1.4	1.2	2.1
H_2O-	.07	.17	.42	.13	.12	.39	.37	.34	.37	.55
H_2O+	.65	.55	1.2	.54	.53	1.6	1.4	1.4	1.6	1.8
TiO_2	02	.22	.05	.03	.50	.24	.03	.38	.18	.04
P_2O_5	1.2	.44	1.5	.46	.28	.97	.76	.58	.92	.66
MnO	.06	.02	.04	.02	.02	.04	.07	.05	.00	.05
CO_2	40.5	41.4	31.4	42.4	42.4	25.5	27.4	26.6	27.5	25.5
S	.25	.25	.6	.15	.15	.5	.6	.2	.4	.5
Sum	100	100	100	100	100	100	100	100	100	100
Six-step semiquantitative spectrographic analyses										
B	0	0	30	0	0	30	30	<30	<30	30
Ba	10	20	150	15	10	150	200	150	150	200
Ce	0	0	100	0	0	150	100	0	100	0
Co	0	0	3	0	0	3	3	3	3	3
Cr	3	3	20	3	3	30	20	20	20	30
Cu	.5	.5	5	.3	.5	7	5	5	5	7
Ga	0	0	5	0	0	5	5	5	3	7
La	0	0	30	0	0	50	30	0	30	0
Ni	0	0	<30	0	0	<30	<30	<30	<30	<30
Pb	3	0	5	0	0	7	5	3	5	5
Sc	0	0	5	0	0	5	5	3	3	5
Sr	500	700	700	500	500	700	700	700	500	500
V	7	10	20	10	10	20	20	20	15	30
Y	3	5	10	0	0	15	15	10	10	10
Yb	0	0	1	0	0	1.5	1.5	1	1	1
Zr	0	10	50	0	0	30	50	30	20	30

Pomeroy, G. W. Weir, and D. E. Wolcott. W. C. MacQuown, Jr., of the University of Kentucky also participated in the mapping, and both MacQuown and Black have made major contributions to interpreting the stratigraphy. M. O. Smith, M. C. Noger, and the late James Poteet of the Kentucky Geological Survey were of much help in supervising the drilling program.

Dr. A. C. McFarlan, for many years chairman of the Department of Geology of the University of Kentucky, introduced me to the Middle Ordovician rocks of Kentucky. His wide knowledge of the geology of the state was of much assistance, and his own studies of the Ordovician made my task much easier than it would have been otherwise.

Unpublished biostratigraphic correlations based on the conodont fauna by Walter C. Sweet (written commun., 1965) were of great assistance in several areas where exposures were incomplete and the lithologic correlations were ambiguous.

GEOLOGIC SETTING

Rocks of late Middle Ordovician age are brought to the surface by two domes along the Cincinnati arch—the Nashville dome of central Tennessee and the Jessamine dome of central Kentucky. The rocks of the Nashville dome were described by Wilson (1949); those of the Jessamine dome are the subject of this report.

The Jessamine dome is broad, irregular, and gentle; the strata dip generally 20 to 30 feet per mile westward and somewhat less northward. The dome is cut by two major normal-fault systems—the Kentucky River fault zone and the West Hickman-Bryan Station fault zone—that intersect in the Little Hickman quadrangle near the apex of the dome (fig. 1). The Kentucky River and the nearby Irvine-Paint Creek fault zones extend to basement (Bayley and Muehlberger, 1968). These basement faults are ancient features and apparently were active in Cambrian time (McGuire and Howell, 1963; Webb, 1969).

McFarlan (1943, p. 132) recognized two main periods in the development of the Jessamine dome, one in the pre-mid-Devonian and one in the Permian. In addition, McGuire and Howell, (1963, p. 2–4 and 2–23) suggested on the basis of an isopach map of the rocks from the top of the Knox Group

Lexington Limestone and the Clays Ferry Formation

Artis, and G. W. Chloc, U. S. Geological Survey. Six-step semiquantitative (usual detectability limits do not apply here); O, looked for but not detected.

Lexington Limestone—Continued										Clays Ferry Formation				
Tanglewood Limestone Member					Millersburg Member									
LC–3	LC–8	LC–6	LC–12	LC–22	LC–17	LC–15	LC–14	LC–20	LC–5	LC–7	LC–16	LC–24	LC–11	LC–13
Chemical analysis—Continued														
2.2	0.94	1.3	7.4	4.6	23.5	33.1	10.8	22.5	14.1	39.8	31.4	20.0	31.4	14.9
.46	.67	.96	.56	1.2	6.8	10.8	3.2	7.4	4.3	12.5	9.5	5.8	9.5	4.3
.39	.27	.37	.16	.37	1.3	1.8	1.0	1.5	1.0	1.3	1.2	1.1	1.5	1.0
.20	.12	.10	.10	.48	1.7	1.8	.92	1.5	.96	2.6	2.2	.80	1.7	.88
2.4	1.4	1.4	1.8	7.6	6.0	3.1	3.2	4.5	2.9	3.3	3.5	1.8	4.0	1.6
50.4	52.1	52.2	48.5	42.0	27.5	22.3	40.5	29.9	39.4	16.8	24.4	36.1	23.8	40.3
.09	.16	.20	.13	.03	.16	.32	.23	.19	.22	.42	.32	.28	.30	.20
.22	.14	.14	.28	.38	2.2	3.4	1.1	2.4	1.3	4.0	2.7	2.5	3.0	1.4
.19	.17	.23	.10	.21	.55	.61	.20	.63	.32	.73	.48	.48	.58	.31
.69	.42	.50	.32	.74	2.6	2.7	1.1	1.7	3.4	3.3	2.4	1.2	1.9	1.5
.04	.30	.62	.24	.31	.05	.49	.58	.24	.21	.03	.37	.18	.03	.16
2.4	1.8	6.0	.16	1.8	1.2	1.2	.23	.95	.47	.58	.47	.46	.58	.70
.11	.04	.12	.02	.17	.08	.06	.08	.05	.07	.06	.09	.04	.07	.08
39.5	41.0	35.7	40.2	39.8	26.3	17.6	36.4	25.9	30.7	14.1	21.0	29.1	21.4	32.1
.3	.2	.3	.15	.3	.5	.6	.35	.6	.4	.15	.25	.45	.4	.35
100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Six-step semiquantitative spectrographic analyses—Continued														
0	0	0	0	0	30	70	<30	50	<30	100	50	30	50	<30
15	7	10	15	20	200	300	100	300	150	300	300	150	300	200
0	0	0	0	0	100	150	150	150	100	200	150	0	150	150
0	0	0	0	0	3	7	0	5	5	10	7	3	5	3
5	3	3	3	7	30	70	20	50	20	70	50	20	50	30
.5	.3	.5	.3	7	7	15	5	10	5	15	10	5	10	10
0	0	0	0	0	7	10	3	7	5	10	7	5	7	5
0	0	0	0	0	50	50	30	50	30	100	50	0	50	50
0	0	0	0	0	<30	30	<30	30	<30	50	30	<30	30	<30
10	10	20	0	5	7	7	3	7	3	5	0	5	7	5
0	0	0	0	0	5	10	3	7	5	10	7	5	7	5
500	500	700	700	300	500	500	700	700	500	500	700	1000	500	1000
7	5	7	5	10	30	50	15	30	20	50	50	20	30	20
7	7	7	0	7	10	15	10	15	10	20	15	15	15	15
0	0	0	0	0	1	1.5	1	1.5	1	2	1.5	1.5	1.5	1.5
0	0	0	10	10	30	50	15	50	20	70	50	30	50	30

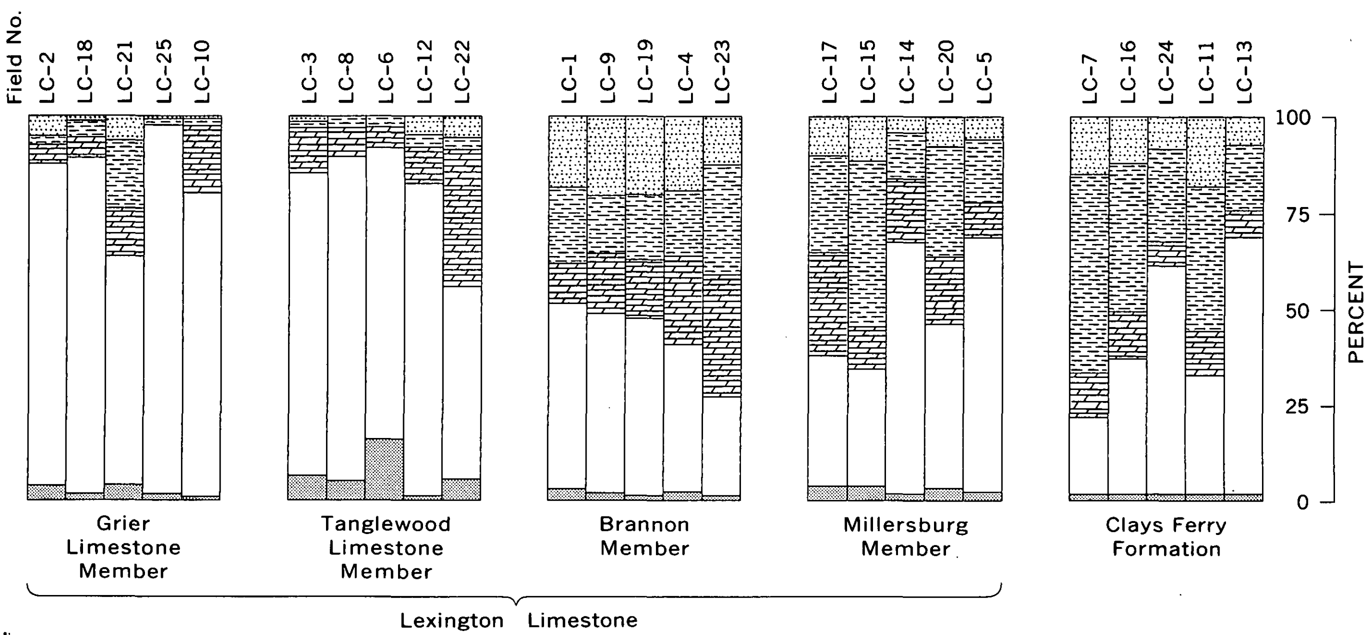
to the base of the Lexington Limestone that the dome was initiated in pre-Lexington Middle Ordovician time, but a more detailed isopach map of the same interval compiled by D. E. Wolcott (written commun., 1970) shows no relation to the Jessamine dome or the Cincinnati arch. There is no evidence for the presence of the dome in pre-Middle Ordovician time (McGuire and Howell, 1963, p. 4–1 to 4–5; Woodward, 1961, p. 1650) or in the Late Ordovician (Scotford, 1964).

The oldest rocks exposed on the Jessamine dome are limestone and dolomite of the High Bridge Group of Wilderness Age (Cooper, 1956), which crop out mostly in the gorge of the Kentucky River and the lower parts of its tributaries. The maximum exposed thickness of these rocks is in the Wilmore and Little Hickman quadrangles where about 400 feet crops out above the level of the Kentucky River.

The High Bridge Group consists of three formations. The basal formation is the Camp Nelson Limestone, which is composed of calcilutite interlaced with dolomite. The interlaced dolomite bodies resemble burrows. About 300 feet of the Camp Nelson is exposed. The Camp Nelson is overlain by the Oregon Formation which is characterized by finely crystalline calcareous dolomite. The Oregon is generally about 25 feet thick but thickens to 60 feet in the Coletown and Ford quadrangles and thins to 6 feet in the southern part of the Wilmore quadrangle through intertonguing with the overlying Tyrone Limestone. The Tyrone Limestone, the youngest formation of the High Bridge Group, is 60 to 100 feet thick and is typically calcilutite, though in places it contains much interlaced dolomite. Mud cracks have been observed throughout the formation.

Several bentonites occur in the upper part of the High Bridge Group. One is generally 1 inch or less thick and is about 80 feet below the top of the Tyrone. Another, the pencil cave bentonite of drillers, is as much as 2 feet thick and is 15 to 25 feet below the top of the Tyrone. These two bentonites are widespread and persistent. A third, the mud cave bentonite of drillers, is at the contact with the overlying Lexington Limestone and is present only locally. Other bentonites have been noted locally in the Tyrone in the subsurface and in the Curdsville Limestone Member of the Lexington Limestone.

The fine grain size of the carbonates of the High



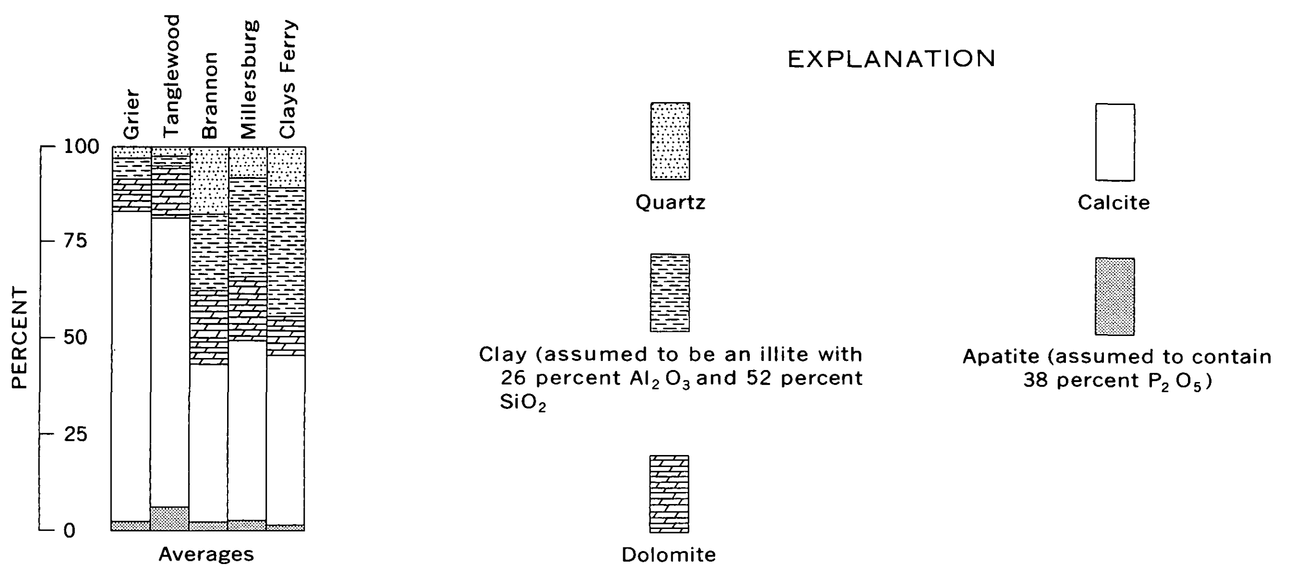


FIGURE 3.—Normative mineralogy of 25 samples of the Lexington Limestone and Clays Ferry Formation. Calculated from analyses in table 2.

Bridge Group, the abundance of mud cracks in the Tyrone Limestone and the Oregon Formation, and the presence of algal mats and intraformational breccias, particularly in the Tyrone, indicate that these rocks were deposited as lime mud on tidal flats and in shallow lagoons.

The Lexington Limestone rests disconformably on the Tyrone Limestone. The Lexington weathers to form the gentle, rolling topography of the inner Blue Grass region of Kentucky. Soils formed on the Lexington are commonly deep, phosphatic, and fertile, and outcrops on the uplands are generally sparse and small. Subsurface drainage is well developed, and much of the area is pockmarked with sink holes. Near the major drainages, soils are thinner and outcrops more abundant.

The Lexington Limestone is overlain by interbedded limestone and shale of early Cincinnatian age (mostly Edenian). These rocks are comparatively impervious, are easily eroded, and form a belt of rough hill country—the Eden shale belt—around the inner Blue Grass. In most of the area of this report, these rocks contain interbedded limestone and shale in about equal amounts and are assigned to the Clays Ferry Formation (Weir and Greene, 1965). Near the Ohio River, however, shale is dominant, and the sequence is known as the Kope Formation (Weiss and Sweet, 1964).

STRATIGRAPHY

LEXINGTON LIMESTONE

The Lexington Limestone was named by M. R. Campbell in 1898. As with most units that have complex facies relations and have been studied over a period of many years, the nomenclature of the Lexington has undergone many changes, the most recent of which have resulted from the recent 1:24,000-scale geologic mapping program. The reader is referred to Black, Cressman, and MacQuown (1965) for a discussion of the history of the stratigraphic nomenclature.

Black, Cressman, and MacQuown (1965) redefined the Lexington Limestone as a heterogeneous sequence of mostly bioclastic and fossiliferous limestone and minor shale of Middle Ordovician age,[1] underlain by calcilutite of the Tyrone Limestone and overlain by interbedded limestone and shale of the Clays Ferry Formation. Campbell (1898) did not give a type section, but Black, Cressman, and MacQuown (1965, p. 7) designated exposures in roadcuts along Interstate Highway 64 east of its crossing with the Kentucky River as a reference section. This is measured section 86 (table 1).

The thickness of the Lexington Limestone is shown in figure 4. The formation is more than 320 feet thick along a west-east line extending from north of Frankfort through Georgetown and Paris.

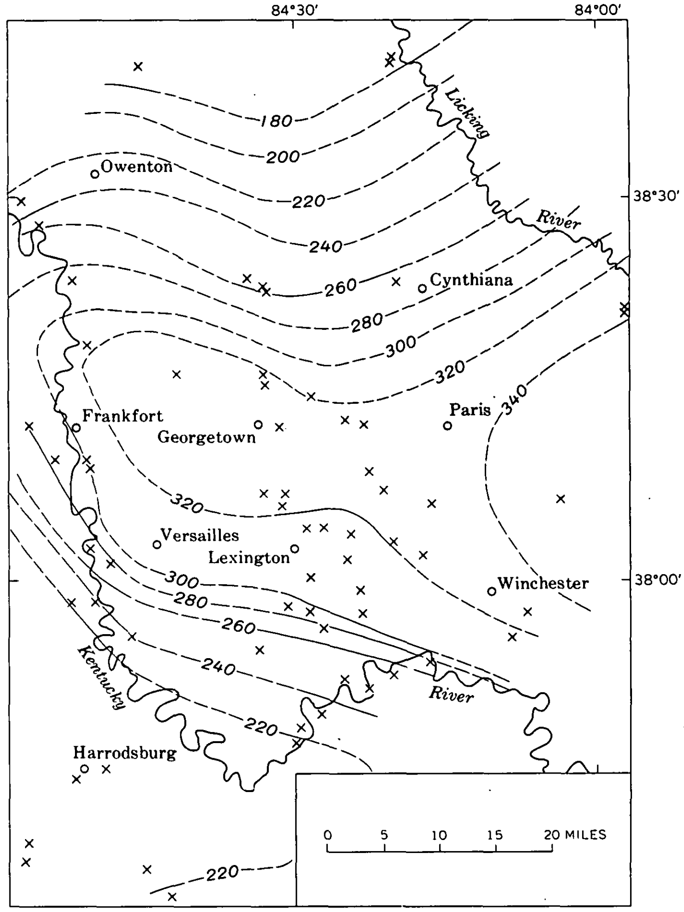


FIGURE 4.—Isopach map of Lexington Limestone. Contour interval 20 feet; contours dashed where less accurate; ×, measured section.

It thins northward to less than 200 feet at the north edge of the report area and southward to less than 220 feet near Harrodsburg. The thinning results mostly from intertonguing of the upper part of the Lexington with the Clays Ferry Formation.

The Lexington Limestone has been divided into 11 members which are described in the following sections.

CURDSVILLE LIMESTONE MEMBER

DEFINITION

The Curdsville Limestone Member is the basal unit of the Lexington Limestone. It consists of from less than 20 to about 40 feet of bioclastic calcarenite and calcirudite, which is sandy and chert bearing in part, and subordinate calcisiltite and irregularly bedded to nodular fossiliferous limestone. In the central and northern parts of the report area, this member is overlain by the Logana Member of the Lexington and in the southern part, by the Grier Limestone Member of the Lexington.

[1] Bergström and Sweet (1966, p. 288) correlated the base of the Cincinnatian Series as defined by the base of the Kope Formation at Cincinnati with a horizon nearly 40 feet below the top of the Lexington Limestone at its reference section, and if Cincinnatian Series is considered synonymous with Upper Ordovician, the Lexington Limestone is of both Middle and Late Ordovician age. Bergström and Sweet (1966, p. 296) correlated the top of the Trenton Group near Trenton Falls, New York, with a horizon 92 feet above the base of the type Cincinnatian (see also Flower, 1957, and Fisher, 1962), and if the top of the Middle Ordovician is defined as the top of the Trenton Group at its type area, the Lexington is entirely Middle Ordovician in age. Thus, the assignment of the Lexington Limestone to the Middle or Middle and Upper Ordovician is as much a matter of the definition of the series as it is of correlation. Sweet and Bergström (1970b) have suggested that the top of the Champlainian Series be placed at the top of the Shermanian Stage of Kay (1960), a horizon which they correlate with the base of the Cincinnatian Series at Cincinnati. It remains to be seen whether their proposal will be generally accepted.

The Curdsville was named by Miller (1905, p. 18) for a now-abandoned station on the Southern Railway in Mercer County. Miller did not designate a type section, but parts of the member are exposed in the type area in cuts along the main line of the railroad north of a spur to the Kentucky Utilities Company plant at Herrington Lake.

LOWER CONTACT

Near and beyond the Kentucky River south and southeast of Lexington, the Curdsville Limestone Member rests directly on the mud cave bentonite of local usage, the uppermost bentonite of the Tyrone Limestone (fig. 5). Elsewhere, the bentonite is absent, at least in part by pre-Curdsville erosion, and the Curdsville rests directly on light-colored, commonly mud-cracked calcilutite of the Tyrone. Where calcarenite of the Curdsville rests directly on calcilutite of the Tyrone, the contact may be tightly cemented.

As noted by Miller (1925, p. 131, 132), the contact between the Curdsville Limestone Member and the Tyrone Limestone is disconformable, at least where the mud cave bentonite is missing. Where the Curdsville rests directly on limestone of the Tyrone, the contact is generally irregular with a relief of several inches (fig. 6); and sparse fragments of the Tyrone Limestone are present in the basal few feet of the Curdsville, even where the underlying bed is the mud cave bentonite. Assuming the mud cave bentonite to be the last bed of the Tyrone to have been deposited, the magnitude of the pre-Curdsville disconformity can be estimated by contouring the thickness of the interval between the base of the pencil cave bentonite of local usage, the most widespread bentonite of the Tyrone Limestone, and the Tyrone-Lexington contact (fig. 7). Where both the pencil cave and mud cave bentonites are present, this interval is generally about 25 feet, though at one locality in the Lawrenceburg quadrangle it is only 18 feet. Although data are sparse north of Lexington and east of Winchester, they suggest (fig. 7) that not more than about 10 feet of the uppermost Tyrone was removed before Curdsville deposition. Maximum erosion seems to have been in the central and eastern part of the area. The Tyrone-Lexington

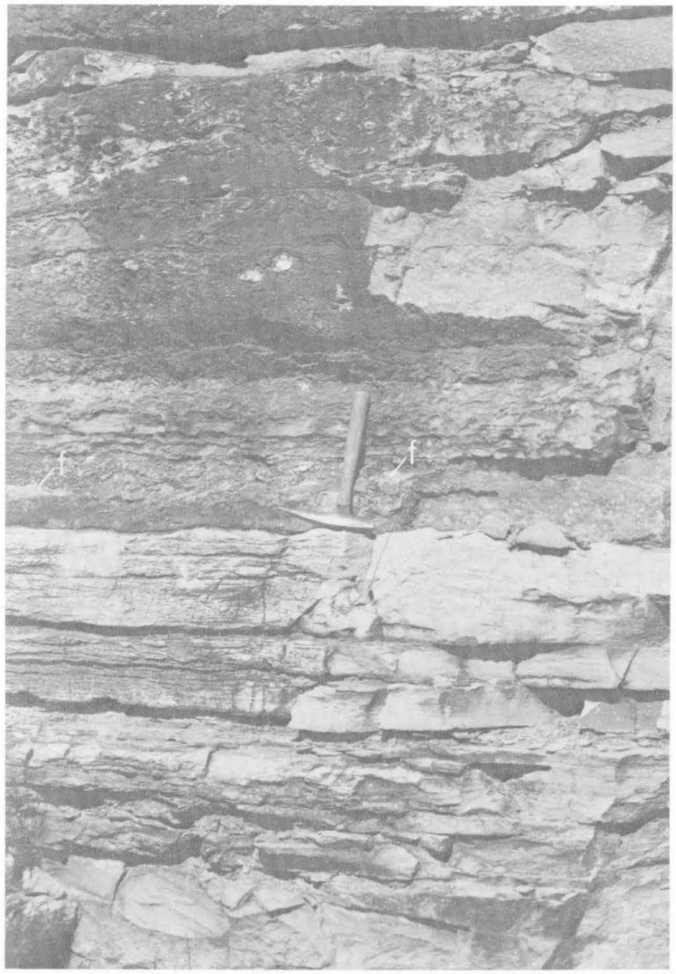


FIGURE 6.—Disconformity between Lexington Limestone and Tyrone Limestone in roadcut on Kentucky Route 33 in Danville quadrangle. Hammerhead marks contact between bioclastic calcarenite and calcirudite of Curdsville Limestone Member of Lexington above and calcilutite of Tyrone below. Note fragments of Tyrone Limestone (f) in basal bed of Curdsville.

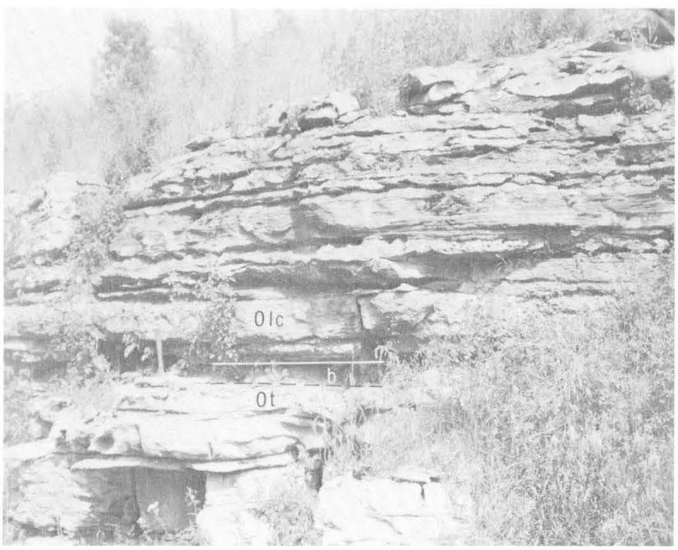


FIGURE 5.—Contact of Lexington Limestone and Tyrone Limestone in railroad spur to Kentucky Utilities Company plant near locality 174 in Tyrone quadrangle. Curdsville Limestone Member (Olc) of Lexington rests on bentonite (b, mud cave bentonite of local usage) at top of Tyrone Limestone (Ot).

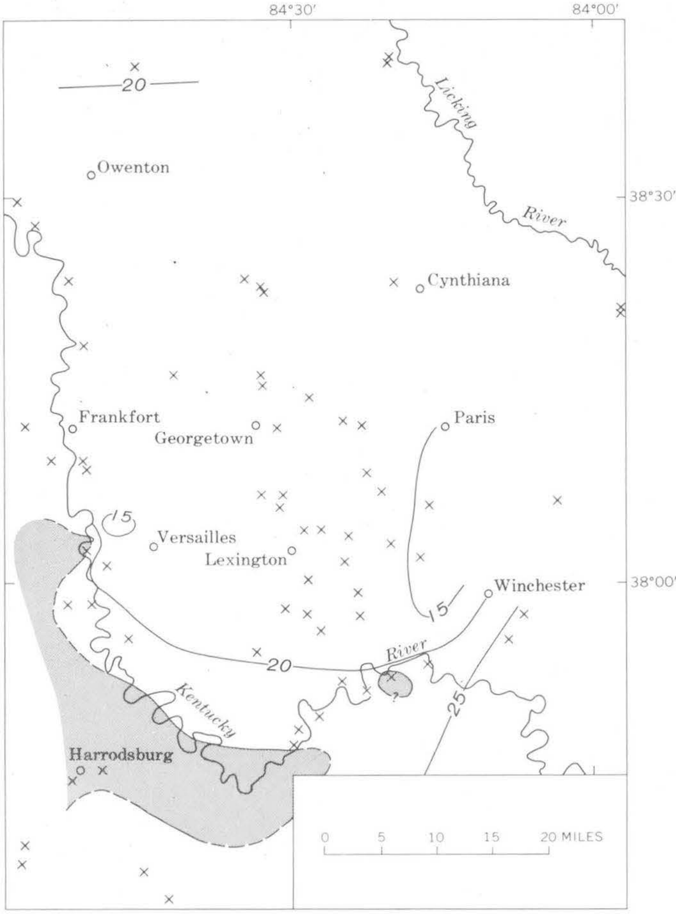


FIGURE 7.—Distribution of mud cave bentonite of drillers (patterned areas) and approximate thickness of interval between base of pencil cave bentonite of drillers and base of Lexington Limestone. Contour interval 5 feet. Line representing edge of mud cave bentonite is solid where based on mapping and dashed where edge is inferred. ×, measured section.

disconformity probably does not indicate any great interval of time. The fragments of Tyrone Limestone in the basal Curdsville Limestone Member show that some of the Tyrone was lithified before Curdsville time, but much of the Tyrone was deposited in an intertidal environment where cementation could have been rapid.

The pencil cave bentonite in the upper part of the Tyrone Limestone is isochronous, as are all bentonite beds. If the upper part of the Tyrone and the entire Curdsville Limestone Member of the Lexington are facies equivalents, the thickness between the bentonite and the Tyrone-Curdsville contact should vary considerably and systematically. The bentonite is nowhere less than 15 or more than 25 feet below the contact, indicating that little or none of the Curdsville could be the time equivalent of the uppermost Tyrone.

The Tyrone Limestone accumulated in quiet, shallow water and was periodically exposed to the air, whereas the basal Curdsville bioclastic calcarenites and calcirudites were deposited in agitated water of the inner infralittoral zone. The disconformity, then, probably resulted from a slight deepening of the water which permitted the formation of waves of sufficient energy to erode the uppermost part of the Tyrone Limestone and to break, sort, and transport the debris of fossils that could thrive in the more aerated water.

UPPER CONTACT

North of a line from Harrodsburg to near Winchester (fig. 8) the Curdsville Limestone Member is overlain by interbedded calcisiltite and shale of the Logana Member of the Lexington Limestone, but south of the line it is overlain by nodular and irregularly bedded fossiliferous limestone of the Grier Limestone Member of the Lexington. The contact between the Curdsville and Logana Members is sharp at any one locality; regionally this contact rises in the section from west and northwest to the southeast. Where the Curdsville is overlain by the Grier Limestone Member, the contact is gradational; calcarenites of the lower 15 to 20 feet of the Curdsville grade upward through as much as 15 feet into rocks characteristic of the Grier, and it is generally not possible to map a consistent boundary.

LITHOLOGY

The Curdsville Limestone Member was studied in considerable detail by MacQuown (1967), and most of the following discussion is based on his report. MacQuown divided the Curdsville into three parts for descriptive purposes. The parts are gradational, and the contacts between them are arbitrary. The lower part is 10 feet thick and is composed of light-colored (pale yellowish orange to light gray), finely to coarsely crystalline, bioclastic limestones that consist of calcirudites, crossbedded and ripple-marked calcarenites, and laminated calcisiltites. These types are closely interbedded and are all represented as calcarenites on the columnar sections (pls. 1–6) in this report. The grains are abraded and sorted fragments of crinoids, bryozoans, and brachiopods. Whole and broken brachiopod and mollusk shells are common, and many are silicified. The limestones contain 5 to 10 percent subrounded fine quartz sand, and chert nodules occur in several layers. Cryptocrystalline apatite is present in amounts of several percent, as fillings in openings and pores in bryozoans and crinoid fragments, and as trilobite fragments.

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The middle unit described by MacQuown (1967), 10 feet to 20 feet above the base of the member, consists of bioclastic calcarenite and calcirudite similar to that in the basal unit interbedded with argillaceous calcisiltite and shale. Ball-and-pillow structure is common in the calcisiltite, and nodular chert is locally abundant in the calcarenite and calcirudite. The uppermost unit, from 20 feet above the base of the Curdsville Limestone Member to the base of the overlying Logana Member, ranges from 0 to about 20 feet in thickness. It consists of medium-gray irregularly bedded fossiliferous limestone interbedded with bioclastic calcarenite. Chert is rare. Locally, the uppermost foot or so is a brachiopod coquina. Elsewhere the uppermost bed may be a dark, fetid, very fine grained calcarenite similar to, but slightly coarser than, calcisiltite in the Logana Member. The unit is very similar to much of the Grier Limestone Member.

Several thin bentonites are present in the lower 20 feet of the Curdsville Limestone Member but most are too thin to show on the columnar sections (pls. 1–6). The bentonites are discontinuous and of only local value in correlation. As noted by MacQuown (1967, p. 29), the discontinuous nature of the bentonites is explained by submarine erosion by waves and currents.

THICKNESS AND EXTENT

The Curdsville is present throughout the area of this report. It thins westward, from 40 feet in Nicholas County to less than 20 feet west of Frankfort (fig. 8). The westward thinning results largely from a facies change of the upper Curdsville into interbedded calcisiltite and shale of the lower part of the Logana Member. Where the Logana is absent, the contact of the Curdsville with the overlying Grier Limestone Member is so indefinite that thickness trends cannot be determined.

ENVIRONMENT OF DEPOSITION

The Curdsville Limestone Member, like the rest of the Lexington Limestone, was deposited in normal marine water as shown by the fauna. The salinity of the water was thus approximately 35 parts per thousand and the pH was about 8.1 to 8.3. The bioclastic calcarenite and calcirudite, crossbedded in part, that makes up much of the lower 20 feet of the member was formed in a high-energy environment, probably in water above surf base as used by Dietz (1963); however, the interval also contains beds of calcisiltite, unabraded fossils, and articulated pelecypods, all indicative of a low-energy environment. The close interbedding of calcarenite, calcirudite, and calcisiltite resulted from frequent changes or local variations in energy; the most likely explanation of the frequent changes is that the coarser fragments accumulated in small bars while finer material was deposited in topographic lows. Migration of the bars would have resulted in interbedding of coarser and finer grained sediments.

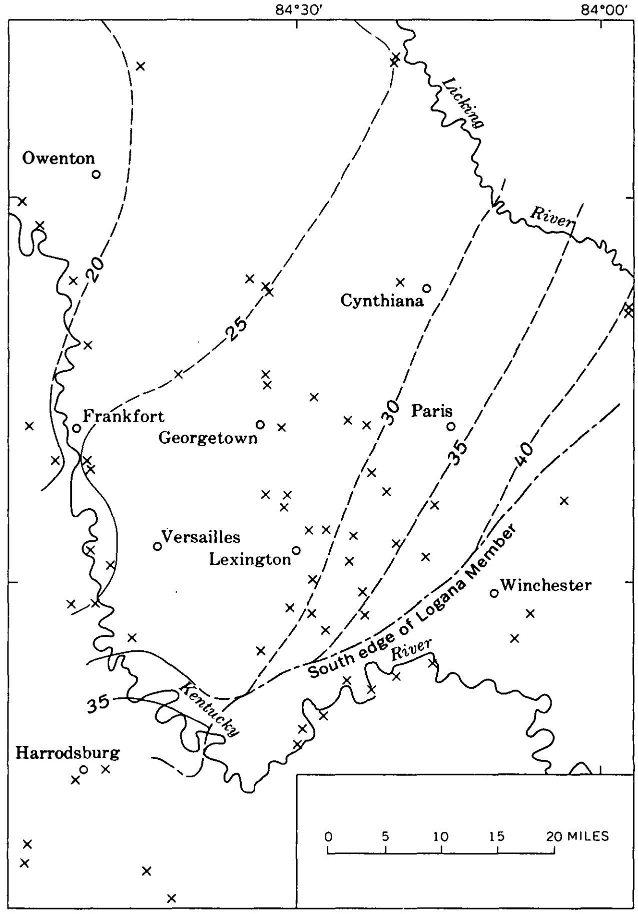


FIGURE 8.—Isopach map of Curdsville Limestone Member of Lexington Limestone. Contour interval 5 feet; solid where based on mapping, dashed where inferred; ×, measured section.

The fossiliferous limestone of the upper part of the Curdsville was deposited in slightly deeper water. The currents were sufficient to supply oxygen and food but were not strong enough to break and abrade many of the shells. The environment was similar to that in which most of the Grier Limestone Member was deposited (p. 19).

The vertical sequence of rock types in the Curdsville, high-energy shallow-water deposits in the lower part grading to deeper water deposits at the top, record a marine transgression. The lines of section (pl. 7) and the isopach map of the member (fig. 8) suggest that transgression was from the northwest toward the south and southeast.

LOGANA MEMBER

DEFINITION

In all but the southeastern part of the area, the Curdsville Limestone Member is overlain by the Logana Member of the Lexington Limestone. The Logana Member was named by Miller (1905, p. 19) for Logana Station (now abandoned) in the Valley View quadrangle, southern Jessamine County. Type exposures were presumably in railroad cuts east of Logana Station. A lithologic unit that corresponds to Miller's description of the Logana is not present at the type locality; however, exposures in a roadcut along the entrance road leading from U.S. Highway 62 to the Kentucky Utilities Company plant on the east side of the Kentucky River (measured sec. 174), which fit Miller's description of the Logana and which conform to most subsequent usages of the term, were designated a reference section by Black, Cressman, and MacQuown (1965, p. 15–17).

At the reference section, the Logana Member is 31 feet thick. It consists there of three major parts: a lower unit, 13 feet thick, of interbedded calcisiltite and shale; a middle unit, also 13 feet thick, mostly of brachiopod coquina but containing a thin zone of calcisiltite and shale in the lower part; and an upper unit, 5 feet thick, of calcisiltite and shale similar to the lower unit.

CONTACTS

At the reference section, the basal calcisiltite and shale unit of the Logana rests conformably on the evenly to irregularly bedded fossiliferous calcarenite of the Curdsville Limestone Member. The contact is generally sharp. In some areas, though, the uppermost few feet of the Curdsville is dark-brownish-gray, very fine grained calcarenite similar to calcisiltite of the Logana, and the contact is gradational through a few inches to a foot.

The Logana is overlain conformably by irregularly bedded fossiliferous limestone of the Grier Limestone Member; the contact is placed at the top of the highest unit of interbedded calcisiltite and shale. In parts of the Keene and Wilmore quadrangles, the basal bed of the Grier is a brachiopod coquina similar to that within the Logana, the uppermost calcisiltite and shale unit of the reference section is not present, and the brachiopod coquina of the Logana merges with the thin basal coquina of the Grier to form a single unit which is placed in the Grier.

LITHOLOGY

The interbedded calcisiltite and shale, the characteristic assemblage of the Logana, contains nearly equal parts of limestone and shale. The calcisiltite, which is generally argillaceous, is in tabular to broadly lensing beds mostly 0.2 to 0.3 foot thick (fig. 9). On fresh surfaces, the calcisiltite is brownish gray to olive gray and light olive gray. Some of the darker beds have a petroliferous odor. The calcisiltite beds weather out as yellowish-gray to very light gray smooth-surfaced slabs that form distinctive and easily recognizable float. Most beds are unfossiliferous but a few contain abundant pelecypods that may be silicified. John Pojeta (oral commun., 1966) has noted some beds in which the interior contains closely packed articulated pelecypods, whereas both the upper and lower surfaces contain dalmanellid brachiopods.

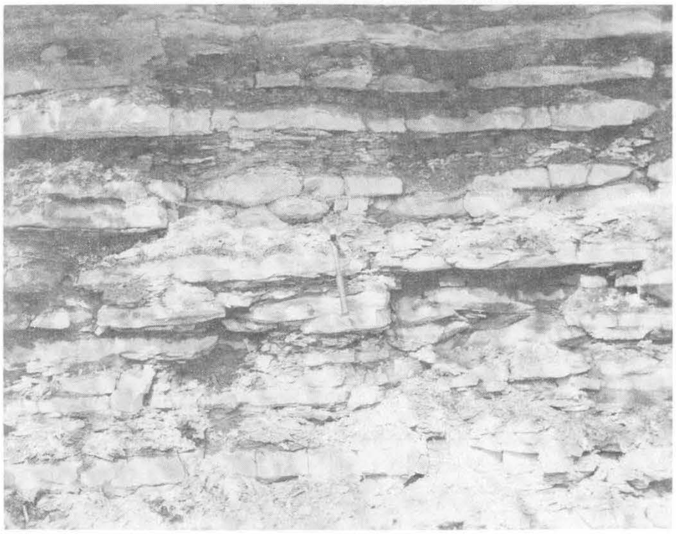


FIGURE 9.—Interbedded calcisiltite and shale in lower part of Logana Member of Lexington Limestone. Roadcut on entrance to Kentucky Utilities Company plant, east side of Blackburn Memorial Bridge, U.S. Highway 62, Woodford County. This is the reference section (174) of the Logana Member (Black and others, 1965, p. 15–17).

The interbedded shale is brownish gray, fissile, calcareous, and partly dolomitic. X-ray diffraction analysis of one sample of the shale indicated the presence of both illitic and chloritic clay, some quartz, and traces of potassium feldspar (J. J. Connor, written commun., 1967). The diffraction pattern is similar to that of samples of shale from other members of the Lexington Limestone.

The brachiopod coquina consists of a tightly packed mass of *Dalmanella* valves oriented parallel to bedding. The coquina crops out as ledges several feet thick, commonly with broadly irregular surfaces, but in artificial exposures the unit is seen to consist of wavy beds mostly 0.1 to 0.6 foot thick (fig. 10). Fresh surfaces are light brownish gray,

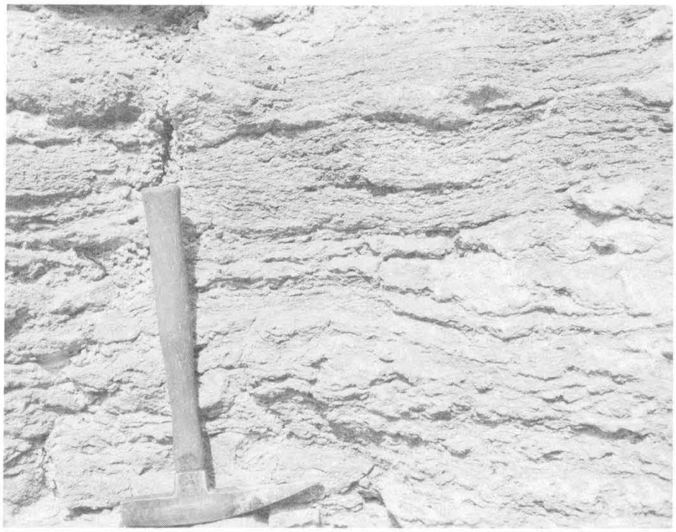


FIGURE 10.—Roadcut exposure of brachiopod coquina in Logana Member of Lexington Limestone. Same locality shown in figure 9.

but weathered bedding surfaces typically have a reddish cast and a somewhat satiny sheen. In thin sections, brachiopod valves are set in a matrix of dark-colored microspar, but patches of clear medium and coarsely crystalline spar are common, mostly adjacent to the brachiopod valves (fig. 11). Many

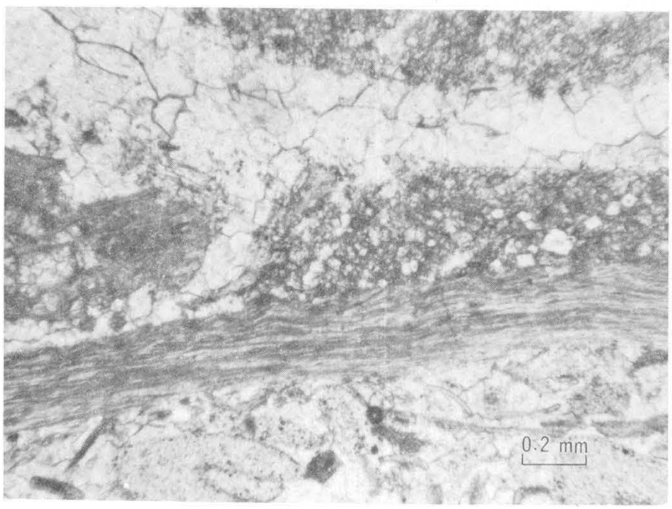


FIGURE 11.—Photomicrograph of brachiopod coquina from Logana Member. Bedding is parallel to brachiopod valve. Plane-polarized light.

valves are partly or wholly silicified. In Folk's (1962) terminology, the rock is a poorly washed biosparrudite.

THICKNESS AND EXTENT

The Logana Member thins southward from a maximum of 50 feet at Falmouth (measured sec. 196) to a featheredge in the Little Hickman, Nicholasville, and Coletown quadrangles (fig. 12). The

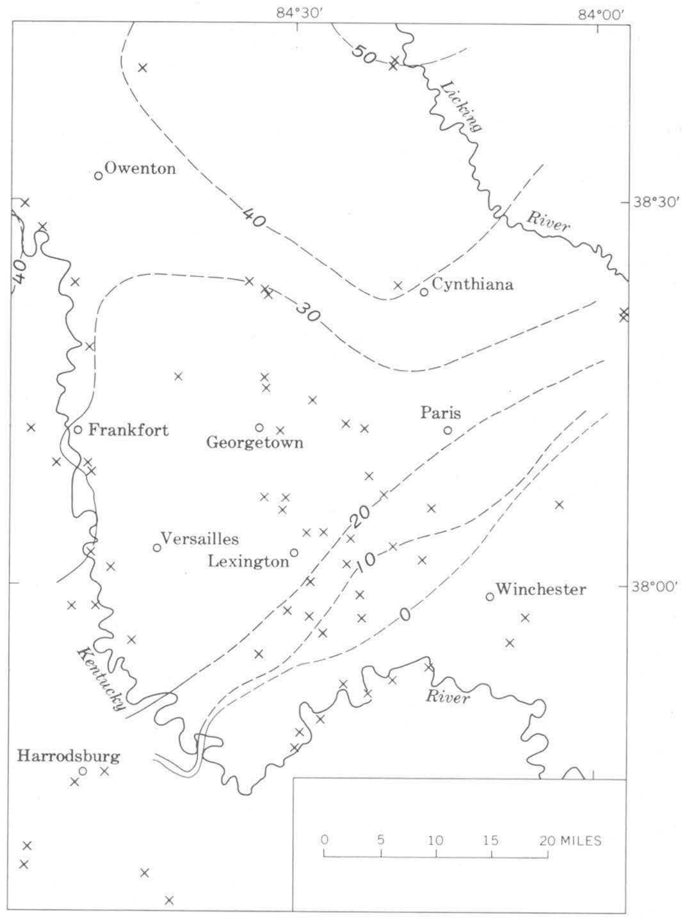


FIGURE 12.—Isopach map of Logana Member of Lexington Limestone. Contour interval 10 feet; solid where based on mapping; dashed where inferred; ×, measured section.

thinning results largely from intertonguing and intergradation of the upper part of the Logana with the lower part of the Grier Limestone Member, and to a lesser extent from intertonguing of the basal Logana with the uppermost part of the Curdsville Limestone Member. Thus, the Logana is a southeastward-thinning wedge with a slightly transgressive lower contact and a regressive upper contact. Transgression was apparently from the northwest and west and regression was toward the north.

The member contains the three-fold division of the reference section over much of the area. The brachiopod coquina has been traced at the surface from Frankfort to the featheredge of the Logana in the Wilmore and Nicholasville quadrangles, and it extends beyond the member as an identifiable bed in the lower part of the Grier Limestone Member in the southern part of the Wilmore and Little Hickman quadrangles and the northern part of the Valley View quadrangle. The coquina may also extend northward in the subsurface into Owen, Harrison, and Nicholas Counties, although information is too sparse to demonstrate continuity.

ENVIRONMENT OF DEPOSITION

The Logana Member was deposited during the culmination of the initial transgression of Lexington time, and it accumulated in deeper water than the calcarenite and fossiliferous limestone of the Curdsville Limestone Member below or the fossiliferous limestone of the Grier Limestone Member above. The interbedded calcisiltite and shale accumulated below wave base, as shown by the fine grain size and the absence of current structure. The depth of wave base cannot be determined, but it was surely less in the epicontinental sea (that had limited fetch) of Ordovician time than on the continental shelf of today.

The oxygen content of the bottom water was low as evidenced by the paucity of fossils, the absence of animal burrows, and the relatively dark color of both the shale and the limestone; and the sea floor was probably below the compensation depth (the depth below which oxygen produced by photosynthesis is insufficient to meet the respiration requirements of the marine plants). In the present ocean, this depth varies greatly, but it ranges from 25 to 45 m (meters) in clear coastal waters (Holmes, 1957, p. 123). At least periodically, though, the oxygen content was sufficient to permit the growth of pelecypods found in some beds.

The calcisiltite beds consists of silt-sized fragments of crinoids and brachiopods set in a microspar matrix. The fossil fragments, and possibly most of the finer carbonate, were derived by winnowing of shallower water sediments. The presence of articulated pelecypods in some beds suggests that deposition of the calcisiltite was rapid. The calcisiltites probably resulted from intermittent periods of intensified winnowing of shallow-water sediments that bordered the Logana to the southeast and deposition of the winnowed fines in deeper water in which terrigenous muds were accumulating.

The brachiopod coquina formed in water in which turbulence was sufficient to supply oxygen and organic particles to the brachiopods and to disarticulate and orient the brachiopod valves but insufficient to break and abrade the valves or to remove all the lime mud.

GRIER LIMESTONE MEMBER

DEFINITION

The Logana Member is directly overlain by the Grier Limestone Member which consists predominantly of thin and irregularly to nodular-bedded, poorly sorted, fossiliferous limestone. The Grier was named by Cressman (1964) for Grier Creek in the south-central part of the Tyrone quadrangle. At the type section (measured sec. 89) the Grier is approximately 115 feet thick.

CONTACTS

At Falmouth (measured sec. 196), the contact between the Grier and the underlying Logana Member is 76 feet above the base of the Lexington Limestone; the contact becomes progressively lower in the section toward the south through intertonguing of the lower Grier with the upper Logana and is 50 to 60 feet above the base of the Lexington Limestone near Frankfort and 40 to 45 feet above the base just south of the city of Lexington. In the southern part of the area beyond the pinchout edge of the Logana, the Grier rests directly on the Curdsville Limestone Member; the Curdsville-Grier contact there is commonly gradational through as much as 10 or 15 feet.

Throughout most of the area the Grier is overlain conformably by well-sorted calcarenite of the Tanglewood Limestone Member of the Lexington Limestone, but in parts of the Versailles, Lexington East, Georgetown, and Midway quadrangles, it is overlain with apparent conformity by calcisiltite and shale of the Brannon Member of the Lexington. The upper part of the Grier and the lower part of the Tanglewood are complexly intertongued. The Tanglewood Limestone Member pinches out northward, and in the three northernmost measured sections the Grier is conformably overlain by interbedded limestone and shale of the Clays Ferry Formation (measured sec. 190) or the Point Pleasant Formation (measured secs. 195, 196).

LITHOLOGY

The Grier Limestone Member contains a variety of rock types, but the general aspect is of thin and irregular beds, abundant fossils, and poor sorting. The most common bedding assemblage is sets about 0.5 foot thick of nodular-bedded fossiliferous calcisiltite to very poorly sorted fossiliferous calcarenite with minor shale partings, alternating with slightly irregular beds about 0.4 foot thick of poorly sorted fossiliferous calcarenite (fig. 13). The most conspicuous fossils are brachiopods and bryozoans. Gastropods are common in some calcisiltites. Locally the sets of nodular-bedded limestone are thinner and the fossiliferous calcarenite is more conspicuous.

FIGURE 13.—Outcrop of Grier Limestone Member of Lexington Limestone showing characteristic nodular-bedded limestone sets alternating with irregular beds of calcarenite. Exposure in gully north of Bluegrass Parkway west of bridge over Kentucky River, Anderson County.

Another rock type, less common than those described above and occurring as widely spaced thin sets, consists of very fossiliferous calcilutite and calcisiltite in even to wavy beds 0.1 to 0.5 foot thick interbedded with minor shale. The fossils are mostly dalmanellid brachiopods.

The uppermost 15 to 30 feet of the Grier Limestone Member from Lexington to Frankfort and Versailles and south to the Kentucky River consists of rubbly weathering limestone made up of nodules of poorly sorted fossiliferous calcarenite set in a matrix of dolomitic calcisiltite. This unit in part intertongues with the basal part of the Tanglewood Limestone Member and in part grades laterally into the alternating sets of irregularly and modular-bedded limestone more typical of the Grier.

PETROGRAPHY

Microscopically, limestones of the Grier Limestone Member consists of a wide variety of mixtures of whole and broken fossils, fossil fragments of all sizes, microspar, and clear medium-crystalline sparry calcite cement. The clear spar is largely the result of precipitation in open spaces rather than of recrystallization of lime mud; little direct evidence of recrystallization or replacement has been observed, and, in general, the amount of clear spar is directly related to the sorting of the allochems. The most common fossil fragments are of bryozoans brachiopods, and crinoids. Ostracodes are abundant in some beds, and pelecypods and gastropods are present. Scattered trilobite fragments have also been noted. The microspar consists of anhedra averaging about 10 microns in diameter and is commonly dark in color and clouded with organic matter or clay; it may contain many dolomite rhombs. Clear sparry calcite occurs as casts of mollusks, as fillings of bryozoan zooecia, as patches commonly adjacent to fossils in rocks with microspar matrix, and as cement in some calcarenites. Brown crystocrystalline apatite is present in many rock specimens in amounts of a few percent. The apatite fills bryozoan zooecia and pores in crinoid plates and less commonly occurs as steinkerns of ostracodes and minute gastropods.

The rocks that result from the combination of the various textural elements range from sparse and packed biomicrosparite and biomicrosparrudite (fig. 14*A*), poorly washed biosparite and biosparrudite (fig. 14*B*), to unsorted biosparite (fig. 14*C*). Sorted biosparites have been noted but are rare. The most common rock type is poorly washed biosparite.

SUBDIVISIONS

Several units within the Grier Limestone Member have proven useful in mapping and correlation. The lowest of these, not shown on the stratigraphic columns and sections in this report but of considerable value in mapping, is a distinctive sequence of several feet of bryozoan limestone containing large crinoid columnals near the top, overlain by 5 to 10 feet of lentincular- to nodular-bedded brachiopod coquina. The crinoids are approximately 105 feet above the base of the Lexington Limestone. The squence has been identified from the north edge of the Salvisa quadrangle to the south edge of the Danville quadrangle and eastward into the Little Hickman quadrangle.

The base of the next subdivision, the Macedonia Bed (Black and others, 1965, p. 19) is 10 to 15 feet above the crinoid bed. The Macedonia consists of as much as 15 feet of argillaceous calcisiltite in even to broadly lensing smooth-surfaced beds, mostly 0.2 to 0.4 foot thick, interbedded with 10 to 40 percent shale. It closely resembles the interbedded calcisiltite and shale of both the Logana and Brannon Members, but it contains less shale. In part of the Frankfort East quadrangle, the Macedonia Bed contains a middle unit of dalmanellid coquina closely resembling that of the middle unit of the Logana Member. However, the dalmanellid in the Macedonia is *Heterorthina macfarlani* Neuman whereas that in the Logana Member is *Dalmanella sulcata* Cooper (Neuman, 1967). The Macedonia Bed thins both east and west of a line extending south-southeast from Frankfort and is probably a narrow southward-extending tongue. The distribution of the Macedonia Bed is shown in figure 15.

A calcarenite unit as much as 30 feet thick and a little more than 100 feet above the base of the Grier Limestone Member is exposed in several roadcuts north and west of Frankfort and can be traced in surface exposures northward to the Gratz quadrangle (fig. 15). The calcarenite is well exposed a few miles west of Frankfort on the Devils Hollow road (measured sec. 191). The unit there is 30 feet thick and consists of two parts. The lower 18 feet is light-gray fine- to medium-grained well-sorted calcarenite with few distinct bedding surfaces; it weathers yellowish gray and breaks into large angular blocks. Faint crossbedding may be seen in some exposures. The upper 12 feet is mostly light-gray fine- to medium-grained bioclastic calcarenite, crossbedded in part, in well-defined beds 0.1 to 0.5 foot thick. Northward at measured section 61, the calcarenite unit is 16 feet thick and consists of grayish-orange fine-grained calcarenite containing scattered, randomly oriented, strophomenid valves and some bryozoan fragments. Farther north near Gratz (measured sec. 62), the unit is 27 feet thick and consists of calcarenite similar to that at measured section 61 but contains some beds of nodular fine-grained calcarenite. The calcarenite unit is more similar in lithology to the Tanglewood Limestone Member than to the rest of the Grier; but inasmuch as it does not seem to be continuous with the Tanglewood, it is retained in the Grier Limestone Member.

In the Georgetown and Lexington West quadrangles, two units as much as 5 feet thick and composed of calcisiltite and calcilutite containing many silicified gastropods have been mapped as key beds in the upper part of the Grier Limestone Member (Cressman, 1967; Miller, 1667). One of these units, designated informally as the *Loxoplocus* bed, is in several measured sections near Lexington and is useful in local correlation.

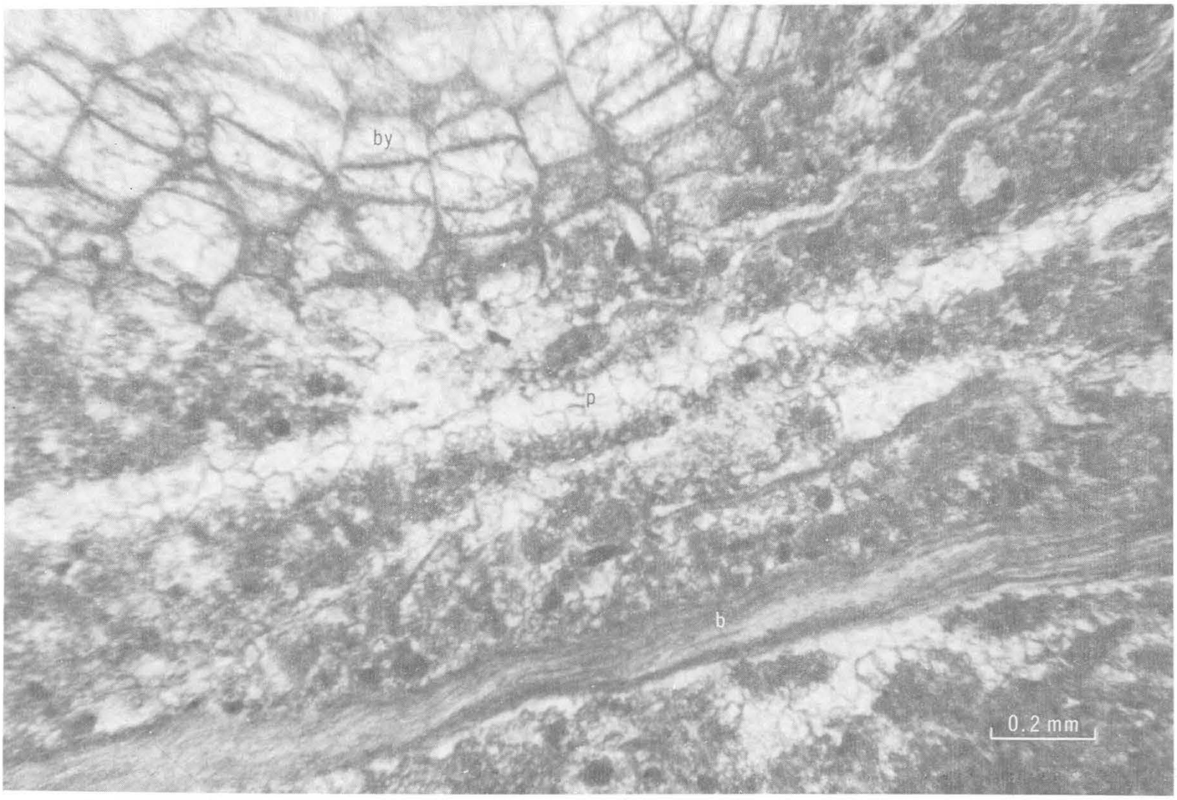
In parts of Fayette, Scott, and Jessamine Counties, the top of the Grier Limestone Member is marked by a bed of argillaceous calcilutite and calcisiltite as much as 5 feet thick that was named the Cane Run Bed by Black, Cressman, and MacQuown (1965, p. 20). The distribution of the unit is shown in figure 15. Although both the upper and lower surfaces of the Cane Run Bed are planar, bedding within it is commonly contorted. Chert nodules are abundant, and the unit weathers to a cherty residuum. Southward near the Kentucky River, the unit consists of planar-bedded calcisiltite and shale. A somewhat similar but thinner and less continuous bed of chert-bearing calcisiltite, commonly with contorted bedding, has been noted near the Kentucky River west of Versailles at about the same stratigraphic position as the Cane Run Bed, but it does not seem to be continuous with the Cane Run. In fact, contorted calcisiltite beds are commonly though not invariably, present at the contact between typical nodular-bedded and irregularly bedded fossiliferous limestone of the Grier and overlying tongues of Tanglewood regardless of the stratigraphic position of the tongue.

THICKNESS AND EXTENT

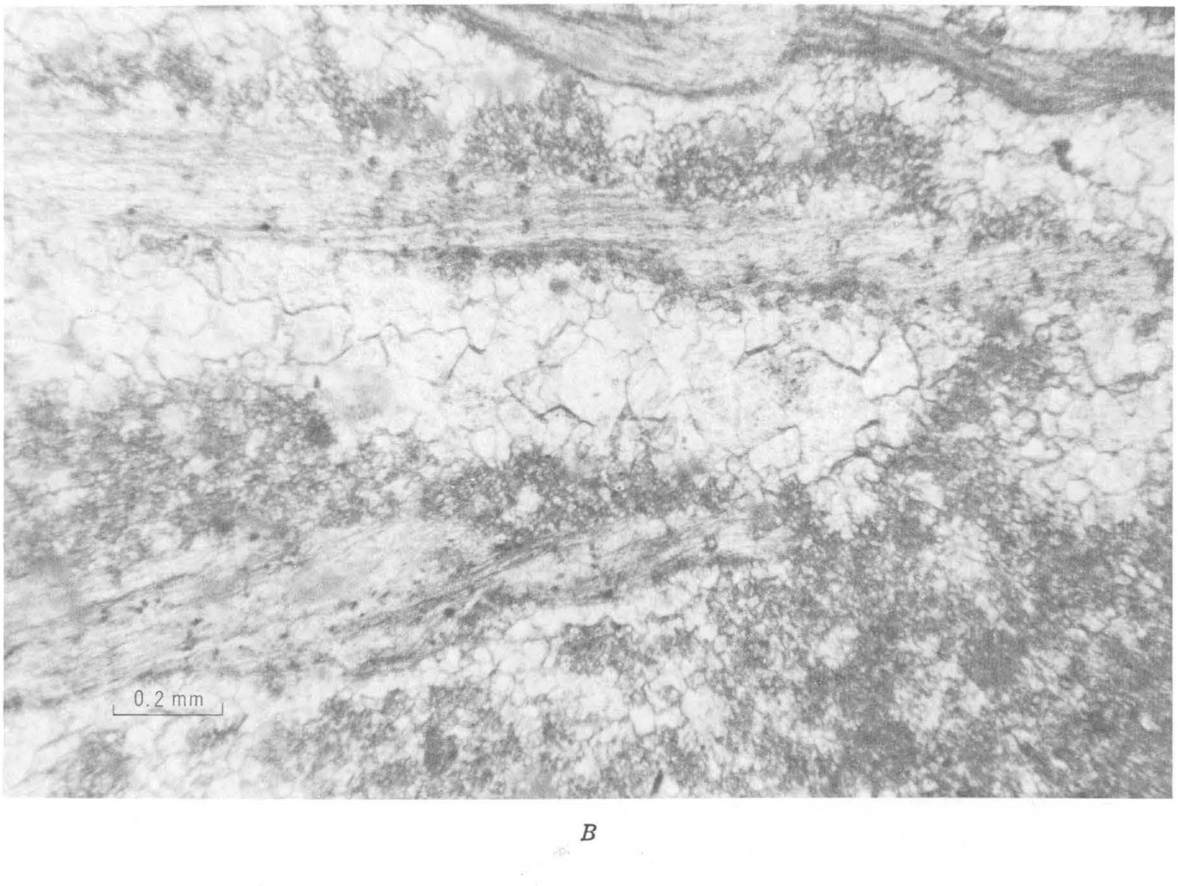
The Grier Limestone Member is present throughout the entire area. It ranges in thickness from about 100 feet at Falmouth (measured sec. 196) to a maximum of nearly 180 feet in the Sideview quadrangle (measured sec 1000). Thickness changes result mostly from intertonguing of the lower part with the Logana Member and of the upper part with the Tanglewood Limestone Member. The effects of the intertonguing on the thickness of the Grier are somewhat erratic, and data are insufficient to construct an accurate isopach map. In general, the Grier is about 130 feet thick near Lexington. It thins northward largely by intertonguing with the Logana (pl. 7, *B–B′* and *C–C′*), but the effect is partly compensated by the top of the Grier rising in the section at the expense of the overlying Tanglewood Limestone Member. North of the pinchout edge of the Tanglewood, the Grier may also thin by passing of the upper part into the basal Clays Ferry Formation. The Grier thickens eastward of Lexington both by replacing the entire Logana down section and by intertonguing witht he lower part of the Tanglewood section (pl. 7 *E–E′*). It thins south of Harrodsburg by intertonguing with the lower part of the Tanglewood Limestone Member (pl. 7, *F–F′*) and is only 60 feet thick in the northern Stanford quadrangle (measured sec. 1007).

ENVIRONMENT OF DEPOSITION

The abundance, kind, and state of preservation of the fossils and the poor sorting of the limestone indicate that most of the Grier Limestone Member was deposited in shallow, aerated, only moderately agitated water of approximately normal marine salinity. Much of the sea floor was populated by a mixed bryozoan-crinoid fauna. E. L. Yochelson has suggested (oral commun., 1965) that the association of gastropods, which were of grazing habit, with lime mud indicates that the calcite fines were of algal origin. Inasmuch as most lime mud in recent sediments has been pelletted by organisms, much of



A



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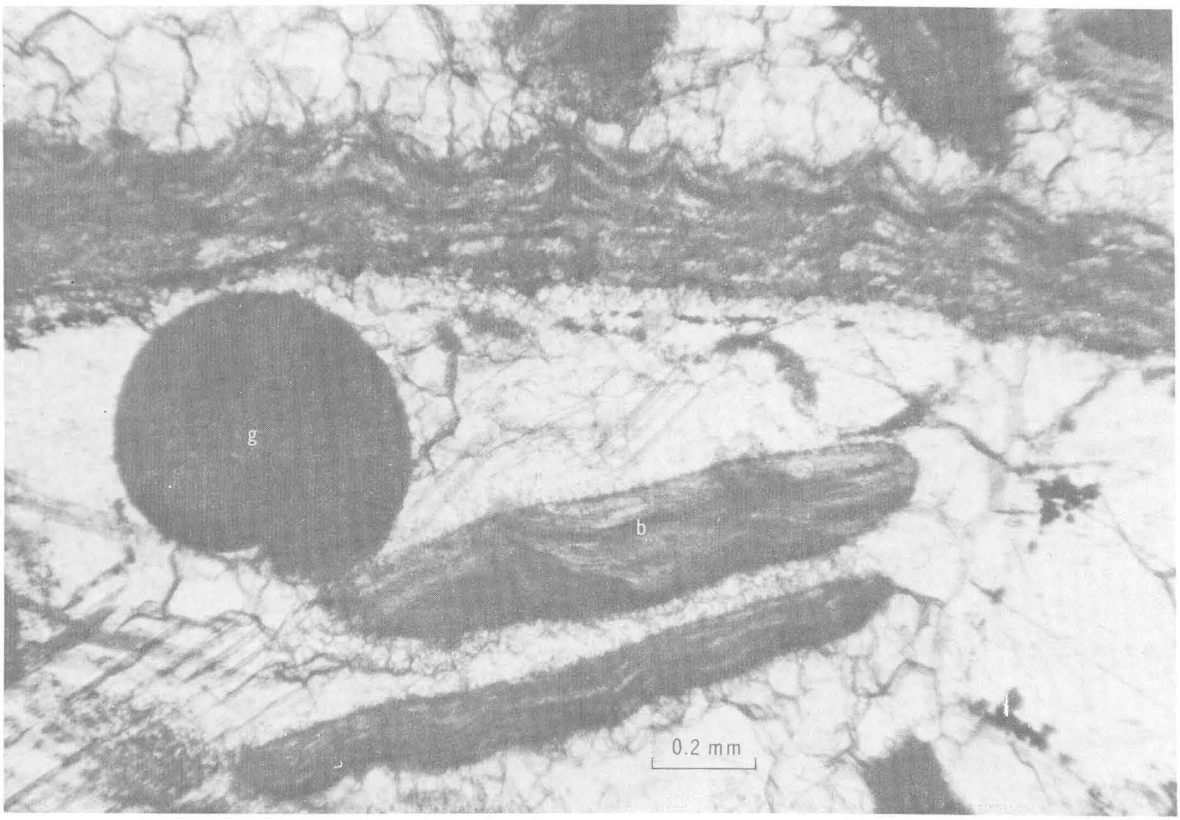

C

FIGURE 14 (left and above).—Photomicrographs of the Grier Limestone Member. *A*, packed biomicrosparrudite; note large bryozoan (by), brachiopod (b), and pelecypod (p) fragments; matrix is microspar. *B*, poorly washed brachiopod biosparrudite. *C*, unsorted biosparite; grains are mostly brachiopods (b); note phosphatic gastropod steinkern (g). Plane-polarized light.

the microspar in the Grier was probably originally in the form of pellets that were subsequently obliterated during diagenesis. The lenticular and nodular beds very closely resemble structure in recent sediments that are attributed to churning by burrowing organisms (Moore and Scruton, 1957) and are evidence of an abundant infauna. Some of the pelecypods were infaunal (John Pojeta, written commun., 1969), but most of the churning must have been by soft-bodied organisms that left no fossil record.

Currents were sufficient to supply oxygen and food to the large fauna of suspension feeders, distribute crinoid columnals, and winnow some of the carbonate mud, but they were too weak to thoroughly comminute and sort the skeletal debris or to remove all of the lime mud. Intermittently, stronger currents winnowed most of the fines to produce beds of unsorted calcarenite and rarely to produce ripple marks. These stronger currents probably resulted from periodic storms.

The water depth cannot be determined accurately. Photosynthesis is at a maximum at depths of 5 to 10 m in average coastal waters and at depths of 10 to 15 m in tropical oceanic waters (Holmes, 1957, p. 122). Suspension feeders are likely to thrive at about the same depths, so that much of the Grier probably accumulated in depths of less than 15 m of water.

The Macedonia Bed was deposited under conditions similar to those for the Logana Member.

OCCURRENCE OF THE PHOSPHATE

The following discussion applies to phosphate of the Millersburg Member as well as to that of the Grier Limestone Member. Phosphate in the Tanglewood Limestone Member is discussed on page 31.

Both the Millersburg and the Grier contain an average of 0.8 percent P_2O_5 (table 2). I do not know any suitable published estimate of the composition of the average limestone, but the P_2O_5 values of nearly all the limestone analyses published by Graf (1960) are less than 0.2 percent and most are

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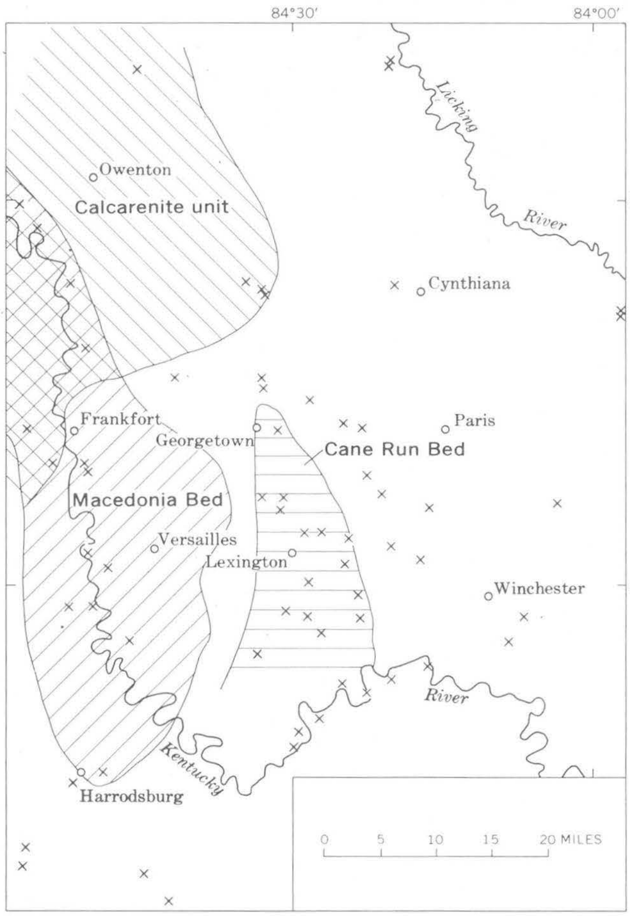

FIGURE 15.—Distribution of subdivisions of Grier Limestone Member of the Lexington Limestone. ×, measured section.

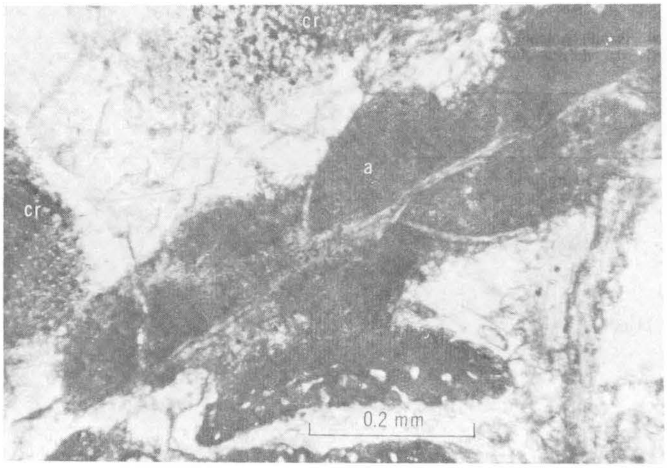

FIGURE 16.—Photomicrograph of limestone from Grier Limestone Member showing cryptocrystalline carbonate-fluorapatite (a) filling bryozoan zooecia. Zooecial walls are calcite. Note apatite filling pores and partly replacing crinoid fragments (cr). Plane-polarized light.

less than 0.1 percent. The Grier and Millersburg, therefore, contain several times more phosphate than most other limestones.

The phosphate occurs as cryptocrystalline carbonate-fluorapatite that gives an X-ray diffraction pattern closely similar to that of carbonate-fluorapatite of the Phosphoria Formation (Permian) of Idaho (R. A. Gulbrandsen, written commun., 1965). It is present as fillings in bryozoan zooecia (fig. 16) and in pores in crinoid plates, and to a lesser extent as gastropod and ostracode steinkerns and as partial replacements of crinoid plates; it is clearly diagenetic. Furthermore, it seems mostly to have filled voids, and only minor replacement of preexisting calcium carbonate has taken place, as indicated by the observation that calcite of the thin zooecial walls of bryozoans generally bear no sign of replacement, even where the chambers are entirely filled with phosphate.

ORIGIN OF THE PHOSPHATE

In the freshly deposited sediments, the sites now filled by apatite were microenvironments occupied by decaying organic matter and at least partly isolated from the surrounding pure water and the overlying sea water. Bacterial decomposition would have released phosphate, supersaturated the water in the local environment, and initiated the precipitation of apatite (Beerstecher, 1954, p. 64). Gulbrandsen (1969, p. 379) suggested that phosphate in a reducing environment, which in the Grier would have been the microenvironments in the skeletal material, might be reduced to phosphite and hypophosphite by bacterial reduction. Both phosphite and hypophosphite are more soluble than phosphate, and Gulbrandsen (1969) further suggested that the concentration of phosphorus in solution could thereby be built up to a concentration well above that which could be held as phosphate. Subsequent oxidation would then result in the precipitation of apatite. A reduction of the pH that commonly results from the microbial decomposition of organic matter in an anaerobic environment (Oppenheimer and Kornicker, 1958) would have prevented the simultaneous precipitation of calcium carbonate. The amount of phosphate released in such a site would account for only a small amount of the apatite eventually deposited there, so diffusion from the surrounding pore water would have been required.

Rocks similar in lithology to the Lexington Limestone and of approximately the same age are present throughout much of the Eastern United States and southern Ontario, but as far as can be judged from the literature, only those of central Tennessee and central Kentucky are unusually phosphatic. Presumably, then, central Tennessee and central Kentucky were supplied with marine waters that contained more phosphate than was needed to support the flora and fauna, whereas elsewhere nearly complete recycling of the phosphate was required to support life. This interpretation, in turn, implies that both central Tennessee and central Kentucky had fairly direct access to waters of the open ocean. Inasmuch as the photic zone is generally depleted in phosphate by organic activity, the water must have been drawn from greater depths. This has implications for paleogeography which will be discussed later.

PERRYVILLE LIMESTONE MEMBER

The Perryville Limestone Member, which occurs in the southwest part of the area, was named by Nickles (1905,p. 15) for Perryville in Boyle County, but the unit was first described by Foreste (1912, p. 32) as follows:

> In Boyle county, and in the southern half of Mercer County, in Kentucky, the top of the Lexington Limestone is formed by a rather coarse-grained, more or less cross-bedded, gray limestone, 4 or 5 feet in thickness, overlying a fine-grained limestone section, about 20 feet thick. The fine-grained limestone forms the Perryville member of the Lexington Limestone. The upper part of the Perryville member, varying from 5 to 8 feet in thickness, is very hard, breaks with a splintery fracture, has a dove color, and frequently is marked with little whitish spots, which caused W. M. Linney to apply the term Upper Birdseye Beds to this part of the Lexington section. Westward at Perryville, Nevada, and Cornishville the underlying part of the Perryville bed is darker, softer, and much more richly fossiliferous. In fact, it is the richest fossil horizon in the Lexington section. Eastward, at Danville, a mile and a half northwest of Faulconer, and near Harrodsburg, this lower part of the Perryville section is whiter and even more richly fossiliferous. It contains the fauna described by Ulrich from the vicinity of Danville and Burgin and forms the Faulconer division of the Perryville.

In addition to naming the Faulconer, Foerste (1912, p. 32) also termed the 4 or 5 feet of beds above the Perryville the Cornishville Limestone. The hard light-colored beds between the Faulconer and Cornishville Limestones were named the Salvisa Member of the Perryville Limestone division of the Lexington Limestone by Miller (1913, p. 329), and the following year, Foerste (1914) included the Cornishville, together with the Salvisa and Faulconer, in the Perryville Limestone.[2] This usage has persisted, although the rank assigned to the Perryville and its constituent units has varied and although there has been considerable confusion about its correlation and extent (McFarlan and White, 1948). None of these authors published measured sections or detailed lithologic descriptions.

Although it is thus difficult to know exactly what the earlier workers intended to include in either the Perryville or its subdivisions, units can be identified in the southwestern part of the area that seem to fit their descriptions. In northwestern Boyle County near the town of Perryville, the Brannon Member, only a few feet thick, is underlain by about 5 feet of nodular-bedded fossiliferous limestone very similar to much of that in the Grier Limestone Member. The nodular beds are underlain by nearly 15 feet of very light gray calcilutite interbedded with brownish-gray calcilutite, both in even beds from several inches to nearly a foot thick. These beds rest on about 40 feet of brownish-gray somewhat fossiliferous calcilutite in rough-surfaced beds. The fossiliferous calcilutite rests on calcarenite that is part of the Tanglewood Limestone Member. The Perryville Limestone Member of the Lexington Limestone, as used herein, includes those beds between the calcarenite of the Tanglewood below and the interbedded calcisiltite and shale of the Brannon Member above. The nodular fossiliferous limestone at the top is the Cornishville Bed, the interbedded light-gray and brownish-gray calcilutite is the Salvisa Bed, and the fossiliferous brownish-gray calcilutite is the Faulconer Bed.[3] I believe these assignments to be consistent with the original definitions.

There is no complete exposure of the Perryville Limestone Member that can serve as a reference section, but exposures of the Cornishville and Salvisa Beds in a quarry 0.4 mile south of Perryville (measured sec. 30B) can serve as a reference section for those units, and exposures in the Boyle County quarry north of Perryville (measured sec. 30A) can serve as a reference section for the Faulconer Bed. Descriptions of these two sections follow.

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[2] Faulconer is in the Danville quadrangle and Salvisa in the Salvisa quadrangle. Neither unit is exposed closed to the locality for which it was named.

[3] The Perryville was first adopted by the U.S. Geological Survey as the Perryville Member of the Lexington (Neuman, 1967, p. 5). The Cornishville Bed and Salvisa Bed were adopted on the basis of mapping by Wolcott and Cressman (1971) who also revised the Perryville Member to Perryville Limestone Member. The Faulconer Bed was adopted on the basis of mapping by Cressman (1972).

Reference section of Cornishville and Salvisa Beds of Perryville Limestone Member of Lexington Limestone

[Measured in small abandoned quarry 0.4 mile south of Perryville on east side of road that meets intersection of U.S. Highways 150 and 68 in Perryville, Boyle County, Ky. (measured sec. 30B). Kentucky coordinates, south zone, E. 2,222,200 ft, N. 478,500 ft. Measured by G. W. Weir and R. C. Greene, 1962, and modified by E. R. Cressman, 1969]

	Thickness (feet)
Lexington Limestone:	
Perryville Limestone Member (incomplete):	
Cornishville Bed:	
Limestone, light-brownish-gray to pale yellowish-brown; nodular beds 2 to 4 inches thick. Contains abundant brachiopods and bryozoans in calcisiltite to fine-grained calcarenite matrix. Overlain by interbedded calcisiltite and shale of Brannon Member	5.0
Total thickness of Cornishville Bed of Perryville Limestone Member	5.0
Salvisa Bed:	
Calcilutite, yellowish-gray; contains blebs of clear calcite about 1 mm in diameter; beds 2 to 6 inches thick; contains scattered pods of coarse white calcite and of white chert	7.5
Calcilutite, medium-brownish-gray to light-olive-gray; weathers light gray with greenish cast; in fairly even beds 2 to 6 inches thick; contains sparse scattered pods of coarsely crystalline brown calcite; fossils common, chiefly brachiopods	3.7
Calcilutite, very light gray; contains abundant blebs and vertical tubes of clear calcite; contains a few ostracodes and brachiopods, but fossils generally sparse. Underlain by irregularly bedded fossiliferous calcilutite of Faulconer Bed. Base of unit is 8 feet above quarry floor	2.3
Total thickness of Salvisa Bed of Perryville Limestone Member	13.5

Reference section of Faulconer Bed of Perryville Limestone Member of Lexington Limestone

[Measured in Boyle County quarry on west side of U.S. Highway 68, 1 mile northeast of its intersection with U.S. Highway 150, north of Perryville, Ky. (measured sec. 30A). Kentucky coordinates, south zone, E. 2,234,100 ft, N. 485,100 ft. Measured by E. R. Cressman, 1969]

	Thickness (feet)
Lexington Limestone:	
Perryville Limestone Member:	
Salvisa Bed (basal part only):	
Calcilutite, grayish-brown, in even beds 0.4 to 0.8 foot thick; contains some ostracodes, gastropods, and cephalopods. Exposed at top of quarry. Grades from unit below	4.0
Incomplete thickness of Salvisa Bed of Perryville Limestone Member	4.0

Reference section of Faulconer Bed of Perryville Limestone Member of Lexington Limestone—Continued

	Thickness (feet)
Lexington Limestone—Continued	
Perryville Limestone Member—Continued	
Faulconer Bed:	
Calcilutite, medium-gray; lower third contains lenses of trilobite and brachiopod(?) debris; upper two-thirds contain abundant colonial corals (probably *Tetradium*), many in growth position; large ostracodes present throughout. Lenses of fossil debris and corals result in nodular structure that contrasts with smooth, even beds of overlying Salvisa Bed	13.5
Calcarenite, medium-gray, very fine grained, bioclastic; laminated; irregular chert layer less than 0.5 foot thick occurred 0.1 foot below top	2.4
Calcarenite, pale-yellowish-brown, very fine to fine-grained, bioclastic; thin shale partings separate irregular to lenticular beds; stromatoporoids 1.8 feet above base; chert nodules 0.5 foot above base. Forms conspicuous light-colored layer in quarry wall	2.8
Calcilutite, brownish-gray; in rough-surfaced beds 0.2 to 1 foot thick; thin irregular shale partings between some beds; some beds have nodular internal structure resulting from lenses of comminuted fossils; some large pelecypods; stromatoporoids 4 feet above base	9.3
Calcilutite, brownish-gray; in lenticular beds 0.2 foot thick; contains stromatoporoids	1.0
Calcilutite, brownish-gray; in rough-surfaced beds mostly 0.4 foot thick; thin irregular shale partings between some beds; contains lenses of comminuted fossil debris; stromatoporoid 4.5 foot above base	11.0
Total thickness of Faulconer Bed of Perryville Limestone Member	40.0
Tanglewood Limestone Member:	
Calcarenite, medium-grained, bioclastic; in even beds 0.3 to 0.8 foot thick and in nodular-bedded units 0.3 to 0.8 foot thick. Some beds contain large bryozoan fragments, but fossils generally are sparse. Base of unit is quarry floor. Grier Limestone Member exposed in stream bed 11 feet below quarry floor	8.0
Incomplete thickness of Tanglewood Limestone Member	8.0

The thickness and extent of the Perryville Limestone Member are shown in figure 17 and the stratigraphic relations of the Perryville to other units of the Lexington are shown in figure 18.

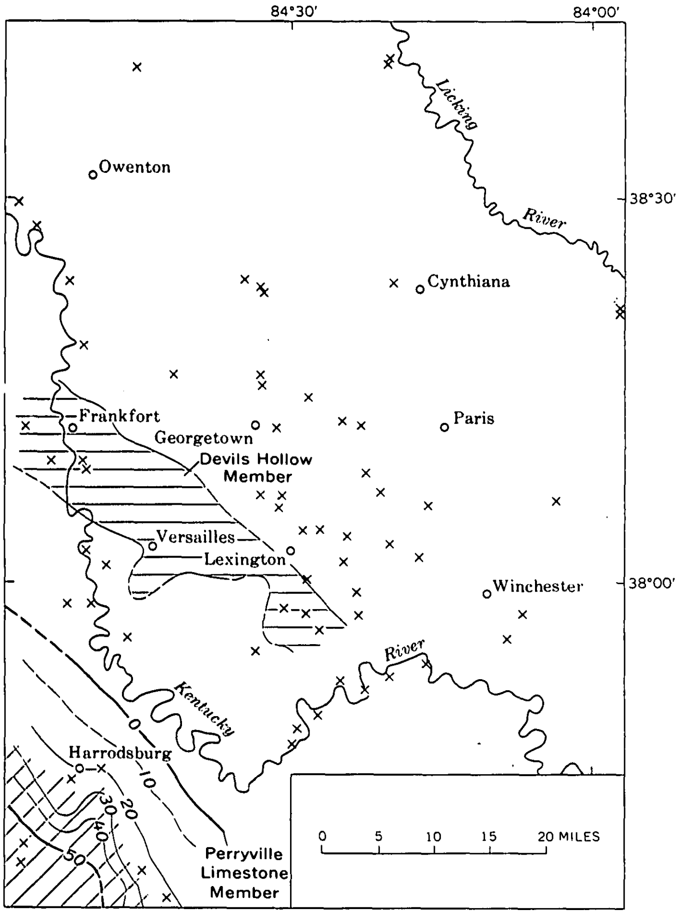


FIGURE 17.—Distribution of Perryville Limestone Member and Devils Hollow Member of Lexington Limestone. Contours show thickness of Perryville Limestone Member; contour interval is 10 feet. Diagonal lines show distribution of Faulconer Bed. Contacts and contours solid where based on mapping; dashed where inferred. ×, measured section.

FAULCONER BED

The Faulconer Bed consists of brownish-gray fossiliferous calcilutite in rough-surfaced beds commonly about 0.5 foot thick (fig. 19). Some beds have a nodular internal structure that is inconspicuous in fresh exposures but becomes more obvious on weathering. Mollusks are the most conspicuous fossils, though brachiopods are present in some beds. Colonial corals, probably *Tetradium*, are common in the upper part and many are in growth position. Stromatoporoids are present throughout, though not in great abundance. Pockets and lenses of small fossil debris are common and probably resulted from burrowing. Many beds have a fetid odor when broken, and thin black shale partings separate some beds. Interbeds of fine-grained calcarenite are present in the unit in much of the Danville quadrangle, particularly near the contact with the underlying Tanglewood Limestone Member.

Microscopically, rocks of the Faulconer Bed consist of ostracodes, pelecypods, and gastropods and less abundant bryozoans, brachiopods, and crinoid plates set in a matrix of micrite and microspar (fig. 20). The fabric ranges from matrix supported to grain supported. Flakes of organic matter are distributed throughout the matrix. The fossils show little breakage and no abrasion, and many ostracodes consist of both valves. Algae (probably *Girvanella*) coat many fossil fragments. There is no obvious sorting, lamination, or orientation. By analogy with recent carbonate sediments, the minute matrix was probably originally pelleted, though only a few indistinct pellets are now visible. In bedding and partly in fossil content, the Faulconer Bed resembles the Grier Limestone Member, but it differs from the Grier in the brownish-gray color of the fresh rock, the more abundant micrite and microspar, the smaller amount of shale and dolomite, the near absence of authigenic apatite, the abundance of algal material, and the relative paucity of bryozoans and crinoid debris.

The Faulconer Bed is 40 feet thick at its reference section; it thins northeastward to a featheredge near Harrodsburg as a result of intertonguing with the Tanglewood Limestone Member (fig. 18).

SALVISA BED

The Salvisa Bed consists of interbedded light-gray to light-olive-gray calcilutite interbedded with brownish-gray calcilutite. The brownish-gray calcilutite is similar to much of that in the Faulconer, and the Salvisa is characterized by the light-gray type. Both types of limestone are only sparingly fossiliferous, ostracodes being the most abundant fossil. The beds range from several inches to more than 1 foot thick and are smooth surfaced and even. The light-gray calcilutite resembles much of the limestone in the Tyrone Limestone. It weathers nearly white, contains specks and small tubes of clear calcite, and breaks with a subconchoidal fracture. The Salvisa contains less than 3 percent dolomite, very little authigenic apatite, and only a few percent of silt and clay.

The following section, measured in an abandoned quarry (fig. 21), illustrates the lithology of the unit in more detail than does the reference section (p. 24).

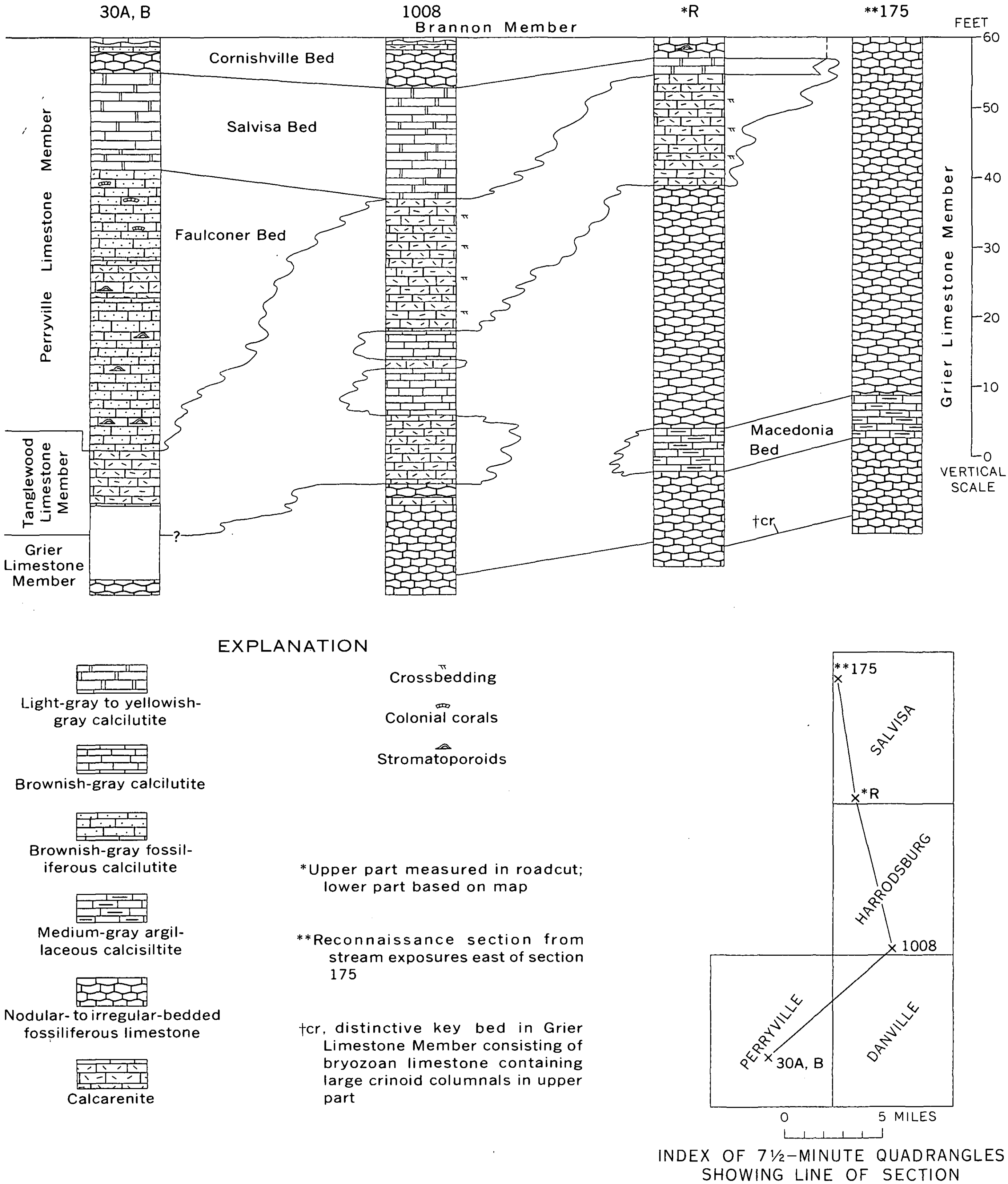


FIGURE 18.—Relation of Perryville Limestone Member to Tanglewood and Grier Limestone Members of Lexington Limestone.

FIGURE 19.—Outcrop of Faulconer Bed of Perryville Limestone Member near Atoka, Danville quadrangle.

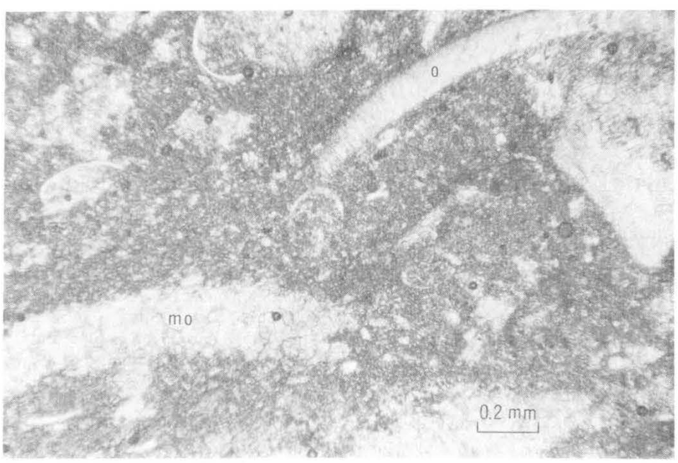


FIGURE 20.—Photomicrograph of packed biomicrite from Faulconer Bed of Perryville Limestone Member. Consists of ostracodes (o) and mollusks (mo) in a micrite matrix. Plane-polarized light.

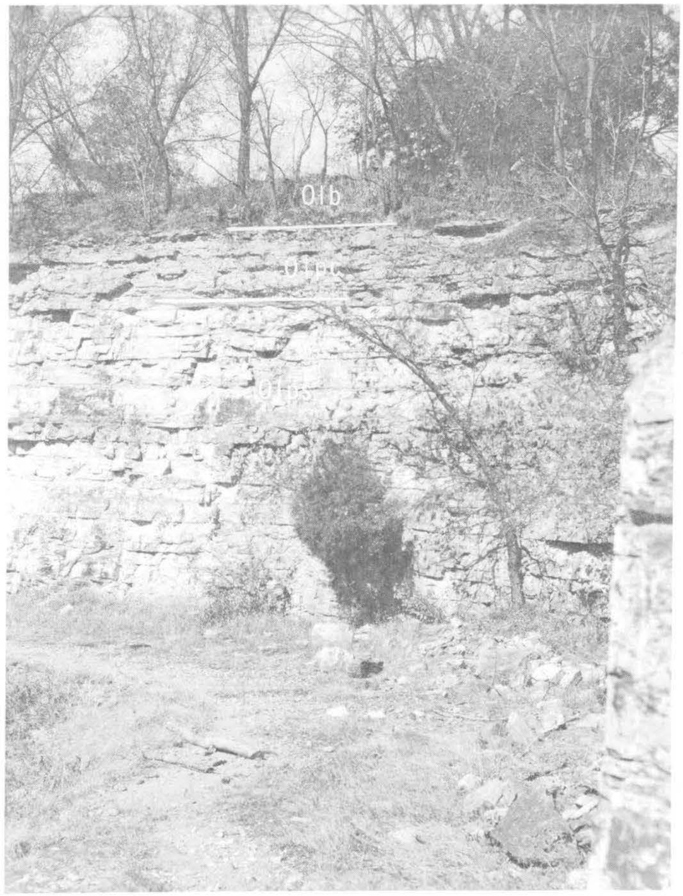


FIGURE 21.—Quarry exposure of part of Perryville Limestone Member near Mud Meeting House in Danville quadrangle (measured sec. 1009). Olb, Brannon Member; Olpc, Cornishville Bed of Perryville Limestone Member; Olps, Salvisa Bed of Perryville Limestone Member. Quarry floor is base of Salvisa Bed.

Section of Salvisa Bed of Perryville Limestone Member of Lexington Limestone

[Measured in abandoned quarry on west side of Dry Branch Road 1.2 miles north of Mud Meeting House, Danville quadrangle, Mercer County, Ky. (measured sec. 1009). Kentucky coordinates, south zone, E. 2,256,850 ft, N. 513,150 ft. Measured by E. R. Cressman, 1969]

	Thickness (feet)
Lexington Limestone:	
Perryville Limestone Member:	
Cornishville Bed not measured.	
Salvisa Bed:	
11. Inaccessible	3.0±
10. Calcilutite, brownish-gray to light-olive-gray; contains inconspicuous irregular partings	1.4
9. Calcilutite, light-gray, slightly glauconitic; in single bed; fossil debris, mostly of ostracodes and gastropods, concentrated in tubes and discontinuous layers; contains some minute vertical tubes of clear calcite that are most abundant at top	1.5

Section of Salvisa Bed of Perryville Limestone Member of Lexington Limestone—Continued

	Thickness (feet)
Lexington Limestone—Continued	
Perryville Limestone Member—Continued	
Salvisa Bed—Continued	
8. Calcilutite, argillaceous, dark-brownish-gray, fetid, laminated	0.5
7. Calcilutite, brownish-gray to olive-gray; contains abundant gastropods and cephalopods and a few fragments of colonial corals (probably *Tetradium*); large calcite-lined vugs in basal foot	0.9
6. Calcilutite, light-gray to light-brownish-gray; contains many small vertical tubes of clear calcite; top of bed channeled by 0 to 0.4 foot of dark-brownish-gray fetid fine-grained calcarenite composed largely of ostracode fragments	1.2
5. Calcilutite, light-gray; forms single laminated bed; top and bottom 0.05 foot are argillaceous; laminae are crinkly	1.2
4. Calcilutite, brownish-gray; contains minute vertical tubes of clear calcite; grades from bed below through a thin breccia zone	0.5
3. Calcarenite, light-gray, fine-grained, slightly glauconitic; shale partings 0.9 and 1.4 foot above base; crosslaminated in part	1.9
2. Calcilutite, light-gray to yellowish-gray; in even beds mostly 0.2 foot thick; bedding surfaces are slightly irregular and inconspicuous; beds grouped in two sets, each about 2 feet thick	4.1
Total thickness of Salvisa Bed of Perryville Limestone Member	9.8
Faulconer Bed (incomplete):	
1. Calcilutite, dark-brownish-gray; in irregularly surfaced beds 0.1 to 0.4 foot thick; some beds have nodular internal structure; contains some colonial corals (probably *Tetradium*). Base of unit is base of exposure	3.5
Incomplete thickness of Faulconer Bed of Perryville Limestone Member	3.5

Microscopically, the light-colored calcilutite ranges from featureless micrite to pelmicrite and pelsparite in which the closely packed micrite pellets average about 40 microns in diameter. The rock grades from micrite to pelmicrite within some thin sections, and most of the micrite was probably originally pelleted. Ostracode valves, oriented parallel to bedding, and a few gastropods may be present, but they are scattered and float in the micrite (fig. 22*A*). Patches of clear sparry calcite are common; some are obviously burrow fillings, but others seem to have resulted from recrystallization of the micrite. Pelsparite (fig. 22*B*) is present locally but is not common. The pellets were occasionally winnowed and transported short distances. Figure 22*C* is a photomicrograph of a sample from a small channel filling at the top of a calcilutite bed. The rock consists of current-deposited ostracode shells and pellets derived by winnowing of a sparsely ostracodal pelmicrite similar to the bed in which it fills channels. The brownish-gray calcilutite consists of a mixture of silt-sized fossil fragments and micrite pellets. The dark color results from disseminated organic matter.

The contact between the Salvisa Bed and the underlying Faulconer Bed is placed at the base of the lowest even-bedded light-gray calcilutite. At the reference section of the Faulconer Bed (p. 24), the contact is less obvious and may be gradational through a thickness of more than 5 feet.

CORNISHVILLE BED

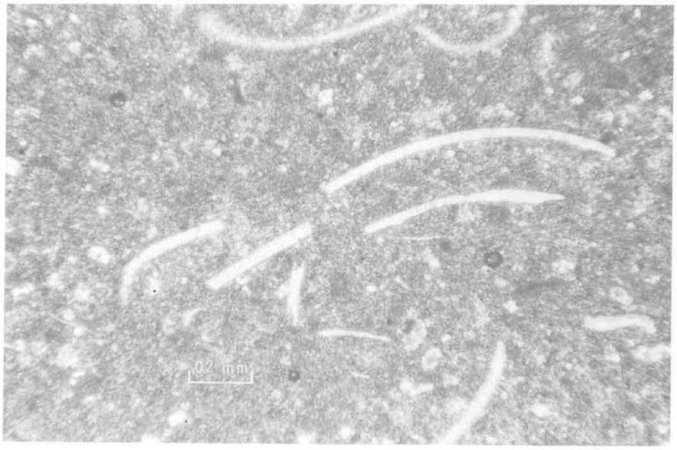
The Cornishville Bed of the Perryville Limestone Member is coextensive with the member. It ranges in thickness from 2 feet to nearly 10 feet. The Cornishville is nearly everywhere overlain by the Brannon Member, though locally the Sulphur Well Member may cut out the Brannon and rest directly on the Cornishville. The contact between the Cornishville Bed and the interbedded calcisiltite and shale of the Brannon is sharp and planar; the contact with the underlying Salvisa Bed is commonly gradational through about 1 foot of thoroughly burrowed rock.

The Cornishville Bed is mostly nodular-bedded calcisiltite and fine-grained calcarenite containing abundant brachiopods and a few bryozoans. Locally it contains beds of crossbedded calcarenites, and stromatoporoids may be common. The unit closely resembles much of the Grier Limestone Member and is actually a tongue of the Grier, but because it is so thin, it is more conveniently considered as part of the Perryville Limestone Member. Near the town of Cornishville, the unit is mostly calcarenite. The name Cornishville is carried as far as the underlying Salvisa Bed can be identified.

ENVIRONMENT OF DEPOSITION

The depositional environment of the Cornishville Bed was similar to that of the Grier Limestone Member (p. 19) and will not be discussed here.

Both the Faulconer and Salvisa Beds were de-



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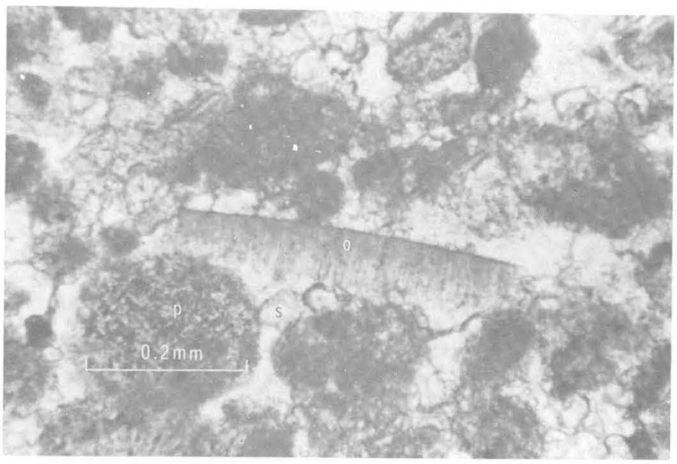

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posited in shallow quiet water. Shallow water is suggested by the fauna in the Faulconer and by the light color of much of the Salvisa. The abundant micrite and lack of sorting are evidence of lack of turbulence. The fauna of the Faulconer Bed would have required marine water of approximately normal salinity, but the restricted fauna—ostracodes and gastropods—of most of the Salvisa Bed suggest more saline water.

The Perryville Limestone Member is separated from the temporally equivalent upper half of the Grier Limestone Member to the north by calcarenite (fig. 18). Thus, the shallow quiet water in which the Perryville was deposited was separated from the more agitated water to the north by a zone of calcarenite bars. The lack of authigenic phosphate in the Perryville is evidence that the area south of the bars did not connect directly with deeper waters of the sea as did the area of Grier deposition, and the bars must have restricted the interchange of water. In Faulconer time, the rate of interchange was sufficient to maintain normal marine salinity in the Perryville area, but in Salvisa time the circulation was more restricted, and higher salinities resulted south of the bars.

REGRESSIVE SEQUENCES

In several exposures in the Danville quadrangle, the Salvisa Bed consists of two regressive sequences. In the measured section along Dry Branch Road (p. 27), the lower sequence begins with the dark-brownish-gray calcilutite of the Faulconer Bed (unit 1), passes upward through light-colored calcarenite and calcilutite and terminates with the breccia of unit 4 and the laminated bed of unit 5. The upper sequence begins with the calcilutite and dark-colored ostracodal calcarenite of unit 6 and passes upward to light-colored calcilutite of units 9 and 10; the top is inaccessible in the quarry (unit 11), but elsewhere it consists of a light-colored laminated bed that at least locally contains some breccia. The uppermost 1 or 2 feet of the Salvisa Bed and the overlying Cornishville Bed record a transgression that culminated in deposition of the Brannon Member. The laminae and breccia at the top of each of the two cycles are typical of intertidal deposits, whereas the light-colored calcilutite, pelletal in part, is typical of shallow subtidal deposits in

FIGURE 22 (left).—Photomicrographs of the Salvisa Bed of the Perryville Limestone Member. *A*, sparse ostracode biomicrite. *B*, pelsparite; o, ostracode fragments; p, micrite pellet; s, sparry calcite cement. *C*, ostracode biopelmicrite; o, ostracode fragments; p, elongate micrite pellet. Plane-polarized light.

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areas of restricted circulation and high salinity such as parts of Florida Bay. The dark beds at the base of each sequence contain corals and mollusks and were deposited in less restricted water of approximately normal salinity.

Pelletal limestones generally show little evidence of compaction (Beales, 1965, p. 52). Therefore, if each regressive sequence in the Salvisa Bed represents sediment filling of the basin during a stand of sea level, the depth of water during deposition is approximated by the distance of a bed below the intertidal deposits at the top of each sequence. Thus the dark calcilutites were deposited in about 5 and 6 feet of water for the upper and lower sequences, respectively, and the light-pelleted calcilutites were deposited in depths of 0 to 6 feet.

TANGLEWOOD LIMESTONE MEMBER

DEFINITION

The Tanglewood Limestone Member is an extensive irregular body of bioclastic calcarenite that makes up much of the upper part of the Lexington Limestone in the Inner Blue Grass region (Black and others, 1965, p. 21). The member was named for a suburb of Frankfort, and the type section is exposed in roadcuts along Interstate Highway 64 near the Frankfort-Lawrenceburg interchange (measured sec. 88). The Tanglewood intertongues complexly with other members of the upper Lexington Limestone and with the lower part of the Clays Ferry Formation; any body of calcarenite that can be shown or reasonably inferred to be continuous with the Tanglewood of the type section is considered a tongue of the member.

CONTACTS

Because of the intertonguing of the Tanglewood Limestone Member with other units, the contact relations are too complex to describe briefly, and readers are referred to the stratigraphic sections (pls. 1–7). In general, where tongues of the Tanglewood rest directly on fossiliferous limestone of the Grier Limestone Member and on nodular fossiliferous limestone and shale of the Millersburg Member of the Lexington, the contact is gradational through a foot or so, but where it rests on calcisiltite and shale of the Brannon Member of the Lexington or on tongues of the Clays Ferry Formation, the contact is generally sharp and planar. Where a tongue of the Tanglewood is overlain by nodular fossiliferous limestone and shale of the Millersburg Member, the contact may be gradational through as much as 5 feet, but where the Tanglewood is overlain by the Clays Ferry Formation, the contact is generally sharp and planar.

LITHOLOGY

The Tanglewood Limestone Member typically consists of pinkish-gray medium-grained well-sorted bioclastic calcarenite, but, as with other members of the Lexington Limestone, there is considerable variation. Though the color is most commonly pinkish gray to light gray, it sometimes may be medium gray and brownish gray, and though most of the member is medium grained, it ranges from very fine to very coarse grained. Fossils and large fossil fragments are uncommon, but some beds of medium-grained calcarenite contain abundant bryozoan fragments as much as 20 mm in diameter, and silicified brachiopods may be common near contacts with the Millersburg and Stamping Ground Members and the Greendale Lentil.

Beds in the Tanglewood, mostly 0.2 to 1 foot thick, are generally smooth surfaced and planar to wavy, contrasting markedly with rough-surfaced beds of the Grier Limestone Member. Many beds contain alternating more and less phosphatic laminae from less than 1 to 5 mm thick. Low-angle, small- to medium-scale crossbedding is common (fig. 23). The crossbedded sets are mostly wedge shaped or planar. Sets are generally 3 to 5 inches thick, but some are as much as several feet thick (S. V. Hrabar, oral commun., 1970). Crossbedded units, though conspicuous, make up only 10 to 25 percent of the volume of the Tanglewood.

MINERALOGY AND PETROGRAPHY

The five analyzed samples of the Tanglewood Limestone Member averaged 74 percent calcite, 13 percent dolomite, 6 percent apatite, and 5 percent quartz and clay (fig. 3). These values are probably close to the average composition of the member. The composition varies considerably among samples, particularly in apatite content. The five analyzed samples ranged from less than 1 to 16 percent apatite, and the range would be greater for smaller samples. Samples from the other members are fairly uniform in phosphate content.

Microscopically, limestone of the Tanglewood typically is sorted and rounded biosparite (fig. 24). Allochems are mostly abraded crinoid, bryozoan, brachiopod, and ostracode fragments. Pellets of probable fecal origin are rare but compose a large part of a few samples. The sparry calcite cement is medium to very coarsely crystalline and is in optical continuity with calcite in adjacent or included crinoid fragments. The rock is thoroughly cemented, and porosity is negligible.

PHOSPHATE CONTENT

Calcarenites are the most phosphatic rocks of the Lexington Limestone. Near Lexington, the Tanglewood Limestone Member averages 2.4 percent P_2O_5, whereas the Grier Limestone, Brannon, and Millersburg Members average about 0.8 percent. The phosphate content of the calcarenites varies greatly from bed to bed and from lamina to lamina. The concentration of apatite in certain laminae is clear evidence that the phosphatic grains in the calcarenite facies were concentrated by currents.[4] The apatite in the Tanglewood is present as fillings of bryozoan zooecia, as fillings in pores in crinoid plates, as minute gastropod steinkerns (fig. 24*C*), and as replacements of crinoid fragments (fig. 24*B*). Thus phosphate occurs in the same manner in calcarenite of the Tanglewood as it does in the fossiliferous limestone and nodular fossiliferous limestone and shale facies of the Lexington, but it differs from that of the other facies in that the grains are abraded and sorted and replacement is more advanced. The apatite grains in the calcarenite, like the carbonate grains, were reworked from a sediment similar to that of the Grier Limestone Member and the Millersburg Member. Replacement of the skeletal grains by apatite has proceeded farther in the calcarenite than in the parent sediments; this suggests that the carbonate sand was worked and reworked intermittently over long periods.

THICKNESS AND EXTENT

The Tanglewood Limestone Member is present throughout all but the northernmost part of the area (fig. 25). In general, the Tanglewood is between 60 and 100 feet thick in a broad band extending eastward from Frankfort and Versailles; it thins northward, westward, and southward from this central belt but thickens again south of Harrodsburg.

The distribution and variations in thickness of the Tanglewood Limestone Member result from the intertonguing of the Tanglewood with the Perryville, Grier, Brannon, Sulphur Well, and Millersburg Members of the Lexington Limestone and with the lower part of the Clays Ferry Formation. The complex intertonguing is illustrated on plate 7. In general, the Tanglewood resembles a series of lenses of various sizes stacked en echelon with successively higher units to the east.

SUBDIVISIONS

The only named subdivision of the Tanglewood Limestone Member is the Nicholas Bed. The Nicholas was originally named by Foerste (1909, p. 294) for Nicholas County. Measured section 173 was measured in the type area. Black, Cressman, and MacQuown (1965) placed the unit in the Lexington Limestone as the Nicholas Limestone Member. Lithologically, the Nicholas cannot be distinguished from the Tanglewood Limestone Member, and it merges southwestward with other tongues of the Tanglewood; therefore, in this report the rank of the Nicholas is reduced to that of bed and it is included in the Tanglewood. The maximum thickness of the Nicholas Bed in sections measured for this report is 43 feet at section 173; however, W. F. Outerbridge (oral commun., 1973) has found it to be at least 80 feet thick in the east-central part of the Millersburg quadrangle. The age of the Nicholas is changed from Middle Ordovician to Late Ordovician.

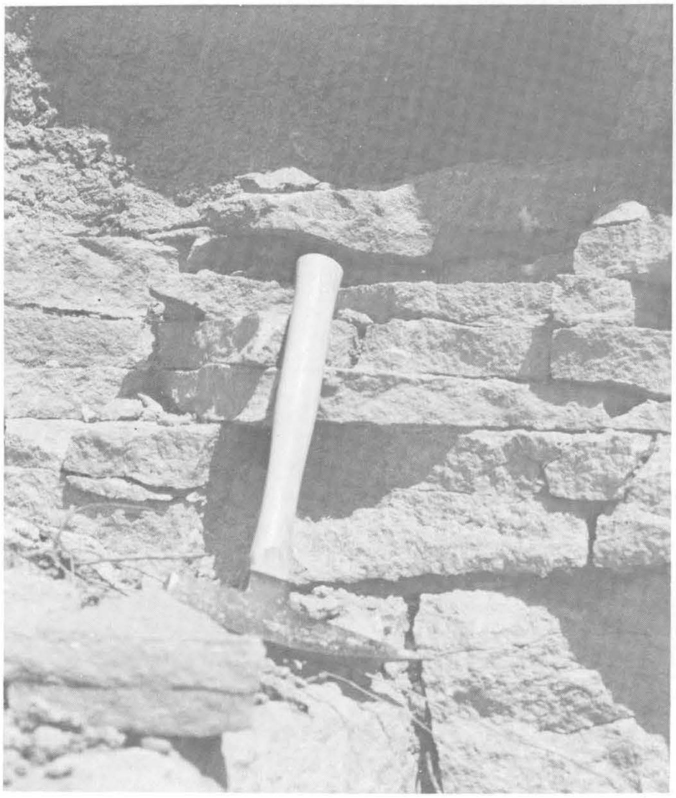
In parts of the Frankfort West, Frankfort East, and Versailles quadrangles, the Devils Hollow Member is separated from calcarenite of the Tanglewood Limestone Member by a unit as much as 5 feet thick that is informally designated the *Constellaria* bed. The *Constellaria* bed consists of calcareous, dolomitic shale containing a great profusion of large bryozoan fragments, *Constellaria* being the most conspicuous. In surface exposures, the argillaceous matrix weathers rapidly and the outcrop is strewn with loose bryozoans. Although this bed is lithologically unlike the rest of the Tanglewood Limestone Member, it is, because of its thinness and limited extent, included in the Tanglewood.

ENVIRONMENT OF DEPOSITION

The broken and rounded skeletal fragments, the generally good sorting, the abundant sparry calcite cement, the lack of clay and silt, and the common crossbedding all indicate that bioclastic calcarenite of the Tanglewood Limestone Member was deposited in very shallow, turbulent water. The grains are mostly fragments of bryozoans, crinoids, and brachiopods which do not usually thrive in the high-energy environment required by the texture and structure of the calcarenite. Therefore, the organic material was brought in from elsewhere—presumably from less agitated water where the Grier Limestone and Millersburg Members were accumulating—and was broken, abraded, and sorted in the area of calcarenite deposition.

Crossbedding in the calcarenite resembles the accretion deposits described by Imbrie and Buchanan (1965, p. 164) in calcarenites of the Bahamas; the dip of the cross strata is much less than 30°, there is no obvious sorting within beds and

[4] Smith and Whitlatch (1940, p. 42) reached the same conclusion for phosphate in the Bigby Limestone of Tennessee, which is approximately the same age as, and of similar lithology to, the calcarenite of the Lexington.



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B

FIGURE 23 (above and facing page).—Exposures of Tanglewood Limestone Member of Lexington Limestone. *A*, upper part of member in roadcut on U.S. Highway 60 about 1.8 miles south of interchange with Interstate Highway 64, Franklin County. *B*, crossbedding a few feet above the top of the Brannon Member in roadcut on U.S. Highway 60 about 2½ miles north of Versailles. *C*, crossbedding and ripple bedding about 10 feet above top of Brannon Member in roadcut on U.S. Highway 62 near entrance to J. T. S. Brown Distillery, Anderson County.

sets, and the sets are generally less than 6 inches thick. Imbrie and Buchanan (1965) ascribe this crossbedding in the Bahamas to deposition from high-velocity currents. Hrabar, Cressman, and Potter (1971) found crossbedding in the Tanglewood to be bimodal, and the modes are approximately perpendicular to the local isopach of the Tanglewood. They interpret the bimodality as the result of deposition by tidal currents. Some beds have been burrowed, and others that have no obvious internal structure may have been homogenized by burrowing after stabilization of the lime sand.

Much of the calcarenite was cemented soon after deposition. In roadcuts (measured sec. 176) along the Bluegrass Parkway on the west side of the Kentucky River, large blocks of calcarenite apparently slumped or slid into the underlying partly consolidated Brannon Member and were then eroded to a planar upper surface on which the Sulphur Well Member of the Lexington was deposited (fig. 26). Bedding within the block of calcarenite shows little distortion, and the calcarenite must have been at least partly cemented before slumping. Other similar examples are seen in measured sections 88 and 179.

In many areas, the calcarenite rests in planar contact on argillaceous calcisiltite in which the bedding is contorted. The contorted calcisiltite may be either the top of an interval of interbedded calcisiltite and shale or a single bed separating calcarenite from fossiliferous limestone below. The Cane Run Bed of the Grier Limestone Member is the most conspicuous example of the latter. McKee and Goldberg (1969) have shown experimentally that convolute bedding can be produced in clays when overlying sands are deposited either irregularly or with a tangential component. By analogy, the contorted bedding in calcisiltite beneath calcarenites in the Lexington probably resulted from calcarenite bars migrating across the top of the finer grained sediment. In the case of the contorted calcisiltite of the Cane Run Bed and other similar unnamed beds, the

C

calcisiltite probably was formed from fine skeletal material winnowed from and subsequently overridden by the calcarenite bars.

BRANNON MEMBER

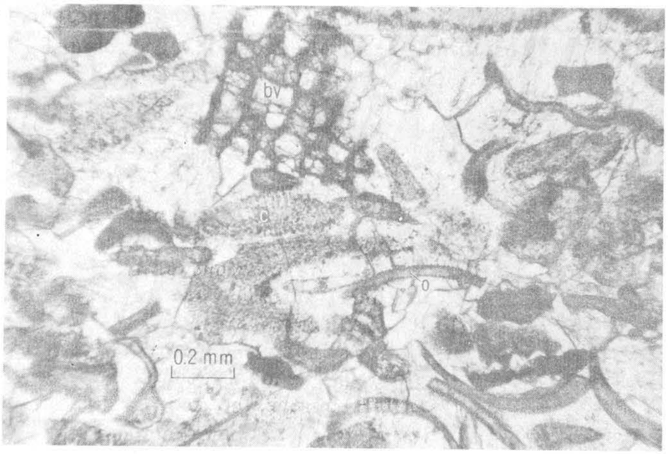
DEFINITION

The Brannon Member is a distinctive unit of interbedded calcisiltite and shale, as much as 30 feet thick, in the middle of the Lexington Limestone in the area from Frankfort, Lexington, and Winchester south to and beyond the Kentucky River. The base of the Brannon ranges from 180 feet above the base of the Lexington in the Salvisa quadrangle to 200 feet above the base of the Lexington in the Hedges quadrangle. The member was named by Miller (1913, p. 324) for Brannon Station in the Nicholasville quadrangle.

CONTACTS

Throughout most of its area of exposure, the Brannon Member is both underlain and overlain by the Tanglewood Limestone Member of the Lexington. Locally, the sub-Brannon tongue of the Tanglewood is absent through intertonguing with the Grier Limestone Member, and the Brannon rests directly on the Grier. In the southwest part of the report area, the Brannon rests on the Cornishville Bed of the Perryville Limestone Member. Where the subjacent unit is a tongue of the Tanglewood Limestone Member, the Brannon is separated from the well-sorted bioclastic calcarenite typical of the Tanglewood by 2 to 5 feet of irregularly bedded, poorly sorted fossiliferous limestone that is similar to the Grier but is included in the Tanglewood because of its thinness. The basal contact of the Brannon is either sharp and planar or gradational through a few inches. Black, Cressman, and MacQuown (1965, p. 21) described a thin bentonite just above the base of the Brannon at one locality in the Versailles quadrangle, one in the Lexington West quadrangle, and three in the Coletown quadrangle and suggest that the base of the member is nearly isochronous.

A tongue of the Tanglewood Limestone Member overlies the Brannon Member over most of the area, but south of a line extending from the northwest corner of the Salvisa quadrangle through the Keene quadrangle to the northwest corner of the Valley View quadrangle the Brannon is overlain by irregularly bedded, somewhat argillaceous, bryozoan limestone of the Sulphur Well Member of the Lexington. The upper contact between the Brannon and the Tanglewood is apparently conformable and is locally



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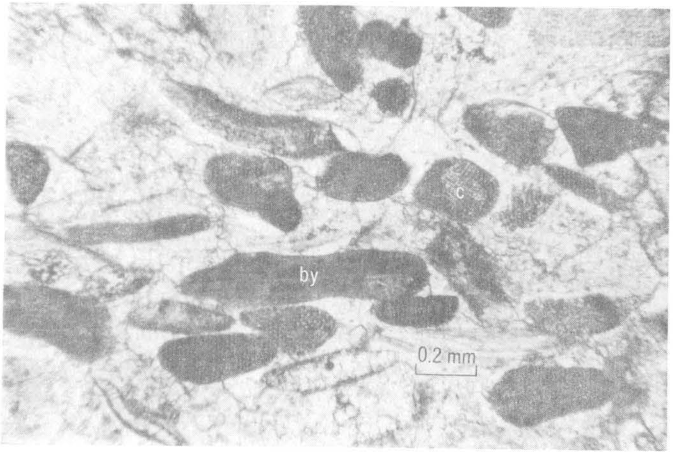

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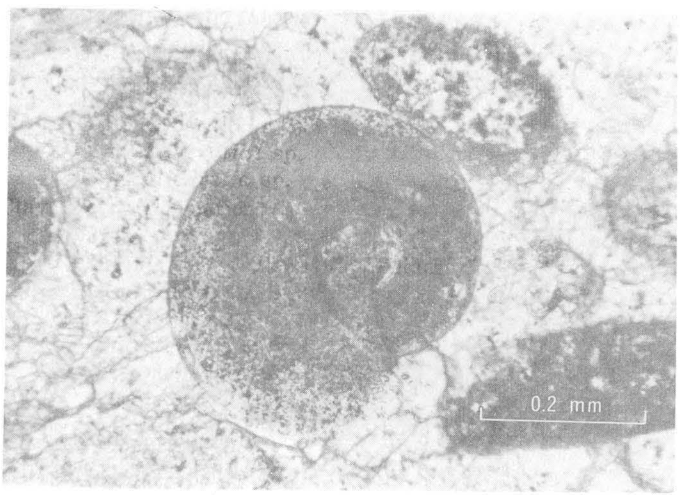

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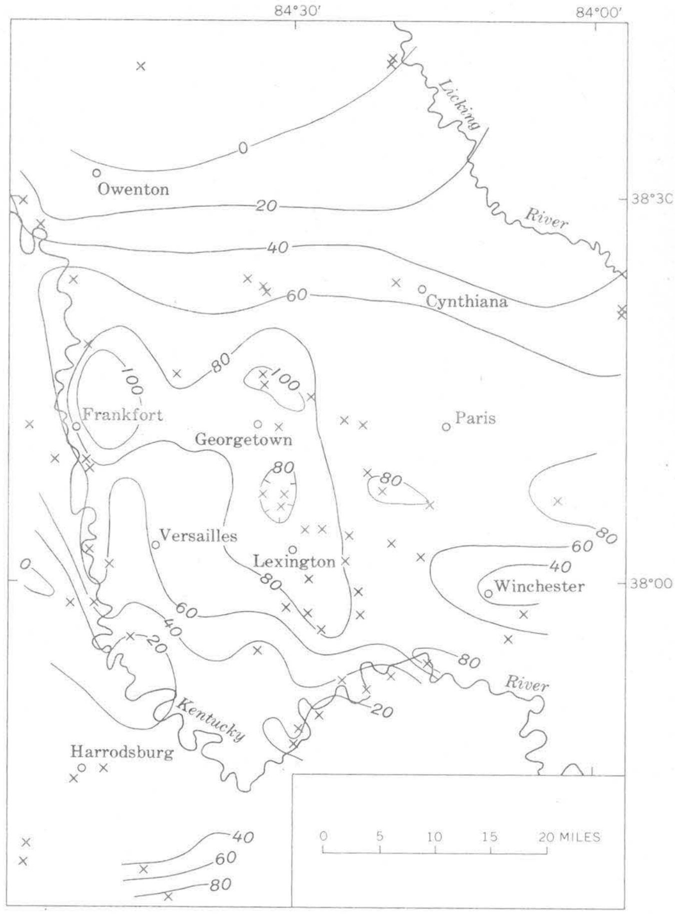


FIGURE 25.—Isopach map of Tanglewood Limestone Member of Lexington Limestone. Contour interval 20 feet; ×, measured section.

gradational through a few feet. In places ball-and-pillow structure common in the uppermost Brannon also involves the lowermost beds of the Tanglewood.

Where the Brannon is overlain by the Sulphur Well Member, the contact also seems conformable, but evidence in the Salvisa quadrangle suggests that the contact is actually a disconformity. The Brannon Member there thins southwestward from 20 feet to 2 or 3 feet in a distance of 2½ miles; the overlying Sulphur Well Member maintains a thickness of 25 to 30 feet over the same distance, and there is no

FIGURE 24 (left).—Photomicrographs of biosparites from Tanglewood Limestone Member. *A*, biosparite composed of broken and abraded crinoid (c) and bryozoan (by) fragments and ostracode valves (o). *B*, biosparite composed largely of broken and abraded partly phosphatized crinoid fragments (c). Calcite inclusions in individual phosphatized crinoid fragments show common extinction and are in optical continuity with surrounding calcite cement. Note bryozoan fragment (by) with apatite-filled zooecia. *C*, phosphatic steinkern of a minute gastropod. Plane-polarized light.

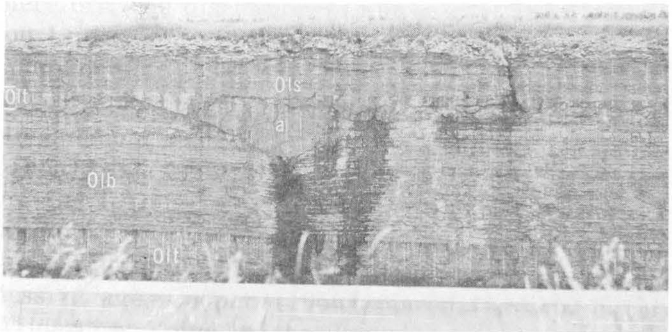


FIGURE 26.—Roadcut exposure on Bluegrass Parkway west of Kentucky River (Salvisa quadrangle) showing tilted block of calcarenite in upper part of Brannon Member of Lexington Limestone. Ols, Sulphur Well Member; a, calcarenite block; Olb, Brannon Member; Olt, tongue of Tanglewood Limestone Member.

FIGURE 27.—Outcrop of Brannon Member of Lexington Limestone showing the characteristic interbedding of calcisiltite and shale. Note lensing bed about 2 feet above the hammer. Roadcut on Bluegrass Parkway about 1 mile east of Lawrenceburg interchange, Anderson County.

intertonguing between the two members or between the Sulphur Well and the overlying unit. Furthermore, the thickness and distribution of the Brannon south of the Kentucky River is irregular and cannot be interpreted in terms of facies change. Locally, the basal bed of the Sulphur Well Member contains pebbles of calcisiltite similar to that of limestone of the Brannon Member. One such exposure is in a roadcut of U.S. Highway 150 on the eastern outskirts of Perryville.

LITHOLOGY

The Brannon Member characteristically consists of interbedded argillaceous calcisiltite and shale in nearly equal amounts. The calcisiltite is medium to light gray and is generally in smooth-surfaced tabular beds 0.2 to 0.3 foot thick, although some beds are lenticular (fig. 27). The shale is calcareous and is dark to medium gray in fresh exposures. Fossils are sparse, but a few thin-shelled brachiopods may be present on the surface of limestone beds. On uplands, the Brannon weathers to a clayey soil containing abundant porcelaneous to porous and punky chert fragments.[5] On steeper slopes near the major drainages, the position of the Brannon Member is marked by smooth-surfaced light-gray calcisiltite slabs.

Throughout much of the area, the uppermost beds of the Brannon Member are contorted. There are two types of disturbed bedding. The most common type is similar to the ball-and-pillow structure (fig. 28) illustrated by Pettijohn and Potter (1964, pl. 101–103). In places the structure involves the basal beds of the overlying Tanglewood Limestone Member; elsewhere, the contorted zone is entirely in the Brannon and is separated from the Tanglewood by several feet of horizontally bedded calcisiltite and shale. Some of the pillows contain small irregular chart nodules.

The second type of disturbed bedding consists of layers as much as several feet thick of rounded equant pebble-sized fragments of calcisiltite in an argillaceous limestone or calcareous shale matrix. This type may be seen in several roadcuts on the Bluegrass Parkway between measured section 176 and the Lawrenceburg interchange. In places, fragments from the underlying beds are incorporated in the base of the pebbly layers, and resistant beds below may be broken and imbricated or in the form of ball-and-pillow structure. The pebbly layers commonly cut the underlying beds at low angles. The extent of individual pebbly layers is not known, but they are definitely discontinuous and lense out in some exposures. The imbrication of resistant beds below the pebbly layers and the complete disruption of bedding within these layers suggests that they formed by viscous flow, possibly triggered by rapid deposition of calcarenite on top of a sequence of interbedded unconsolidated lime silt and terrigenous mud.

PETROGRAPHY AND MINERALOGY

Microscopically, the calcisiltite consist of coarse silt-sized and very fine sand-sized skeletal fragments,

[5] Campbell (1898), misled by this abundant chert residuum, included the Brannon and some of the overlying beds in his Flanagan Chert.

FIGURE 28.—Ball-and-pillow structure in Brannon Member of Lexington Limestone. Beds above hammer are contorted whereas those below are planar and continuous. Roadcut exposure on U.S. Highway 60 about 2 miles north of Versailles.

mostly of brachiopods and crinoids, set in a matrix of microspar. The microspar anhedra are mostly 10 to 20 microns in diameter. Dolomite rhombs as large as 80 microns across are scattered through the matrix, and chemical analyses (table 2) indicate that dolomite makes up about one-third of the total carbonate (fig. 3).

Clay and scattered quartz silt are also present. The ratio $SiO_2:Al_2O_3$ for the five samples of the Brannon in table 2 ranges from 3.6 to 7.2 compared with 3.1 to 3.5 for the samples of the Millersburg Member of the Lexington and the lower part of the Clays Ferry Formation, the two other argillaceous units that were sampled. This relation, together with the cherty residuum commonly derived from the Brannon, suggests that much of the silica in the Brannon is authigenic and disseminated.

An X-ray diffraction pattern of a shale sample from the Brannon Member shows it to consist of both chloritic and illitic clays, quartz, dolomite, and small amounts of potassium feldspar (J. J. Connor, written commun., 1967).

THICKNESS AND EXTENT

The Brannon Member thins both northeastward and southwestward from a maximum of a little more than 30 feet a few miles south of Versailles and at Clays Ferry (measured sec. 22) (fig. 29). The northeastward thinning results largely from intertonguing of the Brannon with part of the Tanglewood Limestone Member. Black, Cressman, and MacQuown (1965, p. 21) note that near its north edge near Wallace in the northern part of the Versailles quadrangle, in roadcuts on the bypass north of Versailles Road in Lexington, and in the reference section (measured sec. 86) of the Lexington Limestone, the Brannon is divided into two tongues separated by a tongue of the Tanglewood. Elsewhere, intertonguing is at too small a scale to be detected in mapping. In the Georgetown and Lexington East

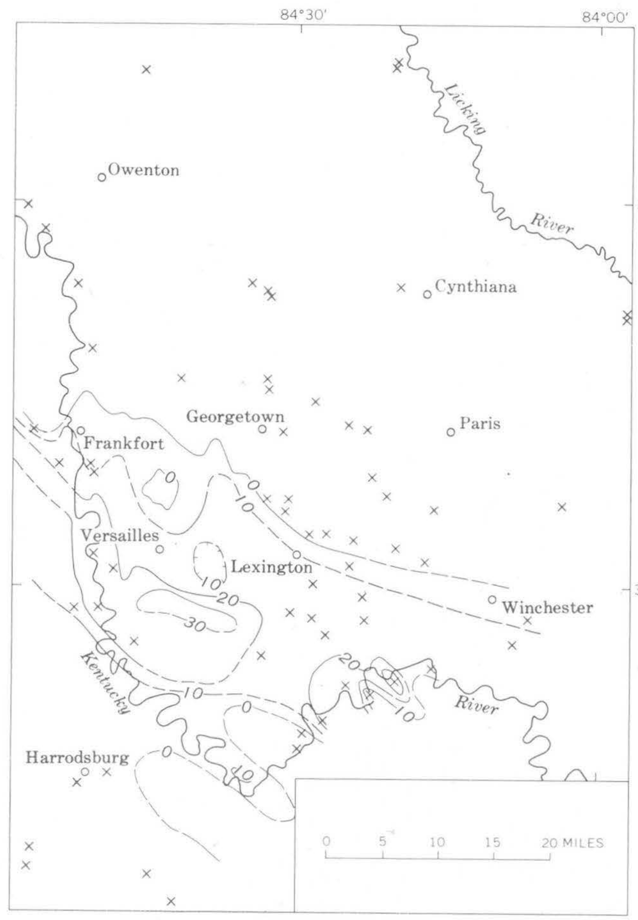


FIGURE 29.—Isopach map of Brannon Member of Lexington Limestone. Contour interval 10 feet; solid where based on mapping, dashed where inferred; ×, measured section.

quadrangles, the Brannon passes northward into a belt 1 mile or so wide of calcarenite containing very abundant silicified bryozoans, and it then passes into well-sorted calcarenite. Elsewhere the Brannon may pass directly into well-sorted calcarenite. As discussed earlier, the southward thinning of the Brannon may have resulted from erosion before deposition of the overlying unit.

ENVIRONMENT OF DEPOSITION

The Brannon Member is very similar in lithology to the interbedded calcisiltite and shale of the Logana Member, and the depositional environment must also have been similar; that is, the depth of water was mostly below wave base and below the compensation depth which is assumed to have been about 25 m (p. 17). Periods of greater turbulence winnowed fine bioclastic debris from shallower areas, and the winnowed material was deposited in the deeper water to form the calcilutites.

SULPHUR WELL MEMBER

In the southwest part of the report area, the Brannon Member of the Lexington Limestone, where present, is overlain by as much as 35 feet of bryozoan limestone in irregular to lenticular beds that are separated by thin shale beds and partings. This unit was named the Sulphur Well Member of the Cynthiana Formation by McFarlan (1943, p. 20–22) and was subsequently assigned to the Lexington Limestone by Cressman (1968). The type area is in the Little Hickman quadrangle.

Where the Brannon Member is absent, as in much of the Little Hickman quadrangle, the Sulphur Well Member rests on a lower tongue of the Tanglewood Limestone Member or, in some localities, on the Grier Limestone Member. It is overlain by the Clays Ferry Formation (measured sec. 180). The contact of the Sulphur Well Member with the underlying unit—whether Brannon, Tanglewood, or Grier—is sharp and nearly planar. The contact with interbedded limestone and shale of the overlying Clays Ferry Formation is sharp and conformable in the area from Harrodsburg north, but farther east the contact is gradational, passing from bryozoan limestone below to bryozoan-rich shale above.

Limestone of the Sulphur Well Member is mostly poorly sorted bryozoan calcirudite containing much silt- and clay-sized calcite and dolomite matrix. The color is light gray and light olive gray to medium gray. Bryozoans are present throughout the limestone but are most abundant on bedding surfaces. The limestone occurs as lenticular and irregular beds, mostly a few inches thick. The beds are separated by irregular partings and thin irregular beds of shale containing closely packed bryozoan fragments, many as large as 1 inch across, oriented parallel to the bedding (fig. 30). Brachiopods are present, but not abundant, and in parts of the Little Hickman quadrangle, stromatoporoids occur near the base. In general appearance, the Sulphur Well resembles parts of the Grier Limestone Member, differing from the Grier chiefly in the profusion of large bryozoans and in the paucity of other fossils.

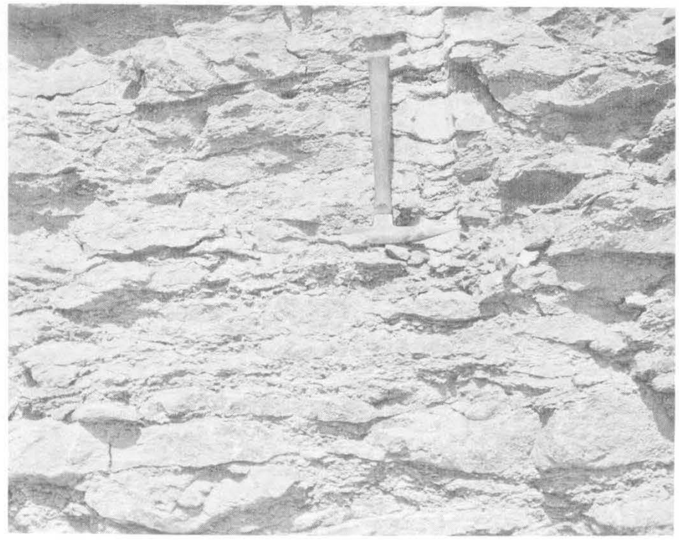


FIGURE 30.—Outcrop of Sulphur Well Member of Lexington Limestone showing lenticular bedding separated by irregular partings and thin irregular beds of shale containing abundant closely packed bryozoan fragments. Roadcut at Lawrenceburg interchange of Bluegrass Parkway, Anderson County.

The extent of the Sulphur Well Member in the report area is shown in figure 31. In its northernmost exposures, the member is about 35 feet thick; from there it grades northward into part of the Tanglewood Limestone Member (pl. 7, *A–A′*, *B–B′*, and *F–F′*). The Sulphur Well thins southward from the maximum thickness of 35 feet to less than 10 feet near Harrodsburg, apparently by the grading of the upper part laterally into bryozoan shale of the basal Clays Ferry Formation.

ENVIRONMENT OF DEPOSITION

The Sulphur Well Member was deposited under conditions similar to those described for the Grier Limestone Member. It accumulated below surf base, mostly at depths of less than 15 m, in moderately turbulent normal marine water. It is uncertain what environmental factors caused the great abundance of bryozoans.

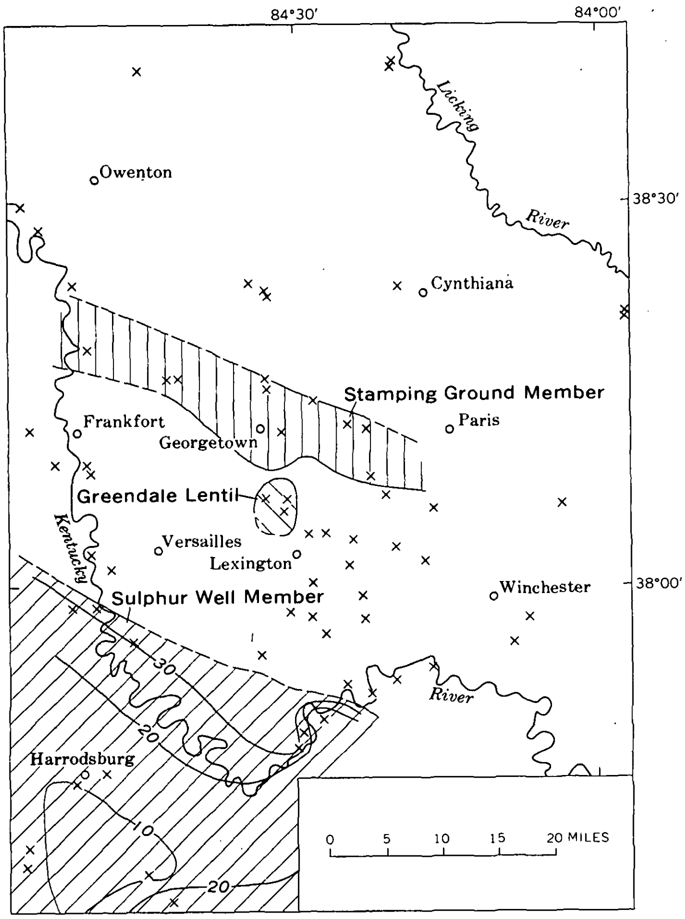


FIGURE 31.—Extent of Sulphur Well Member, Stamping Ground Member, and Greendale Lentil of Lexington Limestone. Line showing edge of members solid where based on mapping, dashed where inferred. Contour interval in Sulphur Well Member, 10 feet; ×, measured section.

STAMPING GROUND MEMBER

A unit of fossiliferous nodular limestone and shale, as much as 15 feet thick, stratigraphically lower than the Millersburg Member and both underlain and overlain by calcarenite of the Tanglewood Limestone Member, has been mapped in parts of the Centerville (Kanizay and Cressman, 1967), Georgetown (Cressman, 1967), and Midway (Pomeroy, 1970) quadrangles. This unit, lithologically similar to both the Millersburg Member and the Greendale Lentil but continuous with neither, is herein named the Stamping Ground Member of Middle Ordovician age. The name is derived from the town of Stamping Ground in western Scott County. The type section (measured sec. 1005), exposed in the upper part of a small quarry on the north side of the Switzer-Stamping Ground road is described below.

Type section of Stamping Ground Member of Lexington Limestone

[Measured in quarry (measured sec. 1005) on the north side of the Switzer-Stamping Ground road, 2,700 feet west of its intersection with U.S. Route 227, Scott County, Ky. Kentucky coordinates, E. 1,868,950 ft, N. 281,700 ft. Measured by E. R. Cressman, 1968]

	Thickness (feet)
Lexington Limestone:	
Tanglewood Limestone Member:	
Calcarenite, light-gray, fine- to medium-grained, bioclastic; contains scattered large brachiopod and trilobite fragments; in planar to wavy beds 0.4 to 1 foot thick; many large stromatoporoids at base. Covered above	3.0
Incomplete thickness of Tanglewood Limestone Member	3.0
Stamping Ground Member:	
Limestone (70 percent) and shale (30 percent): Limestone is medium gray mottled yellowish orange, fossiliferous, poorly sorted, with much dolomitic silt-sized calcisiltite matrix; mostly as nodular beds 0.1 to 0.2 foot thick, but also as irregular beds 0.2 foot thick. Shale is olive gray, calcareous; occurs as irregular partings and thin beds. Member contains many brachiopods; *Rhynchotrema* abundant	9.0
Total thickness of Stamping Ground Member	9.0
Tanglewood Limestone Member:	
Calcarenite, slightly phosphatic, light-gray to light-brown, fine-grained, well-sorted, bioclastic; in wavy beds 0.1 to 0.3 foot thick and planar crossbedded sets 0.2 to 0.3 foot thick; some beds contain scattered large brachiopod and trilobite fragments	8.0
Total thickness of Tanglewood Limestone Member lens	8.0
Grier Limestone Member:	
Calcisiltite, argillaceous; contains abundant chert nodules; bedding contorted in ball-and-pillow structure. Upper contact is planar; lower contact is base of pillows	3.0
Calcisiltite (80 percent) and shale (20 percent) interbedded: Calcisiltite is argillaceous, light brownish gray, fossiliferous, in beds 0.2 to 0.4 foot thick. Shale is calcareous, in beds 0.1 foot thick. Thickness of unit ranges from 1.1 to 1.7 feet; uppermost beds conform approximately to base of pillows in overlying unit; lower contact is planar	1.4
Calcisiltite, argillaceous, light-brownish-gray, fossiliferous; contains grayish-brown chert nodules throughout and chert layer at top. Passes along strike into ball-and-pillow layer	1.1
Limestone (70 percent) and shale (30 percent): Limestone is light-brownish-gray argillaceous fossiliferous calcisiltite and poorly sorted fine-grained bioclastic calcarenite in nodular beds 0.05 to 0.1 foot	

Type section of Stamping Ground Member of Lexington Limestone—Continued

	Thickness (feet)
Lexington Limestone—Continued	
Grier Limestone Member—Continued	
thick. Shale is calcareous, olive gray, and in irregular partings and thin beds. Gastropods, brachiopods, and bryozoans abundant in limestone nodules. Uppermost 1 foot much less argillaceous. Grades through 0.5 foot from unit below	6.0
Limestone (80 percent) and shale (20 percent): Brownish-gray to medium-light-gray, very coarse and coarse-grained, poorly sorted bioclastic calcarenite in irregular beds 0.3 to 0.9 foot thick alternating with sets 0.1 to 0.5 foot thick of nodular-bedded fossiliferous calcilutite and shale. Calcarenite contains abundant brachiopods. Base of unit is floor of quarry	8.0
Incomplete thickness of Grier Limestone Member	18.4

Stromatoporoids, present directly above the Sulphur Well Member at the type section, are also found at or just below the upper contact throughout most of the Georgetown and Centerville quadrangles. The *Rhynchotrema* are commonly silicified in surface exposures.

The contact with bioclastic calcarenite of the Tanglewood Limestone Member below is conformable and sharp or gradational through less than 1 foot. The contact with the overlying Tanglewood is sharp locally, but more commonly it is gradational through several feet.

The known extent of the Stamping Ground Member is shown in figure 31. It grades southward into the Tanglewood Limestone Member, and sparse exposures suggest that it also grades northward into the Tanglewood. South of Paris, Bourbon County, Ky., the underlying tongue of the Tanglewood Limestone Member pinches out, and the Stamping Ground Member cannot be distinguished from the Grier Limestone Member (W. F. Outerbridge, oral commun., 1969).

The member is commonly about 10 feet thick, but at measured section 61 in the Switzer quadrangle it is 22 feet thick.

The depositional environment was similar to that of the Millersburg Member.

GREENDALE LENTIL

A cut of the Southern Railway, 2,000 feet south of Greendale in the northeast part of the Lexington West quadrangle, exposes 10 feet of calcarenite underlain by about 5 feet of poorly exposed irregular-bedded to nodular fossiliferous limestone and shale. Somewhat better exposures of the fossiliferous limestone and shale may be seen in other cuts along the railroad, particularly beneath the U.S. Route 25 overpass about 1 mile north of Greendale, and in several nearby roadcuts along Interstate Highway 75. Earlier workers considered the calcarenite in the railroad cut south of Greendale to be the Nicholas Limestone Member of the Cynthiana Formation (Nicholas Bed of the Tanglewood Limestone Member of the Lexington Limestone of this report). The fossiliferous limestone and shale, thought to be continuous with the Millersburg Member as used in this report, was named the Greendale Limestone Member of the Cynthiana Formation (Foerste, 1906), and the name Greendale was applied widely, though with little precision (McFarlan and White, 1948, p. 1641), to much of the unit herein called the Millersburg Member of the Lexington Limestone. Mapping by Miller (1967) and Cressman (1967) and a core obtained from just east of the Greendale railroad cut (measured sec. 170) have shown that the fossiliferous limestone and shale at the base of the Greendale railroad cut is no more than 15 feet thick and grades laterally in all directions into part of the Tanglewood Limestone Member. This unit is herein redefined and adopted as the Greendale Lentil (Middle Ordovician) of the Lexington Limestone. The widespread misapplication of the term Greendale in the past might make it seem inadvisable to resurrect the name, but no other suitable name is available in the area in which the lentil occurs.

There is no complete surface exposure of the Greendale Lentil, but the cut on the Southern Railway beneath the U.S. Route 25 overpass north of Greendale illustrates its character. In this cut, 7 feet of the Greendale Lentil rest on 2½ feet of the Tanglewood Limestone Member. The Greendale that is exposed consists of about 75 percent limestone and 25 percent shale. Sets that are 0.2 to 1.5 feet thick consist of olive-gray to light-gray fossiliferous argillaceous calcisiltite in nodules and nodular beds 0.1 to 0.2 foot thick separated by irregular shale partings and thin shale beds; these sets alternate with irregular beds 0.2 to 0.5 foot thick of light-gray coarse-grained fossiliferous calcarenite that contains scattered patches of silt-sized carbonate. Much of the calcisiltite is somewhat dolomitic. The exposed beds of the underlying Tanglewood Limestone Member consist of light-gray to light-brownish-gray medium-grained calcarenite that contains scattered randomly oriented brachiopod and trilobite fragments.

The extent of the Greendale Lentil is shown in figure 31. Throughout this area it is 10 to 15 feet thick. A tongue as much as 4 feet thick extends into the Lexington East quadrangle, but because it is thin and difficult to trace, it is there included in the Tanglewood Limestone member.

The Greendale Lentil was mapped in both the Georgetown and Lexington West quadrangles and was informally termed "fossiliferous limestone and shale" on the published geologic maps (Cressman, 1967; Miller, 1967). Another fossiliferous shale and limestone unit shown in the southern part of the Lexington West quadrangle (Miller, 1967) is probably a tongue of the Millersburg Member, and only the unit north of Sandersville is the Greendale. On the geologic map of the Georgetown quadrangle (Cressman, 1967), which shows both the Greendale Lentil and the Stamping Ground Member as "fossiliferous limestone and shale," the Greendale is the stratigraphically higher unit.

DEVILS HOLLOW MEMBER

DEFINITION

The Devils Hollow Member of the Lexington Limestone was named by McFarlan and White (1948, p. 1640). The type area is along the Devils Hollow road a few miles west of Frankfort (about midway between measured secs. 88 and 191). I have not found a complete section at the type locality, but measured sections 86, 88, and 89 are in the vicinity and illustrate the general character of the member.

The Devils Hollow Member at its type locality was described as consisting of 15 feet of porous coarsely crystalline light-gray massive limestone containing a crowded mass of gastropod shells overlain by 10 feet of compact limestone similar to that of the Tyrone Limestone and containing ostracodes (McFarlan and White, 1948, p. 1640). These two rock types intertongue, and the member may consist locally entirely of the Tyrone-like calcilutite, entirely of the gastropod coquina, or, as at the type section, of both types. The two lithologies are intimately related and form an easily recognizable and mappable lithogenetic unit.

For many years the beds now recognized as the Devils Hollow Member were miscorrelated with the Perryville Limestone of the southern Blue Grass, which is actually equivalent to the upper part of the Grier Limestone Member, and a major disconformity was therefore thought to be present at the base of the supposedly continuous Perryville. McFarlan and White (1948) correctly determined the relations between the two units.

CONTACTS

In most of its area of outcrop, the Devils Hollow Member is underlain conformably by calcarenite of the Tanglewood Limestone Member, though in parts of the Frankfort East, Frankfort West, and Versailles quadrangles it rests on bryozoan-rich shale of the *Constellaria* bed of the Tanglewood. It is overlain conformably by either calcarenite of the Tanglewood or nodular fossiliferous limestone and shale of the Millersburg Member of the Lexington.

COQUINA PHASE

The coquina phase of the Devils Hollow Member typically consists of gastropods, mostly 2 to 5 mm but as much as several centimeters in length, cemented by coarsely crystalline sparry calcite cement. The color on fresh surfaces ranges from very pale orange to nearly white. In surface exposures, the rock is very porous; individual pores are as much as 3 or 4 mm across. Inconspicuous bedding surfaces commonly separate rather uneven beds that average 1 or 2 feet thick. In some places beds may be 5 or more feet thick. Low-angle crossbedding has been noted, but exposures are generally too poor to determine whether crossbedding is common. In natural exposures the coquina crops out as massive rounded ledges. On uplands mantled by thick residual soil, the position of the coquina is commonly marked by fragments of porous gastropodal chert.

In the southwest part of the Versailles quadrangle, the southwest corner of the Keene quadrangle, and probably elsewhere along the southern margin of the member, the coquina consists largely of brachiopods rather than gastropods, but in color, porosity, and bedding the brachiopod coquina closely resembles the gastropod coquina of the type locality.

Microscopically, the coquina is an unsorted biosparrudite. The gastropod shells are composed of medium- and coarsely crystalline calcite (fig. 32).

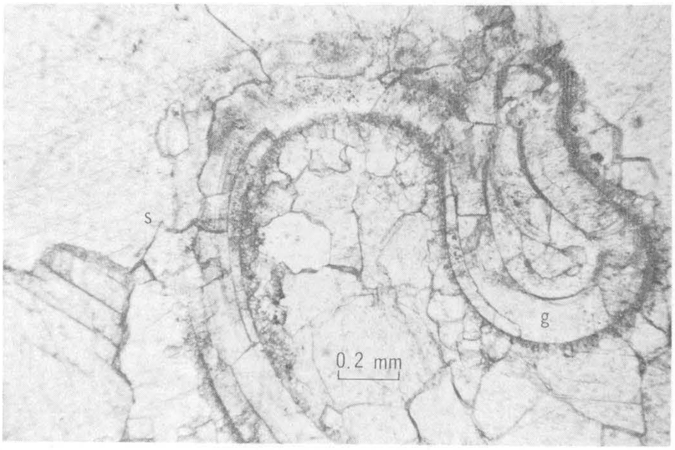


FIGURE 32.—Photomicrograph of gastropod coquina from Devils Hollow Member; g, gastropod; s, sparry calcite cement. Plane-polarized light.

Interiors of the gastropods are filled with coarsely crystalline sparry calcite, but the interstitial sparry calcite is mostly finely to medium crystalline. Sand-sized fragments of bryozoans and brachiopods are also present. The apparent poor sorting of the allochems is misleading and probably has resulted from the greatly different hydraulic properties of the various shells and shell fragments.

FINE-GRAINED PHASE

The fine-grained phase of the Devils Hollow consists of two closely related rock types. One is light-greenish-gray to light-gray calcilutite that has conchoidal to subconchoidal fracture. It generally contains scattered ostracodes about 1 mm across and a few gastropod shells. In some exposures the rock is laminated. Some laminae are slightly irregular and may have formed as an algal mat. In thin section, much of the calcilutite consists of abundant ostracode fragments and indistinct pellets of micritic calcite that average 50 microns in diameter; all these are set in a micrite matrix.

The second fine-grained type is brownish-gray somewhat argillaceous calcilutite. Fossil fragments in the calcilutite are concentrated in irregular bodies that probably resulted from burrowing. The rock contains abundant brownish-black streaks that in thin section are seen to consist of a mosaic of finely crystalline calcite that contains more abundant flakes of organic matter than does the surrounding rock. Stromatoporoids are common, but, rather than being dome shaped as elsewhere in the Lexington, they generally are in the form of irregular wispy layers.

Microscopically, the brownish-gray calcilutite consists of closely packed silt-sized fragments of ostracodes, bryozoans, and crinoids in a micrite or microspar matrix. Much of the micrite is in the form of pellets about 50 microns in diameter. Irregular patches of sparry calcite are common.

THICKNESS AND EXTENT

The Devils Hollow Member ranges from 0 to nearly 30 feet in thickness, but data are too sparse to construct an isopach map of this unit. The distribution of the member is shown in figure 17.

In the area near Frankfort, the Devils Hollow Member in the center of its outcrop belt is mostly calcilutite whereas near the northern and southern borders of the belt it is mostly coquina. In the intermediate areas, the basal part is generally coquina and the upper part calcilutite, and in some exposures the two types are interbedded (Pomeroy, 1968). Elsewhere the member is too poorly exposed to determine the relations of the two rock types.

ENVIRONMENT OF DEPOSITION

The calcilutites of the Devils Hollow Member resemble those of the Perryville Limestone Member and were deposited in a similar environment—that is, they were deposited at depths of less than a few meters in quiet protected waters of relatively high salinity. The association of gastropodal calcirudite with the calcilutite suggests an intertidal environment that had extensive algal mats on which gastropods fed; but I have seen no mudcracks or intraformational breccias, and most of the laminated beds do not closely resemble those known to be of algal origin. Therefore, the calcilutite probably accumulated as very shallow subtidal banks as pelletal lime mud and fossil debris. The dark calcilutite was deposited in waters a few meters deep, and the light calcilutite formed just below water level in the last stages of basin filling. The gastropodal calcirudite probably accumulated on beaches or possibly in channels between banks. The areal distribution of the Devils Hollow Member indicates that the sediments formed in a narrow northwest-trending lagoon that connected with more open waters to the southwest.

MILLERSBURG MEMBER

DEFINITION

The Millersburg Member, originally named by Foerste (1914, p. 112), was adopted by Black, Cressman, and MacQuown (1965, p. 24) as the name for the body of nodular and irregularly bedded fossiliferous limestone and shale in the upper part of the Lexington Limestone. The town of Millersburg is in northeastern Bourbon County. There is no type section, but Black, Cressman, and MacQuown (1965, p. 25) designated exposures on the Athens-Boonesboro road just west of Interstate Highway 75 as a reference section (measured sec. 159 of this report). The Millersburg Member complexly intertongues with the Tanglewood Limestone Member of the Lexington and with the lower part of the Clays Ferry Formation, and any body of nodular fossiliferous limestone and shale that can be shown, or reasonably inferred, to be continuous with the reference section is considered part of the Millersburg Member.

CONTACTS

Tongues of the Millersburg Member may be both underlain and overlain by tongues of either the Tanglewood Limestone Member of the Lexington or by the Clays Ferry Formation or underlain by one and overlain by the other. In parts of the Frankfort East and Tyrone quadrangles, the Millersburg rests on the Devils Hollow Member of the Lexington. Contacts of the Millersburg with the overlying and underlying units are generally gradational through several inches to several feet. In the Lexington East, Clintonville, Centerville, and eastern Georgetown quadrangles, the Millersburg Member grades through as much as 5 feet from the underlying tongue of the Tanglewood, and the distinctive pelecypod *Allonychia flanaganensis* Foerste is common in the transition beds.

LITHOLOGY

The Millersburg Member is characterized by nodular bedding of the limestone, abundant whole and broken fossils, silt- and clay-sized carbonate matrix, and abundant shale. The amount of shale is difficult to estimate because of the nodular bedding of the limestone, but it generally appears to be about one-third of the member. Normative quartz and illite were calculated as 8 percent and 26 percent, respectively, from the average of five chemical analyses (table 2; fig. 3). The analyses also indicate that an average of a little more than a quarter of the total carbonate is dolomite. The P_2O_5 content averages about 0.8 percent (nearly 3 percent apatite).

Characteristically, the Millersburg Member consists of limestone nodules several inches in diameter alined along bedding and set in a matrix of calcareous shale (fig. 33). In most exposures, nodular-bedded limestone sets several feet thick alternate with irregular limestone beds several inches thick and with sets of irregular beds 1 or 2 feet thick. The nodular bedding dominates except near contacts

FIGURE 33.—Outcrop of Millersburg Member of Lexington Limestone showing characteristic nodular bedding and rubbly weathering. Roadcut on the Athens-Boonesboro road about ¾ mile northwest of interchange with Interstate Highway 75.

with the Tanglewood Limestone Member. Because of the nodular bedding and the abundance of shale, artificial exposures weather rapidly and natural exposures are uncommon.

The limestone nodules are mostly fossiliferous calcilutite and calcisiltite whereas the irregular beds are poorly sorted calcarenite, commonly containing patches of silt- and clay-sized carbonate. Bryozoans, brachiopods, mollusks, and trilobite fragments are abundant. Stromatoporoids and colonial corals are present in several zones though nowhere in such abundance as to form reefs. The limestone ranges in color from medium gray and brownish gray to medium light gray and yellowish gray.

PETROGRAPHY AND MINERALOGY

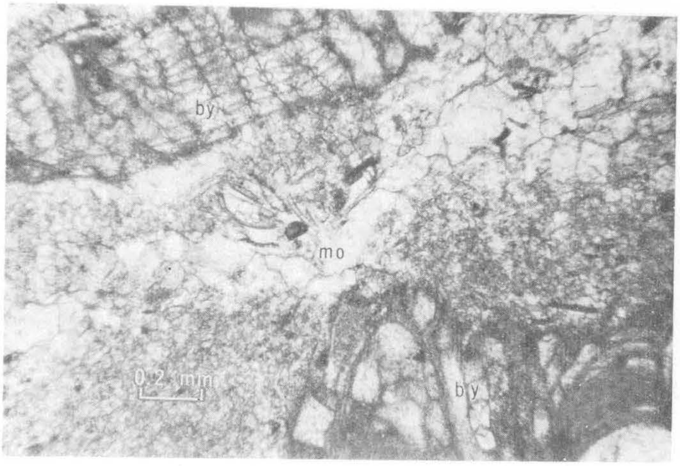
I have not examined the nodular limestone microscopically, but several thin sections of the irregularly bedded calcarenite show that it consists of biomicrosparrudite (fig. 34*A*) and poorly washed biosparite and biosparrudite (fig. 34*B*). Crinoid plates are the most common allochem, but bryozoan, brachiopod, and molluskan fragments are also abundant. Apatite fills bryozoan zooecia, pores in crinoid plates, and interiors of some small gastropods and to some extent replaces crinoid plates. Microspar occurs mostly in fossil cavities, as patches adjacent to fossil fragments, and between closely spaced fossil fragments.

The shale is calcareous and is olive gray to medium gray. X-ray diffraction analysis of the acetic acid insoluble fraction shows the dominant clay mineral to be chlorite; illite and mixed-layer clay are also present; the insoluble fraction also contains fairly abundant quartz and some pyrite and potassium feldspar (J. J. Connor, written commun., 1967).

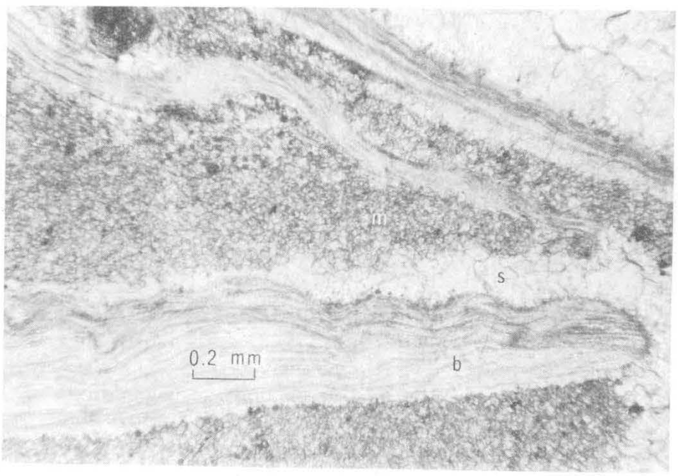
THICKNESS AND EXTENT

As shown in figure 35, the Millersburg Member is more than 90 feet thick at measured section 1000 in westernmost Montgomery County and thins to a featheredge north of Cynthiana and Owenton, west of Frankfort, and near the Kentucky River south of Lexington and Winchester. The thinning results largely from facies changes, details of which are shown in the Stratigraphic sections (pls. 1–7).

Rocks included in the Millersburg near Gratz (measured sec. 62), Sadieville (measured sec. 192), and Cynthiana (measured sec. 198) may not actually be continuous with the main body of the member. Thin units lithologically similar to the Millersburg but lower in the section and apparently not connected with the main body, are present in the subsurface in measured sections 196 and 190 near



A



B

FIGURE 34.—Photomicrographs of Millersburg Member. *A*, Biomicrosparrudite; by, bryozoan; mo, possible mollusk; matrix is microspar. *B*, Poorly washed biosparrudite containing large brachiopods (b), sparry calcite cement (s), and patches of microspar (m). Plane-polarized light.

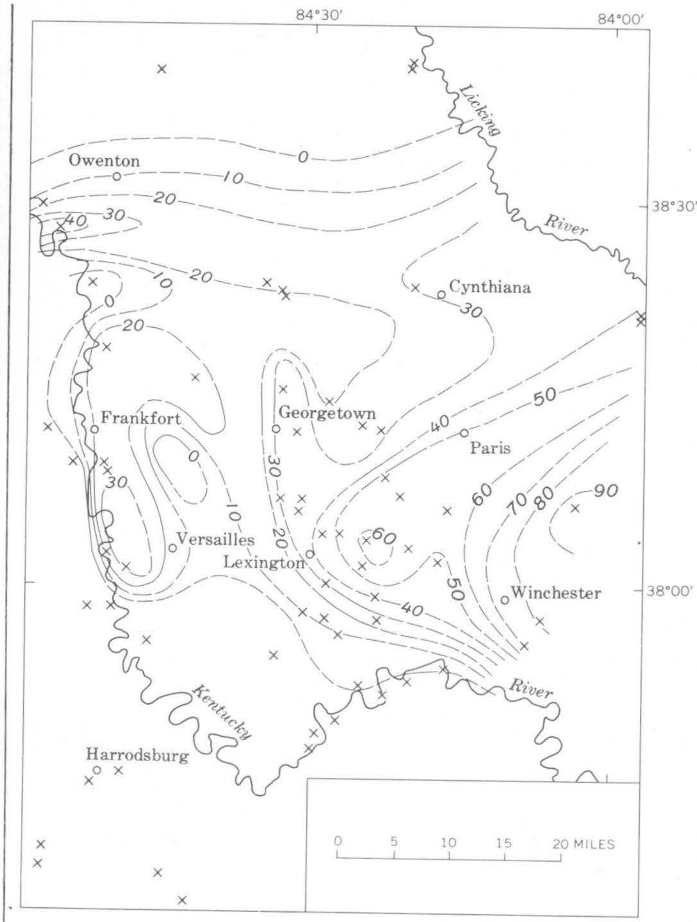


FIGURE 35.—Isopach map of Millersburg Member of Lexington Limestone. Contour interval 10 feet; solid where based on mapping, dashed where inferred; ×, measured section.

the north edge of the area; in this report, these relatively thin units are included in the Grier Limestone Member.

ENVIRONMENT OF DEPOSITION

The Millersburg Member is similar to much of the Grier Limestone Member in bedding style and fossil content but contains nearly as much shale as the Brannon Member and as the Clays Ferry Formation. The profuse fossils indicate that the Millersburg, like the Grier Limestone Member, was deposited in shallow, aerated, moderately turbulent normal marine water. As with the other members, absolute water depths can only be approximated. Pojeta (1966, p. 159) noted that the large pelecypod *Allonychia flanaganensis*, common near the base of the Millersburg Member in the eastern half of the area, nearly always occurs as single valves, and he took this as evidence of accumulation in a nearshore area of vigorous wave action. However, *Allonychia* grew near the shallow margin of the facies, and the abundance of unbroken fossils, poor sorting, the abundance of lime mud, and the large amount of shale suggest that most of the Millersburg was deposited in water of only moderate turbulence. The abundance of fossils suggests that much of the Millersburg like the Sulphur Well and Grier Limestone Members was formed at depths of less than 15 m.

The abundance of shale, as compared with the small amount in the otherwise similar fossiliferous limestone facies, may have resulted from a larger supply of mud in later Lexington time. Bryozoans, corals, and other organisms would have acted as baffles to entrap both lime mud and terrigenous mud As in modern sediments, the lime mud was probably derived both from algae and the breakdown of skeletal material; much of it may have been in the form of fecal pellets before diagenesis destroyed some of the original texture.

The nodular structure typical of the Millersburg Member resulted from burrowing by a dominantly soft-bodied infauna. Differential settling of limestone layers into underlying shale beds does not seem a likely explanation; the Millersburg contains nearly as much shale as the Brannon and Logana Members of the Lexington and parts of the Clays Ferry Formation, all of which are evenly bedded, and there is no obvious reason why differential settling would have affected the Millersburg but not the other units. Furthermore, the nodular structure of the Millersburg, particularly that observed in cores, very closely resembles structure attributed to burrowing in Holocene marine sediments as described by Moore and Scruton (1957). Finally, a shallow level sea floor with enough oxygen and nutrients to support a large epifauna generally has an abundant and active infauna, and evidences of such an infauna should be and certainly appear to be present in the Millersburg.

CLAYS FERRY FORMATION

The unit of interbedded shale, limestone, and siltstone that overlies the Lexington Limestone was named the Clays Ferry Formation by Weir and Green (1965). The type section (measured sec. 22) is in northern Madison County.

The lower part of the Clays Ferry Formation, the only part considered herein, intertongues with the upper part of the Lexington Limestone. Contacts between the Clays Ferry and the Lexington are either sharp and planar or gradational through 1 or 2 feet. The Clays Ferry is less resistant than most of the Lexington Limestone, and the upper most ledge of the Lexington is commonly overlain by yellowish-gray clayey soil containing limestone slabs of the Clays Ferry (fig. 36).

The Clays Ferry Formation is characterized by interbedded limestone and shale (fig. 37). The limestone, mostly in even beds 1 to 6 inches thick, makes up 30 to 60 percent of the formation (Weir and Green, 1965, p. 8). The limestone consists of several types. Most common in the lower part of the formation are medium- to dark-gray argillaceous calcisiltite, medium-gray brachiopodal limestone, and medium-gray crinoidal calcarenite. The calcisiltite is mostly unfossiliferous but may contain crinoid stem fragments on bedding surfaces, and some beds are gastropodal. The brachiopodal limestone most commonly consists of crowded *Rafinesquina*, *Sowerbyella*, or *Dalmanella*, with much lime mud in the interstices. In some beds, closely packed *Rafinesquina* valves are stacked at high angles to the bedding. The various limestone types may be interbedded, or one type may predominate in an interval of 10 to 30 feet. In general, thin tongues of the Clays Ferry consist mostly of unfossiliferous calcisiltite and shale, but as the tongues thicken and merge with the main body of the formation, fossiliferous beds become more common.

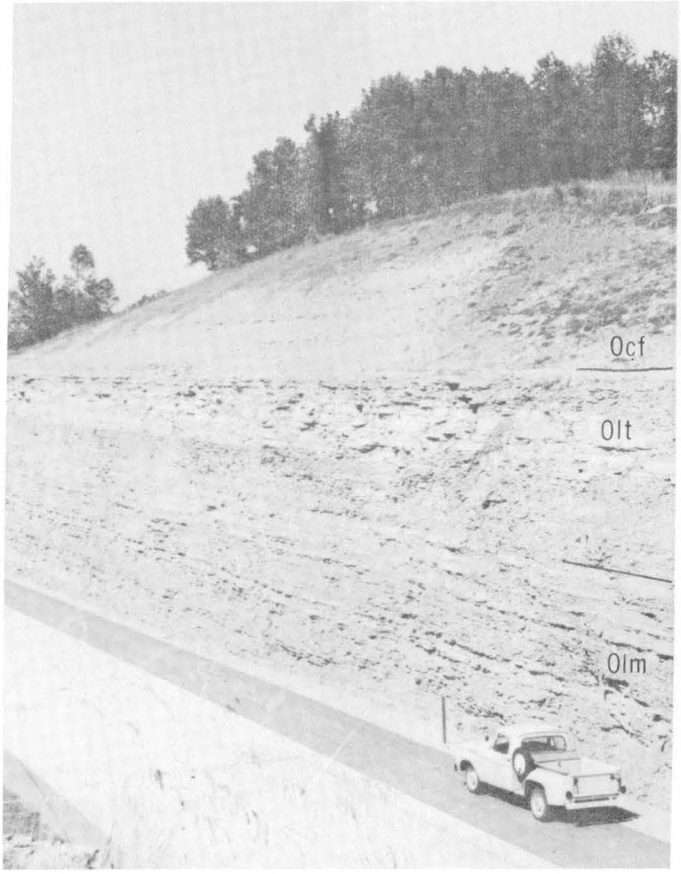
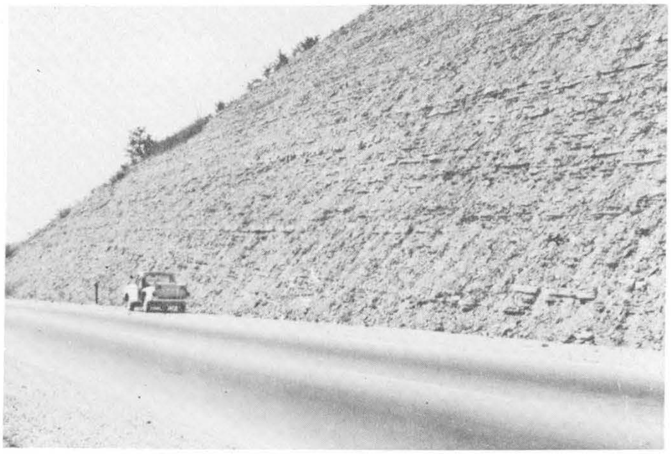
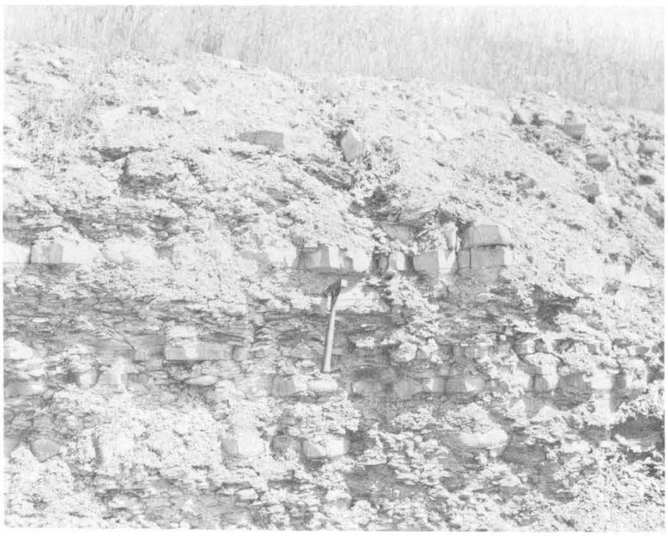


FIGURE 36.—Contact of Lexington Limestone and Clays Ferry Formation in roadcut on westbound lane of Interstate Highway 64 east of the Kentucky River. This is the reference section of the Lexington Limestone (measured sec. 86). Ocf, Clays Ferry Formation; Olt, tongue of Tanglewood Limestone Member of Lexington Limestone; Olm, Millersburg Member of Lexington Limestone.

The average normative composition calculated from the average of the chemical analyses of tongues of the Clays Ferry Formation (table 2; fig. 3) is 1.5 percent apatite, 43 percent calcite, 9 percent dolomite, and 44 percent quartz and clay. The composition of these tongues is very similar to that calculated for the Millersburg Member of the Lexington Limestone, and the differences between the Millersburg Member and the Clays Ferry Forma-



A



B

FIGURE 37.—Exposures of Clays Ferry Formation. *A*, roadcut on Interstate Highway 75 (first roadcut southeast of bridge over Kentucky River). This is part of the type section (measured sec. 22) of the Clays Ferry Formation. *B*, lower Clays Ferry Formation in roadcut at Lawrenceburg interchange of Bluegrass Parkway, Anderson County.

tion are more structural and textural than compositional. That is, the Millersburg is nodular bedded and uniformly fossiliferous whereas the Clays Ferry Formation consists of rather evenly interbedded limestone and shale which is fossiliferous only in part.

Intertonguing between the lower part of the Clays Ferry Formation and the upper part of the Lexington Limestone is illustrated on plate 7. Much of the intertonguing is mappable at the scale of 1:24,000 (for example, see Black (1967, 1968) and Cressman (1968)). Tongues of the Clays Ferry Formation within the Lexington Limestone in many localities contain disrupted bedding in the upper part of the tongues, particularly where the overlying unit is calcarenite of the Tanglewood Limestone Member of the Lexington. The disrupted bedding, similar to that in the Brannon Member (p. 35), may be either the ball-and-pillow type or a crosscutting pebbly layer. Both types probably resulted from relatively rapid and irregular deposition of calcarenite on the unconsolidated or semiconsolidated Clays Ferry tongue.

In the northern part of the area, the Clays Ferry Formation intertongues and possibly intergrades with the more shaly Kope Formation.

The less fossiliferous parts of the Clays Ferry Formation, especially the basal 30 feet at the type section and in the southwestern part of the area and the tongue of the Clays Ferry north of Georgetown, closely resemble the interbedded calcisiltite and shale of the Logana and Brannon Members of the Lexington Limestone and were deposited in a similar environment; that is, in quiet water probably at least 25 m deep. The more fossiliferous parts of the Clays Ferry were probably deposited at slightly shallower depths where the oxygenation and light would have, at least periodically, permitted the growth of the benthos. Yet, the currents were seldom strong enough to remove silt- and clay-sized particles or to comminute even thin and delicate shells.

KOPE FORMATION

The name Kope Formation was proposed by Weiss and Sweet (1964) for a dominantly shale unit in the Maysville area of Kentucky and Ohio. The name has since been extended westward to Cincinnati (Ford, 1967) and to Indiana (Brown and Lineback, 1966).

The Kope Formation differs from the partly equivalent and somewhat similar Clays Ferry Formation principally in containing more shale; the Kope of the type area is 70 to 80 percent shale (Weiss and Sweet, 1964), whereas the Clays Ferry Formation is 30 to 60 percent shale (Weir and Greene, 1965, p. 8). Furthermore, shale beds 3 or more feet thick are common in the Kope Formation but are rare in the Clays Ferry. The interbedded limestones of the two formations are similar in character.

Rocks assigned to the Kope are present only in measured sections 62 and 196 of this report. The unit has been described in considerable detail by Weiss, Edwards, Norman, and Sharp (1965).

The deposition of the Kope Formation has been discussed in detail by Weiss, Edwards, Norman, and Sharp (1965). It suffices here to say that conditions were somewhat similar to those in which the Clays Ferry Formation was deposited. The dominance of shale may have resulted from deposition in deeper water or it may reflect proximity to the terrigenous source and distance from the carbonate shelf. The absolute depth was not great, and Weiss, Edwards, Norman, and Sharp (1965, p. 64) agree with Bucher's (1917) estimate of a maximum of 25 m.

POINT PLEASANT FORMATION

At Cincinnati and eastward along the Ohio River, the Lexington Limestone and the Kope Formation are separated by about 100 feet of limestone and shale, interbedded in various proportions but averaging about half-and-half, that are approximately correlative with the upper part of the Lexington Limestone of the Lexington area and to the lower part of the Clays Ferry Formation. The nomenclature of this interval along the Ohio has had a long and confusing history (Weiss and others, 1965, p. 17–21). In recent years these beds most commonly have been assigned to the Cynthiana Formation, a name that is no longer used by the U.S. Geological Survey. In the current U.S. Geological Survey-Kentucky Geological Survey mapping program, they are assigned to the Point Pleasant Formation, a name originally proposed by Orton (1873).

The Point Pleasant Formation resembles the Clay Ferry Formation in the regular interbedding of limestone and shale, and much of the lower part of the Point Pleasant cannot be distinguished lithologically from the Clays Ferry to the south. However, the upper part of the Point Pleasant differs from the Clays Ferry in containing thicker beds and somewhat less shale. In addition, the upper Point Pleasant contains beds of crossbedded calcarenite that may be lenticular and are as much as 10 feet thick. Another distinctive rock type in the upper Point Pleasant is calcirudite consisting of abundant trilobite and gastropod fragments in a calcilutite matrix.

In the area of this report, beds that can be assigned to the Point Pleasant Formation with confidence are present only in the Falmouth section (measured sec. 195). The rocks in Gallatin County called Lexington Limestone by Brown and Anstey (1968) and Anstey and Fowler (1969) should also be termed Point Pleasant.

The lithology of the Point Pleasant has been described in detail by Weiss, Edwards, Norman, and Sharp (1965).

FAUNA

The stratigraphic position and ranges of fossils collected during this study are shown on plates 1 through 6. In this part of the report the fossils are listed by the stratigraphic member in which they occur. Credits for the identifications are given on page 2. The collections are stored in the U.S. National Museum.

- Lexington Limestone:
  - Curdsville Limestone Member:
    - Brachiopoda:
      - *Dalmanella* sp.
        - *fertilis* (Ulrich)
      - *Hesperorthis tricenaria* (Conrad)
      - *Platystrophia colbiensis* Foerste
      - *Plectocamera* sp.
      - *Rafinesquina* sp.
        - *trentonensis* (Conrad)
      - *Rhynchotrema* sp.
        - *kentuckiensis* Fenton and Fenton
      - *Sowerbyella*? sp.
        - *curdsvillensis* Foerste
      - *Zygospira* sp.
    - Gastropoda:
      - *Liospira* sp.
      - *Loxoplocus* (*Lophospira*) sp.
      - *Tropidodiscus* sp.
    - Pelecypoda:
      - *Vanuxemia* sp.
    - Trilobita:
      - *Calyptaulox* cf. *C. strasburgensis* (Cooper)
      - *Raymondites* cf. *R. ingalli* (Raymond)
  - Logana Member:
    - Brachiopoda:
      - *Dalmanella* sp.
        - *fertilis* (Ulrich)
        - *sulcata* Cooper
      - *Rafinesquina trentonensis* (Conrad)
      - *Rhynchotrema* sp.
      - *Rostricellula minuta* Cooper
      - *Zygospira* sp.
    - Monoplacophora:
      - *Cyrtolites* aff. *C. retrorsus* Ulrich and Scofield
    - Gastropoda:
      - *Carinaropsis cymbula* Hall
      - *Liospira* aff. *L. decipiens* (Billings)
      - *Loxoplocus* (*Lophospira*) sp.
    - Pelecypoda:
      - *Ambonychia* sp.
      - *Colpomya faba* (Emmons)
      - *Cyrtodontula* sp.
      - *Deceptrix* sp.
      - *Modiolodon oviformis* (Ulrich)
      - *Palaeoneilo socialis* (Ulrich)
      - *Similodonta* aff. *S. hermitagensis* (Bassler)
      - *Whiteavesia* sp.
    - Ostracoda:
      - *Ceratopsis intermedia* Ulrich
      - *Jonesella* aff. *J. obscura* Ulrich

- Lexington Limestone—Continued:
  - Grier Limestone Member:
    - Anthozoa:
      - *Favistina* cf. *F. stellata* (Hall)
      - *Tetradium* sp.
    - Bryozoa:
      - *Amplexopora* sp.
        - *minor* Brown
        - cf. *A. winchelli* Ulrich
      - *Batostoma* cf. *B. humile* Ulrich
      - *Ceramoporella* sp.
      - *Constellaria* cf. *C. teres* Ulrich and Bassler
      - *Cyphotrypa* sp.
        - *acervulosa* (Ulrich)
      - *Dekayia*? sp.
      - *Eridotrypa* sp.
      - *Escharopora* sp.
      - *Graptodictya* sp.
      - *Hallopora* sp.
        - *multitabulata* (Ulrich)
      - *Hemiphragma* sp.
        - cf. *H. tenuimurale* Ulrich
      - *Heterotrypa* sp.
      - *Homotrypa* sp.
        - *callosa* Ulrich
      - *Mesotrypa* sp.
      - *Peronopora*? sp.
        - cf. *P. granulifera* Ulrich
      - *Prasopora falesi* (James)
        - cf. *P. falesi* (James)
        - cf. *P. simulatrix* Ulrich
      - *Stictopora* sp.
        - *neglecta* (Ulrich)
      - *Stigmatella* cf. *S. conica*(?) Brown
        - *multispinosa* Brown
    - Brachiopoda:
      - *Dalmanella* sp.
        - *fertilis* (Ulrich)
      - *Hebertella frankfortensis* Foerste
      - *Heterorthina macfarlini* Neuman
      - *Lingulella*? sp.
      - *Pachyglossella* sp.
      - *Pionodema rectimarginata* Neuman
      - *Pionomena recens* Neuman
      - *Platystrophia* sp.
      - *Rafinesquina* sp.
        - *trentonensis* (Conrad)
      - *Rhynchotrema* sp.
        - *increbescens* (Hall)
        - *cf. R. increbescens* (Hall)
      - *Sowerbyella* sp.
      - *Strophomena* sp.
      - *Zygospira* sp.
        - cf. *Z. modesta* (Hall)
    - Monoplacophora:
      - *Archinacella* sp.
        - *simulatrix* Ulrich and Scofield
      - *Cyrtolites* sp.
        - *retrorsus* Ulrich and Scofield
    - Gastropoda:
      - *Bucania* sp.
        - cf. *B. sublata* Ulrich and Scofield
      - *Bucanopsis* sp.
        - *carinifera* Ulrich

- Lexington Limestone—Continued:
  - Grier Limestone Member—Coninued:
    - Gastropoda—Continued:
      - *Carinaropsis* sp.
        - *cymbula* Hall
      - *Clathrospira*? sp.
        - *subconica* (Hall)
      - "*Cyclora*" sp.
      - cf. *Cyclora* sp.
      - *Eotomaria* sp.
      - *Holopea* cf. *H. parvula* Ulrich in Ulrich and Scofield
      - *Hormotoma* sp.
      - *Liospira*? sp.
        - *progne* (Billings)
      - *Loxoplocus* (*Lophospira*) sp.
        - (*L.*) *burginensis* (Ulrich in Ulrich and Scofield)
          - cf. *L.* (*L.*) *burginensis* (Ulrich in Ulrich and Scofield)
          - *medialis* (Ulrich and Scofield)
          - cf. *L.* (*L.*) *saffordi* (Ulrich in Ulrich and Scofield)
      - "*Microceras*" sp.
      - cf. *Microceras* sp.
      - *Murchisonia* (*Hormotoma*) sp.
        - (*H.*) *salteri nitida* (Ulrich)
          - *salteri* (Ulrich in Ulrich and Scofield)
          - ?*salteri* (Ulrich in Ulrich and Scofield)
      - cf. *Sinuites* sp.
      - *Sphenosphaera* sp.
        - *clausus* (Ulrich in Ulrich and Scofield)
        - cf. *S. clausus* (Ulrich in Ulrich and Scofield)
        - *troosti burginensis* (Ulrich in Ulrich and Scofield)
      - *Tropidodiscus*? sp.
      - *Tropidodiscus* sp.
    - Pelecypoda:
      - *Ambonychia* sp.
        - *byrnesi* (Ulrich)
        - cf. *A. radiata* Hall
      - *Colpomya* sp.
        - *faba* (Emmons)
      - *Ctenodonta regia* Ulrich
        - aff. *C. regia* Ulrich
      - *Cymatonota* sp.
      - *Cyrtodonta grandis* (Ulrich)
        - aff. *C. subovata* Ulrich
      - *Cyrtodontula* sp.
      - *Deceptrix* sp.
        - *perminuta* (Ulrich)
      - *Modiolodon* sp.
        - *oviformis* (Ulrich)
        - aff. *M. oviformis* (Ulrich)
      - *Palaeoconcha obliqua* (Hall)
      - *Palaeoneilo* sp.
        - *socialis* (Ulrich)
      - *Similodonta* sp.
      - *Vanuxemia gibbosa* Ulrich
      - *Whiteavesia* sp.

Lexington Limestone—Continued:
- Grier Limestone Member—Continued:
  - Trilobita:
    - *Flexicalymene* sp.
    - *Gravicalymene* sp.
    - *Isotelus gigas* Dekay
    - *Proetidella*? sp.
  - Ostracoda:
    - "*Bollia*" aff. "*B.*" *persulcata* (Ulrich)
    - aff. "*Bythocypris*" sp.
    - *Ceratopsis*? sp.
    - *Ceratopsis* sp.
      - *intermedia* Ulrich
      - aff. *C. oculifera* (Hall)
    - *Ctenobolbina* aff. *C. ciliata* (Emmons)
    - *Dilobella* sp.
    - *Leperditella*? sp.
    - *Leperditella* sp.
    - *Milleratia*? sp.
    - *Milleratia* sp.
  - Conulariida:
    - *Conularia* sp.
  - Cane Run Bed:
    - Conulariida:
      - *Conularia* sp.
    - Byrozoa:
      - *Hallopora multitabulata* (Ulrich)
    - Brachiopoda:
      - *Hebertella frankfortensis* Foerste
      - *Pionodema rectimarginata* Neuman
      - *Rafinesquina* sp.
        - *trentonensis* (Conrad)
      - *Zygospira* sp.
    - Monoplacophora:
      - *Cyrtolites* sp.
    - Gastropoda:
      - *Bucania* sp.
      - *Bucanopsis carinifera* Ulrich
      - *Carinaropsis* sp.
      - *Clathrospira*? sp.
      - *Liospira progne* (Billings)
      - *Loxoplocus* (*Lophospira*) *burginensis* (Ulrich in Ulrich and Scofield)
      - *Sphenosphaera* sp.
        - *troosti burginensis* (Ulrich in Ulrich and Scofield)
    - Pelecypoda:
      - *Ambonychia* sp.
      - *Colpomya faba* (Emmons)
      - *Similodonta* sp.
  - Macedonia Bed:
    - Bryozoa:
      - *Eridotrypa* sp.
      - *Heterotrypa* sp.
      - *Peronopora* cf. *P. granulifera* Ulrich
      - *Praspora falesi* (James)
    - Brachiopoda:
      - *Hebertella frankfortensis* Foreste
      - *Heterorthina macfarlani* Neuman
      - *Rafinesquina* sp.
        - *trentonensis* (Conrad)
    - Trilobita:
      - *Flexicalymene* sp.
      - *Proetidella* sp.

Lexington Limestone—Continued:
- Grier Limestone Member—Continued:
  - Macedonia Bed—Continued:
    - Ostracoda:
      - *Ceratopsis intermedia* Ulrich
- Brannon Member:
  - Bryozoa:
    - *Amplexopora* cf. *A. winchelli* Ulrich
    - Ceramoporid
    - *Cyphotrypa acervulosa* (Ulrich)
    - *Eridotrypa* sp.
    - *Hallopora* sp.
      - *multitabulata* (Ulrich)
    - *Hemiphragma* cf. *H. tenuimurale* Ulrich
    - *Heterotrypa* sp.
    - *Peronopora* cf. *P. milleri* Nickles
    - *Prasopora* cf. *P. falesi* (James)
  - Brachiopoda:
    - *Hebertella frankfortensis* Foerste
    - *Rafinesquina* sp.
    - *Zygospira* sp.
- Perryville Limestone Member:
  - Salvisa Bed:
    - Brachiopoda:
      - *Hebertella frankfortensis* Foerste
      - *Protozyga*? sp.
      - *Rafinesquina* sp.
        - *trentonensis* (Conrad)
      - *Rhynchotrema* sp.
        - *increbescens* (Hall)
      - *Zygospira* sp.
    - Pelecypoda:
      - *Ambonychia* sp.
      - *Colpomya* cf. *C. faba* (Emmons)
      - *Conocardium* sp.
      - "*Ctenodonta*" aff. "*C.*" *longa* (Ulrich)
      - *Ctenodonta regia* Ulrich
      - *Cyrtodonta grandis* Ulrich
      - *Deceptrix* sp.
      - *Palaeoneilo socialis* (Ulrich)
      - *Vanuxemia* aff. *V. dixonensis* Meek and Worthen
        - cf. *V. nana* (Ulrich)
    - Ostracoda:
      - *Bolbopisthia* cf. *B. progressa reticulata* (Kirk)
      - *Eoleperditia* cf. *E. catheysensis* (Kirk)
      - *Isochilina* cf. *I. ampla* Ulrich
  - Cornishville Bed:
    - Brachiopoda:
      - *Hebertella frankfortensis* Foerste
      - *Platystrophia colbiensis* Foerste
      - *Rafinesquina trentonensis* (Conrad)
      - *Zygospira* sp.
- Sulphur Well Member:
  - Bryozoa:
    - Ceramoporid
    - *Dekayia*? sp.
    - *Eridotrypa* sp.
      - cf. *E. briareus* (Nicholson)
    - *Escharopora* sp.
    - *Graptodictya* sp.
    - *Hallopora* sp.
    - *Heterotrypa*? sp.

Lexington Limestone—Continued:
- Sulphur Well Member—Continued:
  - Bryozoa—Continued:
    - *Heterotrypa* sp.
    - *Homotrypa* sp.
    - *Pachydictya* sp.
    - *Peronopora* sp.
      - *milleri* Nickles
      - cf. *P. milleri* Nickles
    - *Prasopora* cf. *P. falesi* (James)
  - Brachiopoda:
    - *Hebertella frankfortensis* Foerste
    - *Rafinesquina* sp.
    - *Zygospira* sp.
- Stamping Ground Member:
  - Brachiopoda:
    - *Hebertella*? sp.
      - *frankfortensis* Foerste
    - *Platystrophia* sp.
    - *Rhynchotrema increbescens* (Hall)
    - *Zygospira* sp.
  - Gastropoda:
    - cf. *Cyclora* sp.
    - cf. *Loxoplocus* (*Lophospira*) sp.
    - cf. *Microceras* sp.
  - Trilobita:
    - *Proetidella* sp.
  - Ostracoda:
    - cf. *Ceratopsis intermedia* Ulrich
  - Graptolithina:
    - *Diplograptus* sp.
- Millersburg Member:
  - Bryozoa:
    - *Atactoporella* sp.
    - *Ceramophylla*? sp.
    - *Constellaria* sp.
      - cf. *C. florida* Ulrich
      - cf. *C. teres* Ulrich and Bassler
    - *Eridotrypa*? sp.
    - *Eridotrypa* sp.
    - *Escharopora* sp.
      - cf. *E. nodulosa* Ulrich
    - *Graptodictya* sp.
    - *Hallopora onealli* (James)
      - cf. *H. onealli* (James)
    - *Heterotrypa* sp.
    - *Homotrypa* sp.
    - *Mesotrypa* sp.
    - *Peronopora* sp.
  - Brachiopoda:
    - *Hebertella parkensis* Foerste
    - *Orthorhynchula linneyi* (James)
    - *Platystrophia* sp.
      - *colbiensis* Foerste
    - *Rafinesquina* sp.
      - *winchesterensis* Foerste
    - *Zygospira* sp.
  - Gastropoda:
    - *Cyclonema* sp.
    - cf. *Loxoplocus* (*Lophospira*) sp.
    - cf. *Microceras* sp.
  - Pelecypoda:
    - *Ambonychia* sp.
    - *Allonychia flanaganensis* Foerste

Lexington Limestone—Continued:
- Millersburg Member—Continued:
  - Pelecypoda—Continued:
    - *Deceptrix perminuta* (Ulrich)
    - *Palaeoconcha obliqua* (Hall)
  - Trilobita:
    - *Proetidella*? sp.
  - Ostracoda:
    - *Ceratopsis* sp.
      - *intermedia* Ulrich
    - *Warthinia nodosa* (Ulrich)
- Devils Hollow Member:
  - Brachiopoda:
    - *Zygospira* sp.
  - Gastropoda:
    - *Loxoplocus* (*Donaldiella*) cf. *L.* (*D*). *decursa* (Ulrich)
      - (*Lophospira*) aff. *L.* (*L.*) *oweni* (Ulrich)
        - *summerensis* (Safford)
    - *Tropidodiscus* sp.
  - Pelecypoda:
    - *Colpomya constricta* Ulrich
  - Ostracoda:
    - *Eoleperditia* sp.
    - *Teichochilina*? sp.
- Tanglewood Limestone Member:
  - Anthozoa:
    - *Favistina stellata* (Hall)
  - Bryozoa:
    - *Amplexopora* sp.
      - cf. *A. winchelli* Ulrich
    - *Atactoporella*? sp.
    - *Atactoporella* sp.
    - *Ceramophylla*? sp.
    - *Ceramoporella*? sp.
    - *Constellaria* sp.
      - cf. *C. florida* Ulrich
      - cf. *C. teres* Ulrich and Bassler
    - *Cyphotrypa* sp.
      - *acervulosa* (Ulrich)
    - *Dekayia* sp.
    - *Eridotrypa* sp.
    - *Escharopora* sp.
    - *Hallopora*? sp.
    - *Hallopora* sp.
      - *multitabulata* (Ulrich)
      - cf. *H. onealli* (James)
    - *Hemiphragma* cf. *H. tenuimurale* Ulrich
    - *Heterotrypa*? sp.
    - *Heterotrypa* sp.
    - *Homotrypa* sp.
    - *Peronopora* sp.
      - *milleri* Nickles
      - cf. *P. milleri* Nickles
    - *Prasopora* cf. *P. falesi* (James)
    - *Stictopora* sp.
    - *Stigmatella*? sp.
      - cf. *S. conica* Brown
      - *multispinosa* Brown
  - Brachiopoda:
    - *Hebertella* sp.
      - *frankfortensis* Foerste
      - *parkensis* Foreste
    - *Heterorthina macfarlani* Neuman

Lexington Limestone—Continued:
Tanglewood Limestone Member—Continued:
Brachiopoda—Continued:
Platystrophia sp.
amoena McEwan
colbiensis Foerste
elegantula McEwan
Rafinesquina sp.
trentonensis (Conrad)
Rhynchotrema sp.
increbescens (Hall)
cf. *R. increbescens* (Hall)
Strophomena sp.
Zygospira sp.
cf. *Z. modesta* (Hall)
Monoplacophora:
Cyrtolites sp.
Gastropoda:
cf. *Bucania* sp.
Bucanopsis sp.
Cyclonema sp.
cf. *Cyclora* sp.
Liospira sp.
Loxoplocus (*Lophospira*) sp.
cf. *Microceras* sp.
Murchisonia (*Hormotoma*) sp.
Sinuites sp.
Tropidodiscus? sp.
Tropidodiscus sp.
Pelecypoda:
Conocardium sp.
"*Ctenodonta*" aff. *C. pectunculoides* (Hall)
Deceptrix perminuta (Ulrich)
Palaeoconcha obliqua (Hall)
Trilobita:
Flexicalymene? sp.
Isotelus sp.
Proetidella? sp.
Proetus? sp.
Ostracoda:
aff. *Bythocypris* sp.
Ceratopsis? sp.
intermedia Ulrich
aff. *C. oculifera* (Hall)
Ctenobolbina aff. *C. ciliata* (Emmons)
Dilobella? sp.
Dilobella sp.
Leperditella sp.
Milleratia? sp.
Milleratia sp.
Clays Ferry Formation:
Bryozoa:
Amplexopora persimilis Nickles
Arthropora sp.
Atactopora sp.
Batostomella sp.
Ceramophylla? sp.
Ceramoporella? sp.
Constellaria cf. *C. teres* Ulrich and Bassler
Eridorthis sp.
Eridotrypa sp.
cf. *E. briareus* (Nicholson)
Escharopora sp.

Clays Ferry Formation—Continued:
Bryozoa—Coninued:
Hallopora sp.
onealli (James)
cf. *H. onealli* (James)
Hemiphragma sp.
Heterotrypa? sp.
Heterotrypa sp.
cf. *H. frondosa* (d'Orbigny)
Homotrypa sp.
Peronopora sp.
cf. *P. decipiens* (Rominger)
milleri Nickles
Stictopora sp.
Brachiopoda:
Dalmanella sp.
emacerata (Hall)
multisecta (Meek)
Glyptorthis sp.
Hebertella sp.
Platystrophia sp.
cf. *P. amoena* McEwan
elegantula McEwan
Rafinesquina sp.
winchesterensis Foerste
Sowerbyella sp.
cf. *S. rugosa* (Meek)
Zygospira sp.
cf. *Z. cincinnatiensis* Meek
cf. *Z. modesta* (Hall)
recurvirostris (Hall)
Monoplacophora:
Cyrtolites sp.
Gastropoda:
Cyclonema sp.
Liospira sp.
Loxoplocus (*Lophospira*) sp.
Sinuites? sp.
Tropidodiscus sp.
Pelecypoda:
Ambonychia cf. *A. radiata* Hall
Palaeoconcha sp.
Cephalopoda:
Orthonybyoceras sp.
Trilobita:
Acidaspis sp.
Ceraurus? sp.
Cryptolithus? sp.
Flexicalymene griphus Ross
Gravicalymene? sp.
Gravicalymene sp.
Isotelus? sp.
Isotelus sp.
Proetidella sp.
Ostracoda:
Ceratopsis intermedia Ulrich
Leperditella sp.
Milleratia aff. *M. shideleri* Levinson

AGE

Detailed biostratigraphic study of the faunas collected from the Lexington Limestone in conjunction with the mapping program are not yet completed;

therefore, the discussion of the age of the Lexington Limestone presented here is brief and is based upon sparse literature of relatively recent date.

There is general agreement that the Tyrone Limestone belongs to the Wilderness Stage of Cooper (1956), and cephalopods collected from 20 feet below the Tyrone-Lexington contact in the Little Hickman quadrangle were dated by R. H. Flower (written commun. to D. E. Wolcott, 1967) as late Wilderness in age. Cooper (1956) placed the top of the Wilderness Stage at the Tyrone-Lexington contact and considered the Curdsville Limestone Member of the Lexington to be correlative with the Shoreham Formation of Kay (1937) in the Ordovician of New York. However, Bergström and Sweet (1966, p. 295, 296), on the basis of conodont correlations, placed the lower 70 feet of the Lexington (the Curdsville, Logana, and lower Grier) in the Wilderness Stage as correlative with the Kirkfield Limestone of Johnson (1911) of the New York section. (See also Twenhofel (1954, pl. 1).) The Curdsville is a transgressive unit, and the base of the Lexington Limestone must therefore be diachronous (p. 12), but no information is yet available on changes in age of the basal contact across the area of this report, though I suspect such changes are small.

Bergström and Sweet (1966, p. 288) correlated the base of the Edenian Stage (defined as the base of the Kope Formation at Cincinnati) with a horizon about 40 feet below the top of the Lexington at its reference section. Sweet and Bergström (1970a) subsequently revised their correlation and placed the base of the Edenian Stage 70 to 80 feet below the top of the Lexington at the same locality. O. L. Karklins (in Cressman and Karklins, 1970, p. 21), on the basis of preliminary studies of the bryozoans, located the base of the Upper Ordovician (Cincinnatian) at about the top of the Brannon Member approximately 100 feet below the top of the Lexington Limestone at the reference section, thus agreeing with Bergström and Sweet that much of the upper part of the Lexington is Edenian in age.

In terms of the New York section, Bergström and Sweet (1966, p. 295) correlated the Lexington of the reference section with the Kirkfield, Shoreham, Denmark, and lower Cobourg Formations as used by Kay (1943). They also correlate it with the Galena, Dubuque, and lower Moquoketa Formations of Minnesota. Inasmuch as the upper contact of the Lexington is markedly diachronous, the age span will be less than that of the reference section in the southern and northern parts of the area of this report and slightly greater in the eastern part.

FACIES AND PALEOGEOGRAPHY

SUMMARY OF DEPOSITIONAL ENVIRONMENTS

The character and depositional environments of the rock types that make up the Lexington Limestone and equivalent formations within the report area are summarized in table 3. The inferred depositional environments are based on several assumptions. Surf base is assumed to have been no deeper than 5 m; it may have been shallower, but inasmuch as the Lexington was deposited in a shallow inland sea, surf base could not have been as deep as the 10 m determined for the open Pacific coast of the Santa Cruz area of California by Bradley (1958). The lower limits for deposition of fossiliferous limestone and the nodular fossiliferous limestone and shale facies are assumed to have been at the maximum depth of effective photosynthesis—the compensation depth—and this is taken as the boundary between the infralittoral zone shoreward and the circalittoral zone seaward. The depth of 25 m assigned to this boundary is a gross approximation, and it may have been half as deep or twice as deep, depending on turbidity, the type of flora, the water temperature, and the climate.

FACTORS GOVERNING FACIES DISTRIBUTION

The distribution of facies was governed by interaction between the sedimentary materials, the bathymetry, and the currents.

The sedimentary material in the Lexington Limestone is of two types—biogenic carbonate formed within the area and terrigenous clay and fine silt derived from a distant source. The biogenic carbonate was generated in the infralittoral zone where conditions were most favorable for abundant life. Much of the skeletal carbonate accumulated nearly in place. Many whole shells were incorporated in the sediment, and breakage of skeletal material was caused largely by biologic agents rather than currents as shown by the lack of abrasion and sorting. The whole and broken skeletal material accumulated together with lime mud probably produced by algae and by the breakdown of larger skeletal fragments, and the resulting sediment was churned by an infauna. In shallower water the skeletal material was broken, abraded, and sorted to form calcarenite, and calcareous fines were winnowed and transported to the outer infralittoral and circalittoral zones to form calcisiltite.

The rate of production of biogenic carbonate could have been affected by changes in the turbidity, nutrient content, and temperature of the water; by changes in the direction, velocity, and turbulence of water currents; and by evolutionary changes in the

TABLE 3.—*Description of rock types of the*

Facies	Subfacies	Dominant limestone types	Dominant bedding types	Shale
Calcarenite		Sorted and rounded biosparite.	Planar crossbedding; ripple bedding; planar bedding.	Negligible
Fossiliferous limestone	Nodular and irregularly bedded fossiliferous limestone.	Poorly washed biosparite and biosparrudite; unsorted biosparite.	Sets of nodular beds alternating with irregular beds.	Minor partings
Do	Bryozoan limestone	Poorly washed biosparrudite.	Lenticular to irregular	---do
Nodular fossiliferous limestone and shale.		Poorly washed biosparite and biosparrudite; packed biomicrosparrudite.	Nodular	As matrix around nodules; 30 to 50 percent of rock.
Brachiopod coquina		Poorly washed biosparrudite.	Irregular	Negligible
Interbedded limestone and shale.	Argillaceous calcisiltite and shale.	Sparse to packed argillaceous biomicrosparite.	Planar, some lenticular, some contorted.	Interbeds making up about half of unit.
Do	Fossiliferous limestone and shale.	Same as above, but with biomicrosparrudite, poorly washed biosparite and biosparrudite, and sorted crinoidal biosparite.	Same as above; minor ripple bedding.	---do
Shale and and minor limestone.		---do	Planar, some ripple bedding.	Beds totaling 75 to 85 percent of unit.
Calcilutite	Unfossiliferous	Micrite, fossiliferous micrite, pelmicrite.	Planar; minor nodular bedding.	Negligible, some black shale partings.
Do.	Fossiliferous	Packed biomicrite and packed biomicrosparite.	Irregular	Negligible
Gastropod coquina		Gastropodal biosparrudite and brachiopodal biosparrudite.	Crossbedded	---do

biota. I am unable to evaluate how many of these factors might have affected the production of carbonate in Lexington time, but there is no reason to assume that there were sudden or major changes in any of them. Certainly the major factor affecting the amount of carbonate produced was the size of the area within the infralittoral zone; the larger the area, the more biogenic carbonate was produced.

The nearest source of abundant fine terrigenous material was the tectonic lands within and bordering the Appalachian geosyncline 300 miles to the east. Most reconstructions of the paleogeography of late Middle Ordovician time follow Kay (1937) in showing large areas of the Canadian Shield as emergent. However, the evidence seems equivocal, and it depends largely on the age of the Red River fauna (Twenhofel, 1954, p. 257–281). If the Red River fauna is the temporal equivalent of the Lexington Limestone, then its widespread occurrence in Manitoba and Ontario would indicate that little of the shield was land during that time. Even if the shield were largely emergent, it would have been of low relief; and it seems unlikely that it would have contributed as much detritus to the sea as would the tectonic lands within the Appalachian geosyncline. Assuming the tectonic lands in the vicinity of the Appalachian geosyncline to have been the major source, the amount of detritus available probably increased toward the end of Lexington time as the intensity of orogeny increased in the central and northern parts of the geosynclinal area. Whatever the source, the fine detritus within the Lexington Limestone and its lateral equivalents accumulated below wave base and to some extent in shallow waters where it was trapped by the baffling effect of the marine epifauna and flora.

The sediments were modified by tidal currents, storm currents, and fair-weather waves. Hrabar, Cressman, and Potter (1971) studied crossbedding in the Tanglewood Limestone Member and concluded that the crossbedding was formed by tidal currents that were refracted by the shelf so as to move to-and-fro perpendicular to the topography. The crossbedding is bimodal with the modes about 180° apart, and the modes in any one quadrangle tend to be perpendicular to the local isopach of the Tanglewood. I can identify few specific features

Lexington Limestone and related formations

Dolomite (percent of total carbonate)	Apatite	Fauna	Stratigraphic units	Environment of deposition
Mostly 5 to 10 percent	Averages 6 percent, but varies greatly; mechanically deposited.	Sparse; some bryozoans, thick-shelled bryozoans, gastropods, corals; stromatoporoids in transitional beds.	Tanglewood Limestone Member and lower part of Curdsville Limestone Member of Lexington Limestone.	Littoral and inner infralittoral; maximum water depth probably less than 5 m; normal marine salinity.
Variable; mostly 5 to 15 percent.	About 2 percent diagenetic	Brachiopods, encrusting and branching bryozoans, crinoids; bedding evidence of abundant softbodied infauna.	Most of Grier Limestone Member and upper part of Curdsville Limestone Member of Lexington Limestone.	Infralittoral; water depth mostly less than 15 m, but reaching as much as 25 m; normal marine salinity.
Not determined, but appreciable.	Not determined	Large bryozoans	Sulphur Well Member of Lexington Limestone.	Do.
Average 25 percent	About 2 percent; diagenetic	Brachiopods, bryozoans, mollusks, crinoids; locally stromatoporoids and corals; bedding evidence of abundant softbodied infauna.	Millersburg Member, Greendale Lentil, and Stamping Ground Member of Lexington Limestone.	Do.
Not determined, but small.	Not determined	Thin-shelled brachiopods	Part of Logana Member and part of Macedonia Bed of Grier Limestone Member of Lexington Limestone.	Outer infralittoral; water depth 15 to 25 m; normal marine salinity.
Variable; averages 25 to 35 percent.	About 2 percent	Mostly sparse; a few beds with abundant pelecypods.	Most of Logana Member and Macedonia Bed of Grier Limestone Member and Brannon Member of Lexington Limestone; parts of Clays Ferry Formation.	Circalittoral; water depth 25 m and greater; normal marine salinity.
Not determined	Not determined	Thin-shelled brachiopods, mollusks, bryozoans, crinoids.	Most of Clays Ferry Formation; parts of Point Pleasant Formation.	Outer infralittoral and circalittoral; normal marine salinity; depth about 25 m.
Less than 2 percent (Weiss and Norman, 1960, p. 286).	---do	---do	Kope Formation	Same as above, but probably slightly deeper water.
Less than 3 percent	Negligible	Sparse ostracodes and mollusks.	Salvisa Bed of Perryville Limestone Member and part of Devils Hollow Member of Lexington Limestone.	Lagoonal; greater than normal marine salinity; restricted circulation; water depth from intertidal to a few meters.
Less than 5 percent	---do	Pelecypods and ostracodes; some stromatoporoids, bryozoans, crinoids, brachiopods and gastropods.	Faulconer Bed of Perryville Limestone Member of Lexington Limestone.	Protected infralittoral; normal marine salinity; water depth a few meters.
Not determined, but small.	Not determined	Gastropods; some brachiopods.	Part of Devils Hollow Member of Lexington Limestone.	Beaches on shores of lagoon; possibly in tidal channels.

caused by storm currents, though storms must have had a considerable effect. Overturned stromatoporoids observed in several localities probably were toppled by storms, and beds of calcarenite in the Grier and Millersburg Member and the few rippled beds in the Grier may have formed during storms. John Pojeta, Jr. (written commun., 1970), suggested that nested articulated pelecypods found locally in the Logana Member may have been moved and deposited by storm currents. The effect of fair-weather waves is difficult to evaluate, but in conjunction with tide, they probably helped sort and abrade skeletal fragments to calcarenite.

On a gently sloping sea floor, given the sediments and currents described above, biogenic carbonates composed of a mixture of whole and broken shells and lime mud would accumulate in the infralittoral zone; in shallower water the skeletal material would be broken, winnowed, and sorted, largely by tidal currents, and deposited as calcarenite bars; and in deeper water below wave base, carbonate fines winnowed from shallower water would accumulate together with terrigenous mud. If there were no change in sea level and no subsidence, both the calcarenite and the shelly carbonate facies of in infralittoral zone would prograde. If the calcarenite bars became extensive, shallow water behind the bars would be shielded from currents of the open shelf, and the interchange of water would be restricted so than the salinity in that area would increase; in this protected environment, lagoonal lime mud could accumulate and occasionally build up to form tidal flats. With slow subsidence (or eustatic rise of sea level), the facies would continue to prograde, but more slowly,[6] until at some rate of subsidence, sedimentation and subsidence would be in equilibrium; on the other hand, at a rather fast subsidence rate, the facies belts would recede landward. Thus, in the stratigraphic sequence, either no subsidence or slow subsidence would result in a regressive sequence whereas relatively rapid subsidence would yield a transgressive sequence.

[6] If calcarenite progrades more rapidly than the shelly carbonate facies, the rate of carbonate production will be reduced, and the rate of deposition will decrease until more of the sea floor subsides below the depth of vigorous currents and the fauna and flora can spread over a wider area. In other words, there is a critical balance between the area of carbonate production and the area of calcarenite deposition, and intertonguing between calcarenite and the fossiliferous limestone and nodular fossiliferous limestone and shale to some extent represents adjustments to maintain the balance.

FACIES RELATIONS

The stratigraphic relations between members of the Lexington Limestone and between the Lexington and Clays Ferry Formations are illustrated by the stratigraphic cross sections on plate 7. Inasmuch as each member generally consists of one dominant rock type, the sections also illustrate facies relations between the various rock types summarized in table 3.

In order to interpret the lithic relations in terms of facies, it is necessary to determine the time relations between the lithic units. The Lexington Limestone has not yet been zoned paleontologically in great detail, but biostratigraphic studies do suggest that time-rock units maintain approximately the same thickness over the area (Bergström and Sweet, 1966), and time horizons must be nearly parallel to the contact between the Tyrone and Lexington Limestones and the base of the Brannon. The lithic relations themselves suggest some time relations; if two units intertongue, they are obviously at least partly correlative, and a thin tongue of one lithic type with another type must be an approximate time marker. These various features are enough to outline the major features of time and facies but are inadequate to zone the rocks in enough detail to permit the construction of meaningful quantitative facies maps. Therefore, facies relations are shown by the generalized composite fence diagram on plate 8.

Although the facies relations illustrated on plate 8 are intricate in detail, the major features can be summarized briefly. In the basal 100 feet of the section, the general facies sequence is from calcarenite in the southwestern corner northward to fossiliferous limestone and thence to interbedded calcisiltite and shale. In the interval from approximately 100 to 200 feet above the base, the sequence is from calcilutite in the southwesternmost sections northward to calcarenite and thence to fossiliferous limestone. Above 200 feet the facies relations are more complex. In general, calcarenite in the west-central part of the area intertongues eastward and northward with nodular fossiliferous limestone and shale and westward with interbedded limestone and shale, and both the calcarenite and the nodular fossiliferous limestone and shale intertongue northward and southward with interbedded limestone and shale.

Templeton and William (1963, p. 170, 175–179) made an extremely detailed lithologic correlation between the Lexington Limestone of central Kentucky and the Ordovician strata of Illinois. Their correlations were based on the assumption that there is great uniformity of sequence, gradual changes in facies, and continuity of many thin distinctive units (Templeton and Willman, 1963, p. 15). Whatever the validity of their methods and correlations in other parts of the midcontinent, the repetition of rock type and the many facies changes illustrated on plates 1 through 7 and on plate 8 show that their methods cannot be applied to the Lexington Limestone.

PALEOGEOGRAPHY

On plate 9, facies relations within the Lexington are combined with inferences about depositional environments of the rock type to illustrate paleogeography. The illustrations are necessarily subjective because of uncertainties in correlation and because of uncertainties in interpretations of environments.

During the first half of Lexington time the area sloped gently northward. The transgression that began Lexington deposition spread calcarenite across the area and finally culminated in deposition of calcisiltite and shale of the Logana Member. Plate 9*A* illustrates the paleogeography at the time of the maximum transgression; calcarenite deposited in the littoral zone on the southern margin of the area graded northward into calcisiltite and shale deposited in deeper water of the circalittoral zone. Plate 9*B*, which represents a horizon about 150 feet above the base of the Lexington, shows subsequent regression which resulted in the spread of fossiliferous limestone of the infralittoral zone across the northern part of the area; the zone of calcarenite bars moved northward, and calcilutite was deposited in shallow water south of the bars in an area protected from waves and currents of the seas to the north.

Beginning with deposition of the Brannon Member, about 190 feet above the base of the Lexington, the geographic framework changed (pl. 9*C*). The southern part of the area subsided; calcarenite was deposited on the southern margin of the resultant topographic low, and nodular fossiliferous limestone and shale of the infralittoral zone accumulated as a bank that extended west-northwest across the central part of the area; calcarenite accumulated as shelf-edge sand on the margins of the bank while calcisiltite and shale were deposited in deeper waters off both flanks of the bank. This topographic high is the feature referred to as the Tanglewood bank by Hrabar, Cressman, and Potter (1971). Periodically, the calcarenite prograded across much of the bank. This framework persisted to the end of Lexington time, although the size of the bank expanded and contracted in response to minor transgressions and regressions. Plate 9*D*, for example, represents the paleogeography of a horizon 250 feet above the base of the Lexington. During one of these regressions, a lagoon in which the Devils Hollow Member was deposited formed on the bank, separated from more open water by belts of calcarenite. Transgression eventually resulted in limestone and shale being deposited across the entire area, terminating Lexington deposition.

RELATION OF FACIES TO STRUCTURE

Neither the Cincinnati arch nor the Jessamine dome seem to have affected the deposition of the Lexington Limestone, and neither feature was active during Lexington time. Facies trends are mostly at a high angle to the axis of the arch, and there is no obvious feature of facies or thickness that corresponds to the dome. However, some aspects of the Lexington suggest some control of sedimentation by slight movement along preexisting faults.

The southern part of the report area subsided in mid-Lexington time and received deeper water sediments (pl. 9*C*). This subsidence is reflected by a reentrant in the isopachs of the total Lexington Limestone near the southern border of the report area (fig. 4). This reentrant corresponds approximately in trend and location with the Kentucky River and Irvine-Paint Creek fault zones (fig. 1). Both of these fault zones were active as early as the Cambrian (Webb, 1969), and slight movements along them during mid-Lexington time may have caused subsidence.

REGIONAL RELATIONS

Figure 38 shows the thickness of the Lexington Limestone in central Kentucky and the thickness of the limestone facies in rocks of Lexington age in adjacent areas. In Tennessee, Wilson's (1949) laminated argillaceous members are not contoured as part of the limestone facies because they represent a deep-water facies. In general, the limestone facies continue to thin north and west of the report area; in parts of western Kentucky and southern Indiana nearly all of the Lexington interval is shale (Freeman, 1953, figs. 5, 6; Gutstadt, 1958, p. 65, 67). The manner in which the limestone facies thins northward is shown in more detail on plate 10. A similar northward change from limestone in Kentucky to shale in central Ohio is shown by Calvert (1962, p. 41).

Those familiar with Wilson's (1949, 1962) excellent descriptions of the Nashville Group will see many close similarities between the rock type, facies relations, and the inferred environments of the Nashville Group and the Lexington Limestone. A principal difference is that the facies in the Nashville Group strike north-south on a west-sloping sea floor whereas those in the Lexington strike more nearly east-west on a north-sloping sea floor or are irregular. These differences are reflected by the trends of the contours in figure 38.

Plate 11 illustrates the paleogeography and gross facies relations of rocks of approximately the same age as the Lexington Limestone in the Eastern United States. The map is based on data freely interpreted from many sources. Papers by Berry (1968), Gutstadt (1958), and Templeton and Willman (1963) were particularly helpful. Turbidity current directions are from McBride (1962), Krueger (1963), and Middleton (1965). Sediment transport directions in New York, Vermont, and Ontario are from Chenoweth (1952) and Lippit (1959), and in southwestern Ohio, from Weiss, Edwards, Norman, and Sharp (1965, p. 56).

The paleolatitudes on plate 11 are based on the virtual geomagnetic pole for the Ordovician determined by Collinson and Runcorn (1960). Spjeldnaes (1961) noted that the arrangement of world climatic zones of the Ordovician, based on faunal evidence and gross facies distribution, is in accord with the paleomagnetic data. The paleolatitudes indicate that the Eastern United States was in the southern hemisphere in the zone of prevailing easterly trade winds. The prevailing winds shown on plate 11 are those expected from the paleolatitude.

Most of the Eastern and Central United States was the site of shallow-water carbonate deposition during the late Middle Ordovician. Dolomite formed near the Ordovician equator, but elsewhere the carbonates were fossiliferous limestone. The belt of shale and argillaceous limestone that extends from western Tennessee through western Kentucky into Ohio was apparently the site of a channel somewhat deeper than the adjacent carbonated shelf. Sediments in the channel are mostly shale in Ohio and mostly argillaceous limestone in western Tennessee, probably because Ohio was nearer the source of the terrigenous fines.

The carbonate shelf was bordered on the present-day east by a miogeosyncline in which shale and some radiolarian chert were deposited in fairly deep water; siltstone and graywacke were deposited by turbidity currents. Farther east, an archipelago separated the miogeosyncline from a eugeosyncline in which shale and volcanic rocks accumulated. A source area east of the eugeosyncline may have been continental or insular; according to McBride (1962, p. 88), the quantity of clastic material in the eugeosyncline suggests that the source was continental.

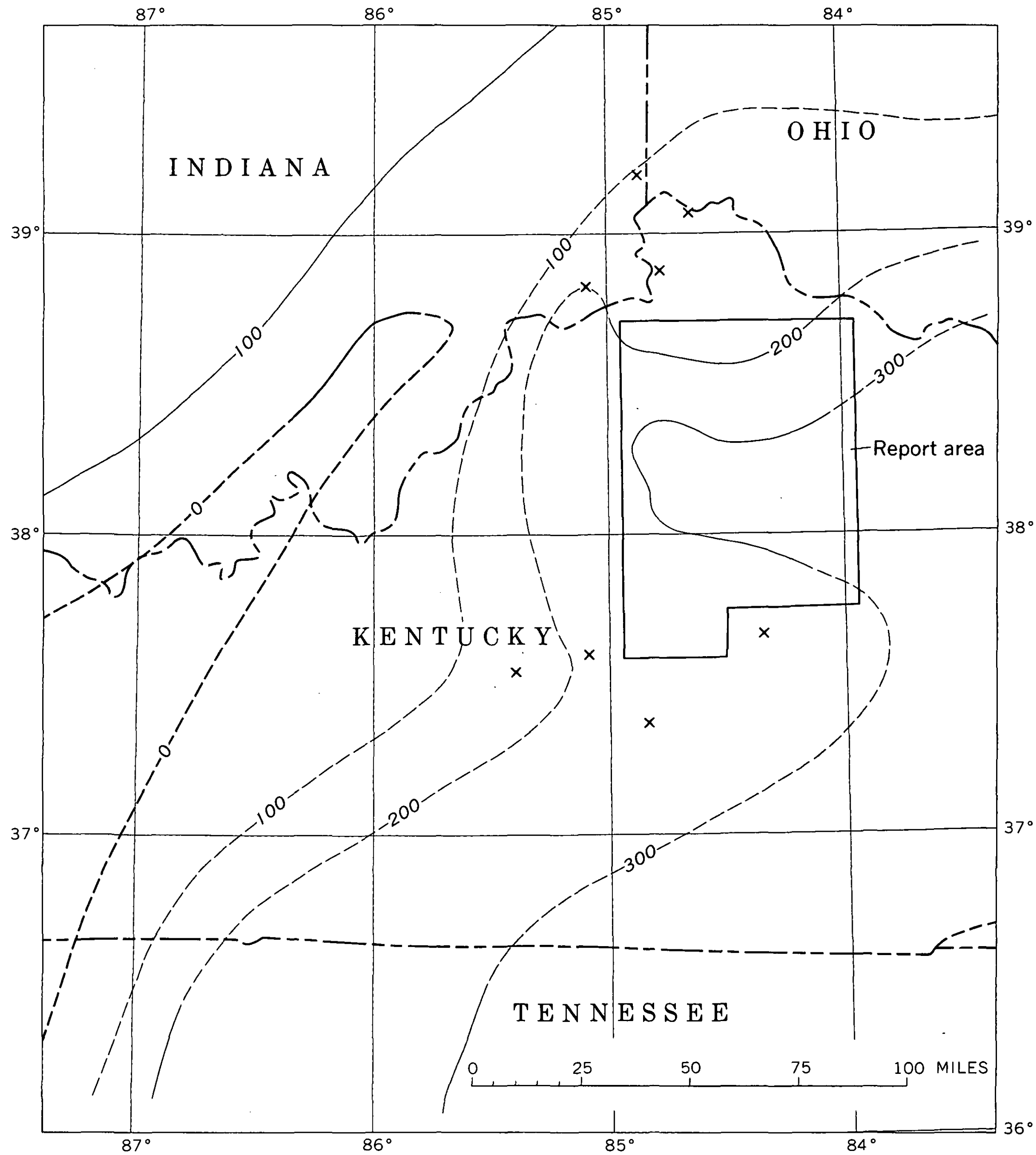


FIGURE 38.—Thickness of limestone facies in rocks of Lexington age in central Kentucky and adjacent parts of Ohio, Indiana, and Tennessee. Contour interval 100 feet. Isopachs solid where based on mapping and closely spaced sections; dashed where inferred. Solid-line isopachs in Indiana from Wilson (1949); thickness in Ohio from Bergström and Sweet (1966, p. 277) and Calvert (1962, p. 41, pl. 1); approximate location of zero isopach in Kentucky from Freeman (1953, fig. 6); ×, subsurface section outside report area.

In the Ouachita foldbelt south of the carbonate shelf, bedded chert and shale accumulated slowly in rather deep water in a starved basin, or leptogeosyncline (King, 1969, p. 63). The slow rate of sedimentation in that area suggests that land areas were distant.

Current directions on the carbonate shelf in New York—determined from ripple marks, crossbedding, and fossil orientation—were to the present-day northeast (Chenoweth, 1952; Hawley, 1957); this direction is nearly opposite to that which would be expected from the prevailing wind and current directions inferred from the paleolatitudes, probably because the currents were tidal and therefore perpendicular to the slope of the sea floor. In northern Kentucky and southwestern Ohio, current directions in the Point Pleasant Formation and lower part of the Kope Formation were to the present-day west-southwest (Weiss and others, 1965, p. 56), in accord with the inferred Ordovician wind and current directions; it also seems reasonable to postulate a current flowing southwest along the central channel.

The phosphatic nature of the Lexington Limestone and of the equivalent limestones in central Tennessee requires that these two areas had direct access to waters from below the photic zone and that the area had fairly direct access to the open ocean (p. 23). Considering the regional setting, the only possible source for such water would have been the channel of western Tennessee and Kentucky, which must have connected with deeper water that bordered the carbonate shelf on the present-day south. Earlier, I suggested that the current in the channel flowed to the southwest, so in order to draw water from the south it is necessary to further postulate a counter current flowing northward along the east side of the channel. Currents in the southern hemisphere are deflected to the left by the Coriolis force; thus, during Ordovician time, a counter current flowing toward the present-day north along the east side of the channel would upwell near the carbonate shelf edge to bring phosphate-rich water from below the euphotic zone to the surface. (See McKelvey (1967) for a discussion of the relation of sedimentary phosphate deposits to upwelling.) Thus the phosphatic nature of the rocks implies the existence in Ordovician time of an ancestral Mississippi embayment.

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