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GEOLOGY OF THE ILLINOIS PARTS OF THE CAIRO, LA CENTER, AND THEBES QUADRANGLES

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ABSTRACT

The Cairo, La Center, and Thebes Quadrangles of extreme southern Illinois, lie in the northernmost extension of the Gulf Coastal Plain and are underlain by strata of chiefly Cretaceous and Tertiary age, although Paleozoic strata crop out locally. The Kimmswick Limestone and Maquoketa Formation of Ordovician age, Girardeau, Edgewood, Sexton Creek, St. Clair, and Moccasin Springs Formations of Silurian age, and the Bailey Formation of Devonian age are exposed in the Thebes Quadrangle. The Mississippian St. Louis Limestone is exposed in the La Center Quadrangle. The Late Cretaceous (Gulfian Series) Tuscaloosa, McNairy, and Owl Creek Formations, the Paleocene Clayton and Porters Creek Formations, the Eocene Wilcox Formation, and the Pliocene "Lafayette" Formation are well exposed in each of the three quadrangles. Pleistocene deposits consist of valley-train materials in the major valleys, slackwater deposits in tributary valleys, and loesses in the upland areas.

Clay, sand and gravel, and tripoli form a large part of the mineral resources of the area. Limestone is quarried locally, and ground water is plentiful for industrial use.

INTRODUCTION

The Cairo, La Center, and Thebes Quadrangles (pl. 1) include parts of southernmost Illinois, northwestern Kentucky, and southeastern Missouri. The area that is mapped for this report, about 400 square miles, covers the parts of these quadrangles, and a small part of the Wickliffe Quadrangle, that lie within Illinois. It includes parts of Alexander, Massac, and Pulaski Counties (fig. 1).

Cretaceous and Tertiary strata underlie most of this area and are the northernmost sediments deposited in the Mississippi Embayment. Beneath these sediments, Ordovician, Silurian, Devonian, and Mississippian strata are exposed locally, mainly in the northwestern part of the Thebes Quadrangle. The entire upland area was covered by Pleistocene loess, which thins eastward from 40 to 50 feet along the

Mississippi River bluffs to 10 to 15 feet in the La Center Quadrangle.

Agriculture is the chief industry in the area. Orchards and truck farms are prevalent in the uplands on the well drained loess soils, and cotton, soy beans, and corn are raised in the bottomlands on the alluvial soils.

The mineral resources include clay, sand, gravel, ganister, tripoli, and ground water. The development of ground-water resources is perhaps the most important requirement for future expansion of industry in the area.

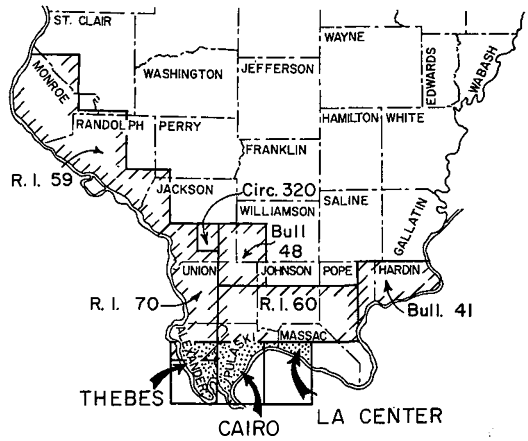

Fig. 1 - Location of the Cairo, La Center, and Thebes Quadrangles, Illinois.

Field work on the Cretaceous and Tertiary sediments was started in the area by Pryor in the summer of 1957 and continued into the spring of 1959. This was the first detailed mapping of these sediments in Illinois, although the general distribution of the formations had been shown by Lamar and Sutton (1930). The Paleozoic strata in the northern part of the Thebes Quadrangle were first mapped in detail by J. M. Weller (Weller and Ekblaw, 1940) but were restudied and the mapping revised by Ross during the autumn of 1960. Other investigations in the area are listed in the references.

This report briefly summarizes the major aspects of the geology of the Cairo, La Center, and Thebes Quadrangles. Detailed notes and well records may be consulted in the technical files of the Illinois State Geological Survey at Urbana, Illinois.

Lowell Reed of the Survey staff served as a field assistant with Pryor and collected many of the well records and well samples. Discussions of the problems with J. C. Frye, J. E. Lamar, G. E. Maxey, P. E. Potter, D. H. Swann, and H. B. Willman, all of the Survey, were particularly helpful.

PHYSIOGRAPHY

The Cairo, La Center, and Thebes Quadrangles lie largely in the Gulf Coastal Plain, but the northwestern part of the Thebes Quadrangle is in the Ozark Plateau Province. The major topographic features of the area include the junction of the Mississippi and Ohio Rivers on a broad flood plain, the narrow gorge of the Mississippi River at Thebes, the broad Cache Valley, which is an abandoned channel of the Ohio River, the maturely eroded upland underlain by resistant Paleozoic rocks, and the low lying, gently rounded hills of unconsolidated Cretaceous and Tertiary sediments.

The highest elevation in the area, in the north part of the Thebes Quadrangle, is about 720 feet above sea level; the lowest, at the junction of the Mississippi and Ohio Rivers south of Cairo in the Wickliffe Quadrangle, is slightly below 300 feet. The total relief is about 425 feet. In the area of dissected Paleozoic rocks in the Thebes Quadrangle, many hills rise as much as 200 feet above the valley bottomlands. The flood plain of the Mississippi and Ohio Rivers is characterized by abandoned channels, bars, and natural levees but the relief seldom exceeds 10 feet.

	SYSTEM	SERIES	GROUP	FORMATION	GENERALIZED ROCK COLUMN	THICKNESS IN FEET
FORMATIONS EXPOSED	QUATERNARY	Pleistocene		loesses and valley fill		0 - 250
FORMATIONS EXPOSED	TERTIARY	Pliocene		"Lafayette" Gravel		5 - 50
FORMATIONS EXPOSED	TERTIARY	Eocene		Wilcox		50 - 250
FORMATIONS EXPOSED	TERTIARY	Paleocene		Porters Creek		50 - 170
FORMATIONS EXPOSED	TERTIARY	Paleocene		Clayton		
FORMATIONS EXPOSED	CRETACEOUS	Gulfian		Owl Creek		25 - 470
FORMATIONS EXPOSED	CRETACEOUS	Gulfian		McNairy (Levings Mbr.)		
FORMATIONS EXPOSED	CRETACEOUS	Gulfian		Tuscaloosa		
	MISSISSIPPIAN	Valmeyeran	MERAMEC	Ste. Genevieve		0 - 400
	MISSISSIPPIAN	Valmeyeran	MERAMEC	St. Louis		
	MISSISSIPPIAN	Valmeyeran	MERAMEC	Salem		
	MISSISSIPPIAN	Valmeyeran	OSAGE			200 - 300
	DEVONIAN	Upper		New Albany		150 - 200
	DEVONIAN	Middle		Grand Tower		150 - 200
	DEVONIAN	Middle		Dutch Creek		0 - 10
	DEVONIAN	Lower		Clear Creek		450 - 550
FORMATIONS EXPOSED	DEVONIAN	Lower		Bailey		180 - 250
FORMATIONS EXPOSED	SILURIAN	Niagaran	BAINBRIDGE	Moccasin Springs		110 - 150
FORMATIONS EXPOSED	SILURIAN	Niagaran	BAINBRIDGE	St. Clair		20 - 50
FORMATIONS EXPOSED	SILURIAN	Alexandrian		Sexton Creek		20 - 40
FORMATIONS EXPOSED	SILURIAN	Alexandrian		Edgewood		0 - 15
FORMATIONS EXPOSED	SILURIAN	Alexandrian		Girardeau		0 - 30
FORMATIONS EXPOSED	ORDOVICIAN	Cincinnatian		Maquoketa — Orchard Cr. Mbr.		15 - 25
FORMATIONS EXPOSED	ORDOVICIAN	Cincinnatian		Maquoketa — Thebes Mbr.		65 - 160
FORMATIONS EXPOSED	ORDOVICIAN	Cincinnatian		Cape		0 - 2?
FORMATIONS EXPOSED	ORDOVICIAN	Champlainian		Kimmswick		100 - 130
	ORDOVICIAN	Champlainian		Plattin		600 - 850
	ORDOVICIAN	Champlainian		Joachim		240 - 360
	ORDOVICIAN	Champlainian		Dutchtown		130 - 160
	ORDOVICIAN	Champlainian		St. Peter		0 - 150
	ORDOVICIAN	Champlainian		Everton		90 - 150
	ORDOVICIAN	Canadian		Jefferson City		350 - 600
	ORDOVICIAN	Canadian		Roubidoux		300 ±
	CAMBRIAN			not differentiated		2800 ± 300
	PRECAMBRIAN					

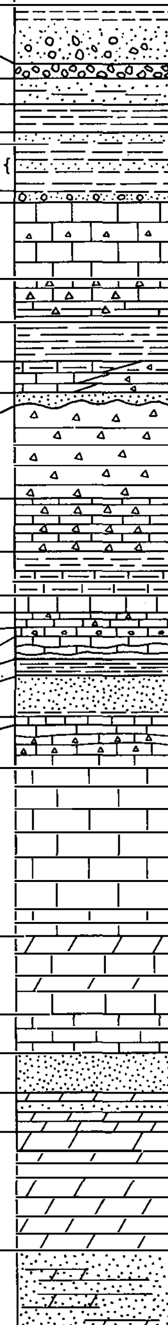

Fig. 2 - Columnar section of strata present in map area.

STRATIGRAPHY

The stratified rocks in the area are approximately 9600 feet thick and overlie the Precambrian crystalline rocks (fig. 2). No Paleozoic rocks are exposed in the Cairo Quadrangle, but Ordovician, Silurian, and Devonian rocks are exposed in the Thebes Quadrangle, and Mississippian rocks are exposed at one place in the La Center Quadrangle. Throughout most of the area the Paleozoic rocks are overlain by Cretaceous and Tertiary sediments, which attain a maximum thickness of 600 feet. Pleistocene sand, silt, and gravel as much as 200 feet thick underlie the terraces and recent flood plains. Pleistocene loess, up to 40 feet thick, blankets most of the upland area.

The deepest well in the area, located in sec. 9, T. 15 S., R. 1 E., is 3885 feet deep and penetrates the top of the St. Peter Sandstone. However, older rocks are encountered in several wells in the southern part of the Thebes Quadrangle. Reports by Weller (1940), Weller and Ekblaw (1940), and Grohskopf (1955) give descriptions and additional information concerning the sequence of Cambrian and Lower Ordovician rocks thought to underlie the area.

ORDOVICIAN SYSTEM

The strata of Ordovician age exposed in the area belong to the Champlainian (Middle) and Cincinnatian (Upper) Series, but formations of the Canadian (Lower) Series are encountered in wells. The character of the older formations is shown in the following record of a well drilled in the Cache Valley, in sec. 17, T. 16 S., R. 1 W. (table 1).

Champlainian Series

Kimmswick Limestone

The oldest formation exposed in the area is the Kimmswick Limestone, which was named (Ulrich, 1904, p. 111) for exposures at Kimmswick, Missouri. In the map area it is exposed along the Mississippi River banks and bluffs from Little Rock Island near Gale southward to Orchard Creek. It consists largely of light gray to white fragments of fossils cemented with clear, crystalline calcite. Crinoid columnals and plates are the dominant constituents, but local lenses have abundant bryozoan fragments. Brachiopods (*Rafinesquina*) are common on bedding planes.

The two most nearly complete exposures in the Thebes Quadrangle lie south of the footings of the railroad bridge across the Mississippi at Thebes, in the north-central part of sec. 17, T. 15 S., R. 3 W., and half a mile farther south on the river bank and in the bluff to the east in the south-central part of the same section. At the bridge section the lower 25 feet of limestone forms 6- to 12-inch ledges, has silicified layers 2 to 4 inches thick, irregular wavy bedding planes, and locally small bioherms. *Receptaculites* is common in the lowest 8 feet exposed at the base of the bridge but is rare in overlying beds. The upper 50 feet of the Kimmswick exposed in the bluffs a half mile to the south has more massive beds, 1 to 2 feet thick, which have very few chert bands or nodules and which pass laterally into bioherms 5 to 6 feet thick.

TABLE 1

Cache Oil Co. - George Moses well No. 1, SW$\frac{1}{4}$ NE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 17, T. 16 S., R. 1 W., Pulaski County. Elevation 335 feet above sea level. Summarized from description of samples by E. Atherton and P. M. Busch.

	Thickness (ft.)	Depth (ft.)
No samples	143	143
Devonian System		
Bailey Formation		
Chert, white to dark gray, dolomitic	362	505
Limestone, gray to dark gray, silty, argillaceous, dense	123	628
Silurian System		
Niagaran Series		
St. Clair and Moccasin Springs Formations		
Limestone, gray, green, brown, silty, argillaceous, dense to lithographic	157	785
Alexandrian Series		
Sexton Creek Formation		
Limestone, brownish gray, slightly cherty and dolomitic, fine, dense	45	830
Ordovician System		
Cincinnatian Series		
Maquoketa Formation		
Siltstone, gray, calcareous, sandy, dolomitic	50	880
Shale, dark gray to brownish gray, silty, sandy	80	960
Siltstone, dark gray, sandy	15	975
Shale, black to brownish black, silty, pyritic at base	66	1041
Champlainian Series		
Kimmswick Formation		
Limestone, light gray to brownish gray, cherty, fine to coarse, dense	134	1175
Decorah Formation		
Limestone, gray to yellow, argillaceous, sandy, fossiliferous, fine	15	1190
Plattin Formation		
Limestone, grayish brown to dark brown, dolomitic, cherty, fine, dense	150	1340
Limestone, yellow-brown to grayish brown, dolomitic, argillaceous, fine, dense	349	1689
Dolomite, grayish brown to dark brown, argillaceous, fine	41	1730
Limestone, grayish brown to dark brown; dolomite, argillaceous; shaly at base	74	1804
Joachim Formation		
Limestone, brown to yellow-brown, argillaceous, fine, dense	109	1913
Dolomite, dark brown to grayish brown, argillaceous, fine	31	1944
Limestone, dark brown to grayish brown, argillaceous, fine	61	2005
Dolomite, yellow-gray to brown, calcareous, argillaceous, fine to coarse, compact	68	2073

TABLE 1—continued

	Thickness (ft.)	Depth (ft.)
Limestone, yellow-gray to grayish brown, dolomitic, sandy, argillaceous	69	2142
Dutchtown Formation		
Limestone, dark brown, dolomitic, argillaceous, fine, firm	53	2195
Dolomite, gray to yellow-gray, calcareous, sandy, argillaceous, fine, firm	55	2250
Limestone, yellow-gray to dark brown, sandy, argillaceous	25	2275
St. Peter Formation		
Sandstone, yellow-gray to orange, fine to coarse, incoherent	69	2344
Sandstone, yellow-gray to reddish orange, fine to coarse, incoherent	41	2385
Sandstone, pale yellowish orange, fine to coarse, silty, incoherent	40	2425
Everton Formation		
Dolomite, yellowish gray to dark brown, sandy, argillaceous, fine to coarse	30	2455
Sandstone, grayish brown, fine to medium	10	2465
Dolomite, grayish brown, sandy, fine, incoherent	56	2521
Canadian Series		
Jefferson City Formation		
Dolomite, grayish brown to dark brown, sandy, argillaceous at base, cherty, fine to sugary	126	2647
Shale, brownish gray, dolomitic, weak	5	2652
Dolomite, light gray to brownish gray, sandy, fine	8	2660
Dolomite, grayish brown to dark brown, sandy, argillaceous, shaly, fine	45	2705
Dolomite, yellowish gray to grayish brown, sandy, silty, fine, sugary	124	2829
Dolomite, yellowish brown to grayish brown, cherty, sandy	71	2900
Dolomite, grayish brown to dark brown, argillaceous, cherty, fine to coarse, sugary, incoherent	30	2930
Roubidoux Formation		
Sandstone, yellowish gray, fine to coarse, incoherent	6	2936

Cincinnatian Series

Cape Limestone

The Cape Limestone, named by Templeton and Willman (in press; quoted by Gutstadt, 1958) for exposures in Cape Girardeau, Missouri, is a massive bed of gray, coarse-grained limestone, slightly more argillaceous than the underlying Kimmswick Limestone. It differs from the Kimmswick in having finer shell fragments that are better sorted and rounded, and in having more clear calcite cement. Bedding is less irregular in the Cape. The type section is in Cape Girardeau, Missouri, where the limestone is about 8 feet thick. Weller and Ekblaw (1940, p. 8) mentioned that T. E. Savage recorded the thickness of the Cape at two localities near Thebes as $3\frac{1}{2}$ and $1\frac{1}{2}$ feet, but did not find his exposures. The Cape Limestone formerly was called "Fernvale" but the name was changed when it was found that it was not equivalent to the type Fernvale in Tennessee.

Maquoketa Formation

The shale, siltstone, and sandstone overlying the Cape Limestone are referred to the Maquoketa Formation, which was named originally by White (1870, p. 180-181), for exposures along Little Maquoketa River, Dubuque County, Iowa. The Maquoketa has three well defined members, a lower shale member, a middle sandstone member (Thebes Member) and an upper shale member (Orchard Creek Member) having thin bands of fine-grained limestone. The lower member is not well exposed in the Thebes Quadrangle. At Cape Girardeau 12 feet of shale, similar to the shale in the Orchard Creek Member, lies between the Cape Limestone and typical Thebes Sandstone. Weller (1940, p. 63) reported 30 feet of shale between the Cape Limestone and interbedded shale and siltstone typical of the Thebes Member in a well near the center of sec. 35, T. 15 S., R. 2 W.

Thebes Sandstone Member. - Worthen (1866, p. 139) named the Thebes Sandstone for exposures of silty sandstone at Thebes, Illinois. It extends into southeastern Missouri and is a regularly bedded, commonly massive, brown sandstone or siltstone. It is exposed in discontinuous outcrops along the Mississippi River bluffs from a mile north of Gale southward to Powder Mill Hollow (NW$\frac{1}{4}$ SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 28, T. 15 S., R. 3 W.) (fig. 3).

Sixty-five feet of sandstone are well exposed at low water on the Mississippi River bank in the SE$\frac{1}{4}$ sec. 5, T. 15 S., R. 3 W. Cross-bedding and cusps are common 20 to 30 feet above the base of the exposure. Several types of fucoid marks are common in the upper 35 feet. The most common types are long, straight, cylindrical marks 1 to 2 inches across and 12 to 18 inches long. At the highway cut southeast of Gale, NE$\frac{1}{4}$ NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 4, T. 15 S., R. 3 W., petaloid marks are common in the upper 8 feet.

The base of the Thebes Sandstone was not observed and is apparently represented by weakly resistant shaly beds.

The top of the Thebes Sandstone is well exposed in the highway cut southeast of Gale, along the river bank south of Rock Island, and at the St. Louis and Southwestern railroad overpass at the eastern edge of Thebes. At the road cut near Gale, the change from Thebes Sandstone into the overlying Orchard Shale Member is abrupt and without appreciable transition. Along the bank of the Mississippi River south of Rock Island in the SE$\frac{1}{4}$ sec. 5, T. 15 S., R. 3 W., and at the St. Louis and Southwestern Railroad overpass east of Thebes (SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 8), 2- to 4-inch beds of sandstone of Thebes lithology occur for 7 or 8 feet up into the Orchard Creek Shale, suggesting intertonguing between the two members.

Nine miles east of these outcrops in the well near the center of sec. 35, T. 15 S., R. 2W., Weller (1940, p. 63) reported only 30 feet of sandstone underlain and overlain by siltstone and shale. Northward the Thebes Sandstone thins consistently and is only 20 feet thick in Ste. Genevieve County, Missouri, and is absent farther north. The Thebes is apparently a lenticular sandstone body that intertongues with shales of the lower part of the Maquoketa.

Orchard Creek Shale Member. - The Orchard Creek Shale was named by Savage (1909, p. 515) for thin bands of interbedded blue-gray shale and fine-grained limestone exposed in the banks of Orchard Creek about 2 miles south of Thebes. It is

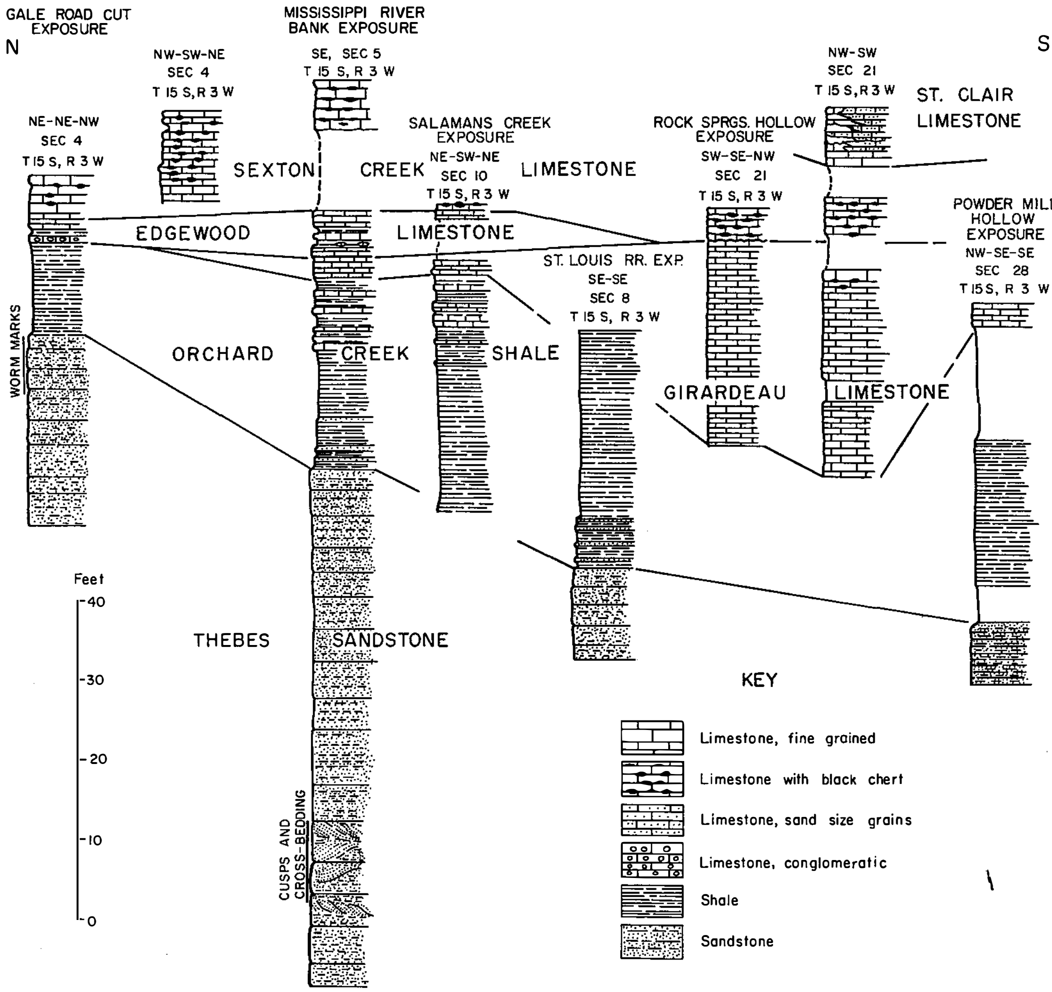

Fig. 3 - Stratigraphic relations of the Thebes Sandstone Member and Orchard Creek Shale Member of the Maquoketa Formation, Girardeau Limestone, Edgewood Limestone, and Sexton Creek Limestone in the Thebes Quadrangle.

exposed in discontinuous outcrops along the Mississippi River bluffs from Powder Mill Hollow (NW$\frac{1}{4}$ SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 28, T. 15 S., R. 3 W.) northward to Gale and along Salamans Creek near the center of sec. 10, T. 15 S., R. 3 W. In section 5 along the river bank it reaches 27 feet thick and in section 10 nearly 30 feet. Savage reported a thickness of 22 feet along Orchard Creek, but this exposure is now covered.

Because the Orchard Creek Shale weathers easily and is rarely well exposed, many exposures mentioned by Savage (1908, 1909) are no longer visible, among them, unfortunately, the type section along the "banks of Orchard Creek". At low water the section along the Mississippi River banks in the SE$\frac{1}{4}$ sec. 5, T. 15 S., R. 3 W., reveals the Orchard Creek Shale and its relations to the underlying Thebes and the overlying Girardeau Limestone (fig. 3).

The base of the Orchard Creek Shale is well exposed at the highway cut near

Gale (NE$\frac{1}{4}$ NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 4, T. 15 S., R. 3 W.), along the Mississippi River bank (SE$\frac{1}{4}$ sec. 5), and at the railroad overpass at the east edge of Thebes (SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec.8). At the latter two localities, thin beds of sandstone like the Thebes Sandstone are interbedded with Orchard Creek Shale vertically through 7 or 8 feet. The top of the Orchard Creek Shale is well exposed in the highway cut southeast of Gale, along the Mississippi River bank (SE$\frac{1}{4}$ sec. 5), and on Salamans Creek (center sec. 10). At the highway cut the overlying Edgewood Limestone, which contains pebbles derived from the Girardeau Limestone, rests unconformably on the Orchard Creek. The upper 10 feet of Orchard Creek Shale in the river bank section and the upper 12 feet in the Salamans Creek section have thin, dark brown, sublithographic, limestone beds interbedded with shale overlain by a few feet of sublithographic Girardeau Limestone. Their contact is not exposed at Powder Mill Hollow (NW$\frac{1}{4}$ SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 28), where 18 feet of Orchard Creek Shale lacking limestone beds is exposed and the lowest exposure of Girardeau Limestone is 15 feet above.

The Orchard Creek Shale has been assigned to the Silurian System in many previous reports, largely on the basis of fossils described by Savage (1913). However, during the present mapping Ross found the characteristic Cincinnatian graptolite Climacograptus putillus (Hall) in the exposures beneath the railway trestle at Powder Mill Hollow, and it appears from this study that Savage's fossils suggesting a Silurian age may have come from limestone beds in the upper few feet of the shale. Because the entire shale unit seems more closely related to the Maquoketa than to the overlying Girardeau Limestone, the Silurian age of which has also been questioned, the Orchard Creek is assigned to the Ordovician System.

SILURIAN SYSTEM

The formations of Silurian age in this area (fig. 2) have been assigned to the Alexandrian (Lower) Series and the Niagaran (Middle) Series. Alexander County is the type area for the Alexandrian Series (Savage, 1909). The formations in the Niagaran Series belong to the Bainbridge Group (Lowenstam, 1949).

Alexandrian Series

Girardeau Limestone

The Girardeau Limestone was named by Swallow (1855, p. 109) for fossiliferous, blue-gray limestone in 2- to 6-inch beds, 40 to 50 feet thick, exposed 1$\frac{1}{2}$ to 2 miles above Cape Girardeau, Missouri. It is known from only a few outcrops in southeastern Missouri and southwestern Illinois.

The formation consists of lenticular and irregularly bedded sublithographic limestone having few sand-size shell fragments in a dark brown, very fine-grained, silt-sized, calcareous matrix. The upper surfaces of these 2- to 6-inch beds commonly have a thin $\frac{1}{4}$-inch layer of coarse shell fragments and occasional larger fossils.

The basal part of the Girardeau Limestone has shaly interbeds, such as those seen in the SE$\frac{1}{4}$ sec. 5, T. 15 S., R. 3 W., along the Mississippi River bank and along Salamans Creek near the center of sec. 10, same township. The thicker exposures of the formation, such as those at Orchard Creek and at Cape Rock north of Cape Girardeau, Missouri (sec. 28, T. 31N., R. 14 E.), have few shale partings and have silicified silty interbeds commonly containing black nodular chert bands similar to those in the Sexton Creek Limestone. Lenses of well sorted fossil fragments are common at the bedding planes.

The top of the Girardeau Limestone is marked by a major unconformity separating it from the overlying Edgewood Limestone and Sexton Creek Limestone (fig. 3). The thickness of the Girardeau Limestone is highly variable because of differential erosion at this unconformity. About 30 feet of Girardeau Limestone is well exposed in the bed of Orchard Creek in SW$\frac{1}{4}$ SE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 21, T. 15 S., R. 3 W., but the base is not exposed.

Savage (1913) described the fauna of the Girardeau as being of Silurian age. However, no comparable unit nor fauna is known elsewhere in the Silurian of the Central States and the lithology has been considered by many to be more typical of late Ordovician strata.

Edgewood Limestone

The Edgewood Limestone was named by Savage (1909, p. 517) for a massive, gray, crystalline limestone, 4 feet thick, having conglomerate pebbles and oolites (Noix Oolite Member?) exposed 3 miles north of Edgewood, Pike County, Missouri. In the Thebes Quadrangle the Edgewood is a thin and discontinuous unit and was apparently deposited only in the northern part of the area (fig. 3). It is well exposed at only two localities—in the highway cut southeast of Gale (NE$\frac{1}{4}$ NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 4, T. 15 S., R. 3 W.) and along the Mississippi River bank (SE$\frac{1}{4}$ sec. 5, same township). It may be seen in a poorer exposure at a third locality on Salamans Creek (NE$\frac{1}{4}$ SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 10, same township). Farther south where the underlying Girardeau Limestone is thicker, the Edgewood is commonly missing.

In the lower 2 feet of the Edgewood Limestone, conglomerate pebbles of Girardeau lithology are mixed with oolites that have dark radial streaks and fibrous concentric patterns and are well cemented with clear calcite in a well sorted, medium-grained, detrital limestone.

These oolite beds probably are equivalent to the Noix Oolite Member at the base of Edgewood Formation near Louisiana, Missouri. One bed in the upper part has very fine quartz sand grains dispersed in a matrix of large clear, twinned, calcite crystals; another bed, 2 feet higher, has rounded sand-size fragments of dark, lithographic limestone, probably derived from the Girardeau Limestone, imbedded in a clear calcite matrix.

Sexton Creek Limestone

The Sexton Creek Limestone was named by Savage (1909, p. 518) for 16 to 70 feet of limestone exposed along Sexton Creek in Alexander County, Illinois. Savage recognized a thin-bedded, hard, cherty lower part and a more massive, pink or reddish, mottled upper part. The upper part of this sequence was later removed from the Sexton Creek and placed in the Bainbridge Limestone (Ulrich, 1911; Miser, 1920), and still later (Lowenstam, 1949) was assigned to the St. Clair Limestone and classified as a formation in the Bainbridge Group.

The basal beds of the Sexton Creek Limestone and their contact with the underlying Edgewood Limestone may be seen in the highway cut a quarter of a mile southeast of Gale in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 4, T. 15 S., R. 3 W. A quarter of a mile southeast of that locality in a small highway cut, 11 feet of Sexton Creek Limestone is exposed beneath the Pleistocene deposits and about 8 feet of limestone is exposed in cuts along the gravel road and the Illinois Central Railway tracks north of Thebes in the SE$\frac{1}{4}$ sec. 5 of the same township.

Scattered outcrops of Sexton Creek Limestone are exposed in the Mississippi River bank in the northern part of the NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 21, T. 15 S., R. 3 W., where they lie beneath the St. Clair Limestone, and along the road and the Missouri Pacific Railway from Orchard Creek south to Powder Mill Hollow (fig. 3). The Sexton Creek Limestone 5$\frac{1}{2}$ miles north of Gale is nearly 40 feet thick, but southward it thins markedly and is apparently less than 15 feet thick south of Gale. Thinning of the Sexton Creek and Edgewood Limestones suggests overlap onto an irregular erosion surface that had been filled only partially by Edgewood deposits. Another possibility is that the top of the Sexton Creek Limestone was eroded prior to St. Clair deposition.

At Orchard Creek and southward the Sexton Creek Limestone rests directly on the Girardeau Limestone, and the limestones are difficult to distinguish as both are dominantly fine-grained, dark, lithographic limestone. The Sexton Creek Limestone at Cape Rock (sec. 28, T. 31 N., R. 14 E.), northeast of Cape Girardeau, Missouri, and in the highway cut southeast of Gale consists of crinoidal debris and coarse sand-size shell fragments in a finer grained matrix cemented with clear calcite. In this area and farther north, the Sexton Creek has persistent bands of black chert nodules that provide a convenient means of distinguishing the Sexton Creek and Girardeau Limestones. South of Thebes the Sexton Creek is thin or absent (0 to 5 feet) over the thicker sections of the Girardeau Limestone, and here also the Girardeau contains black chert nodules. The Sexton Creek Limestone is equivalent to the Kankakee Limestone of northern Illinois and the Brassfield Limestone of Indiana, Ohio, and Kentucky.

Niagaran Series

St. Clair Limestone

The St. Clair Limestone was named by Penrose (1891, p. 102-103, 166-174) for exposures near St. Clair Springs, 8 miles northeast of Batesville, Independence County, Arkansas. It is coarsely crystalline, granular, fossiliferous, light gray, pink, and chocolate brown limestone. In Illinois these strata were considered the lower part of the Bainbridge Formation until differentiated by Lowenstam (1949, p. 13).

In the Thebes Quadrangle the St. Clair is exposed in only a few scattered outcrops along the Mississippi River bluffs. Its contact with the underlying Sexton Creek Limestone is not well exposed although, along the Mississippi River at low water just southwest of the mouth of Orchard Creek (NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 21, T. 15 S., R. 3 W.) 4 feet of Sexton Creek Limestone is exposed about 8 feet below red and pink limestones of the St. Clair (fig. 3). In this exposure the St. Clair consists of 6- to 8-inch beds of red-brown silty limestone intertongued with more massive 12- to 18-inch beds of pink limestone that have abundant fossil fragments and appear to be local bioherms. In the Missouri Pacific Railway cut at the north side of Powder Mill Hollow (SW$\frac{1}{4}$ NE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 28, T. 15 S., R. 3 W.) 6 to 7 feet of St. Clair are exposed in steeply dipping beds. Between the road and the upper railway (Missouri Pacific) at the south line of sec. 21, T. 15 S., R. 3 W., scattered outcrops of St. Clair are exposed in a shallow syncline.

Neither the top nor the base of the St. Clair is exposed in the area but its thickness is estimated as being between 10 and 20 feet.

The St. Clair Limestone is equivalent to strata included in the lower part of the Joliet Formation in northern Illinois (Lowenstam, 1949).

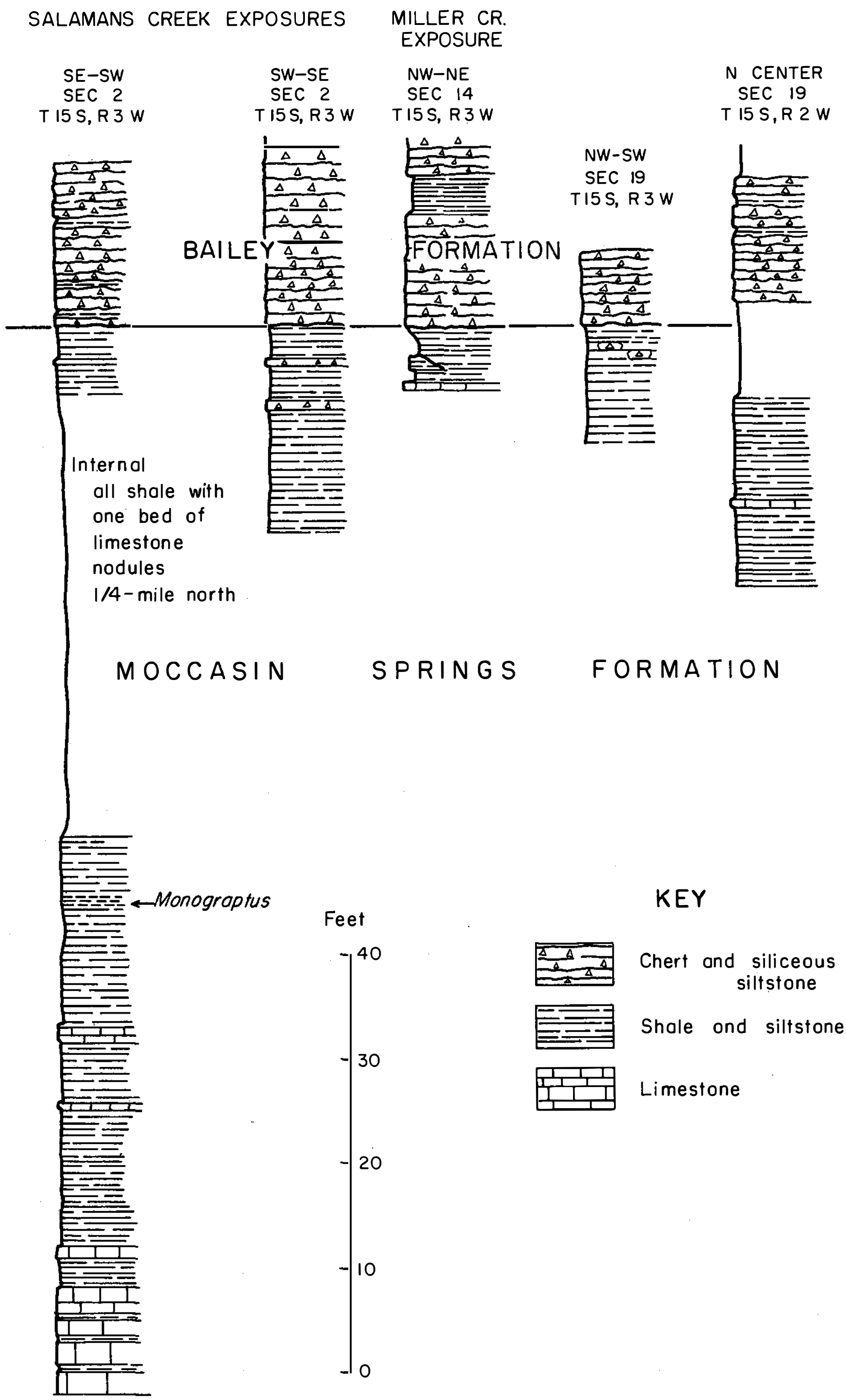

Fig. 4 - Stratigraphic relations of the Moccasin Springs and Bailey Formations in the Thebes Quadrangle.

TABLE 2

Geologic section compiled from three outcrops near center of south line of sec. 2, T. 15 S., R. 3 W., Alexander County, Illinois.

	Thickness (ft.)
Devonian System	
Bailey Formation	
Chert and siliceous siltstone, weathers gray-green to olive-brown; 2- to 8-inch beds; ¼-inch silty interbeds	25
Silurian System	
Niagaran Series	
Moccasin Springs Formation	
Siltstone, weathers olive-green; two 2-inch chert beds	8
Siltstone, very argillaceous, green to olive-brown; ¼-inch laminae, but commonly spalls with conchoidal fracture	12
Covered (this interval exposed ¼ mile to the north where it is similar to the siltstone unit above)	31
Shale, light olive-green; 1/16- to ¼-inch laminae: two silty brown beds 7 feet below top contain lower Ludlovian (Late Silurian) *Monograptus* (Ross, 1962)	17
Siltstone, red-brown, with a few thin green layers like beds above; a few limy beds; ¼- to 6-inch beds	24
Limestone, red-brown and green-gray, fine grained, silty; 6- to 10-inch beds separated by 1- to 2-inch silt partings; no visible megafossils	10
Covered; estimated 90 feet to 6-inch bed of Edgewood Limestone which is exposed about 1200 feet down stream.	

Moccasin Springs Formation

The Moccasin Springs Formation was named by Lowenstam (1949, p. 16-18) for red and mottled red and gray to greenish gray, very fine grained, silty, argillaceous limestone and calcareous siltstone, exposed about three-quarters of a mile south of Moccasin Springs, Missouri, along the bluffs of the Mississippi River.

The entire Moccasin Springs Formation is not exposed in the Thebes Quadrangle, but incomplete sequences are exposed in the banks of Salamans Creek, north branch of Miller Creek (fig. 4), and in the Mississippi River bluffs to the south in the SW¼ sec. 21 and N½ sec. 28, T. 15 S., R. 3 W.

About 100 feet of the Moccasin Springs Formation is exposed along the south side of Salamans Creek and is described in table 2.

The sequence in table 2 represents the upper part of the Moccasin Springs Formation and the basal beds of the Bailey Formation. The contact between the two formations is gradational through 8 to 10 feet, and the first occurrence of ledge-forming chert and siliceous siltstone is arbitrarily taken as the base of the Bailey Formation (fig. 4).

The lower beds in the Moccasin Springs Formation are discontinuously exposed beneath Cretaceous sediments in the bed of Orchard Creek in Rock Springs Hollow (sec. 21, 22, and 23, T. 15 S., R. 3 W.). About 30 feet of mottled red-brown to green limestone is exposed in the bed of the creek in the SE¼ SW¼ sec. 22, where the beds weather into 1- to 3-foot blocks and contain abundant megafossils and microfossils. Farther west in the SE¼ SE¼ sec. 21, a 4-foot block of massive, medium gray to pink, very fine-grained limestone with brown-red spots and many Foraminifera and Ostracoda dips 8 degrees to the northwest and may be faulted to its present position. Closely similar limestone occurs about 80 feet above the base of the formation north of Cape Girardeau, Missouri. In the SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 28 nearly 40 feet of the Moccasin Springs is exposed in a gully between the upper railway (Missouri Pacific) and the road (SE$\frac{1}{4}$ SE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 28) just north of Powder Mill Hollow. Along the axis of the Thebes anticline in sec. 19, T. 15 S., R. 3 W., the upper 15 feet of the Moccasin Springs Formation are exposed in several road cuts.

The Moccasin Springs Formation is estimated to be 120 to 130 feet thick throughout most of the Thebes Quadrangle.

DEVONIAN SYSTEM

The strata of Devonian age in the Thebes Quadrangle are part of the Lower Devonian Bailey Formation. They consist largely of limestone and chert and underlie much of the upland area in the northern part of the quadrangle.

Bailey Formation

The Bailey Limestone was named by Ulrich (1904, p. 110) for argillaceous limestone and shale, about 100 feet thick, exposed near Bailey's Landing, a former landing a short distance above Red Rock Landing on the Missouri shore of the Mississippi River in Perry County, Missouri.

In the Thebes Quadrangle, surface exposures of the Bailey generally contain little limestone, and where calcium carbonate is present it generally is a cement in siliceous siltstone. The siliceous beds in the Bailey Formation can be divided into four lithologic types that are interbedded in various proportions:

1. Black to dark gray irregular beds of nodular chert that lack porosity and generally are one-half to 3 inches thick and commonly irregularly cut across bedding planes.
2. Olive-gray to green-gray siliceous siltstone that is porous and generally well cemented by either calcium carbonate or, more commonly, silica. It is finely laminated and may pass laterally into friable, less well cemented siliceous siltstone. Bedding is irregular.
3. White-weathering novaculitic chert in 1- to 2-foot beds, commonly interbedded with 1- to 3-inch beds of the same lithology. The broken surface is saccharoidal. Many of the blocks have dark gray centers similar to type 1.
4. Cream to red-brown friable tripoli, or uncemented siliceous siltstone, that generally is in 2- to 4-inch beds.

Many small outcrops of the Bailey Formation occur along streams and roads in the eastern half of T. 15 S., R. 3 W., and in the northwestern half of T. 15 S., R. 2 W. The lower part of the formation is exposed discontinuously along the north branch of Miller Creek in secs. 14, 11, and 12, T. 15 S., R. 3 W., and sec. 7, T. 15 S., R. 2 W. A transitional contact between the underlying shales of the Moccasin Springs Formation and the cherty siltstones of the Bailey is well exposed along Salamans Creek in the SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 2, T. 15 S., R. 3 W. (fig. 4).

Lithologically, the lower 60 feet is composed dominantly of olive-gray siltstone (lithologic type 2) and numerous thin layers of dark gray nodular chert (lithologic type 1). Above these, the white-weathering chert (lithologic type 3) and olive-gray siltstone (lithologic type 2) are interbedded for about 100 feet. The

TABLE 3

Record of well near Olmsted. R. G. Williams, Trustee - W. L. Richey well No. 1, in SW¼ SE¼ SW¼ sec. 9, T. 15 S., R. 1 E., Pulaski County. Elevation 479 feet (D.F.) above sea level. Summarized from description of samples by Frank E. Tippie and Wayne A. Pryor.

	Thickness (ft.)	Depth (ft.)
Quaternary System		
Pleistocene Series	50	50
Tertiary System		
Pliocene Series	30	80
Paleocene Series	22	102
Cretaceous System	328	430
Mississippian System		
Valmeyeran Series		
Osage Group		
Chert, grayish brown; siltstone, siliceous; glauconitic at base	205	635
Springville Formation		
Siltstone, greenish gray	15	650
Kinderhookian Series		
Chouteau Dolomite		
Dolomite, light buff, silty, argillaceous	6	656
Devonian System		
New Albany Shale	1389	
Shale, black to green, pyritic, slightly silty	174	830
Middle and Lower Devonian (undifferentiated)	1215	2045
Silurian System	335	2380
Ordovician System	1505	3885

succeeding 15 feet are massive, white-weathering chert having a few thin 6- to 8-inch beds of olive-gray siltstone, and are overlain by a few feet of thinner bedded white chert and siltstone (lithologic types 2 and 3). These beds give the Bailey Formation a total thickness of about 180 feet. The Grassy Knob Chert, Backbone Limestone, and Clear Creek Chert (Weller and Ekblaw, 1940) if present in the Thebes Quadrangle have not been recognized as separate from the chert and siltstone of the Bailey Formation.

As much as 100 feet of the upper part of the Bailey Formation is well exposed in several quarries and mines in the cliffs from Olive Branch northeast to the Jonesboro Quadrangle.

MISSISSIPPIAN SYSTEM

In the Cairo Quadrangle, Mississippian rocks are encountered in wells only in the northern part of the area, where they are overlain by Cretaceous sediments. They are present underlying younger sediments in the La Center Quadrangle and are absent in the Thebes Quadrangle. The Mississippian rocks are dominantly shale in the lower part and chert and limestone in the upper part. Only the St. Louis Limestone is exposed. The general character of these rocks is described in table 3.

St. Louis Limestone

The St. Louis Limestone, named by Englemann (1847, p. 119-120) for exposures in eastern Missouri and southern Illinois and later restricted by Ulrich (1904), includes hard yellow-gray to light blue-gray fossiliferous limestone that reaches 110

TABLE 4

Geologic section exposed along Post Creek in center of sec. 2, T. 15 S., R. 2 E., Pulaski County.

	Thickness (ft.)
Quaternary System	
Pleistocene Series	5+
Loess	
Cretaceous System	
Gulfian Series	
McNairy Formation	
Sand, white to gray, well sorted, very micaceous; silty clay laminae near base; well cross-stratified; sharp contact with underlying unit	45±
Tuscaloosa Formation	
Gravel, white to light gray; pebbles and cobbles range from ½ inch to 20 inches in diameter, but dominant size is 1 to 3 inches; pebbles and cobbles angular to subrounded, composed of light gray, fossiliferous chert and dense, black chert. Matrix light gray to white, compact to soft fine grained silica and/or clay	10±
Little Bear Soil	
Iron oxide, yellow-brown to vermillion, interlaminated with light gray, greasy, carbonaceous clay; and contains silicified remains of bryozoans and crinoids. The iron oxides (geothite, lepidochrosite, and hematite) are vesicular and in convolute beds. Grades downward into red clays	4±
Clay, red to reddish brown, very greasy, poorly laminated at top, becoming laminated near bottom, with silicified bryozoan remains. Sharp contact with underlying limestone	3±
Mississippian System	
Valmeyeran Series	
St. Louis Limestone	
Limestone, light gray, fossiliferous (silicified); several thin shale beds; numerous large black chert nodules. Upper surface extremely irregular	15
	Creek level

feet in thickness and has chert in its upper part. Fifteen feet of St. Louis strata are exposed along Post Creek in the La Center Quadrangle near the center of sec. 2, T. 15 S., R. 2 E., where their upper surface is an exhumed karst topography (table 4).

LITTLE BEAR SOIL

The name Little Bear Soil (Mellen, 1937) is applied throughout the eastern part of the Mississippi Embayment to isolated erosional remnants of an ancient residual soil formed on Paleozoic rocks and buried by Cretaceous and Tertiary sediments (fig. 5). In the area of this report the Little Bear Soil consists of red and brown clays and iron oxides approximately 7 feet thick (tables 4, 6). An excellent outcrop of the Little Bear Soil along Post Creek in sec. 2, T. 15 S., R. 2 E., Pulaski County, shows the relations between it and the underlying and overlying materials (fig. 6). In the lower 2 feet of the Little Bear Soil in the Post Creek exposure, the only clay mineral is illite, as in the underlying St. Louis Limestone, but in the upper 5 feet kaolinite and montmorillonite gradually become dominant. Brown to black limonite in beds and nodules and angular fragments of chert are abundant in the soil.

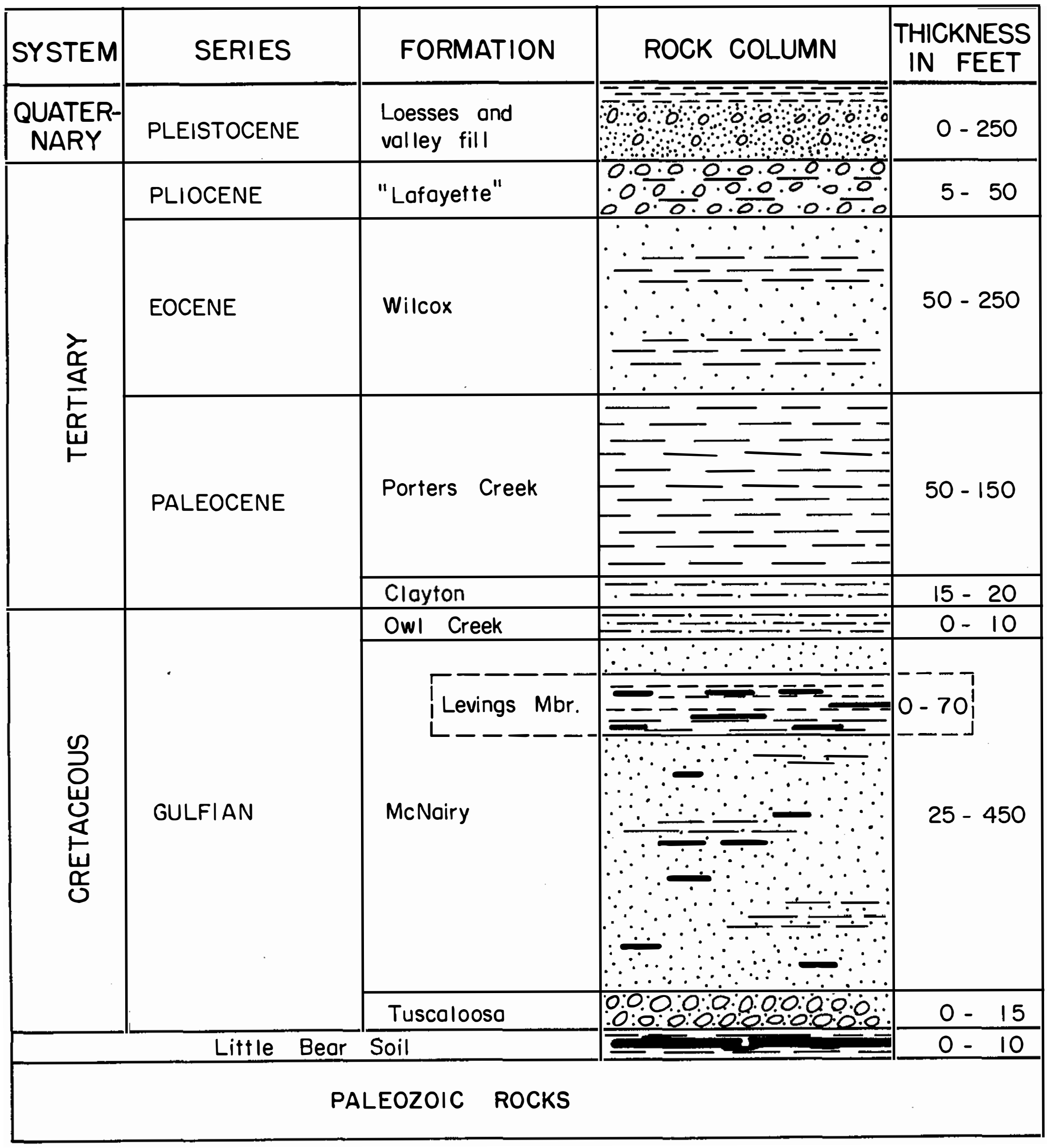

Fig. 5 - Detailed columnar section of Cretaceous-Tertiary strata in Cairo Quadrangle.

CRETACEOUS SYSTEM

Gulfian Series

The sediments of the Cretaceous System consist largely of nonmarine sands with thin beds of lignitic silt and clay, lignite, and gravel. The Cretaceous sediments attain a maximum thickness of 470 feet in the central part of the area, but range widely in thickness in response to the uneven surface developed on the underlying Paleozoic rocks (pl.2).

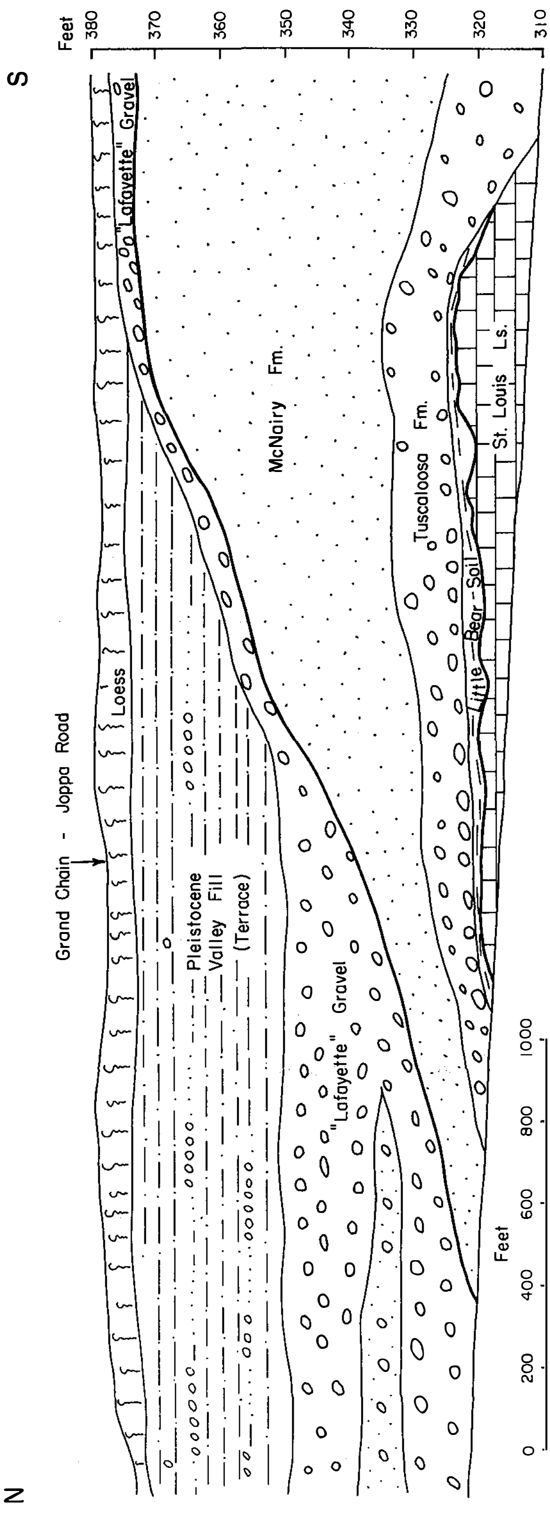

Fig. 6 - Section along Post Creek.

Tuscaloosa Formation

The Tuscaloosa Formation was named by Smith and Johnson (1887) for 1000 feet of pebbly, micaceous sand exposed along the Tuscaloosa (Black Warrior) River near Tuscaloosa, Alabama. In the Thebes Quadrangle it is well exposed along the Missouri Pacific Railroad, north of Fayville where it overlies the Little Bear Soil or rests directly on the Paleozoic rocks. In the Cairo Quadrangle it crops out along Boar Creek, and in the La Center Quadrangle it is exposed along Post Creek (fig. 6; tables 4, 6, and 7). The Tuscaloosa Formation consists of nonmarine chert gravels in a matrix of white clay and fine-grained silica and ranges up to 20 feet thick.

The Tuscaloosa Formation is present as a series of isolated outliers throughout the eastern part of the Mississippi Embayment. It is similar in character and position to the Tuscaloosa Formation of Alabama. Similar deposits in Kentucky and Tennessee have been called a basal conglomerate of the McNairy in some reports. These sediments were deposited in a nonmarine fluvial environment and were locally derived, probably from the adjacent highland rim.

McNairy Formation

The McNairy Formation was named by Stephenson (1914, p. 17-18) as a member of the Ripley Formation for nonglauconitic sands and clays in the Mississippi Embayment. Pryor (1959) recognized it as a formation in Illinois where it overlies either the Paleozoic rocks, the Little Bear Soil, or the Tuscaloosa Formation. The upper surface is an unconformity and the formation ranges from 25 to 450 feet thick. The McNairy Formation is well exposed along the Ohio River bluff in the vicinity of U. S. Dam 53

TABLE 5

Geologic section compiled from outcrops along creek in NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 18, T. 15 S., R. 2 E., Pulaski County, 1$\frac{1}{2}$ miles southeast of the village of Levings.

	Thickness (ft.	in.)
Cretaceous System		
Gulfian Series		
McNairy Formation		
Sand, red at top grading down to buff, very micaceous, fine to medium, cross-stratified	30	
Levings Member		
Silt, white to light gray, very micaceous, clayey, structureless except in lower part where it is interlaminated with underlying material	27	6
Silt, dark brownish gray, very micaceous, very clayey, slightly lignitic, abundant pyrite nodules, leaf-bearing, well laminated	10	
Silt, light brown, very micaceous, very clayey, slightly lignitic	3	6
Silt, black to grayish brown, very micaceous, very clayey, very lignitic; abundant pyrite nodules; abundant leaf fossils; well laminated	2	6
Silt, black, very micaceous, slightly clayey, very carbonaceous, slightly lignitic; abundant pyrite nodules; well laminated	3	
Lignite, black to dark brown		3
Silt, black, very clayey, micaceous, carbonaceous with rootlets at top, structureless	2	9
Silt, black; clay, black, interlaminated, very micaceous, very lignitic in upper one foot, very pyritic	5	
Lignite, black to dark brown, very silty		2
Silt, black, very carbonaceous, slightly micaceous, very pyritic, slightly laminated at base grading upward into massive structure with plant rootlets	2	
Clay, black to grayish black, very silty, very micaceous; abundant pyrite nodules	3	
Base concealed at river level		

in the eastern part of the Cairo Quadrangle, north of Fayville in the western part of the Thebes Quadrangle, and along Post Creek in the La Center Quadrangle.

The McNairy Formation is composed of nonmarine, fine, cross-stratified, micaceous sands, with numerous thin beds of lignitic silt and clay (tables 4, 5, 6, 7).

Levings Member. - In the upper part of the McNairy Formation there is a well defined lignitic silt and clay unit called the Levings Member (Pryor, 1959). The type outcrop for the Levings Member is a stream cut, several hundred yards southwest of U. S. Dam 53 (table 5). The Levings Member ranges from zero to 70 feet thick and occurs throughout the northern part of the upper Mississippi Embayment.

The McNairy Formation is the result of deltaic deposition in the northern end of the Mississippi Embayment. The sands represent fluvial deposition, and the lignitic clays and silts represent floodplain and interdistributary deposits. The deltaic

TABLE 6

Record of well 2 miles west of Villa Ridge--W. E. Vick-Boyd no. 1, in NW¼ NE¼ SW¼ sec. 5, T. 16 S., R. 1 W., Pulaski County. Elevation 400 feet above sea level.

	Thickness (ft.)	Depth (ft.)
Quaternary System		
Pleistocene Series	60	60
Tertiary System		
Pliocene Series	40	100
Paleocene Series	5	105
Cretaceous System		
Gulfian Series		
McNairy Formation		
Levings Member		
Clay and silt, dark brown to gray-brown, very micaceous, very lignitic in lower part, pyritic	65	170
Lower part of McNairy		
Sand, white to light gray, very silty to clean, very micaceous, slightly cherty, fine, lignitic in lower 5 feet	60	230
Clay, dark grayish brown, slightly silty, very micaceous, laminated, slightly lignitic	10	240
Sand, white in upper part, grayish black in lower part, very micaceous, fine, pyritic and lignitic at base	20	260
Silt, grayish brown to black, very micaceous, pyritic, lignitic	5	265
Sand, light brown, very micaceous, fine to medium	35	300
Silt, dark gray, very clayey, very micaceous, lignitic	20	320
Clay, brown, red to buff, slightly silty in upper part, slightly laminated	25	345
Tuscoloosa Formation		
Gravel, very sandy, white to brown, clayey, chert pebbles, in part cemented	17	362
Little Bear Soil		
Clay, reddish brown, fragments of iron oxide, badly weathered chert fragments	5	367
Devonian System	Total depth	1366

deposits were built southwestward from the head of the embayment and the marine equivalents of the McNairy Formation did not reach far into Illinois. In the Vick Oil Co.-Smith no. 1 (pl. 2), in the southern part of the Thebes Quadrangle, calcareous sands encountered in the McNairy Formation suggest the sands were deposited on a marine delta platform.

Cross-bedding in the McNairy shows that the sands were transported to the southwest (Pryor, 1959, p. 114, 117, and 123). Heavy minerals in the McNairy sands (see table 8) suggest that these sediments were derived from the Blue Ridge Mountains and Piedmont Plateau of the southern Appalachians (Potter and Pryor, 1961).

TABLE 7

Geologic section compiled from exposures along Missouri Pacific Railroad, south one mile from Rock Springs Hollow, in SW¼ sec. 21, T. 15 S., R. 3 W., Alexander County.

	Thickness (ft.)	(in.)
Quaternary System		
Pleistocene Series		
Loess	+20	
Tertiary System		
Pliocene Series		
"Lafayette" Gravel		
Gravel, red and black, cherty, well cemented, slightly sandy	2	6
Cretaceous System		
Gulfian Series		
McNairy Formation		
Sand, red to reddish brown, medium to fine grained very micaceous, clayey; scattered black chert pebbles; locally numerous quartzite lenses up to 5 feet long and 2 feet thick	4-6	
Tuscaloosa Formation		
Gravel, white with black pebbles, very clayey; frequently present as a channel filling, compact to hard	2-6	
Silica clay and silt, fine grained silica, compact to hard, white with occasional pebbles, numerous plant rootlets and frequent silicified logs and stumps	2-5	
Clay, white, lavender to green, kaolinite; blocky; grades into overlying silica rock	15±	
Little Bear Soil		
Iron oxide zone, silicified in part, convolute, grading downward into unsilicified iron oxides	5±	
Clay, red to red brown; abundant iron oxide bands; numerous lenses of carbonaceous white clay at top	5±	
Silurian System		
Girardeau Limestone	10±	

Owl Creek Formation

The Owl Creek Formation named by Hilgard in 1860 (see also Stephenson, 1955, Grohskopf, 1955, and Pryor, 1959) for exposures of dark blue micaceous marl at Owl Creek Bluff, near Ripley, northeastern Mississippi. It unconformably overlies the McNairy Formation and its upper surface is marked by an erosional unconformity in Illinois. The Owl Creek Formation is poorly developed in the type area and occurs as thin erosional remnants. It ranges from 0 to 10 feet thick. It does not occur in the La Center Quadrangle.

The Owl Creek Formation consists of glauconitic, sparsely fossiliferous, silty clays and silts (table 9). In well samples it is difficult to differentiate the Owl Creek Formation from the overlying Clayton Formation, but they are readily differentiated in several excellent outcrops along the Ohio River bluffs and along the Cache River near Unity.

The Owl Creek Formation represents deposition in a shallow marine shelf environment during the last northward transgression of the Cretaceous seas. This

TABLE 8

Heavy Minerals in Sands of the McNairy Formation in the Cairo, Thebes, and La Center Quadrangles

Mineral	Sample A*	Sample B†	Sample C‡
Andalusite	Tr.	Tr.	Tr.
Chloritoid	-	Tr.	1
Epidote	Tr.	-	-
Garnet	Tr.	Tr.	Tr.
Hypersthene	1	1	1
Ilmenite	1	6	6
Kyanite	44	40	50
Leucoxene	Tr.	2	Tr.
Magnetite	Tr.	-	-
Monazite	1	2	2
Rutile	8	7	8
Sillimanite	14	14	5
Staurolite	12	8	18
Tourmaline	15	13	11
Zircon	4	13	1
Xenotime	-	1	-

* A- Post Creek, center sec. 2, T. 15 S., R. 2 E., Pulaski Co.
† B- Ohio River bluff, SE¼ NE¼ NW¼ sec. 26, T. 15 S., R. 1 E., Pulaski Co.
‡ C- Bluff at Fayville, SW¼ SW¼ SE¼ sec. 34, T. 15 S., R. 3 W., Alexander Co.

transgression apparently was short-lived and was followed by a rapid regression of the seas, ending Mesozoic deposition at the head of the Mississippi Embayment. The heavy minerals in the Owl Creek Formation are identical with those of the McNairy Formation, suggesting the same source area.

The upper part of the Owl Creek Formation shows weathering prior to deposition of the Clayton Formation.

TERTIARY SYSTEM

The Tertiary System is represented by Paleocene, Eocene, and Pliocene sediments which have a total maximum thickness of 470 feet (fig. 5). The Tertiary sediments consist of marine clays, lignitic nonmarine sands and clays, and ferruginous, nonmarine sands, and chert gravels.

Paleocene Series

The Paleocene Series includes the Clayton Formation (below) and the Porters Creek Formation (fig. 5). Paleocene sediments range from 65 to 170 feet thick and are exposed in a continuous series of outcrops along the Ohio River bluffs and along the Cache River bluffs.

Clayton Formation

The Clayton Formation was named by Langdon (1891; see also Grohskopf, 1955) for exposures of white sand, siliceous limestone, and basal conglomeratic sandstone near Clayton, Alabama. In Illinois it unconformably overlies the Owl Creek and McNairy Formations and ranges from 15 to 20 feet thick. It is one of the most uniform units exposed in this area and is readily identified in well samples (fig. 7).

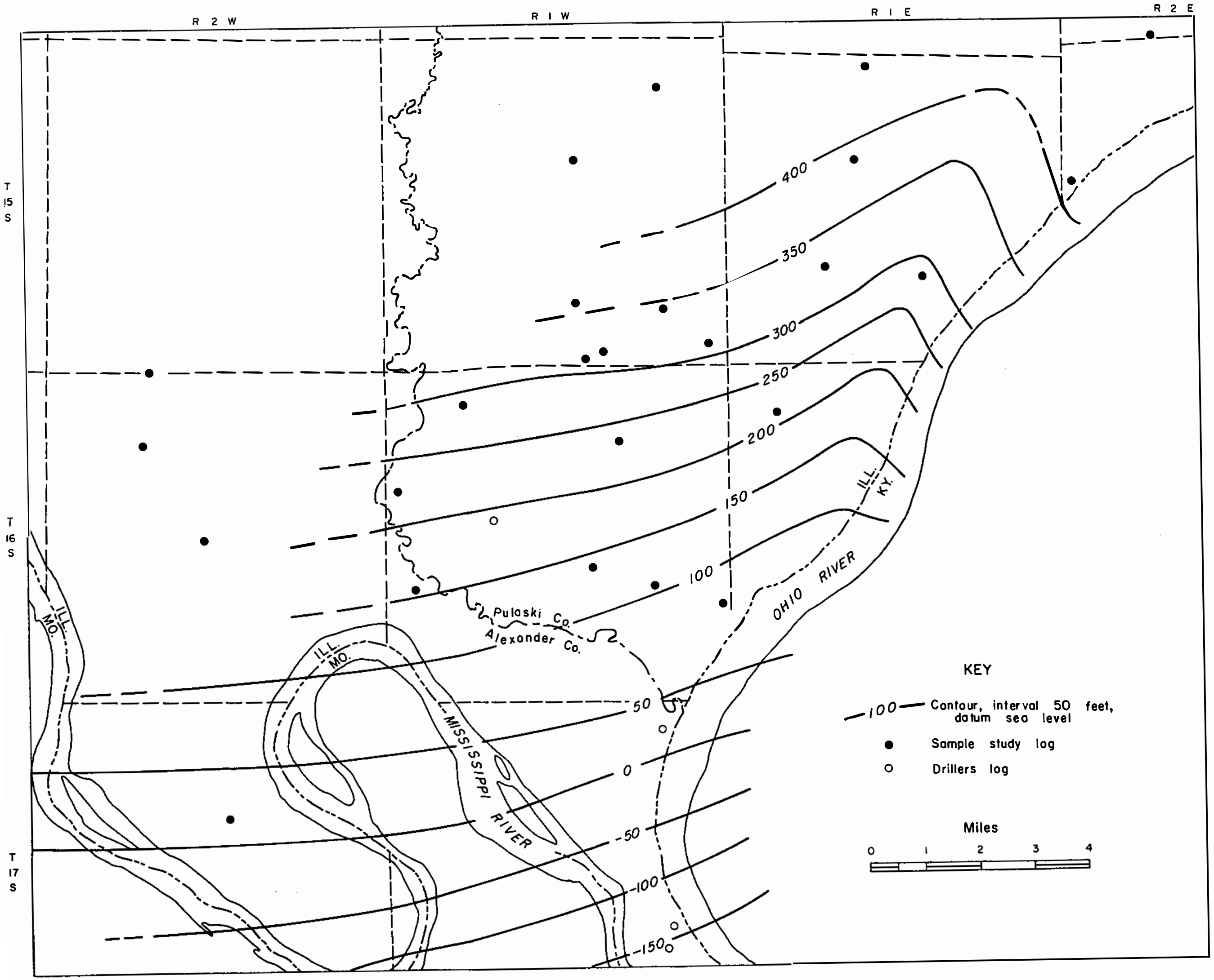

Fig. 7 - Structure map on base of Clayton Formation.

TABLE 9

Geologic section in creek along north side of road in SE¼ NW¼ NE¼ sec. 13, T. 15 S., R. 1 E., Pulaski County

	Thickness (ft.)	(in.)
Quaternary System		
Pleistocene Series		
Loess	10±	
Tertiary System		
Paleocene Series		
Porters Creek Formation		
Clay, dark gray, slightly micaceous, conchoidal fracture, massive, tough	40	
Clayton Formation		
Clay, light creamy buff, light grayish green to dark green, very glauconitic, silty, sandy at base, very micaceous; glauconite and siderite occur in discrete lenses reaching 1 x 3 x 6; lower 4 to 11 inches very sandy, yellow-brown, with abundant white and black chert pebbles and iron oxide fragments	18	
Cretaceous System		
Gulfian Series		
Owl Creek Formation		
Clay, yellow-brown, very silty, very micaceous, very glauconitic; upper 3 to 5 inches marked by iron oxides and hematitic nodules; numerous "U" shaped borings filled with glauconite from overlying Clayton Formation	5	6
McNairy Formation		
Levings Member		
Silt, white to light gray, clayey, very micaceous, structureless	25	
Base concealed		

In the northern part of the Mississippi Embayment the Clayton Formation consists of glauconitic, sparsely fossiliferous and micaceous green to buff clays (tables 9 and 10). The bottom 6 inches to 1 foot commonly is pebbly.

The Clayton Formation is the most fossiliferous Coastal Plain sediment in Illinois. The fossils are chiefly foraminifera and other microfossils and are found in several wells in the area, but have not been found in outcrop. The presence of Globigerinoides daubjergensis establishes a Danian (early Paleocene) age for the Clayton Formation in this area.

The Clayton Formation was deposited on a shallow marine shelf. The presence of heavy minerals suggests the Clayton sediments were derived from the same source area as the underlying Cretaceous sediments.

Porters Creek Formation

The Porters Creek Formation was named by Safford (1864; see also Lamar, 1928; Grohskopf, 1955) for exposures of laminated clay on Porters Creek, Hardeman County, Tennessee. In Illinois it conformably overlies the Clayton Formation and is unconformably overlain by the sediments of the Eocene Series. The Porters Creek clay is well exposed in the vicinity of Olmsted in the Star Enterprises clay pit, and along the Ohio River bluffs and adjacent stream valleys south of U. S. Dam 53. It

TABLE 10

Geologic section compiled from outcrops along creek in NE$\frac{1}{4}$ sec. 7 and S$\frac{1}{2}$ sec. 6, T. 16 S., R. 1 W., near Cache River bluffs, Pulaski County.

	Thickness (ft.)	(in.)
Quaternary System		
Pleistocene Series		
Loess	20	
Tertiary System		
Pliocene Series		
"Lafayette" Gravel		
Gravel, red to red-brown, in part cemented; several armored clay pebbles present, well bedded	15	
Paleocene Series		
Porters Creek Formation		
Clay, gray to grayish black, poorly exposed in lower 40 feet	60	
Clayton Formation		
Clay, green to grayish green, very glauconitic, slightly sandy, slightly micaceous	8	10
Clay, light green to buff, very sandy, very glauconitic, abundant chert and limonite pebbles, chert pebbles coated with green pigment	1	2
Cretaceous System		
Gulfian Series		
Owl Creek Formation		
Sand, reddish brown to buff, very micaceous; upper 1 to 2 inches extremely limonitic, slightly glauconitic. Contact with overlying Clayton Formation indicates subaerial exposure	4	
	River level	

ranges from 50 to 150 feet thick, thickening to the south.

The Porters Creek Formation includes massive, sparsely fossiliferous, blocky, and essentially unlaminated, black to grayish tan clays (tables 9, 10, and 11).

Radiolaria and Hystrichospheridae are the dominant fossils, but Foraminifera also are found in the Porters Creek Formation. At most outcrops, the Porters Creek contains casts and molds of pelecypods and gastropods and abundant fish scales and shark teeth.

The Porters Creek Formation was deposited on a marine shelf, but farther from shore than the Clayton Formation. Heavy minerals in the formation also indicate a source area in the southern Appalachians.

Deposition of the Porters Creek clays in the Mississippi Embayment was followed by an interval in which the upper part of the Porters Creek was eroded and truncated.

Table 11 presents the general character of the Porters Creek Formation in the subsurface in the Thebes Quadrangle.

Eocene Series

The Eocene sediments of this area have been assigned to the Wilcox Formation (Lamar and Sutton, 1930; Stearns, 1958, p. 1098).

TABLE 11

Record of well $1\frac{1}{2}$ miles south of Unity. Schneider - G. C. Droge, no. 1.
in $SW\frac{1}{4}$ $NW\frac{1}{4}$ $NW\frac{1}{4}$ sec. 18, T. 16 S., R. 1 W., Pulaski County.
Elevation 450 feet above sea level.

	Thickness (ft.)	Depth to bottom (ft.)
Quaternary System		
Pleistocene Series		
Loess, silt, yellow brown to brown, slightly calcareous in lower 20 feet	47	47
Tertiary System		
Pliocene Series		
"Lafayette" Gravel		
Sand, yellow-brown, gravelly, silty, medium to coarse	13	60
Sand, red-brown to yellow-brown, gravelly, silty, clayey at base, coarse	15	75
Gravel, brown to yellow-brown, sandy, clayey	13	88
Eocene Series		
Wilcox Formation		
Clay, white, silty, slightly micaceous	7	95
Clay, light grayish brown, very sandy, micaceous, lignitic, pyritic, laminated	10	105
Clay, light gray, sandy, micaceous, lignitic, pyritic, slightly calcareous at base	10	115
Paleocene Series		
Porters Creek Formation		
Clay, dark gray, very micaceous, slightly carbonaceous	5	120
Clay, dark gray, very micaceous, slightly glauconitic, sideritic	20	140
Clay, dark gray, very micaceous, carbonaceous, slightly pyritic	10	150
Clayton Formation		
Clay, gray to dark greenish gray, slightly silty, very micaceous, very glauconitic, very sideritic, calcareous at base, fossiliferous	15	165
Cretaceous System		
Gulfian Series		
Owl Creek Formation		
Sand, very clayey, gray, micaceous, glauconitic, slightly carbonaceous	10	175
McNairy Formation		
Sand, white, fine to medium fine; limonite; cemented clay and silt, pyritic, slightly micaceous, lignitic	10	185
Sand, very clayey, very silty, gray-brown, very micaceous, fine to very fine, lignitic	5	190
Clay, very silty, sandy, gray brown, very micaceous, very lignitic	5	195
	Total depth	

TABLE 12

Geologic section of gravel pit along Cache River bluff in $NE\frac{1}{4}$ $SW\frac{1}{4}$ $SW\frac{1}{4}$ sec. 7, T. 16 S., R. 1 W., Pulaski County.

	Thickness (ft.)
Quaternary System	
Pleistocene Series	
Peoria Loess	8
Roxana Loess	15
Loveland Loess	13
Tertiary System	
Pliocene Series	
"Lafayette" Gravel	
Gravel, brown to reddish brown; boulders present ranging up to 30 inches long; several coarse sand lenses up to 2 feet thick	15
Eocene Series	
Wilcox Formation	
Sand, white to yellow-gray, slightly micaceous, fine to medium grained; abundant dark heavy minerals; numerous clay lenses and beds up to 5 inches thick, lower 9 feet clayey	20
Paleocene Series	
Porters Creek Formation	
Clay, black to dark gray, fossiliferous (molds and casts)	20
	Covered

Wilcox Formation

The name Wilcox was first used by Crider and Johnston (1906) as a replacement for the Eocene "Lignitic" Group. The unit includes a complex succession of sands, clays, lignites, and marls that are exposed in Wilcox County, Alabama. In Illinois this unit is considered of formational rank and it unconformably overlies the Porters Creek Formation and is overlain unconformably by Pliocene gravels and Pleistocene sediments. The Wilcox is 50 to 250 feet thick, with the thickest part to the south of Cairo.

The Wilcox in its type area consists of interbedded, micaceous, lignitic clays, silts, and sands. A small outcrop of cross-stratified, coarse sands 15 feet thick thought to be Wilcox is present above the Porters Creek Formation on the east side of the Star Enterprises clay pit, near Olmsted. One of the best outcrops of Wilcox sediments in Illinois is along the Cache River bluffs, in the Thebes Quadrangle (tables 11 and 12).

Wilcox sediments resulted from fluvial deposition in a floodplain and upper deltaic environment. Cross-bedding indicates transportation of the sediments to the southwest (Potter and Pryor, 1961) and heavy minerals indicate a source area similar to that of the preceding Cretaceous and Paleocene sediments.

Pliocene Series

Gravel and sand that cap most of the hills in the Cairo and La Center Quadrangles and in the southern part of the upland area in the Thebes Quadrangle are called "LaFayette" Gravel and assigned to the Pliocene Series (Lamar and Sutton, 1930; Weller, 1940; Leighton and Willman, 1949; Potter, 1955). Others consider these deposits to be of Pleistocene age (Fisk, 1944).

"Lafayette" Gravel

The "Lafayette" Gravel unconformably overlies the Cretaceous and early Tertiary sediments and locally overlaps onto the Paleozoic rocks. It is well exposed at many localities, especially along the Ohio River bluffs, and is encountered in many wells. It ranges up to 50 feet thick, generally thickening to the east. The "Lafayette" Gravel caps most of the hills in this area. In the La Center and Cairo Quadrangles the base of the gravel slopes gently to the west from an elevation of about 450 feet to about 390 feet above sea level. In the Sante Fe Hills north of Fayville in the Thebes Quadrangle it rests on bedrock surfaces as high as 580 feet.

The "Lafayette" Gravel is composed of interbedded chert, gravel, and sand (tables 7 and 10) deposited in a fluviatile environment. The sands are reddish brown to yellowish brown, fine to very coarse quartz sand, in part micaceous and clayey. The gravels consist chiefly of rounded, well polished, bronze-colored chert pebbles. In places the gravels are cemented by iron oxides.

QUATERNARY SYSTEM

Pleistocene Series

Sediments of Pleistocene age directly overlie Cretaceous and Tertiary formations in most of the area, but in the northern part of the Thebes Quadrangle they overlie Paleozoic formations. The Pleistocene sediments (fig. 8) include three major types of deposits: (1) valley fill deposits — largely sand, silt, and gravel transported into the area by meltwater from glaciers; (2) loess deposits — silt blown from the glacial outwash onto the upland areas; and (3) Recent alluvium — mostly silt and silty sand underlying the floodplains of rivers and streams.

The Pleistocene history of the area is complex (Weller, 1940; Fisk, 1944; Leighton and Willman, 1949, 1950), as would be expected from its location at the junction of the Mississippi and Ohio Rivers, which together carried the entire discharge of meltwaters from the fronts of glaciers extending from the Appalachian to the Rocky Mountains. In this area the rivers flow from narrow channels onto the broad plain of the lower alluvial valley. Nearby the Tennessee and Cumberland Rivers brought in different types of sediments from the southern Appalachians and bordering plateaus.

Although the history cannot be fully recorded here, the origin of the narrow valley of the Mississippi at Thebes, called the Thebes Gorge, and of Cache Valley is of particular interest. The main bedrock valley that carried the Mississippi River during most of its history turns westward at Cape Girardeau, just north of the Thebes Quadrangle, but the present river flows straight ahead through the narrow Thebes Gorge from Gale to Fayville. The river occupies almost the entire floor of the Thebes Gorge and flows directly on the bedrock surface, which is 150 to 200 feet lower in the broad, alluvium filled, main channel at Cape Girardeau.

The Ohio River also now occupies a narrow channel, formerly the channel of the Tennessee River, in which Cretaceous and Tertiary formations are close to the present bottom of the river. The former channel of the Ohio River was the relatively broad Cache Valley in which bedrock is more than 100 feet lower than that of the

STAGE	SUBSTAGE	LOESS UNIT
RECENT		
WISCONSINAN (Glacial)	Valderan	Peoria
	Twocreekan	
	Woodfordian	
	Farmdalian	
	Altonian	Roxana
SANGAMONIAN		
ILLINOIAN (Glacial)		Loveland
YARMOUTHIAN		
KANSAN (Glacial)		?
AFTONIAN		
NEBRASKAN (Glacial)		

Fig. 8 - Pleistocene nomenclature.

present channel.

The abandoned segments of both the Mississippi and Ohio Valleys are subject to flooding by the rivers during exceptionally high flood stages, and apparently have not been abandoned long. However, the diversion of the rivers apparently preceded deposition of the youngest glacial outwash terraces 8,000 to 10,000 years ago, as remnants of these deposits occur along the new channels. It has been suggested, therefore, that the diversion of the rivers took place slightly earlier at a time of unusually high water when both rivers were able to cross divides at the heads of northward flowing tributaries. Flowing directly ahead, the Mississippi River took advantage of the increased gradient of the shorter channel and rapidly scoured out a new channel to a level low enough to be maintained when the flood stage subsided. Such an interval of unusually high water in the Mississippi Valley, which would be reflected in the Ohio Valley, occurred when great floods of water were discharged into the headwaters of the Mississippi River by rapid melting of the ice when the glacial front began to retreat from the position of the Valparaiso Moraine. The resultant great flood, called the Kankakee Flood in the Illinois Valley, took place 15,000 to 16,000 years ago, and may account for the diversion of the Mississippi and Ohio Rivers to their present channels (Leighton and Willman, 1949).

Although the area of this report is entirely in the nonglaciated region of

TABLE 13

Mississippi River Commission - B. Crippin no. 1, SE$\frac{1}{4}$ NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 26, T. 15 S., R. 1 W., Alexander County. Elevation 341 feet above sea level. Summarized from description of samples by the Mississippi River Commission

	Thickness (ft.)	Depth to bottom (ft.)
Quaternary System		
Pleistocene Series		
Clay, silty, sandy, brown, compact	3$\frac{1}{2}$	3$\frac{1}{2}$
Silt, sandy, gray, soft	2	5$\frac{1}{2}$
Sand, silty, tan and gray, soft	1	6$\frac{1}{2}$
Clay, silty, gray, plastic	10$\frac{1}{2}$	17
Sand, with pea gravel, gray, medium to coarse, slightly silty	23	40
Sand, with pea gravel, gray, fine to medium, slightly silty, wood fragments in upper part	40	80
Sand, very gravelly, gravel up to 1$\frac{1}{2}$ inches in diameter, gray, medium to coarse	15	95
Sand, very gravelly, gravel up to 1 inch in diameter, gray, fine to coarse	5	100
Sand, with gravel, brownish gray, medium to coarse	18	118
Sand, very gravelly, gravel up to 2 inches in diameter, grayish brown, coarse	5	123
Mississippian System		
	Total depth	123

southern Illinois, during the Illinoian Stage of glaciation the glaciers were only 25 miles north of the Cache River Valley (Lamar, 1925).

Valley Fill Deposits

Thick valley fill deposits underlie the bottomlands of the Cache Valley and the broad floodplains of the Mississippi and Ohio Rivers.

In the Cache Valley the deposits are as much as 160 feet thick and consist largely of pebbly sand (table 13).

The valley fill of the Mississippi and Ohio Rivers in the southern part of the Thebes and Cairo Quadrangles is as much as 250 feet thick. The fill materials are largely sand and pebbly sand (tables 14, 15). Gravel and silt beds are present and the gravel is more common and coarser in the lower part of the fill.

Terrace Deposits

Much of the bottomland of the Cache Valley is a terrace, the surface of which is about 340 feet above sea level and 20 to 30 feet above the level of the Mississippi floodplain. It is separated from the floodplain by a prominent scarp that extends across the valley northwest from Unity. Remnants of terraces at about the same level are present along smaller valleys in the area. Except for a protected area northeast of Mounds, they were largely eroded from the Mississippi and Ohio Valleys before or during the building of the present floodplain. The deposits immediately underlying the terrace surface represent the youngest deposits of the valley fill and were deposited by meltwaters from the glaciers of the Wisconsinan Glacial Stage. The age of the oldest deposits in the deep part of the valley fill is uncertain, and probably not the

TABLE 14

Record of well in Cairo. Weldon Well Co. - St. Mary's Infirmary Well no. 1, in NW$\frac{1}{4}$ NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 25, T. 17 S., R. 1 W., Alexander County. Elevation 314 feet above sea level. Summarized from description of samples by C. L. Horberg.

	Thickness (ft.)	Depth to bottom (ft.)
Quaternary System		
Pleistocene Series		
Silt and fine sand, brown to gray, calcareous	10	10
Sand, brown to gray, calcareous at top, gravelly at base, silty, fine to coarse	40	50
Sand, gravelly, clean, coarse to medium, angular to subrounded	10	60
Gravel, sandy, subrounded to round, cherty	15	75
Gravel, clean, pebbles up to $\frac{1}{2}$-inch, subrounded	7	82
	Total depth	

TABLE 15

Record of well in Dogtooth Bend. Vick Oil Co. - Smith no. 1, in NW$\frac{1}{4}$ NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 15, T. 17 S., R. 2 W., Alexander County. Elevation 325 feet above sea level. Summarized from description of samples by W. A. Pryor and Elwood Atherton.

	Thickness (ft.)	Depth to bottom (ft.)
Quaternary System		
Pleistocene Series		
No samples	40	40
Sand, brown to gray, slightly calcareous, clean, well sorted, medium to coarse	25	65
Sand, gray to brown, slightly silty, slightly calcareous, medium to coarse	3	68
Sand, gray to gray-brown, calcareous, clean, fine to medium	10	78
Sand, gray-brown, slightly to very calcareous, clean, medium, slightly silty at base	22	100
Sand, brown to gray, slightly calcareous, slightly silty, medium to coarse; occasional fine gravel	35	135
Gravel, sandy, brown to gray, slightly calcareous, clean	50	185
Sand, gray-brown, slightly calcareous, silty, medium; occasional fine gravel	15	200
Sand, brown, slightly calcareous, very silty, very clayey, very fine	5	205
Tertiary System		
Paleocene System	115	320
Cretaceous System		
Gulfian Series	130	450
Ordovician System	1378	1828
	Total depth	

same in all places, but some of the deposits may be as old as early Pleistocene.

The terraces extend up the tributary valleys and form broad flats that in places surround isolated hills. Deposits in the tributaries consist of slackwater deposits, largely silt. In such places the fill, in considerable part, may be derived from erosion of adjacent slopes. Some of these deposits may record progressive fill by slopewash during a long interval of Pleistocene time, with weathering during interglacial stages represented by zones of clay accumulation (Leighton and Willman, 1949). Such a deposit is well exposed 2 miles southeast of Choat in "badlands" eroded between U. S. Highway 40 and the Chicago, Burlington and Quincy Railroad, SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 21, T. 15 S., R. 4 E., La Center Quadrangle.

Remnants of terraces slightly lower or higher than the terrace in Cache Valley are present locally and indicate the complexity of deposition of the valley fill. A higher and deeply dissected terrace, with its upper surface at an elevation of about 380 feet, is found along the bluffs northeast of Olive Branch and in the lower drainage ways of Salamans and Miller Creeks in the Thebes Quadrangle. A lower terrace, poorly preserved, is present only in the central part of the Cairo Quadrangle near the village of America and south of Olmsted. This terrace is adjacent generally to the Ohio River and occurs at an elevation of about 325 feet above sea level.

Loess

All the uplands in the map area are underlain by loess, a wind blown deposit of silt. These were derived from the bottomlands of the Mississippi River north and west of Gale and from the bottomlands of the Ohio River when it occupied the Cache Valley. The loess is thickest in the bluffs near Gale where it reaches a thickness of 50 feet. It thins gradually to the east where the maximum thickness is about 15 feet.

Three units are recognized in the loess of this area: the Loveland Loess (at the base), Roxana Silt (largely loess), and Peoria Loess (Leighton and Willman, 1950; Frye and Willman, 1960).

The Loveland Loess was blown from outwash on the valley floor during the Illinoian Stage of glaciation. It is a clayey silt deeply weathered to a brownish red or reddish brown. It commonly has a zone of silt mixed with pebbles of underlying rocks at the base that are of colluvial origin and may contain reworked loess deposits older than Illinoian. The Loveland Loess is as much as 6 feet thick in the Mississippi bluffs near Gale, but it thins to 2 or 3 feet in the eastern part of the area, and in many localities it was eroded before deposition of the younger loess.

The Roxana Silt of Altonian age is largely loess but includes colluvial silt at the base. It is the oldest Wisconsinan loess. The Roxana is a medium to dark brown silt with a pink or pinkish cast where relatively thick. It is much less clayey than the Loveland below. It is as much as 25 feet thick in the bluffs near Gale, 5 feet thick near Unity, locally 12 feet thick in the bluffs at Mounds, and generally 2 to 4 feet thick farther east. It is readily distinguished from the Peoria above by its darker color and by the presence of carbonates in the lower Peoria where the Peoria is thick. In the Roxana, carbonates are found only in the thick sections near Gale where fossil snails are common (Leonard and Frye, 1960).

The Peoria Loess is largely of Woodfordian age but may include some loess of Valderan age. It is tan or light buffish gray, well sorted silt that generally composes the upper half to three-fourths of the loess sequence and in places rests directly on pre-loess deposits. It is as much as 40 feet thick in the vicinity of Gale, but it thins eastward until east of Cache Valley it is rarely over 20 feet thick. Carbonates have been leached from the Peoria to a depth of about 15 feet below flat upland surfaces.

TABLE 16

Geologic section exposed along road in SW$\frac{1}{4}$ NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 15, T. 16 S., R. 1 W., Pulaski County.

	Thickness (ft.)	(in.)
Quaternary System		
Pleistocene Series		
Peoria Loess	10	6
Roxana Loess	12	
Loveland Loess	7	6
Tertiary System		
Pliocene Series		
"Lafayette" Gravel	8	
Eocene Series		
Wilcox Formation	14	
Paleocene Series		
Porters Creek Formation	5	
	Covered	

Consequently, the Peoria is entirely noncalcareous where it is less than 15 feet thick. Where it is more than 15 feet thick the lower part is strongly calcareous and contains fossil snails (Leonard and Frye, 1960).

The sequence of loesses is well exposed in a borrow pit just north of the north line of the Thebes Quadrangle at Gale (Frye and Willman, 1960), and it was formerly exposed in a borrow pit in the east bluff of Cache Valley a mile south of Unity (NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 18, T. 16 S., R. 1 W.), in a road cut at Mounds (table 16), in the Illinois Central Railroad cut just south of Villa Ridge, and in road cuts, presently somewhat slumped, at the Post Creek cutoff, 3 miles east of Grand Chain.

Recent Deposits

The alluvial deposits underlying the floodplains of the present streams are composed mostly of sandy silts, with beds and lenses of clays, sand, and gravel. These deposits directly overlie the glacial valley-fill deposits in the major valley. They generally contain more silt than the glacial deposits but are not readily differentiated from them.

Low-lying areas on the floodplains commonly are swamps and marshes. The materials in these areas are primarily organic mucks and generally do not exceed 10 feet thick.

GEOLOGIC STRUCTURE

Structure of Paleozoic Strata

The structure of the Paleozoic strata in the Thebes Quadrangle is difficult to interpret because of discontinuous exposures, thick Pleistocene loess cover, and variations in thickness of the stratigraphic units. In general the beds dip 2 to 4 degrees to the east and northeast, although locally the dips steepen to 10 to 15 degrees to the northwest or southeast adjacent to zones of faulting.

The axis of the broad Thebes Anticline extends east-southeast through Thebes and gradually becomes less pronounced towards Olive Branch. The northeast flank of this anticline is flexed by a gentle syncline and anticline along the Mississippi River in section 5, T. 15 S., R. 3 W. The southwest flank is complicated by several faults and gentle folds. South of Thebes at least four faults that strike northeast are inferred from the outcrops along the Mississippi River bluffs (pl. 1). They appear to be normal faults and, except for a graben at the mouth of Orchard Creek, their northwestern sides are downthrown 50 to 100 feet.

Faulting is difficult to demonstrate in the loess-covered hills east of the river bluffs, although both in the SE$\frac{1}{4}$ of section 21 and in the center of section 10, T. 15 S., R. 3 W., beds dipping steeply to the northwest are suggestive of nearby faults.

Structure of Cretaceous and Tertiary Strata

The Cretaceous-Tertiary sediments dip about 50 feet per mile to the south and southeast as shown by a contour map drawn on the base of the Clayton Formation (fig. 7). Although faults of small displacement have been noted in the Cretaceous-Tertiary sediments west of the Mississippi River in Missouri (Grohskopf, 1955), none were observed in this area.

MINERAL RESOURCES

The mineral resources of the area are clay, sand and gravel, silica (tripoli), novaculite gravel, limestone, and ground water. The area is chiefly agricultural and is dependent on the productivity of the soils. On the uplands and terraces of the area the soils are developed on the Pleistocene loesses and in the bottomlands on Recent alluvium.

Clay

The clay resources in the area mapped consist of Cretaceous and Eocene clays that are chiefly kaolinite, Paleocene clays that are dominantly montmorillonite(Pryor and Glass, 1961), and Pleistocene silty clays in alluvium and loess that are of mixed clay minerals.

The Paleocene clay in the Porters Creek Formation is actively mined in the vicinity of Olmsted by Star Enterprises and is used as sweeping compound and animal litter. These clays have in the past been used as fuller's earth (Lamar, 1928).

The Cretaceous and Eocene clays are not widely utilized in this area, although in the past the Cretaceous clays have been used in the manufacture of pottery. Several miles north of Fayville, in the SW$\frac{1}{4}$ sec. 21, T. 15 S., R. 3 W., clays from the base of the Tuscaloosa Formation are periodically mined on a small scale for refractory clay.

The clay deposits of this area are described in a general report on clay and shale resources in extreme southern Illinois (Lamar, 1948).

Sand and Gravel

Widespread deposits of sand and gravel have been exploited locally in many small pits. The "Lafayette" Gravel has been the chief source of sand and gravel, which is used mainly for road metal.

Sand and gravel have been dredged from the Ohio River in the vicinity of Cairo, and a large sand and gravel bar is present along the Ohio River bank east of Mound City.

The sand deposits of Cretaceous and Eocene age are not being exploited in this area but may have possibilities for use as molding sand. The sand resources of the general area have been described by Shrode and Lamar (1953).

Silica (Tripoli) and Novaculite Gravel

In an area near Olive Branch where the Bailey Limestone is largely chert it contains beds and vein-like areas in which the chert and highly siliceous limestone has been largely altered to a soft, white, powdery silica that has been mined as soft silica, or tripoli. The silica formerly was processed at Olive Branch, but the plant is now idle.

The raw silica is ground to a fine powder in ball mills and sold for filler in paints, buffing compounds, fine abrasive, polishing powder, and use in the manufacture of ceramic products. Production of silica at present is confined to deposits in the Clear Creek Chert immediately north of the Thebes Quadrangle. The occurrence and characteristics of the silica deposits has been described by Lamar (1953).

In some areas the chert is fractured to particles less than 2 inches in diameter. This material, called novaculite gravel, can be quarried with only minor blasting. It is used mainly for road gravel but has had limited use for the manufacture of silica brick (Lamar, 1953).

Limestone

The Paleozoic limestones exposed in the Mississippi Valley bluffs and along tributary streams in the Thebes Quadrangle are of suitable quality for a number of the uses of limestone. At most of the exposures a thick overburden of other bedrock strata and loess would make extensive quarrying difficult, but relatively small quantities of rock for local use can be obtained at some of the exposures described in the section on Stratigraphy. The limestone resources of the area have been described by Lamar (1959).

GROUND WATER

Ground water for domestic use is present in abundance throughout the area and is abundant enough for industrial use in most of the area. The Devonian and Mississippian cherts and Silurian and Ordovician carbonate rocks, as well as the sands and gravels of the Ohio, Mississippi, and Cache Valleys, offer excellent supplies of water for industrial purposes. The sands of the McNairy Formation are a good source of water for domestic use and probably could produce quantities sufficient for industrial needs. The availability of ground water in this area has been discussed by Pryor (1956) and in a publication of the Illinois State Water Survey (1957).

TABLE 17 - Locations of Wells Shown in Cross Sections of Plate 2

Well No.	
1.	Weldon Well Co. - Illinois Central no. 1, SW$\frac{1}{4}$ NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 15, T. 15 S., R. 1 W., Pulaski County
2.	Weldon Well Co. - A. O. Paulisch no. 1, NW$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 27, T. 15 S., R. 1 W., Pulaski County
3.	Schneider-Whelan no. 1, NE$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 34, T. 15 S., R. 1 W., Pulaski County
4.	Vick Oil Co. - Boyd no. 1, NW$\frac{1}{4}$ NE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 5, T. 15 S., R. 1 W., Pulaski County
5.	Schneider - G. C. Droge no. 1, SE$\frac{1}{4}$ NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 18, T. 16 S., R. 1 W., Pulaski County
6.	Gould - O. R. Bourland no. 1, SE$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 19, T. 16 S., R. 1 W., Alexander County
7.	Vick Oil Co. - Smith no. 1., NW$\frac{1}{4}$ NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 15, T. 17 S., R. 2 W., Alexander County
8.	Sargent - H. Richard no. 1, NW$\frac{1}{4}$ SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 4, T. 15 S., R. 1 E., Pulaski County
9.	Williams - W. L. Rickey no. 1, SW$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 9, T. 15 S., R. 1 E., Pulaski County
10.	Case - Olmsted City no. 1, SE$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 22, T. 15 S., R. 1 E., Pulaski County
11.	Vick Oil Co. - Roberts no. 1, NW$\frac{1}{4}$ SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 5, T. 16 S., R. 1 E., Pulaski County
12.	Mound City - Ice Plant no. 1, sec. 36, T. 16 S., R. 1 W., Pulaski County
13.	Halliday Estate no. 3, SW$\frac{1}{4}$ SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 2, T. 17 S., R. 1 W., Alexander County
14.	Cairo Electric Light and Power Co. no. 1, SE$\frac{1}{4}$ sec. 25, T. 17 S., R. 1 W., Alexander County
15.	Halliday Estate no. 4, SW$\frac{1}{4}$ sec. 25, T. 17 S., R. 1 W., Alexander County
16.	Sargent - Richardson no. 1, SE$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 34, T. 14 S., R. 2 E., Pulaski County
17.	Post Creek outcrop, center sec. 2, T. 15 S., R. 2 E., Pulaski County
18.	Wittag - Grand Chain, SW$\frac{1}{4}$ SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 2, T. 15 S., R. 2 E., Pulaski County
19.	Layne-Western - Joppa Compressor Station no. 7, SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 10, T. 15 S., R. 3 E., Massac County
20.	Layne-Western - Electric Energy Inc. no. 2, NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 14, T. 15 S., R. 3 E., Massac County
21.	Cunningham - Weinke no. 1, SE$\frac{1}{4}$ SE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 4, T. 15 S., R. 4 E., Massac County

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