STRUCTURAL FRAMEWORK OF THE MISSISSIPPI EMBAYMENT OF SOUTHERN ILLINOIS

Dennis R. Kolata, Janis D. Treworgy, and John M. Masters

Illinois Institute of Natural Resources
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COVER PHOTO: Exposure of Mississippian limestone along the Post Creek Cutoff in eastern Pulaski County, Illinois. The limestone is overlain (in ascending order) by the Little Bear Soil and the Gulfian (late Cretaceous) Tuscaloosa and McNairy Formations.

Cover and illustrations by Sandra Stecyk.

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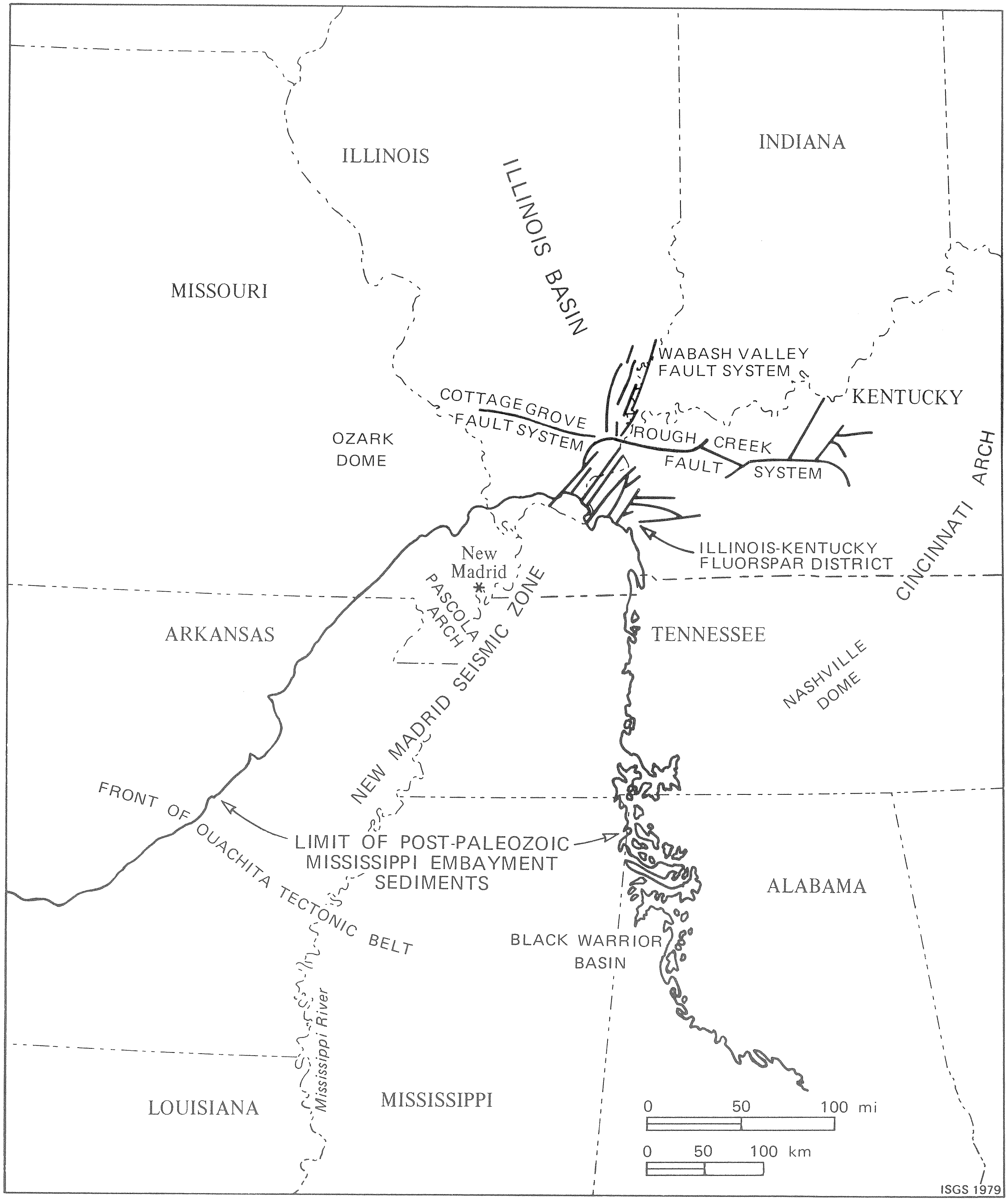

Figure 1. Tectonic setting of the Mississippi Embayment area.

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ABSTRACT

Some of the northeast-trending faults that displace Paleozoic rocks in the Illinois-Kentucky Fluorspar District extend southwestward beneath the Gulfian (late Cretaceous) sediments of the Mississippi Embayment in southernmost Illinois. The relatively uniform thickness of the Cretaceous sediments and nature of the configuration of the base of the Cretaceous indicate that essentially all of the displacement on the faults in the underlying Paleozoic bedrock took place before the Cretaceous sediments overlapped the area. Outcrop and subsurface data indicate that the present relief on the sub-Cretaceous surface throughout the Mississippi Embayment of southern Illinois is due to the combined effects of pre-Gulfian erosion, post-Gulfian solution, and possibly minor deformation during and after Gulfian time. Although deformation of Gulfian or later age is suggested at several sites, the available evidence is too sparse and ambiguous to conclude that tectonic faulting is the cause of these local disturbances.

INTRODUCTION

This study is part of a coordinated program of geological, geophysical, and seismological investigations of the area that lies within a 200-mile radius of New Madrid, Missouri. New Madrid is situated near the epicenter of a series of the most intense earthquakes documented in this country (late 1811 and early 1812), and it is still an area of moderate seismicity. The goal of the program, the New Madrid Seismotectonic Study, is to develop a better understanding of the structural setting and tectonic history of the area in order to evaluate earthquake risk as it applies to the siting of nuclear facilities. The study is funded in part by the U.S. Nuclear Regulatory Commission and includes participants from various state geological surveys and universities. Research activities of the U.S. Geological Survey are also coordinated with this program.

The Mississippi Embayment of southern Illinois (as demarcated by the present boundary of the continuous Cretaceous deposits) lies between the New Madrid Seismic Zone and the highly faulted area of the Illinois-Kentucky Fluorspar District (fig. 1). The seismic zone and the faulting in the Fluorspar District in Illinois both have northeast-southwest trends, and structural continuity is commonly inferred between the two areas. Knowledge of the structural framework and tectonic history of the study area is essential in the evalutation of seismic risk for the Central Mississippi Valley Region and parts of the Wabash and Ohio River Valleys. The main focus of this study is on the evaluation of evidence for faulting during and after Gulfian (late Cretaceous) time in the embayment area of southern Illinois.

This investigation of the structural framework of the southern Illinois portion of the Mississippi Embayment leads to a new interpretation based on a reevaluation of data used in previous studies and on new geological and geophysical (earth resistivity, seismic reflection, and seismic refraction) data. Our principal objectives are: (1) to describe the geologic features of the Paleozoic bedrock; (2) to describe the thickness and distribution of the embayment sediments; (3) to describe and interpret several surficial sites where the embayment sediments are faulted and folded; and (4) to summarize the structural history of the area.

METHOD OF STUDY

Detailed mapping in this investigation is based on outcrop and subsurface information obtained from cores, drilling chips, geophysical surveys, and drillers' logs. All available well cuttings and cores were reviewed. Data were plotted on computer-constructed base maps (ILLIMAP, see Swann et al., 1970) of 1:125,000 scale. The northern limit of continuous Cretaceous deposits in Alexander, Pulaski, Massac, and Pope Counties is the boundary of the study area (fig. 2). A generalized stratigraphic column for this area is shown in figure 3. Stratigraphic data obtained from subsurface and outcrops are listed in tables 1 and 2 (appendix), and their locations are shown on figure 4. Figure 4 also shows the location of supportive data outside of the study area. Four regional maps of the embayment area of southern Illinois were compiled to show: (1) the sub-Cretaceous geology (fig. 5); (2) the configuration of the base of the Cretaceous (fig. 6); (3) the distribution and thickness of the Cretaceous strata (fig. 7); and (4) the structure of the base of the Paleocene Clayton Formation (fig. 8).

Field work began in the fall of 1977 and continued into the summer of 1979. Detailed studies were conducted at selected sites where the embayment sediments show evidence of disturbance. Maps and cross sections of several sites were prepared, and geologic interpretations are given herein.

A conservative approach was taken in preparing the maps for this report, particularly in regard to faulting. The faults shown on the sub-Cretaceous geologic map (fig. 5) are interpreted primarily from studies of well cuttings and cores. Although we suspect that faulting is widespread in the Paleozoic bedrock, no fault was extended beyond areas of control.

GEOLOGIC SETTING

The Mississippi Embayment is an inland extension of the Gulf Coastal Plain, a physiographic and structural province that reaches as far north as the southern tip of Illinois. The axis of the embayment generally coincides with the present course of the Mississippi River. The embayment is a downwarped structural trough that lies between the Ozark Dome on the west and the Nashville Dome on the east (fig. 1). Mostly unconsolidated sediments of Mesozoic and Cenozoic age fill the trough. These sediments form a wedge that thickens southward from an erosional featheredge in southern Illinois to approximately 4,000 feet (Stearns and Marcher, 1962) in northeastern Mississippi and eastern Arkansas.

Except for a few small outliers of clays, sands, and gravels of suspected Gulfian age, the embayment strata in Illinois are confined to the southern part of the Santa Fe Hills in Alexander County and to the area south of the Cache Valley (fig. 2). The Cache Valley is the former channel of the Ohio River. In Illinois the embayment sediments rest unconformably on Paleozoic bedrock that ranges in age from Ordovician to Mississippian (fig. 5). Throughout a large part of the study area the embayment strata are overlain by the Pliocene-Pleistocene Mounds Gravel and Pleistocene loess, colluvium, and alluvium. The maximum depth to the Paleozoic bedrock in southern Illinois is approximately 600 feet; this is at the southern tip of Alexander County. The Gulfian and early Tertiary sediments that fill the embayment trough in Illinois have a southerly dip of about 50 feet per mile.

The structural framework of the embayment area of southern Illinois is complex. The embayment strata have a regional dip to the south toward the center of the embayment trough, whereas the underlying Paleozoic rocks have a regional dip to the northeast toward the Illinois Basin and away from the Ozark Dome and Pascola Arch. In addition, the Paleozoic rocks are broken by numerous northeast-trending faults that extend from the Illinois-Kentucky Fluorspar District southwestward apparently passing beneath the embayment sediments. Based on subsurface data, several northeast-trending faults are postulated within the study area and their locations are shown on the sub-Cretaceous geologic map (fig. 5). Some of the faults can be observed in outcrop north of the study area in Pope and Hardin Counties. The faults are nearly vertical and have as much as 2,000 feet of displacement.

PREVIOUS STUDIES

The structural geology of southern Illinois has been discussed by numerous investigators including Stuart Weller (1920), Butts (1925), J. M. Weller (1940), Clark and Royds (1948), Stonehouse and Wilson (1955), J. M. Weller, Grogan, and Tippie (1952), J. M. Weller and Sutton (1940), and Heyl and Brock (1961). These studies dealt mainly with the geologic structure north of the Mississippi Embayment, with particular emphasis on the Illinois-Kentucky Fluorspar District.

The most detailed investigations of the geology of the Mississippi Embayment area of southern Illinois are those of Pryor and Ross (1962) and Ross (1963, 1964). Ross (1963) made the first analysis of the structural framework of this area. From the field relations, subsurface data, and historical seismicity, Ross (1963, p. 23) concluded that "the structural framework of southernmost Illinois is closely related to the structure of the Illinois-Kentucky Fluorspar District and to the structure of the Mississippi Embayment." Ross (1963, p. 23) reasoned that much of the relief on the sub-Cretaceous surface, shown in his figure 7, is due to faulting which postdates deposition of the Gulfian sediments and which, in part, postdates deposition of the Eocene sediments. Ross (1963, p. 18) supposed that "if the relief on the sub-Cretaceous surface was as great when the Cretaceous strata were deposited as it is now, the

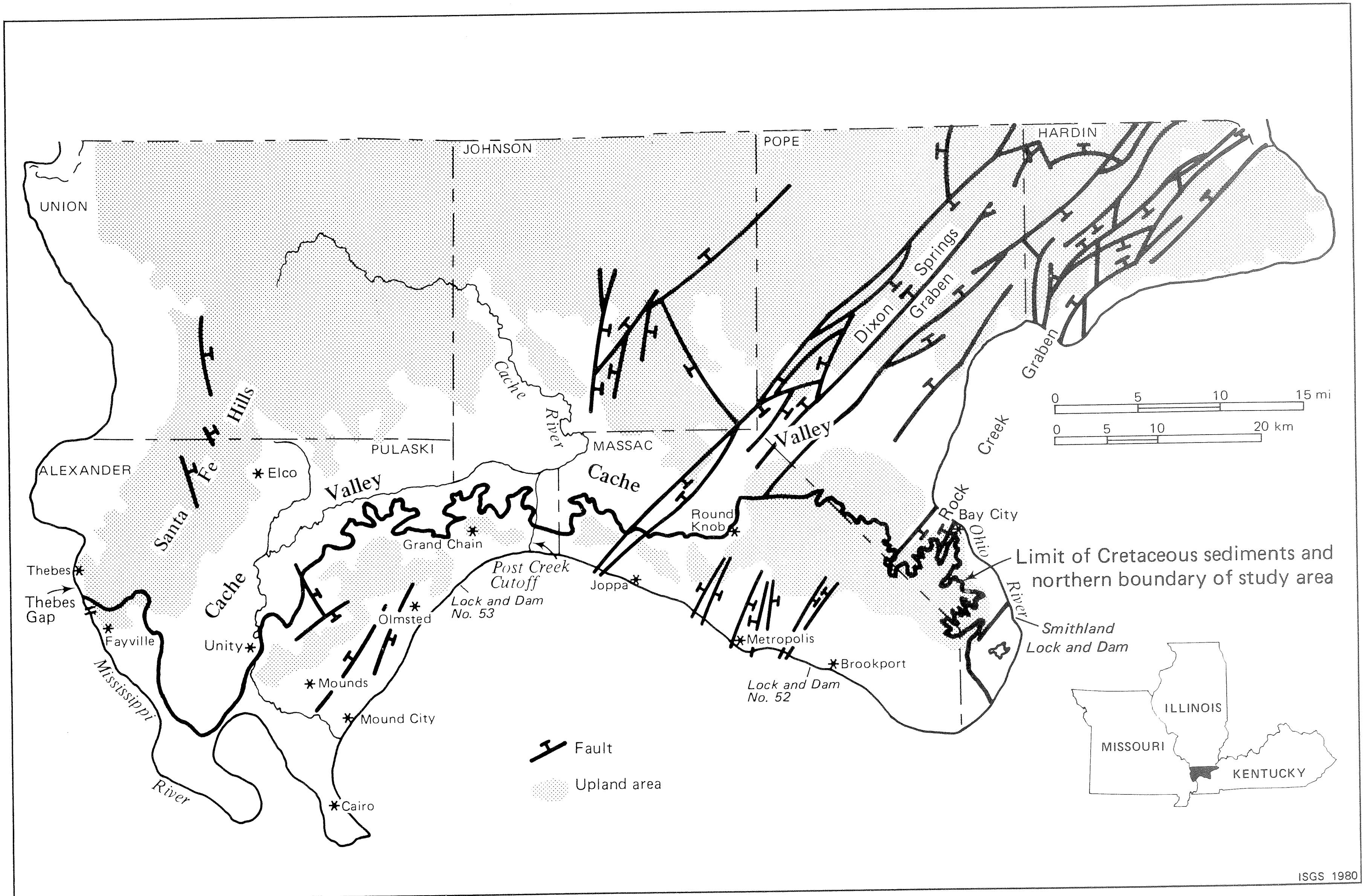

Figure 2. Physiographic map of southernmost Illinois showing the major faults in the Paleozoic bedrock (faults north of the study area taken from Willman et al., 1967). Northern boundary of the study area is marked by the limit of Cretaceous sediments.

Tuscaloosa Formation should locally be much thicker, and its distribution more irregular." The present investigation has shown that the Tuscaloosa is in fact irregular in thickness and distribution. Ross (1963, p. 3) further argued that the evidence "suggests that the fault system which cuts the Paleozoic strata at the head of the Embayment [in the Fluorspar District] extends for a considerable distance southwestward beneath the Embayment sediments and has remained active to the present."

In recent years the term "New Madrid Fault Zone" (Heyl and Brock, 1961) has been applied to the broad belt of northeastward trending faults that extends from southwest of New Madrid, Missouri, northeastward through southernmost Illinois to near Vincennes, Indiana. Burke and Dewey (1973) interpreted the "New Madrid Fault Zone" to be the failed arm of a plume-generated triple rift juncture that led to the formation of the Mississippi Embayment during Mesozoic time. Ervin and McGinnis (1975) accepted the triple rift juncture model, but reasoned on the basis of geological and geophysical data that the embayment is a reactivated rift (Reelfoot Basin of Schwalb, 1969) that originated late in Precambrian time. Accordingly, reactivation of the rift late in Mesozoic time led to isostatic subsidence within the embayment and formation of the elongate depositional trough observed today. Present-day seismicity and the region of principal historical earthquake activity lie along the axis of the rift zone (Hildenbrand, Kane, and Hendricks, 1979), primarily in the Bootheel region of southeastern Missouri. Geophysical studies by Hildenbrand and Hendricks (1977), Kane and Hildenbrand (1977), Braile et al., (1979), and Hildenbrand, Kane, and Hendricks (1979) indicate a rather sharply bounded zone of low gravity and magnetic relief that corresponds with the "New Madrid Fault Zone" as defined by Heyl and Brock (1961).

STRATIGRAPHY

As much as 15,000 feet of Paleozoic strata (fig. 3), ranging in age from Cambrian to Mississippian, overlie Precambrian crystalline rocks. The oldest stratigraphic unit encountered in the study area is the Canadian (lower Ordovician) Shakopee Dolomite observed in the Cache Oil Co. No. 1 George Moses test (table 1, no. 77) in southern Pulaski County. Pryor and Ross (1962, p. 5, 6) describe this well in detail. The deepest well (total depth 4,100 feet) in the area is the Rigney and Dodson Oil Co. No. 1 J. H. Lewis test (table 1, no. 194) in southern Pope County; the well was drilled through a thick succession of Mississippian, Devonian, Silurian, and Ordovician rocks (finished in the Champlainian Platteville Group). A summary description of this well was published by Ross (1964, p. 24-28). A significant deep well located immediately north of the study area is the Texas Pacific Oil Co. No. 1 B. Farley et al. test in southern Johnson County (SE NE SE Sec. 34, T. 13 S., R. 3 E.). The well was drilled to a total depth of 14,284 feet and penetrated a stratigraphic succession that ranges in age from Chesterian to Cambrian.

Discussions of the Paleozoic stratigraphy in the area are given by Weller (1940), Weller and Ekblaw (1940), Grohskopf (1955), Pryor and Ross (1962), Lineback (1966), and Schwalb (1969).

Mississippi Embayment deposits of Gulfian (late Cretaceous) and early Tertiary age overlie the Paleozoic bedrock in the area. These sediments consist primarily of unconsolidated clay, silt, sand, and gravel of both marine and non-marine origin. In the lowland areas these sediments are buried by alluvium. In the uplands they are mostly masked by the Pliocene-Pleistocene Mounds Gravel and Pleistocene loesses.

The post-Paleozoic strata in the area have been described by Lamar and Sutton (1930), Weller (1940), Grohskopf (1955), Potter (1955), Stearns and Armstrong (1955), Stearns (1957), Pryor (1960), Pryor and Ross (1962), Ross (1964), and Willman et al. (1975).

Although post-Cambrian igneous intrusive rocks are known to occur in the surrounding areas, none have been reported in the study area.

The following is a brief description of the stratigraphic units. More detailed discussion is available in the "Handbook of Illinois Stratigraphy," by Willman et al. (1975).

Paleozoic Erathem

ORDOVICIAN SYSTEM

The oldest rocks encountered in drilling or exposed in outcrop in the study area are of the Ordovician Canadian Series. The Cache Oil Co. No. 1 George Moses test (table 1, no. 77) in Pulaski County encountered the most complete Ordovician section to date. The well was drilled through about 150 feet of sandy dolomite of the Champlainian Everton Dolomite and into the upper part of the Canadian Shakopee Dolomite. The Everton is distinguished from the Shakopee by the lack of siliceous oolites and banded or oolitic chert. The Everton is overlain by 150 feet of St. Peter Sandstone that is mostly fine- to medium-grained sandstone with characteristically well-rounded and frosted grains; it is dolomitic in places. About 130 feet of dark-gray to brown, argillaceous, sandy, lithographic limestone and dolomite of the Dutchtown Formation overlie the St. Peter Sandstone. The overlying Joachim Formation is about 360 feet thick and is differentiated from the Dutchtown mainly by its lighter color and greater proportion of dolomite. The Platteville and Galena Groups have a combined thickness of about 760 feet. The Platteville is characterized by grayish-brown, lithographic, dolomitic, cherty, argillaceous limestone, and the Galena mostly consists of light-gray, fine- to coarse-grained limestone. The St. Peter, Dutchtown, Joachim, Platteville, and Galena are all assigned to the

ERA	SYSTEM	SERIES	GROUP	FORMATION	GRAPHIC COLUMN	THICKNESS (ft)
CENOZOIC	QUATERNARY	PLEISTOCENE		Loess, alluvium, and colluvium		0-250
	TERTIARY-QUATERNARY	PLIOCENE-PLEISTOCENE		Mounds Gravel		0-50
	TERTIARY	EOCENE		Wilcox		0-250
		PALEOCENE		Porters Creek		0-150
				Clayton		0-20
MESOZOIC	CRETACEOUS	GULFIAN		Owl Creek		0-10
				Levings Member McNairy		25-455
				Tuscaloosa		0-170
PALEOZOIC	MISSISSIPPIAN	CHESTERIAN		Little Bear Soil*		0-10
				(formations not differentiated in this report)		1000
		VALMEYERAN		Ste. Genevieve		200-240
				St. Louis		350
				Salem		250-425
				Ullin		150-580
				Fort Payne		0-670
				Springville		5-50
		KINDERHOOKIAN	New Albany Shale	Chouteau		0-4
	DEVONIAN	UPPER				100-300
		MIDDLE		Alto-Lingle		0-50
				Grand Tower		0-80
		LOWER		Clear Creek		1200
				Backbone		
				Grassy Knob		
				Bailey		
	SILURIAN	? CAYUGAN ?		Moccasin Springs		200
		NIAGARAN		St. Clair		
		ALEXANDRIAN		Sexton Creek		5-90
				Edgewood		
	ORDOVICIAN	CINCINNATIAN		Girardeau		0-30
			Maquoketa Shale	Scales Thebes Ss. Mbr.		100-300
				Cape		0-8
		CHAMPLAINIAN	Galena			100-150
			Platteville			550-650
			Ancell	Joachim		385
				Dutchtown		200
				St. Peter		100-150
				Everton		90-500
		CANADIAN	Prairie du Chien	Shakopee		3100-3300

*Soil developed on Paleozoic rocks that range in age from Ordovician to Mississippian.

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Figure 3. Generalized stratigraphic column of southernmost Illinois (Cambrian section not shown).

Champlainian Series. The uppermost unit of the Ordovician that is present in the George Moses test is the Maquoketa Shale Group of the Cincinnatian Series, which consists of 210 feet of dark-gray and brown shale, siltstone, and sandstone.

The Galena (Kimmswick Limestone) and Maquoketa Shale (Thebes Sandstone and Orchard Creek Shale) Groups and the Cincinnatian Girardeau Limestone are exposed in the bluffs and ravines of the Mississippi River in Thebes Gap (fig. 2). The Cape Limestone of the Cincinnatian Series overlies the Galena but is not well exposed in Illinois at the present time.

SILURIAN SYSTEM

The Silurian System of southernmost Illinois is about 200 feet thick and consists of strata that are assigned to the Alexandrian (Edgewood Formation and Sexton Creek Limestone) and Niagaran (St. Clair Limestone and Moccasin Springs Formation) Series. Most of the Silurian succession is exposed in the bluffs and ravines in the Thebes Gap area.

The basal part of the Edgewood Formation, which unconformably overlies the Giradeau Limestone, is a thin, discontinuous, massive, gray to buff, finely crystalline limestone. In places the lower 2 feet is a conglomerate of pebbles from the Girardeau Limestone mixed with oolites. The Edgewood is confined primarily to a few outcrops in the northern part of Alexander County. It is absent in the Cache Oil Co. No. 1 George Moses test (table 1, no. 77) in the western part of Pulaski County. The overlying Sexton Creek Limestone consists of about 15 feet of fine-grained, cherty, gray limestone that is mottled red in the upper part.

Above the Sexton Creek is the St. Clair Limestone of the Niagaran Series. The St. Clair is characterized by 10 to 20 feet of light-gray and pink to reddish-brown, fine-grained limestone with abundant fossil fragments (table 2, d). It is overlain by the red-and gray-mottled, calcareous shale of the Moccasin Springs Formation. The Moccasin Springs is approximately 120 feet thick throughout the area.

DEVONIAN SYSTEM

The Devonian System in Illinois is divided into three series—Lower, Middle, and Upper. The Lower Devonian Series, which is about 1,200 feet thick in the area, is characterized by chert and by cherty and silty limestone formations. The basal formation, the Bailey Limestone, is a medium brownish-gray, cherty and silty limestone that is exposed in numerous roadcuts and quarries in the bluffs of the southeastern part of the Santa Fe Hills in Alexander County (fig. 2). Overlying the Bailey, and gradational with it, is the Grassy Knob Chert, which is lighter colored than the Bailey and contains more massive chert and less limestone. In the eastern part of the study area, the Backbone Limestone occurs as a thin, slightly cherty limestone, which separates the Grassy Knob Chert from the overlying Clear Creek Chert. The Backbone is about 20 feet thick in the Rigney & Dodson Oil Co. No. 1 J. H. Lewis test (table 1, no. 194) in Pope County. The Backbone becomes more siliceous in the western part of the study area and is not recognized in the Devonian outcrop area in Alexander County. The Clear Creek Chert is dominantly a chert that is lighter in color than the chert in the underlying formations. It also includes strata of cherty dolomite and limestone. Solution of the carbonates and deep weathering of the chert has modified the original deposits into materials described as novaculite, calico rock, ganister, and tripoli (Lamar, 1953). Tripoli, mainly from the Clear Creek Chert, is produced commercially from several small mines near Elco in the Santa Fe Hills.

Unconformably overlying the Lower Devonian strata are the dominantly limestone formations of the Middle Devonian Series. At the base is the Grand Tower Limestone, which is a light-gray, fossiliferous limestone that ranges up to 80 feet thick in the area. The basal few feet (up to 15 feet) is the Dutch Creek Sandstone Member of the Grand Tower, which grades upward into the limestone. The Dutch Creek is present in the New Illinois Mid-Continent Oil Co. No. 1-A Roscoe Herren test (table 1, no. 33).

Overlying the Grand Tower are the Lingle and Alto Formations of the Middle Devonian Series; they consist of medium- to dark-brownish gray, cherty limestone and interbedded shale. The Lingle is less silty and dolomitic than the overlying Alto Formation and both are generally darker and more shaly than the Grand Tower. The Lingle and Alto Formations, which together reach a thickness of about 50 feet, grade eastward into the basal 40 feet of shale of the New Albany Shale Group.

The Upper Devonian Series consists entirely of gray and black shales of the New Albany Shale Group that are as much as 200 feet thick. The shales have distinctive electrical resistivities but are not subdivided in this report.

MISSISSIPPIAN SYSTEM

The Kinderhookian Series (lower Mississippian) is represented by a discontinous, thin (up to 4 feet), brown, silty, dolomitic limestone that is assigned to the Chouteau Limestone. Locally present at the base of the Kinderhookian Series is a thin shale that is assigned to the New Albany Shale Group. The overlying Valmeyeran Series (middle Mississippian) consists of the Springville Shale, Fort Payne Formation, and the Ullin, Salem, St. Louis, and Ste. Genevieve Limestone, in ascending order. The Springville Shale is a medium to dark brownish- or greenish-gray shale that reaches a thickness of about 50 feet. The Fort Payne Formation overlies the Springville Shale and is a dark siliceous, cherty limestone that ranges from 0 to 670 feet thick in the area. The Ullin Limestone, a light-colored, bryozoan-rich limestone, also ranges greatly in thickness from 150 to 580 feet. The overlying Salem Limestone ranges from 250 to 425 feet thick and consists of fine-grained dolomite and

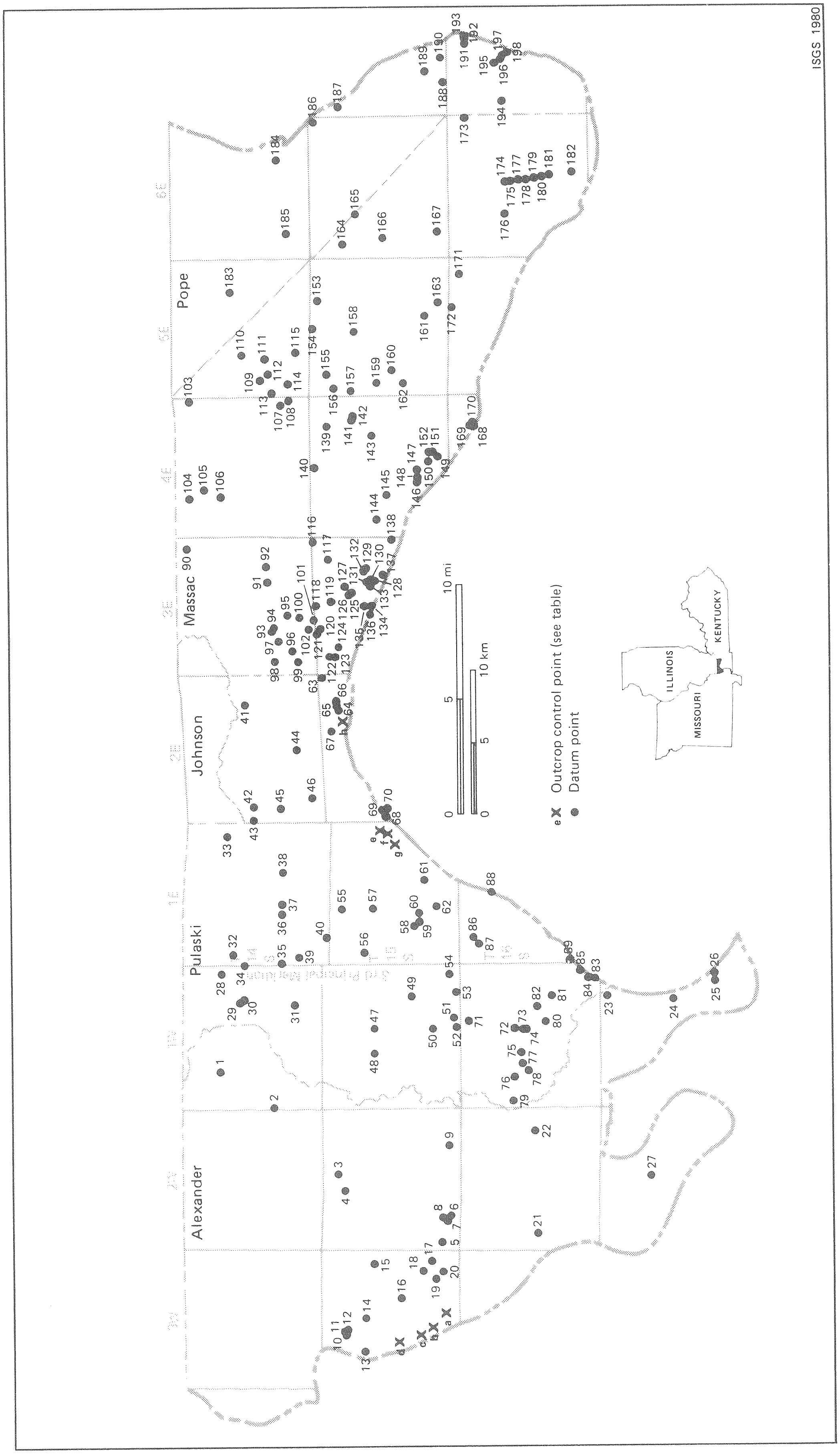

Figure 4. Location of data used in figures 5 through 8 and table 1.

limestone, interbedded with biocalcarenite. The Salem is distinguished from the Ullin by its darker color, its lack of light-colored bryozoan matrix, the presence of endothyrid foraminifera, and its more argillaceous and silty nature. Approximately 20 feet of strata judged to be at or near the Ullin-Salem contact (J. A. Lineback, personal communication, 1979) are exposed in Post Creek Cutoff near the center Sec. 2, T. 15 S., R. 2 E. The Salem is gradational with the overlying St. Louis Limestone. The St. Louis is typically a fine-grained, lithographic, cherty limestone, but it contains beds of Salem-type biocalcarenite in its lower part. Where present in the study area, the St. Louis is about 350 feet thick. Overlying the St. Louis, and gradational with it, is the Ste. Genevieve Limestone, a light-gray oolitic limestone with sandy zones. The Ste. Genevieve is 200 to 240 feet thick.

The lower part of the Chesterian Series (upper Mississippian) consists of alternating limestone, shale, and sandstone units; it occurs in the eastern portion of the study area in parts of Massac and Pope Counties.

LITTLE BEAR SOIL

The contact between the Paleozoic rocks and the overlying Mesozoic and Cenozoic sediments is marked by a prominent unconformity that cuts across rocks that range in age from Ordovician to Mississippian. In places the truncated Paleozoic rocks are overlain by a well-defined residual soil, the Little Bear Soil (Mellen, 1937), that consists of red and brown, silty clay with angular to subangular chert pebbles and lenses and nodules of brown and black limonite. The lithology varies slightly from one area to another, depending upon which Paleozoic unit the soil was developed on. The soil was formed mainly in post-Chesterian, pre-Gulfian time, but local ground-water solution of the limestone bedrock in post-Gulfian time appears to have contributed some insoluble material (clay, siliceous silt and sand, nodules and beds of chert, and silicified fossils). The soil appears to be less than 10 feet thick but is much thicker where there has been a siginificant amount of solution of the bedrock, primarily along joints and faults.

The Little Bear Soil is well exposed along the Missouri Pacific Railroad about 2 miles south of Thebes in SW Sec. 21, T. 15 S., R. 3 W., in Alexander County (Pryor and Ross, 1962, p. 21), and in the Post Creek Cutoff in Sec. 2, T. 15 S., R. 2 E., in easternmost Pulaski County (Pryor and Ross, 1962, p. 16).

▩ Mesozoic Erathem

CRETACEOUS SYSTEM

Gulfian Series

In southern Illinois the Gulfian Series (late Cretaceous) consists of up to 500 feet of mostly nonmarine clay, silt, sand, gravel, and thin beds of lignite that were deposited on a somewhat irregular Paleozoic bedrock surface. Three formations are recognized in the area including the Tuscaloosa, McNairy, and Owl Creek, in ascending order.

Tuscaloosa Formation. The Tuscaloosa Formation (Smith and Johnson, 1887) unconformably overlies the Little Bear Soil, or where the Little Bear is absent, it overlies Paleozoic bedrock. The Tuscaloosa generally consists of well-rounded, white to gray (less commonly black), poorly sorted chert gravel in a matrix of light-gray to white clay (principally kaolinite), fine-grained silica, and less than 5 percent coarse quartz sand. The pebbles and cobbles range from ¼ to 10 inches in diameter, but the dominant size is 1 to 3 inches. Outcrops of the Tuscaloosa along the Missouri Pacific Railroad about 2 miles south of Thebes, Alexander County, are atypical because they contain up to 5 feet of lithified fine-grained silica with a few scattered pebbles and abundant plant rootlet impressions. This unit overlies and is gradational with 10 to 15 feet of greenish-gray clay. The upper part of the Tuscaloosa at this locality consists of the more typical chert gravel.

The Tuscaloosa is commonly 20 to 40 feet thick in Illinois. It is absent at some localities, and it apparently has a maximum thickness of at least 168 feet in the Layne Western No. 5 Metropolis well (table 1, no. 170). Thicknesses of 65 to 75 feet have been interpreted from well cuttings at several localities (table 1). Thicknesses of 0 to 200± feet are reported by Davis, Lambert, and Hansen (1973) in the Jackson Purchase area of Kentucky. The thicker Tuscaloosa deposits appear to have filled sink holes, channels, and other topographically low areas that existed on the Paleozoic bedrock surface in early Gulfian or pre-Gulfian time.

The contact between the Tuscaloosa and overlying McNairy Formation is marked by a change from gravel and coarse sand to fine, silty, micaceous, quartz-rich sand. This is commonly a bedding plane contact, but locally it is gradational (Ross, 1964). The base of the Tuscaloosa is generally difficult to pick in well cuttings where the underlying formation is chert rubble.

Most of the Tuscaloosa Formation of southern Illinois is believed to be of nonmarine origin and was deposited on the northeast flank of the Pascola Arch (Marcher and Stearns, 1962). The gravel was probably derived locally from Devonian and Mississippian cherty limestone. On the basis of pollen studies, Tschudy (1965, p. 23) has shown that the Tuscaloosa deposits at the northern end of the Mississippi Embayment are younger than the type Tuscaloosa of Alabama; this indicates that the formation is a transgressive onlap deposit.

In addition to the outcrops noted south of Thebes, up to 10 feet of the Tuscaloosa is well exposed at the Post Creek Cutoff locality (fig. 2). The isolated gravel deposits situated near Elco in northern Alexander County (NW SW SE Sec. 7, T. 14 S., R. 1 W.) are probably Tuscaloosa gravel preserved in sink holes (Willman et al., 1975).

McNairy Formation. The McNairy Formation (Stephenson, 1914) overlies the Tuscaloosa Formation, or where the Tuscaloosa is absent it overlies the Little Bear Soil; in places the McNairy rests directly on Paleozoic bedrock. From an erosional featheredge along its northern boundary the McNairy thickens gradually southward and reaches a thickness of at least 450 feet near Olmsted, Pulaski County. Throughout much of the area the McNairy is irregularly truncated and covered by the Mounds Gravel. The exception is in southern Pulaski and Alexander Counties where the McNairy is overlain by the Gulfian Owl Creek Formation or early Tertiary sediments.

The fine sands and clays of the McNairy vary considerably both vertically and horizontally within relatively short distances. In part of the area, the McNairy may be subdivided into three lithologic units. The lower unit consists of fine, white to gray, clayey, cross-bedded, micaceous, fine-grained quartz sand that is as much as 120 feet thick in places but locally may be much thicker. The middle part, called the Levings Member of Pryor and Ross (1962, p. 19), is gray to black clay with silt and locally thin beds of lignite; locally marcasite nodules, carbonized plant impressions, and petrified wood are present. This unit is generally 20 to 60 feet thick but in U.S. Army Corps of Engineers boring D-22 near Lock and Dam 53 (NE SE Sec. 13, T. 15 S., R. 1 E.) in Pulaski County, it is approximately 120 feet thick. The Levings appears to thicken at the expense of the lower sandy unit of the McNairy Formation. A similar dark clay unit has been described in the middle of the McNairy Formation in Kentucky (Davis, Lambert, and Hansen, 1973) and in Missouri ("Zadoc Member" of McQueen, 1939). The upper part of the McNairy is similar in lithology to the lower. It is generally less than 60 feet thick throughout the area. Where the formation is overlain by the Mounds Gravel, a 5- to 10-foot orange to brownish-red weathered zone usually occurs at the top of the McNairy. Where the Levings Member is absent, subdivisions are not differentiated in the McNairy Formation.

The McNairy contains a suite of heavy minerals (minerals of high specific gravity) including ilmenite, leucoxene, zircon, kyanite, staurolite, rutile, tourmaline, sillimanite, monazite, and xenotime in general order of abundance (Hunter, 1968). The heavy-mineral suite suggests an origin of the McNairy sediments in the Blue Ridge Mountains and Piedmont Plateau of the southern Appalachians (Potter and Pryor, 1961). According to Pryor (1960, p. 1497), the McNairy was deposited in a "fluvial-upper delta" environment.

The McNairy is exposed at many locations in southern Illinois. The contact with the underlying Tuscaloosa Formation is well exposed in outcrops along the Missouri Pacific Railroad about 2 miles south of Thebes, Alexander County, and in the Post Creek Cutoff in easternmost Pulaski County. The McNairy-Owl Creek contact is exposed in several ravines along the Ohio River northeast of Olmsted (Sec. 13, T. 15 S., R. 1 E.; see Pryor and Ross, 1962, p. 24).

Owl Creek Formation. The Owl Creek Formation (Hilgard, 1869) conformably overlies the McNairy Formation and is confined to southern Pulaski and Alexander Counties. Probably the Owl Creek overlapped the McNairy throughout the area before being largely removed by pre-Tertiary erosion. The Owl Creek consists of up to 10 feet of glauconitic, micaceous, silty, light greenish-gray to brown clay with fine- to coarse-grained sand. Vertical U-shaped burrows are locally abundant in the upper 6 to 12 inches. The contact with the overlying Clayton Formation is marked by a weathered zone that contains oxidized clay and hematitic nodules. Using the potassium-argon method, Reed et al. (1977) dated pelletal glauconite of this unit from 64.4 to 67.2 million years old.

The Owl Creek is well exposed in several ravines northeast of Olmsted (table 2, e-g) and along a creek near the Cache River bluffs east of Unity (NE Sec. 7 and S½ Sec. 6, T. 16 S., R. 1 W.), all in Pulaski County (described sections in tables 9 and 10 of Pryor and Ross, 1962).

▩ Cenozoic Erathem

TERTIARY SYSTEM

Paleocene Series

The Paleocene Series of southern Illinois, represented by the Clayton and Porters Creek Formations, is confined to the southern parts of Pulaski and Alexander Counties (fig. 8). The northern limit of these units is 1 or 2 miles south of the limit of Cretaceous sediments. The Paleocene consists of up to 170 feet of marine clay and small amounts of silt, sand, and gravel. Described sections of the Paleocene Series are given in Pryor and Ross (1962, tables 9-12).

Clayton Formation. The Clayton Formation (Landon, 1891, p. 594) unconformably overlies the Gulfian Owl Creek Formation. It consists of up to 20 feet of very glauconitic, micaceous, mottled, bioturbated, greenish-gray to orange-brown, silty, sandy clay, and clayey sand. Discontinuous partially limonite-cemented lenses of sand are present locally; some lenses contain molds and casts of the bivalve *Venericardia mediaplata* (Reed et al., 1977). Foraminifera and other microfossils have been reported in some well cuttings in the area (Pryor and Ross, 1962). Using the potassium-argon method of dating, Reed et al. (1977) found the pelletal glauconite from the lower part of the Clayton to be 59.4 to 62.0 million years old. The Clayton grades upward into the massive dark clay of the overlying Porters Creek Formation. It is well exposed at the same localities as the Owl Creek Formation described above.

Porters Creek Formation. The Porters Creek Formation (Safford, 1864, p. 361, 368) conformably overlies the Clayton Formation and unconformably underlies the Eocene

Wilcox Formation. The Porters Creek consists of up to 150 feet of ½- to 2-foot beds of massive, blocky, compact, micaceous, at least partly bioturbated, buff to brown and dark-gray to black clay (predominantly montmorillonite). Toward the base it contains more silt or very fine sand and locally contains fish scales, small sharks' teeth, microfossils, and glauconite. The upper part of the Porters Creek is well exposed in clay pits south of Olmsted, in the Ohio River bluffs near Lock and Dam 53, and on the east side of the Cache River near Unity, all in Pulaski County. Because of its absorptive and filtering properties, the Porters Creek is mined commercially at Olmsted.

Eocene Series

Wilcox Formation. The Eocene Series in Illinois is represented by the Wilcox Formation (Claiborne Group, Stearns, 1957). The Wilcox Formation (Crider and Johnson, 1906, p. 5, 9) overlies the Paleocene Porters Creek Formation and is overlain by the Pliocene-Pleistocene Mounds Gravel; it is separated from both units by pronounced unconformities. The Wilcox consists of up to 250 feet of white, fine to coarse, slightly micaceous sand that contains thin lenses of fine gravel of varicolored quartz and chert and beds of light-gray to pinkish-gray clay that are up to 6 feet thick. The northern limit of the Wilcox is 6 or 7 miles south of the limit of Paleocene sediments. The Wilcox crops out in the bluffs between Mounds and the Cache River. One of the better exposures is in a gravel pit on the east side of the Cache River south of Unity (SW SW SW Sec. 7, T. 16 S., R. 1 W.). Here 20 feet of the Wilcox overlies the Porters Creek Formation and underlies the Mounds Gravel.

Pliocene-Pleistocene Series

The Pliocene-Pleistocene Series in Illinois is represented by the Mounds Gravel. It is suspected that the Mounds contains sediments that were reworked early in Pleistocene time, but these reworked sediments are not readily differentiated from those deposited in the late Tertiary. For this reason Willman and Frye (1970) assigned a Pliocene-Pleistocene age to the Mounds Gravel. We follow the same assignment here. Fisk (1944) interpreted these sediments to be entirely of Pleistocene age.

Mounds Gravel. The Mounds Gravel (Willman and Frye, 1970, p. 20) rests unconformably on strata ranging in age from Ordovician to Eocene. It was weathered and deeply eroded before being covered by Pleistocene loess. The Mounds consists of up to 50 feet of medium to dark olive-brown, mostly subangular, cross-bedded chert gravel in a matrix of brown to brick-red clayey quartz sand. The surface of the chert has a glossy patina. When broken open, the chert may be of various colors and textures. The chert pebbles are commonly 2 or 3 inches in their longest dimension, but blocks 2 or 3 feet long of sandstone and reworked cemented gravel have been observed locally. The gravel is cemented in places by hematite and limonite. Detailed descriptions of lithology are given in Lamar and Reynolds (1951) and Potter (1955). The Mounds is well exposed at numerous localities south of the Cache Valley and in the southern Santa Fe Hills between the Cache and Mississippi Rivers.

The source of most of the Mounds Gravel is in the southern Appalachians (Potter, 1955), from which it was carried down the general course of the Tennessee River Valley into the embayment. Willman and Frye (1970, p. 48) noted that the gravel near the Mississippi Valley west of the Cache Valley and south of Thebes contains purple quartzite, jasper, and agate pebbles. These rocks are characteristic of the Lake Superior region and thus indicate a northerly source for some of the Mounds Gravel in that part of southern Illinois.

Three erosional levels upon which the Mounds Gravel rests have been recognized in the southern Illinois area (Fisk, 1944; Leighton and Willman, 1949; Willman and Frye, 1970; Willman et al., 1975). There is some question, however, whether these surfaces represent erosional levels or are due to post-Mounds warping and faulting (Ross, 1963, 1964). As shown later in the report, solution collapse is the cause of some anomalous elevations of the gravel.

QUATERNARY SYSTEM

Pleistocene Series

The Pleistocene Series of southernmost Illinois consists of loess, colluvium, river and stream alluvium, and lake and swamp deposits. Three loesses are differentiated in the area including the Loveland Silt (Illinoian Stage), Roxana Silt (Altonian Substage), and Peoria Loess (Woodfordian Substage and younger). These loesses have a combined maximum thickness of about 50 feet in the bluffs near the Mississippi River and gradually thin eastward to about 15 or 20 feet in Massac and Pope Counties. The loess mantles the uplands and terraces, covering Cretaceous and Tertiary strata throughout a large part of the area. Locally the loess overlies Paleozoic bedrock. More detailed descriptions of the loesses are given by others (Leighton and Willman, 1950; Pryor and Ross, 1962; Willman and Frye, 1970). Water-deposited silt, sand, and pebbly sand form terraces that extend up the tributary valleys and are 20 to 30 feet higher than the floodplains of the Ohio and Mississippi Rivers. The floodplains of the major streams and rivers are underlain mainly by silt, sand, and gravel, which overlie glacial valley-fill sediments of similar composition. Locally, the total valley fill is as much as 150 feet thick (Fisk, 1944).

▩ SUB-CRETACEOUS GEOLOGY

Knowledge of the sub-Cretaceous geology in southern Illinois is important in determining the existence of Cretaceous or later faulting. The amount and quality of outcrop and subsurface data, however, is quite limited. The few bedrock outcrops that are exposed in the area are situated in the uplands adjacent to the Cache Valley and Ohio River bluffs in Pope and Massac Counties, in the Post Creek Cutoff in southeastern Pulaski County, and in the bluffs of the Mississippi River Valley south of Thebes, Alexander County. The relatively few drill holes that penetrate the Paleozoic bedrock commonly are not drilled deep enough to confidently identify the Paleozoic stratigraphic unit. Because of the cyclic nature of some parts of the stratigraphic succession and the lateral facies changes, especially in the Mississippian units, a thick section of rock must be studied to make a positive identification. Some formations are relatively thick and uniform in lithology, and it is very difficult to locate faults in them even where the well control is closely spaced. Many drill holes in the area have been completed in a cherty unit that may be cherty bedrock, residual chert lying over the bedrock, the Tuscaloosa Formation, or a chert gravel bed in the McNairy Formation. Because of these uncertainties, we suspect that the bedrock contact has not always been identified consistently by drillers and by those who have studied samples.

An interpretation of the distribution of Paleozoic strata is shown on the sub-Cretaceous geologic map (fig. 5). The contacts between stratigraphic units on this map are based on subsurface control and the southward projection of outcrop data. Because the bedrock dips northeastward away from the Ozark Dome and Pascola Arch toward the Illinois Basin, successively younger Paleozoic strata occur at the bedrock surface from west to east: Champlainian (middle Ordovician) in western Alexander County, to Chesterian (upper Mississippian) in northern Massac and southern Pope Counties.

The faults that are shown in figure 5 are based on apparent stratigraphic anomalies at the bedrock surface. Trends of the faults are based on a few control points and are inferred from the regional trend of faulting, which is northeastward. Most of the faults that are shown in eastern Massac and southern Pulaski Counties cannot be connected confidently to the faults that project into the area from the Illinois-Kentucky Fluorspar District. We suspect that the fluorspar district faulting extends into the area, but the density, extent, and magnitude of faulting cannot be substantiated with the available subsurface data.

Our sub-Cretaceous geologic map (fig. 5) differs from that published by Ross (1963, fig. 6, p. 15) in that the latter shows a mosaic of bedrock faults much more numerous and extensive than can be substantiated with the available information. There are several reasons for this difference. (1) A check of the landowners or contractors listed in the well records against the county plat books showed that several critical datum points on Ross' map were mislocated, probably because of geographic errors in the records used in his study. (2) A restudy of all drilling samples in the area indicates that some stratigraphic units at the bedrock surface were misidentified. Some of the stratigraphic information used by Ross was obtained from sample studies made by various people over a long period of time and lacked consistency. (3) New subsurface information has become available since Ross' work that does not fit his conclusions.

Ross (1963) described four major northeast-trending graben belts in the embayment of southern Illinois including the America, Dixon Springs, Rock Creek, and Paducah Grabens. According to Ross, the America Graben lies parallel to the Ohio River and extends from near Mound City (T. 16 S., R. 1 E.) to near Olmsted (T. 15 S., R. 1 E.) in southern Pulaski County, about 10 miles. Although we interpret the sub-Cretaceous geology in this area to be somewhat different from that of Ross (1963, fig. 6), we do interpret several northeast-trending faults in the general area including a rather wide graben situated to the west of his America Graben in T. 15 S., R. 1 E. and R. 1 W., and T. 16 S., R. 1 E. and R. 1 W. (fig. 5). Subsurface control in this area is provided by several wells including the Case Engineering Co. No. 1 Olmsted city well (table 1, no. 61), which encountered the Mississippian Fort Payne Formation in the bedrock at 161 feet below sea level. Two miles farther west, the White No. 1 John Goza well (table 1, no. 59) encountered the Devonian New Albany Shale Group at 54 feet below sea level. Three miles southwest of the Olmsted city well, the Vick Oil Co. No. 1 Boyd (table 1, no. 86) and the Vick Oil Co. No. 1 Roberts (table 1, no. 87) tests both encountered Lower Devonian bedrock at sea level elevations of -2 and +13 feet respectively. The stratigraphic relations shown by these wells and several others in the area suggest that at least three parallel faults displace the Paleozoic bedrock. A thrust fault described by Schwalb (1969, p. 16) in the Indian Camp Oil & Development Co. No. 1 T. J. Wilson test in Carlisle County, Kentucky, (20-E-5, 900 ft FSL x 2425 ft FEL of Sec.), may be the southward extension of this structure.

The Dixon Springs Graben is well documented in the outcrop area north of the Cache Valley. It extends from the northeast corner of Pope County southwestward to northwestern Massac County and passes beneath the embayment sediments (figs. 2, 5). Displacement of the faults that bound the graben is nearly 1,000 feet in places (J. M. Weller, 1939, p. 11). On the basis of subsurface data, Ross (1963) extended the graben beneath the embayment sediments through the area just west of Joppa and across the Ohio River into Kentucky. We agree that a graben, probably a segment of the Dixon Springs Graben, underlies the area, but we interpret the bedrock within the graben to be Ste. Genevieve Limestone rather than Chesterian rocks as shown by Ross (1963, fig. 6). The key datum to the new inter-

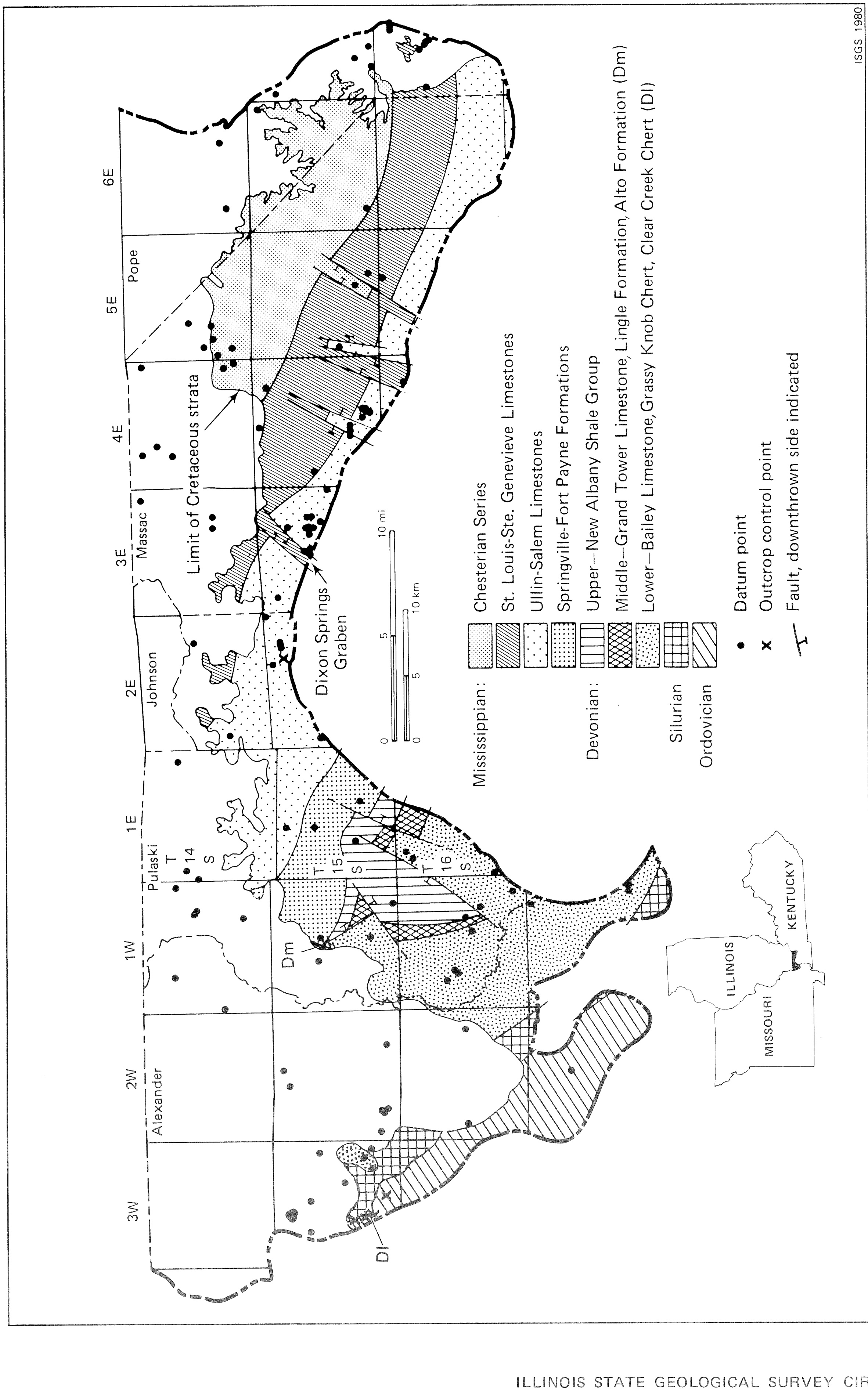

Figure 5. Geologic map showing the sub-Cretaceous strata.

pretation is the Layne Western No. 1 Missouri Portland Cement Co. boring (table 1, no. 135), which encountered Ste. Genevieve Limestone at the bedrock surface. Data on this well apparently were not available to Ross (1963). The nearest subsurface control to the east and west of this boring shows Ullin Limestone at the bedrock surface at a slightly higher elevation. The boring is also significant because the St. Louis and Salem Limestones appear to be faulted out with the Ste. Genevieve resting directly on top of the Ullin Limestone.

The Rock Creek Graben (fig. 2) extends from the northeast corner of Hardin County southwestward through western Livingston County, Kentucky, and back into Illinois west of Bay City in Pope County. In Hardin County the bounding faults have as much as 2,000 feet of displacement, but displacement diminishes considerably to the southwest (J. M. Weller, Grogan, and Tippie, 1952, p. 79). A graben has been interpreted beneath the embayment sediments between Metropolis and Brookport (T. 15 S. and T. 16 S., R. 5 E.)(see fig. 5) on the basis of apparent offsets in the Paleozoic bedrock as observed in closely spaced wells. This graben may be a southern extension of the Rock Creek Graben.

The Paducah Graben, described by Ross (1963) as "a narrow complex fault zone in its Illinois length," could not be substantiated with the available subsurface control and is not shown on our maps.

CONFIGURATION OF THE SUB-CRETACEOUS SURFACE

Configuration of the Paleozoic bedrock surface beneath the Cretaceous sediments is shown in figure 6. The most reliable data used in constructing this map are concentrated in the densely drilled area near Joppa and 4 or 5 miles west of there near the Pulaski-Massac County line, where the bedrock can be seen in outcrop. The data provided by the Paducah Dam site borings (table 1, nos. 174, 175, 177-182) in southeastern Massac County also provide relatively good subsurface control. The area of least information is in southern Pulaski and Alexander Counties, where the bedrock is most deeply buried. Throughout the study area the bedrock is generally covered by either the Little Bear Soil, the Tuscaloosa Formation, or the McNairy Formation.

Generally, a gently undulating surface is shown that dips southward into the embayment trough (fig. 6). The most unusual feature is the northeast-oriented elliptical depression in southeastern Pulaski County that generally coincides with the America Graben of Ross (1963). The depression is about 6 miles wide and nearly 350 feet lower at its center than the elevation of the Paleozoic bedrock in the surrounding area. The northern limit of the feature appears to be in the area of Grand Chain (fig. 2). The southern limit, however, is not clear. It may continue southward through Ballard and Carlisle Counties, Kentucky, in the manner shown by Schwalb (1969, fig. 4, p. 10). Available subsurface data are too sparse in the area to establish the presence or absence of faulting in the Cretaceous sediments. Therefore we show no faulting on the maps of the configuration of the base (fig. 6) or the distribution and thickness (fig. 7) of the Cretaceous.

In Massac and Pope Counties the faults and grabens that project into the study area from the fluorspar district have little or no expression on the configuration of the base of the Cretaceous. This indicates that all or most of the movement on these structures and truncation of the Paleozoic bedrock by erosion occurred before the overlap of the Cretaceous sediments.

Several drill holes in the study area show the bedrock surface to be at anomalously low elevations. These anomalies are considered to be localized because of their proximity to drill holes that encountered bedrock at consistently higher elevations. Because ground water commonly follows joints and faults, we suspect that where limestone occurs at the bedrock surface preferential solution has followed many of these linear features and has formed a karstic surface that reflects the structural fabric of the area. The trend of these joints and faults is predominantly northeast. For example, evidence obtained from closely spaced exploratory borings and outcrops near the Post Creek Cutoff in eastern Pulaski County (discussed later in this paper) indicates that solution has lowered the bedrock surface by as much as 90 feet within a horizontal distance of less than 50 feet. In Post Creek Cutoff (table 2, h), where the bedrock surface is exposed, the predominantly northeast-trending joints are the sites of channel-like sinkholes and cavities (Ekblaw, 1936). A similar karstic topography was encountered during excavation and exploratory drilling at the Smithland Locks and Dam site on the Ohio River in Pope County ("Bedrock Surface Map," by F. W. Swartz, made available by the U.S. Army Corps of Engineers, Louisville District, Geologic Branch).

The effects of solution can present problems in determining the age of faults. For example, solution along quiescent pre-Gulfian faults could result in collapse of the overlying embayment or younger sediments and give the erroneous impression that the faults have been active in relatively recent times. Locally, the geologic relations can be so complicated that the date of latest tectonic faulting may be impossible to determine.

Ross (1963) believed that the present relief on the sub-Cretaceous surface in southernmost Illinois is due primarily to post-Tuscaloosa faulting and warping. He reasoned that if the relief on the sub-Cretaceous surface was as great when the Cretaceous sediments were deposited as it is now, that the Tuscaloosa should be locally much thicker and its distribution more irregular. Furthermore, the close parallel between the major structural feature of his sub-Cretaceous geologic map, his structure contours on the base of the Cretaceous sediments, and his projected trends of structures exposed to the northeast of the embayment

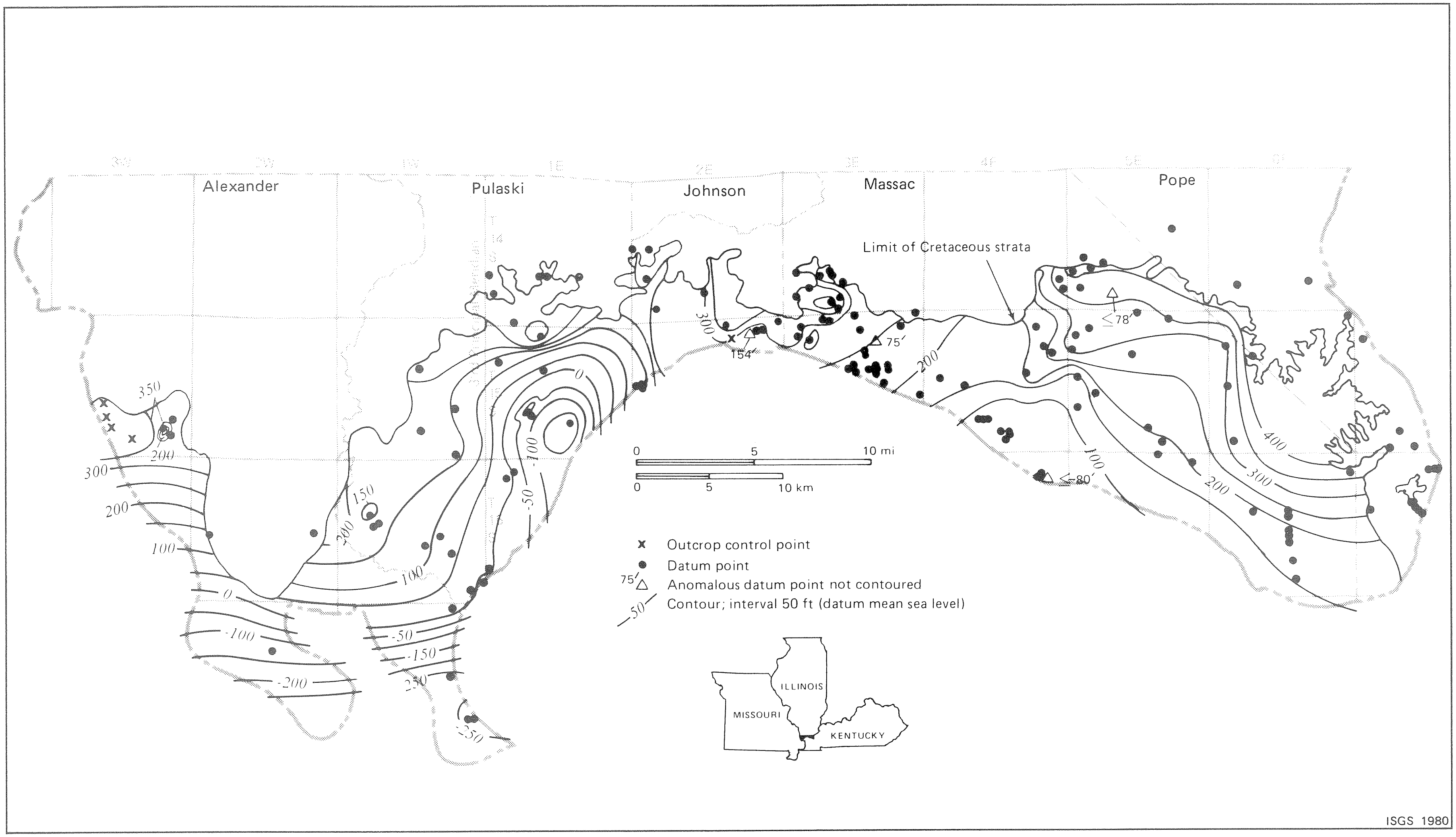

Figure 6. Configuration of the base of the Cretaceous System.

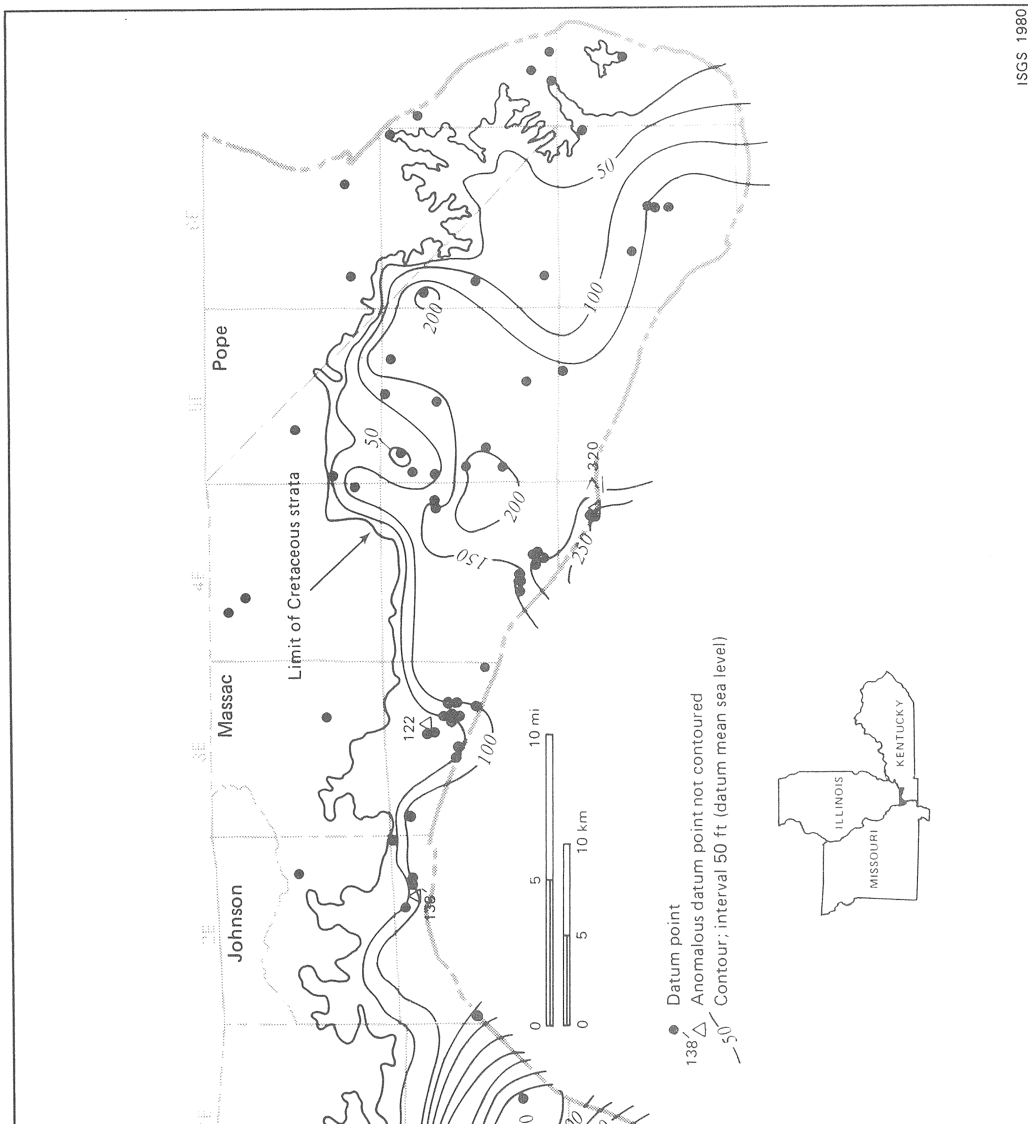

Figure 7. Distribution and thickness of Cretaceous strata.

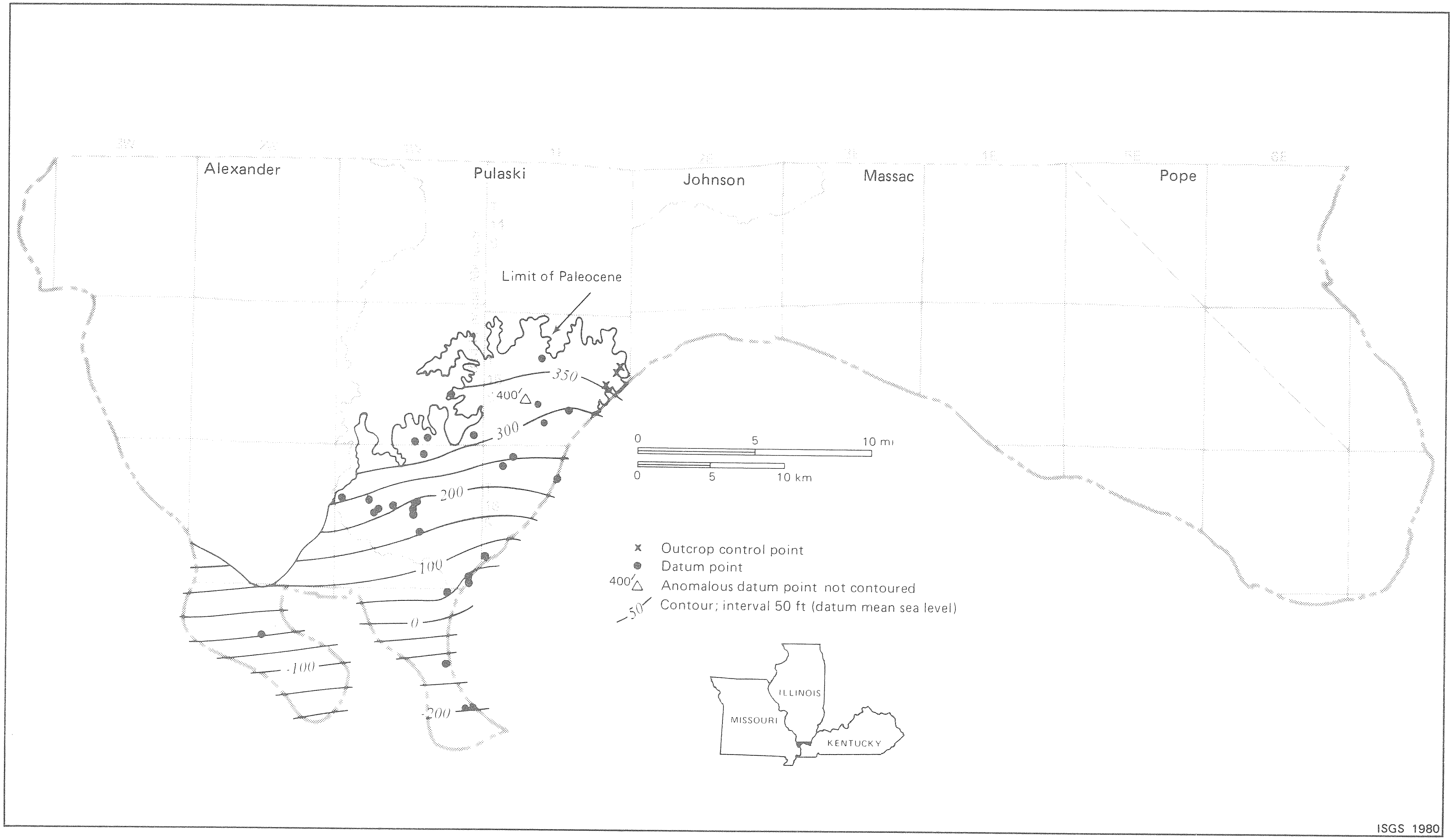

Figure 8. Structure of the base of the Paleocene Clayton Formation.

suggested to him that the faults bounding the grabens of Paleozoic strata were sites of renewed movement after the deposition of Cretaceous sediments.

Primarily this hypothesis assumes that the Tuscaloosa Formation is widespread and uniform in thickness and, therefore, was deposited on a relatively flat surface, which Ross considered a structural datum for post-Gulfian deformation. The available data, however, do not convincingly support this assumption. In well cuttings, which are the main source of subsurface control, the Tuscaloosa commonly is not lithologically distinct from cherty bedrock, residual chert lying over the bedrock, or chert gravel within the lower part of the McNairy Formation. The chert gravel that occurs between the micaceous sand of the McNairy Formation and the bedrock is actually variable in thickness and distribution. This chert gravel is absent in many drill holes throughout the area, and in the Layne Western No. 5 Metropolis well (table 1, no. 170) it apparently is more than 168 feet thick.

In the closely spaced Paducah Dam Site borings (table 1, nos. 174, 175, 177-182) in southeastern Massac County, the chert gravel ranges from 0 to 50 feet thick. The thicker sections of gravel occur where the bedrock surface is at a low elevation, and the gravel is absent in those borings where the bedrock is high. Distribution of the chert gravel appears to be controlled by pre-Gulfian topography.

Available evidence indicates that the present relief on the sub-Cretaceous surface throughout the Mississippi Embayment of southern Illinois is due to the combined effects of pre-Gulfian erosion, post-Gulfian solution, and possibly only minor deformation during and after Gulfian time.

DISTRIBUTION AND THICKNESS OF CRETACEOUS AND TERTIARY SEDIMENTS

The distribution and thickness of Cretaceous sediments, including the Little Bear Soil and the Tuscaloosa, McNairy, and Owl Creek Formations, are shown in figure 7. The Cretaceous sediments undoubtedly covered a much greater area in southern Illinois, but they have been eroded back to an area that is confined primarily to the south side of the Cache Valley. In general the Cretaceous sediments thicken from north to south.

The thickest Cretaceous deposits in Illinois are situated in southeastern Pulaski County in an area that generally corresponds to the America Graben of Ross (1963). The Cretaceous sediments here are about 300 feet thicker than in the surrounding area. It is not entirely clear whether these sediments filled a graben, a series of grabens, or a downwarped basin, all of which would have subsided during Gulfian time, or whether they filled a depression that existed on the sub-Cretaceous surface before the overlap of Cretaceous sediments. A combination of these factors may have influenced the thickness of the Cretaceous sediments. The structure contour map (fig. 8) of the base of the Paleocene Clayton Formation (top of Cretaceous) indicates that the area underwent broad regional sinking in conjunction with the whole Mississippi Embayment area, but there is little or no evidence of localized post-Gulfian subsidence in southeastern Pulaski County.

In Massac and Pope Counties where the prominent grabens in the Paleozoic bedrock project into the embayment area from the northeast, the thickness of the Cretaceous does not appear to change abruptly. This again suggests that the movement on those structures took place before the Cretaceous sediments overlapped the area.

The Paleocene Porters Creek and Clayton Formations are confined to southern Pulaski and Alexander Counties (fig. 8) and dip to the south at about 50 feet per mile. These formations thicken southward in the embayment trough.

AREAS OF DISTURBED CRETACEOUS AND POST-CRETACEOUS SEDIMENTS

All reported sites of suspected faulting (tectonic and gravity) in Cretaceous and post-Cretaceous sediments in the area were field checked, and a reconnaissance was made of areas where geologic mapping suggested possible faulting. The study was hindered by several problems. (1) Because of the unconsolidated nature of the sediments, surface expression of disturbances such as faulting would not be expected to last long after the initial movement. The effects of weathering and erosion would have masked most such features more than a few hundred years old. (2) Subsurface data are sparse and, even where available, not detailed enough to detect small offsets. (3) In some areas gravity-induced disturbances, such as landslides and and solution collapse structures, are not easily distinguished from tectonic faults. Solution collapse is probably common along bedrock faults (tectonic in origin) and joint systems that involve carbonate rocks. The sequence and time of events then becomes even more difficult to interpret.

Sites near Mounds, Round Knob, Post Creek Cutoff, Metropolis, and Thebes Gap (fig. 2) were selected for detailed study. Field studies, exploratory drilling, earth resistivity, and refraction seismography were conducted at these sites.

Mounds

The Mounds site (fig. 9) is located in Moses' and Fulcher's gravel pits, S½ NW SW Sec. 15 and SE NE SE Sec. 16, T. 16 S., R. 1 W., about one-half mile west of Mounds, Pulaski County. The gravel pits are situated on the south side of a prominent bluff that faces the Ohio River Valley. The point of interest is a number of offsets that range from a few inches to about 40 feet and displace strata of the

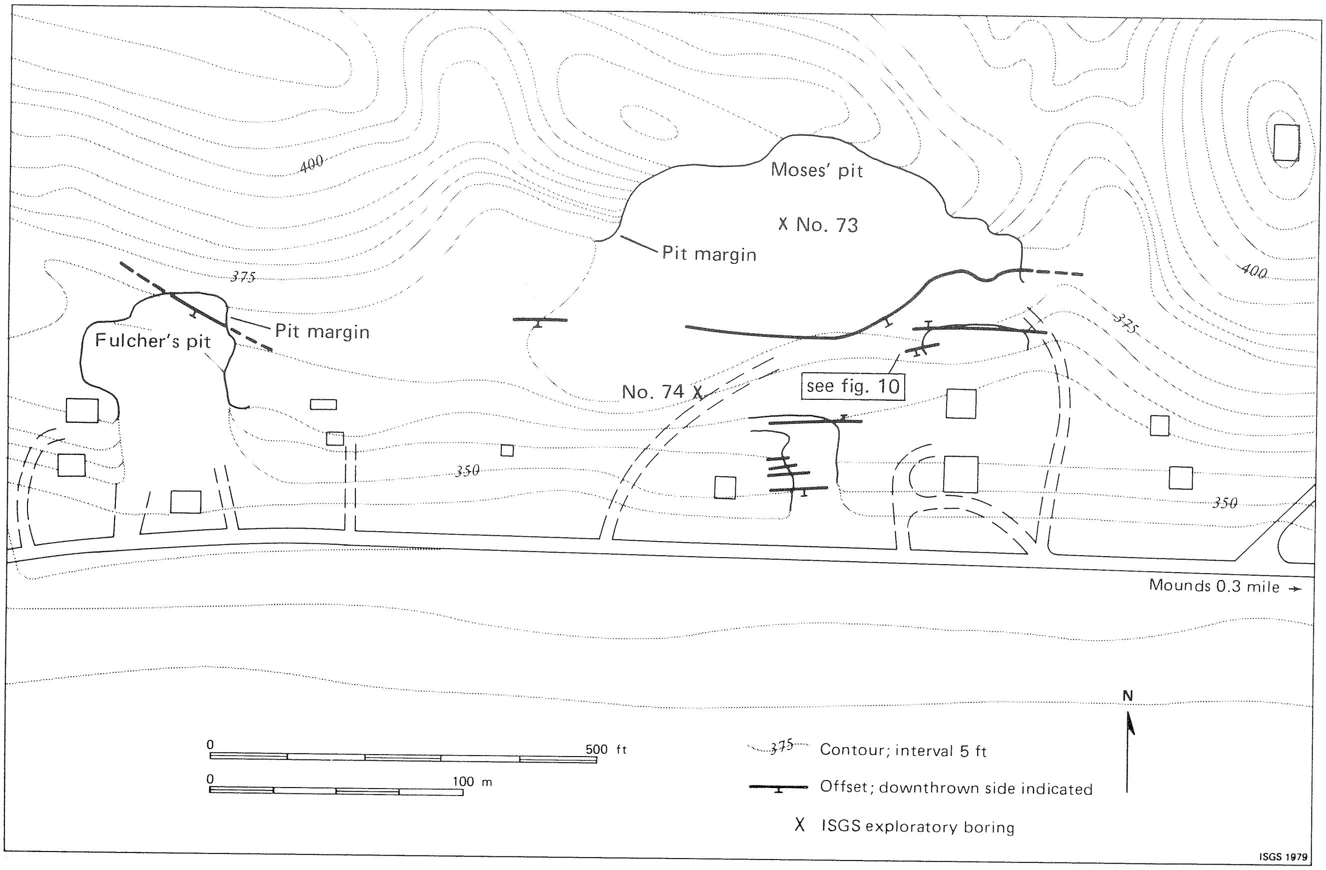

Figure 9. Topographic map of the Mounds site showing location of several offsets.

Eocene Wilcox Formation, Pliocene-Pleistocene Mounds Gravel, and Pleistocene Loveland Silt, Roxana Silt, and Peoria Loess (table 3). All of the observed offsets are generally aligned in an east-west direction parallel to the bluff. The offsets are largest near the bluff and become smaller and more numerous toward the Ohio River Valley. Cumulative displacement is down toward the valley.

The largest observable offset is located 250 to 400 feet north of the main road and extends east-west through Moses' pit, a distance of about 700 feet (fig. 9). The offset is probably continuous with another offset of the same magnitude and relative displacement in Fulcher's pit located about 400 feet west of Moses' pit. The offset is downthrown on the south, and throughout much of the extent it brings the Peoria Loess into juxtaposition with the Wilcox Formation; a displacement of about 40 feet is indicated (fig. 10). In Fulcher's pit the downthrown block has rotated and dips about 10 degrees back toward the bluff.

To determine the nature of this series of offsets, two exploratory holes were drilled through the base of the Paleocene Clayton Formation, one on the upthrown (table 1, no. 73) and one on the downthrown side (table 1, no. 74) of the largest offset (displacement approximately 40 feet) in Moses' pit. Split spoon samples were collected in 10-foot intervals and a gamma ray log was obtained from each hole.

The gamma ray logs show distinct geophysical markers at the base of the Wilcox Formation, at a slightly silty zone characterized by a sharp drop in natural radiation about 40 feet below the top of the Porters Creek, and at a sandy zone characterized by low natural radiation at the top of the Cretaceous Owl Creek Formation. Comparison of gamma ray logs clearly shows that there is no displacement of beds below the middle part of the Wilcox Formation, which indicates that the offsets were caused entirely by landsliding. This is supported by the fact that the offsets generally parallel the bluff and have a cumulative displacement that is down toward the Ohio River Valley. The glide plane was probably in water-saturated sand above one of the prominent clay beds in the Wilcox Formation. The landslide occurred within the last 10,000 years, as evidenced by the fact that the youngest strata present, the Peoria Loess of Woodfordian age, is offset. On the basis of a series of exploratory trenches, McKeown and Russ (1976) also interpreted the offsets at this site to be the result of landsliding.

The exact cause of the landslide is unknown, but the evidence suggests that the Ohio River in the adjacent valley undercut the bluff. Less severe disturbances such as caving of stream banks and local fissuring were evident in this part of southern Illinois following the 1811-1812 New Madrid earthquake (Fuller, 1912). Because the landslide at the Mounds site has no surface expression today the event probably predates the 1811-1812 events.

Round Knob

The Round Knob site (fig. 2), which was first described by Ross (1964, p. 17), is situated on the bank of a tributary of Massac Creek about 3 miles northeast of Round Knob, Massac County (NE SE SE SE Sec. 28, T. 14 S., R. 5 E.). About 6 feet of the Gulfian McNairy Formation and 2 feet of the overlying Pliocene-Pleistocene Mounds Gravel dip about 20 degrees to the northwest and strike northeast. The elevation of the McNairy-Mounds contact is about 435 feet, which is about 65 feet lower than the elevation of this contact in the surrounding hills. This site lies on a linear topographic low, expressed by the tributary valley of Massac Creek and a similarly trending ravine to the northeast. The ravine extends from the valley of Massac Creek northeastward through sections 33, 28, 21, and 22 to the Massac-Pope County line, parallel to the main trend of faulting in the Fluorspar District.

Further evidence of an anomaly in this area is suggested by the O. Richey No. 1 J. Weaver well (table 1, no. 115), which was drilled on this lineament about one-quarter mile southwest of the McNairy-Mounds outcrop. The well was drilled to 78 feet above sea level but bedrock was not encountered; this is unusual because in the surrounding wells the bedrock occurs at between 300 and 400 feet above sea level.

Seismic refraction and earth resistivity surveys were employed to better define the Round Knob structure, but these techniques were not completely successful. Velocities and resistivities of earth materials are slightly different on either side of the structure, but the depth to bedrock and configuration of the bedrock surface were not ascertained. More definitive information on the structure could probably be gained through additional geophysical work, especially reflection seismography, and closely spaced drilling to bedrock. The available data do not indicate whether this structure was caused by tectonic faulting, landsliding, solution collapse, or a combination of these processes.

Post Creek Cutoff

This site (fig. 2) is along the Post Creek Cutoff and a deeply cut ravine that drains into the cutoff from the east approximately 0.3 miles north of the Ohio River (fig. 11) in eastern Pulaski County (NW SE Sec. 2, T. 15 S., R. 2 E.). Immediately north of the mouth of the ravine, about 40

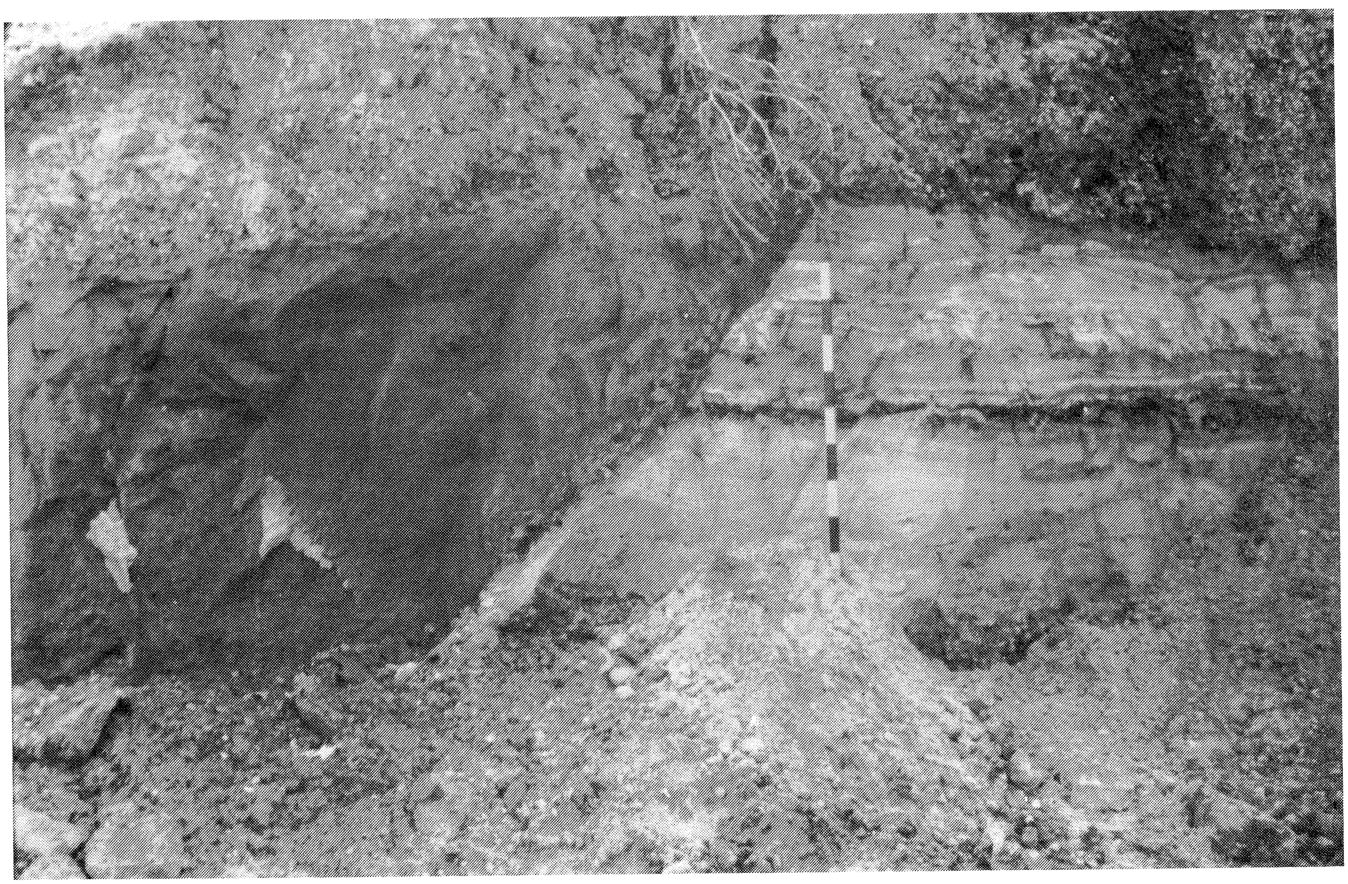

Figure 10. West view of offset between the Pleistocene Peoria Loess on the south (left) and the Eocene Wilcox Formation on the north (right) in Moses' pit near Mounds (see fig. 9). Upper surface of the units has been bladed off and backfilled. Scale is l m.

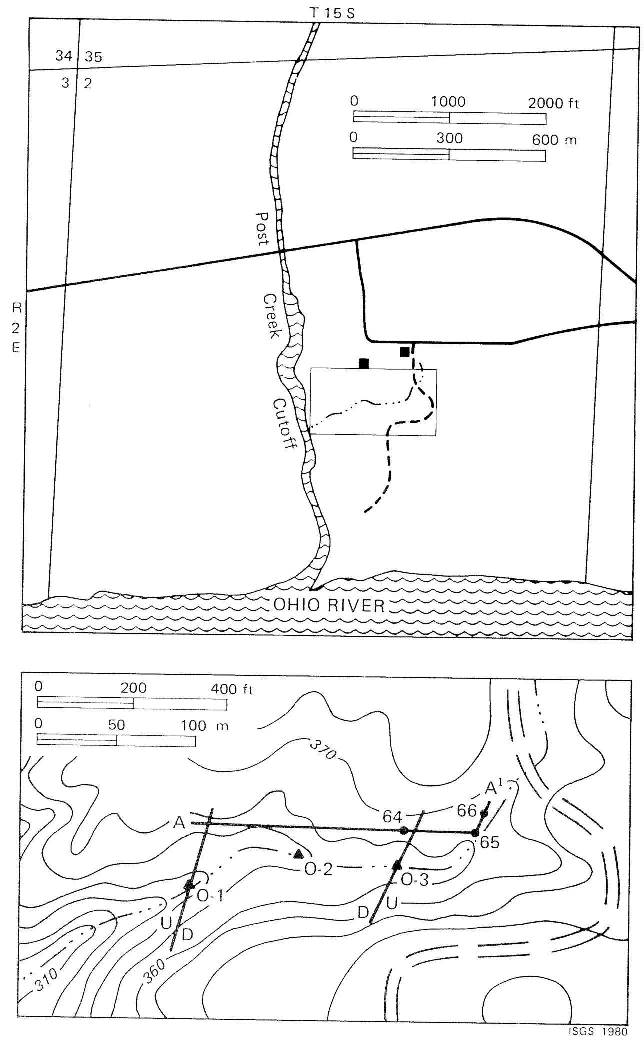

Figure 11. Location of the Post Creek Cutoff site. Inset map shows topography, location of exploratory borings, and position of cross section A-A' (see figure 13).

feet of the McNairy and Tuscaloosa Formations and Little Bear Soil overlie Mississippian limestone that is determined to be near the Ullin-Salem contact (J. A. Lineback, personal communication, 1979). The Mississippian rocks were formerly identified as St. Louis Limestone (Willman and others, 1967). The McNairy is overlain by about 10 feet of Pleistocene gravel and loess. Approximately 500 feet to the east a northeast-trending offset, inferred from stratigraphic relations in the ravine, brings the Mounds Gravel down into juxtaposition with the McNairy. The Mounds is well exposed in the high walls of the ravine eastward to a point that is about 900 feet from the cutoff. Here, strata of the Mounds Gravel and McNairy Formation are tilted 45 degrees west-northwest (fig. 12). It is difficult to determine whether the contact between the two formations is a fault plane or a depositional surface. It may be the result of displacement along the depositional contact. The McNairy strata are essentially flat lying within the ravine east of this contact. The Mounds Gravel is clearly dropped down relative to the McNairy in a block that strikes northeast and is about 400 feet wide.

Three exploratory holes (table 1, nos. 64-66) were drilled at this site to determine the nature of the offsets. Ground elevations of all three holes differed by no more than 2 feet. One hole, no. 64, drilled in the down-dropped block of Mounds Gravel (fig. 13), encountered 70 feet of Mounds Gravel, about 130 feet of the McNairy Formation, and several feet of gravel lying over the bedrock. The latter gravel probably is the Tuscaloosa Formation and Little Bear Soil. Forty feet of bedrock (Ullin Limestone) was cored bringing the total depth of this hole to 250 feet. Two holes, nos. 65 and 66, were drilled to the east of no. 64 at a distance of 150 and 160 feet respectively. The deeper of the two holes, no. 66, was also drilled to a total depth of 250 feet. It encountered 110 feet of the McNairy and Tuscaloosa Formations and Little Bear Soil and about 135 feet of Ullin Limestone. The difference in elevation of the bedrock surface between no. 64 and no. 66 is 90 feet. On the basis of a detailed examination of the rock core in both holes, no. 64 and no. 66, the strata are judged to be at or very close to the same stratigraphic position within the Ullin Limestone. The contact between the Harrodsburg and


Figure 12. South view of steeply dipping contact between McNairy Formation on east (left) and Mounds Gravel on west (right) in ravine near Post Creek Cutoff (see fig. 13). The McNairy and Mounds are truncated and covered by colluvial gravel and silt. Scale is 1 m.

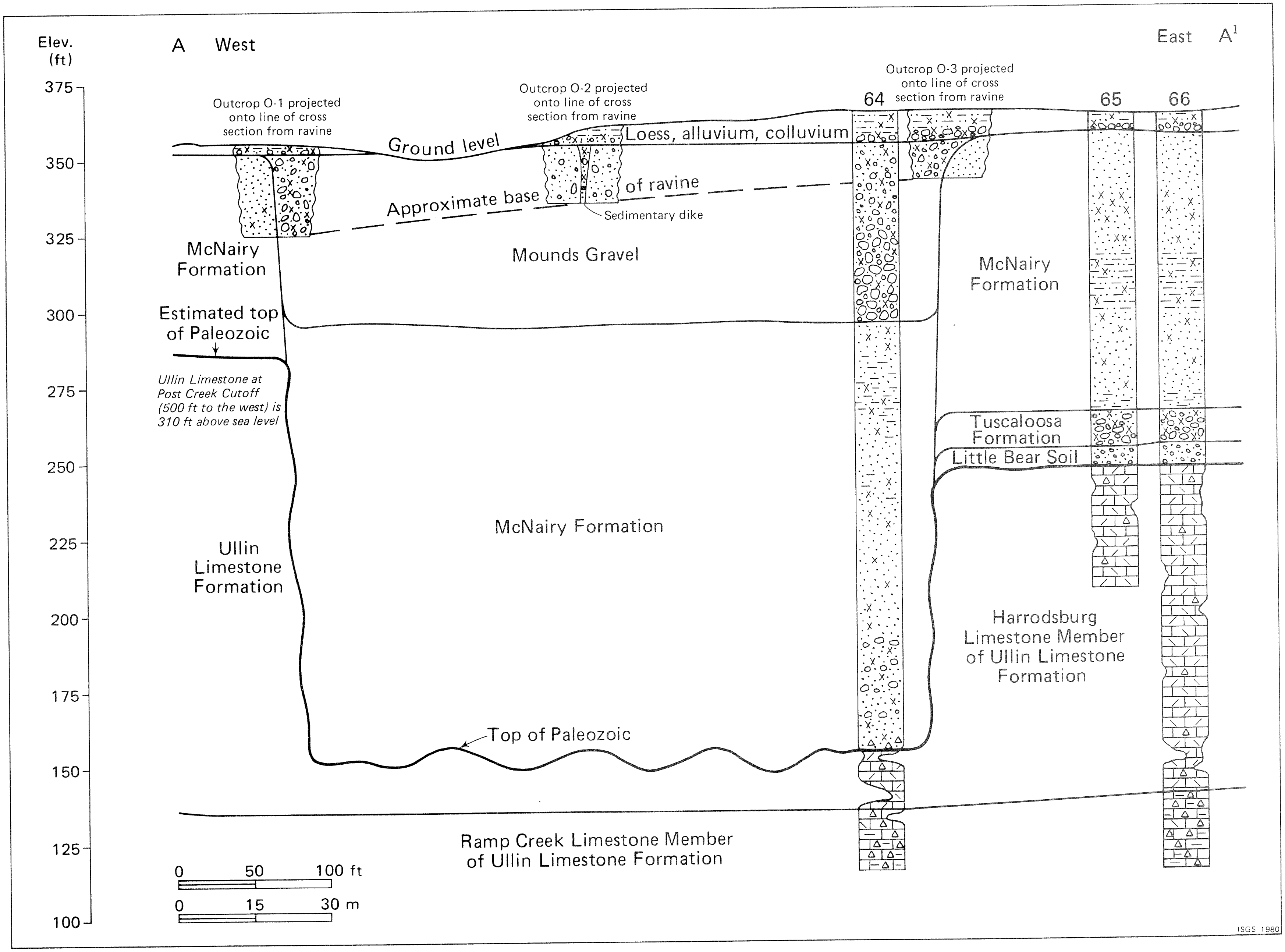

Figure 13. North view of interpretive cross section A-A' (see fig. 11) near Post Creek Cutoff, based on outcrops in ravine and on exploratory borings (see table 1). Cross section shows downdropped block of Mounds Gravel and McNairy Formation in northeast-trending solution cavity in the limestone bedrock.

Ramp Creek Limestone Members is at approximately the same elevation in both holes. This indicates that there is little or no displacement of Paleozoic bedrock between borings.

We conclude that the structure at the Post Creek Cutoff site was caused by solution collapse. Sometime during or shortly after deposition of Mounds Gravel, the limestone at or near the bedrock surface underwent solution, and the overlying Cretaceous strata and Mounds Gravel collapsed either suddenly or gradually into the cavern formed within the Ullin Limestone. Subsequently, the Mounds Gravel and the upper part of the McNairy Formation were stripped from the surrounding area by erosion. An unusually thick remnant of the Mounds Gravel is now preserved in this down-dropped block that is in juxtaposition with the McNairy.

Based on the northeast trend of the McNairy-Mounds contacts and the north-northeast trend of sedimentary dikes and joints in the down-dropped block of Mounds Gravel (fig. 13), we believe that solution of the underlying limestone has followed a predominantly northeast-trending joint system in the bedrock. In support is Ekblaw's description (1936) of the bedrock in test borings and footing excavations for the nearby bridge over the Post Creek Cutoff; a preference is revealed for solution along northeast-trending joints. The overlying sediments have sagged into many of the solution-widened joints.

▩ Metropolis

This site (fig. 2) is on the north bank of the Ohio River immediately west of Fort Massac State Park in Metropolis, Massac County (S½ NE Sec. 12, T. 16 S., R. 4 E.) (fig. 14). The Mounds Gravel is exposed intermittently up to an elevation of 325 feet along the river bank, from just below old Fort Massac 0.5 mile westward to near the intersection of the north-south center line of the NE¼ of Section 12 and the river bank. In NW SW SE NE Sec. 12 (figs. 15, 16) the Mounds Gravel dips about 20 degrees northwest (visible

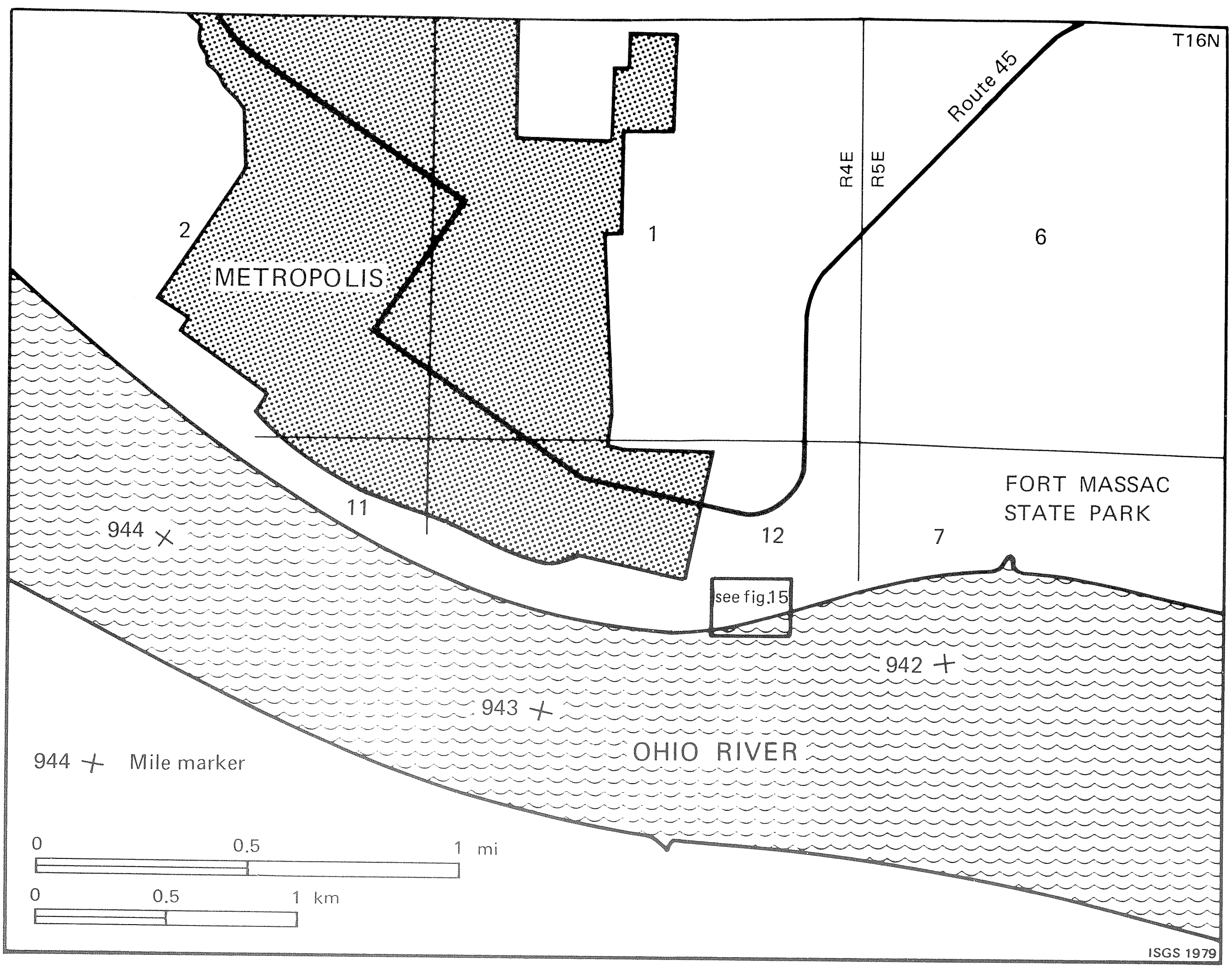

Figure 14. Location of Metropolis site.

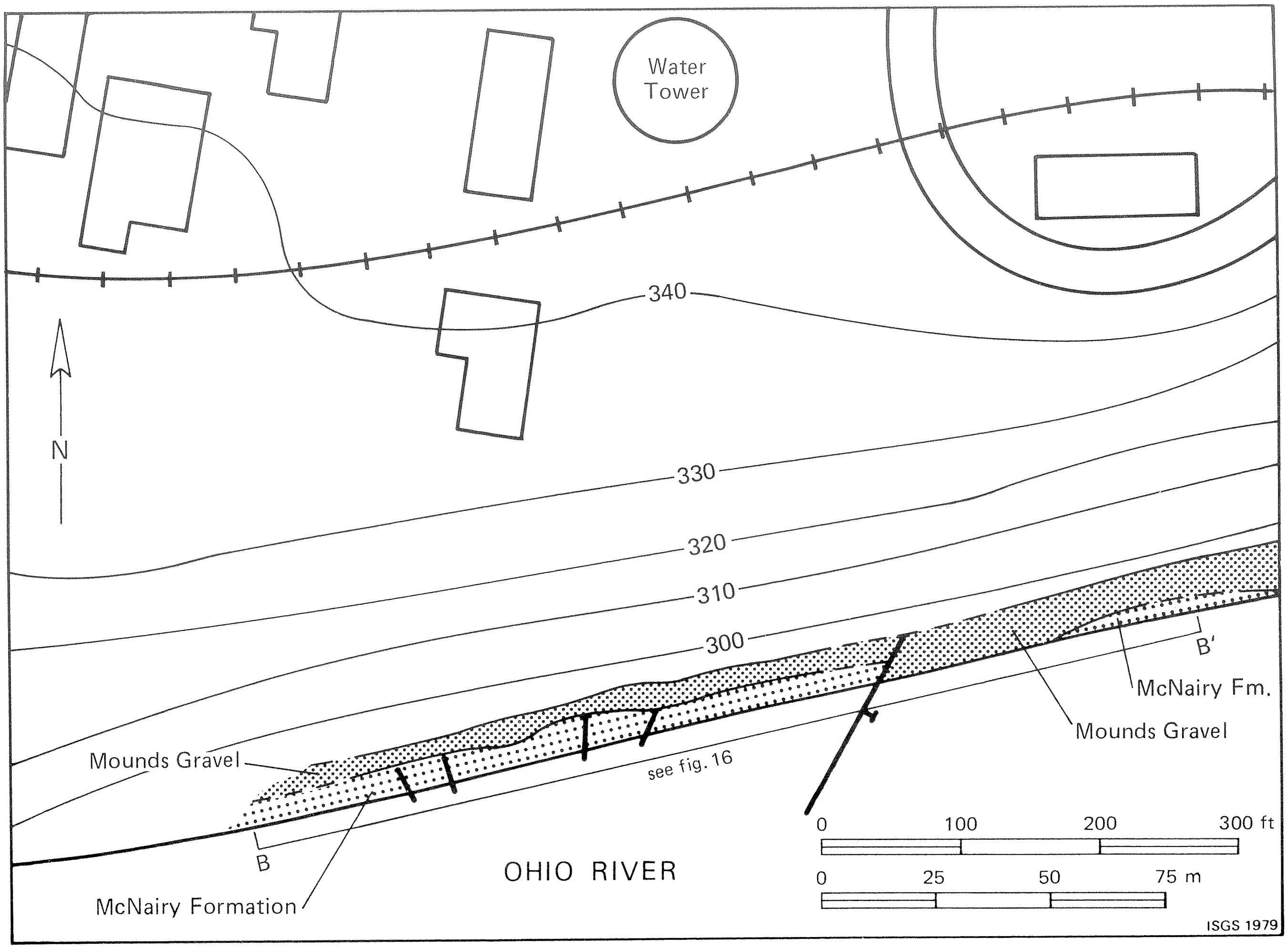

Figure 15. Topographic map showing location of faults and line of cross section B-B′ at the Metropolis site.

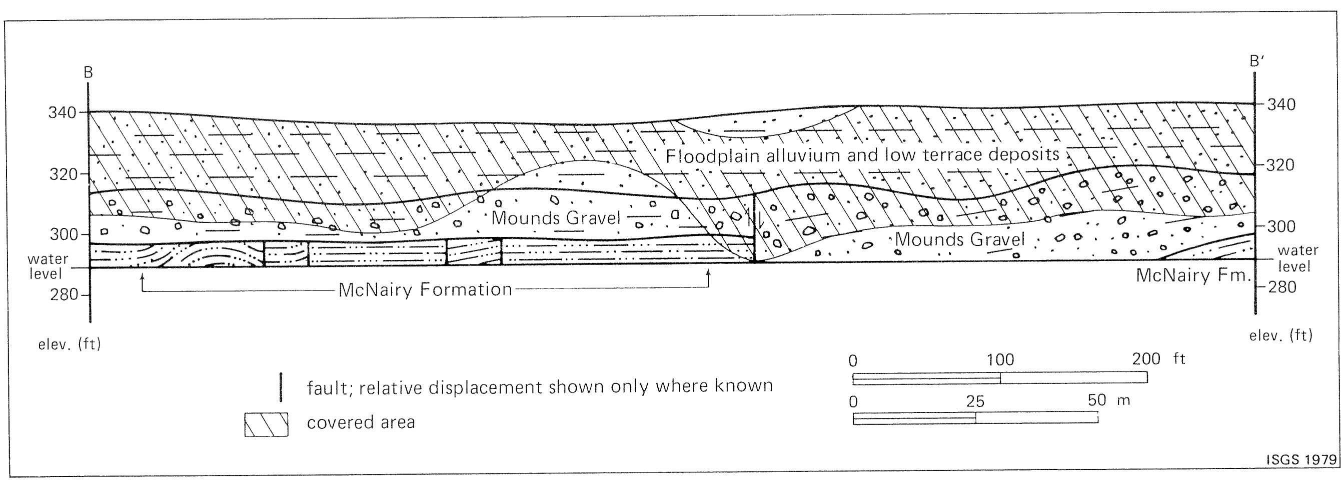

Figure 16. Cross section B-B′ (see fig. 15) showing geology along Ohio River bank at the Metropolis site.

when the river elevation is below 310 feet) and is downthrown approximately 50 feet in juxtaposition with the McNairy Formation. This fault is shown on the U.S. Geological Survey geologic map of the Paducah West and part of the Metropolis Quadrangles (Finch, 1966). The fault was covered by talus at the time of this investigation and its position was inferred from stratigraphic relations in the immediate area. When the elevation of the Ohio River is below 295 feet, faulted and tilted McNairy strata are exposed intermittently along the river bank west of this fault for about 500 feet (figs. 15, 16). All of the faults at this site strike in a northerly direction. The top of the McNairy Formation is truncated to a relatively flat surface and is overlain by the Mounds gravel, which in turn is overlain by floodplain alluvium and low terrace deposits (fig. 16). No faults were observed in the alluvium or terrace deposits. These geologic relations indicate at least two periods of movement. The first occurred after deposition of the McNairy Formation but before the Mounds Gravel was deposited. A second period of movement occurred either during or after deposition of the Mounds Gravel.

A seismic reflection survey made on the Ohio River by Alpine Geophysical Associates, Inc., for the Army Corps of Engineers in 1966 shows an anomaly of reflectors at an elevation of 240 to 270 feet, between mile markers 942 and 943. The anomaly may represent the southward extension of the Metropolis structure under the Ohio River.

The cause of the faults and folds at this locality is unknown. These structures could be caused by solution collapse in the underlying St. Louis and Salem Limestones or they could be the result of movement on the Paleozoic bedrock faults that are known to exist in the Metropolis area (fig. 5). Densely spaced exploratory borings drilled to bedrock and high resolution reflection seismography might provide more definite information.

The elevation of the base of the Mounds Gravel in the area between Metropolis and Brookport is unusually low (about 300 feet). North of this area, in the hilly divide between the Cache Valley and the Ohio River Valley, the Mounds usually caps the hills above 450 feet. The question is whether the Mounds in the Metropolis area was deposited at its present elevation, as proposed by Fisk (1944), Potter (1955), and Willman and Frye (1970), or whether it was lowered by faulting or downwarping. Ross (1963) interpreted the anomalous levels of Mounds Gravel in southernmost Illinois to be the result of faulting. To us the evidence seems too sparse to favor one interpretation over another.

▩ Thebes Gap

Thebes Gap (fig. 2) is a narrow (<1 mi wide) bedrock valley of the Mississippi River that is situated between Thebes and Fayville in Alexander County (fig. 17). It lies near the physiographic boundary between the Ozark Highlands and the Mississippi Embayment of the Gulf Coastal Plain. The northern limit of the embayment sediments extends through the Thebes Gap area. During Pleistocene time the Mississippi River was diverted through the gap and cut through the thin veneer of embayment sediments into the underlying Paleozoic bedrock. The structural and stratigraphic relations of the Paleozoic rocks and younger strata are exposed at numerous localities in the bluffs and ravines adjacent to the river in both Illinois and Missouri.

Paleozoic strata, ranging from the Champlainian (middle Ordovician) Kimmswick Limestone Subgroup to the Lower Devonian Bailey Formation, are exposed in the bluffs. These strata are broken by several, primarily east- and northeast-trending faults, a few of which probably have as much as 100 feet of displacement. The Paleozoic rocks are generally overlain by the Little Bear Soil, but the Tuscaloosa and McNairy Formations locally rest directly on the bedrock. Stratigraphic relations suggest that most of the displacement on the faults observed in the Paleozoic rocks took place before the Gulfian sediments overlapped the area.

In the "Chalk Bluffs" area of Thebes Gap, about one mile north of Commerce, Scott County, Missouri (fig. 17), however, there is some suggestion of small scale movement during and/or after Gulfian time. At this site the contact between the Cincinnatian (upper Ordovician) Thebes Sandstone Member of the Scales Shale and Gulfian-age sediments is exposed intermittently along the bluffs for about 0.75 mile. The Thebes Sandstone is faulted, tilted, and folded but most of this movement is clearly pre-Tuscaloosa in age. The Thebes is overlain by about 12 inches of nearly flat-lying Gulfian-age gravel (Tuscaloosa Formation?), the basal elevation of which varies by as much as 20 feet within a distance of about 100 feet. The uniform thickness and distribution of the gravel and the highly disturbed nature of

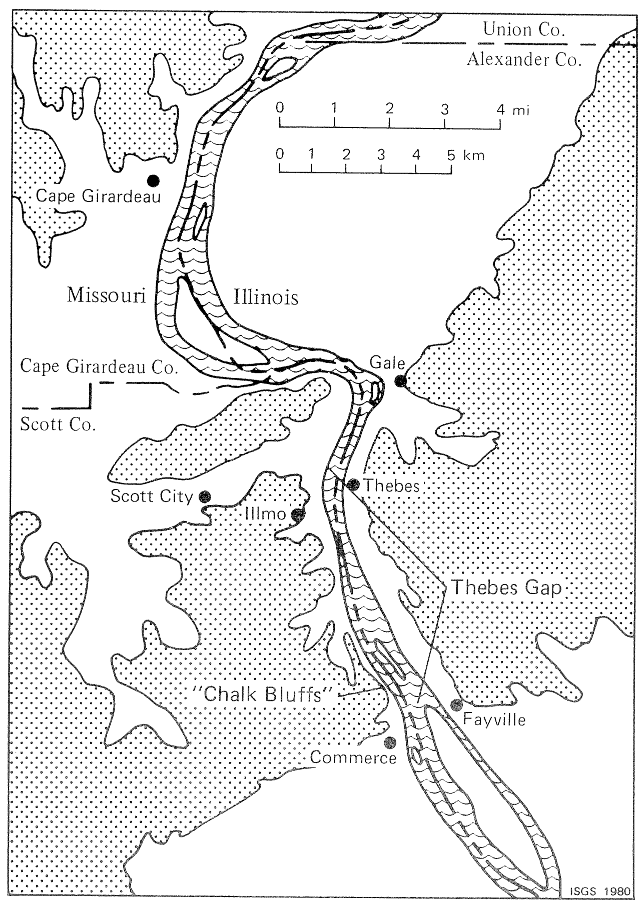

Figure 17. Physiographic map of the Thebes Gap area. Pattern indicates upland areas.

the underlying Thebes Sandstone suggests that the gravel was displaced after deposition. The precise structural relationships are unclear because much of the area between key outcrops is covered. On the Illinois side of Thebes Gap the base of the Cretaceous is at a relatively consistent elevation, and there is no apparent evidence of tectonic activity during and/or after Gulfian time.

McQueen (1939) and Stewart and McManamy (1944) described an outcrop near Commerce (NW SW SW Sec. 19, T. 29 N., R. 15 E) in which the Eocene Wilcox Formation strikes N. 5 degrees W. and dips 65 degrees W. These strata are supposedly overlapped by Mounds Gravel, which dips up to 20 degrees (dip direction not given), and is covered by flat-lying Pleistocene loess. The structural relations described by these investigators suggest recurrent movement in the area in post-Gulfian, pre-Pleistocene time. At the present time the site is covered and not available for study.

STRUCTURAL HISTORY

The northeast-trending faults that displace Paleozoic rocks in the Illinois-Kentucky Fluorspar District extend southwestward beneath the Gulfian (upper Cretaceous) sediments of the Mississippi Embayment in southernmost Illinois. The relatively uniform thickness of the Cretaceous sediments and the configuration of the base of the Cretaceous indicate that essentially all of the displacement on the faults in the underlying Paleozoic bedrock took place before the Cretaceous sediments overlapped the area. The faulting occurred sometime after mid-Pennsylvanian time because strata of this age are involved in the major displacements in the Fluorspar District. Although the hiatus between Pennsylvanian and Gulfian time is more than 100 million years, it is highly probable that the faulting occurred late in Paleozoic time concurrent with the intense tectonic activity of the Appalachian Orogeny, about 250 million years ago.

At no place can it be demonstrated unequivocally at this time that faults of tectonic origin displace post-Paleozoic sediments. There is some suggestion of relatively minor deformation during and/or after Gulfian time in the areas of Thebes Gap, southeastern Pulaski County, Round Knob, and Metropolis, but the available evidence is too sparse and ambiguous to conclude that tectonic activity is the cause of these local disturbances.

During Gulfian and early Tertiary time southernmost Illinois underwent broad, regional subsidence as a result of downwarping within the Mississippi Embayment. The extent and magnitude of subsidence is shown in part on the structure map of the base of the Paleocene Clayton Formation (fig. 8). The 35- to 40-million-year hiatus between Eocene and Pliocene-Pleistocene time does not appear to have been a time of intense or widespread deformation in southern Illinois. No offsets or disturbed zones have been observed in the Pleistocene or Holocene sediments that can be attributed to tectonic faulting.

Earthquake epicenters within the Mississippi Embayment of southern Illinois in historic time appear to show no relationship to known faults. Where the numerous faults of the Illinois-Kentucky Fluorspar District project into the Mississippi Embayment of southern Illinois (Massac and Pope Counties) and adjacent parts of Kentucky (McCracken County), the pattern of seismicity is diffuse. Relative to the areas north (Wabash Valley) and south (New Madrid) of here, southernmost Illinois and western Kentucky have experienced less seismicity in historic time. Furthermore, there is no available geologic evidence to indicate that the fault complex that extends through Massac and Pope Counties is presently active. In southern Alexander and Pulaski Counties the intensities and numbers of historic earthquakes are somewhat greater than in Massac and Pope Counties, but again, there is no available evidence of recent movement on the interpreted faults that underlie Alexander and Pulaski County.

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APPENDIX

Table 1. Wells used to supply data in compiling maps of sub-Cretaceous geology, configuration of base of Cretaceous, thickness of Cretaceous strata, and structure of base of Paleocene Clayton Formation (figs. 4-8)

County Well no. Driller, farm	Location 1/4	1/4	1/4	1/4	Sec.	Twp.	Rng.	ISGS co. no.	Core	Type of Data: Geophys-ical log	Chip samples	Drillers log	Elev. of base of Cretaceous (ft, datum m.s.l.)	Thickness of Cretaceous (ft)	Elev. of base of Paleocene Clayton Fm. (ft, datum m.s.l.)
Alexander County															
1. Ozark farm No. 1	NW	NW	NW	SE	8	14S	1W	7			X	X		0	
2. H. B. Stalcup No. 1 Newell		SE	SW	SW	19	14S	1W	3			X	X		0	
3. Schneider No. 1 Ferris	NE	NE	NW	SW	3	15S	2W	14			X			0	
4. Durham No. 1 W. L. Becker		SW	SE	SE	4	15S	2W	13			X	X		0	
5. Sergent No. 2 Paul Smothers		SE	NE	NW	31	15S	2W				X			0	
6. Schneider-Gwinn, S. J. Campbell					32	15S	2W				X			0	
7. Durham, T. J. Hill	NW	NW	SE	NW	32	15S	2W	18			X			0	
8. Schneider, Clyde Vick	SW	SE	NE	NW	32	15S	2W	19			X			0	
9. Arnold & Middleton No. 1 Hodges		SE	SE	NW	35	15S	2W	20			X	X			
10. Whitebread & Kipping No. 1 Ralph W. Minton		SW	SW	SE	4	15S	3W	21			X	X		0	
11. Whitebread & Kipping No. 2 Ralph W. Minton		SW	SW	SE	4	15S	3W	22			X	X		0	
12. Whitebread & Kipping No. 3 Ralph W. Minton		SW	SW	SE	4	15S	3W	23			X			0	
13. Layne-Western No. 2 City of Thebes		NE	SW	SE	8	15S	3W				X			0	
14. Midwestern Development Co. No. 1 Russek	NE	SW	SW	SW	10	15S	3W	24			X			0	
15. McRaven, Robert H. Parish	SE	SW	NW	NE	13	15S	3W	50				X			
16. Durham, Harry Bennett	NW	SW	SW	NW	23	15S	3W	40			X	X		0	
17. Beanland, Central Alexander County Water District	SW	SE	NW	SE	25	15S	3W	109		X	X	X			
18. Gwin No. 1 James Chaney	NE	SE	SW	NW	25	15S	3W	39			X	X	+340	23	
19. Welch Brothers, B. R. Hall	SE	SE	SE	SE	26	15S	3W	45			X	X	+198	151	
20. Sergent No. 1 Henry Ashworth		NE	NW	NW	36	15S	3W	107				X	+335	65	
21. Prindle & Vick No. 1 Petty		NE	SW	NE	19	16S	2W	26		X	X		+143	0	
22. Gould No. 1 Transient Camp	NE	NW	NW	NW	24	16S	2W	28			X	X	+213	0	
23. Halliday Estate No. 3	NE	NE	SW	NE	2	17S	1W	29				X	+ 2?	54?	+56?
24. Cairo River Railroad Warehouse Co.		NW	NW	NE	23	17S	1W	17		X			-273?	152?	-121?
25. Halliday No. 1 (Cairo Electric Light & Power Co.) 8th & Washington Streets			SW	SE	25	17S	1W	31				X	-211?	25?	-186?
26. E. W. Halliday (1903) No. 4			SW	SE	25	17S	1W	32				X	-217?	24?	-193?
27. Vick Oil Co. No. 1 Smith	SE	NW	NW	NW	15	17S	2W	6		X	X		-125	130	+ 5

E Estimated. ? Datum is questionable.

* Point used as supportive evidence for the configuration of mapping surface although the Cretaceous was absent, or there were insufficient data to determine the presence of the Cretaceous.

** Anomalous datum, point not contoured. † 30 to 60 feet of samples missing near base of Cretaceous.

Table 1. *Continued*

County Well no. Driller, farm	Location 1/4	1/4	1/4	1/4	Sec.	Twp.	Rng.	ISGS co. no.	Core	Type of Data: Geophysical log	Chip samples	Drillers log	Elev. of base of Cretaceous (ft, datum m.s.l.)	Thickness of Cretaceous (ft)	Elev. of base of Paleocene Clayton Fm. (ft, datum m.s.l.)
Pulaski County															
28. Columbia Quarry Co. No. 2A Campbell		NW	NE	SE	12	14S	1W	32	X					0	
29. Columbia Quarry Co. No. 3 Ullin Quarry	NW	NW	NW	SE	14	14S	1W	68	X						
30. Columbia Quarry Co. No. 3 NH Ullin Quarry					14	14S	1W	33	X						
31. Ullin Oil & Gas Co. No. 1 Anderson	NW	SW	SE	SW	26	14S	1W	64				X			
32. Columbia Quarry Co. No. 1 Campbell		SE	SE	SW	7	14S	1E	26	X					0	
33. New Ill. Mid-Continent Oil Co. No. 1-A Roscoe Herren		NE	NE	SW	12	14S	1E	1		X	X	X			
34. Mary Vaugh No. 1 Lawrence Ragsdale		NW	SW	NW	18	14S	1E	2			X	X		0	
35. Sergent No. 1 David Ritter		SE	SW	SW	19	14S	1E	159				X	+336*		
36. Sergent No. 1 C. J. Egner		SW	SW	SW	21	14S	1E	178			X		+250*		
37. Sergent No. 1 Harold K. Lite		SW	SW	SE	21	14S	1E	20246				X	+340*		
38. Sergent No. 1 Robert Cross		SE	SE	SE	22	14S	1E	141				X	+285*		
39. Sergent No. 1 H. E. Modglin		SW	NE	SW	30	14S	1E	179				X	+290*		
40. Sergent No. 1 Jack Hall		NE	SW	SW	32	14S	1E	160				X	+264*		
41. Gould No. 1 Transient Camp		NW	SE	SE	14	14S	2E	31			X	X		0	
42. Sergent No. 1 Hobart Barefield		SW	SW	SE	18	14S	2E	104				X	+150*		
43. Sergent No. 1 E. H. Henderson		NW	SW	SW	18	14S	2E	105				X	+270*		
44. Sergent No. 1 George Inman		SE	SE	SE	28	14S	2E	118				X	+300*		
45. Sergent No 2 Shawnee Junior College		NW	NW	NE	30	14S	2E	134		X		X	+185		
46. Sergent No. 1 Thomas Roach		NE	NE	SE	31	14S	2E	114				X	+260*		
47. Weldon, Illinois Central Railroad		SE	NE	NW	15	15S	1W	9				X	+240	50	
48. McRaven, Village of Pulaski		NW	SE	NW	16	15S	1W	20268			X	X		0	
49. Sergent No. 1 Homer Essex		SE	SW	SE	23	15S	1W	131				X	+145	190	+335
50. Weldon, A. O. Pawlisch		NW	SE	SW	27	15S	1W	54			X		+180	144	
51. Schneider, Hay		SE	NW	SE	34	15S	1W	55			X				+315
52. Schneider, Whelan		NE	SE	SW	34	15S	1W	14			X				+330
53. Weldon, J. H. Aldrich	NW	SE	SE	SE	35	15S	1W	12			X		+205	200	

Table 1. *Continued*

County Well no. Driller, farm	Location 1/4	1/4	1/4	1/4	Sec.	Twp.	Rng.	ISGS co. no.	Type of Data Core	Geophys- ical log	Chip samples	Drillers log	Elev. of base of Cretaceous (ft, datum m.s.l.)	Thickness of Cretaceous (ft)	Elev. of base of Paleocene Clayton Fm. (ft, datum m.s.l.)
Pulaski County (cont.)															
54. Moore No. 1 Endicott		NE	NW	SE	36	15S	1W	5			X				+334
55. Sergent, Henry Richard		SW	SE	NW	4	15S	1E				X	X	+303	97	
56. Sergent No. 1 Larry L. Owens	NE	NE	NE	SW	7	15S	1E	20218				X	+113	315	
57. R. G. Williams, W. L. Richey			SE	SW	9	15S	1E	10			X		+ 49	328	+377
58. Sergent No. 1 John Carroll		SW	NW	SE	20	15S	1E	146				X	⩽- 130	⩽530	+400
59. White No. 1 John Goza		NE	SW	SE	20	15S	1E	38			X		- 54		
60. Luton No. 7 Clyde C. Shafer		SE	SW	SW	21	15S	1E	97				X			+313
61. Case Engineering Co., Olmsted City Well	SE	SE	SE	SW	22	15S	1E	40			X		- 161	455	+294
62. Luton No. 10 Edwin Basse		SW	SE	NW	28	15S	1E	98				X			+285
63. Illinois State Geological Survey No. D-7	NE	SE	NE	NE	1	15S	2E	20221		X	X (Split spoon)	X	+320	25	
64. Illinois State Geological Survey No. 1 John Miller		SW	NW	SE	2	15S	2E	20280	X	X	X (Split spoon)		+154**	141**	
65. Illinois State Geological Survey No. 2 John Miller		SE	NW	SE	2	15S	2E	20282	X		X (Split spoon)		+246	111	
66. Illinois State Geological Survey No. 3 John Miller		SE	NW	SE	2	15S	2E	20281	X	X			+245	111	
67. Sergent No 1 Aoudy Eddleman		SE	SW	NE	3	15S	2E	109				X	+370	50	
68. U. S. War Department, Lock and Dam 53		SE	SW	NW	18	15S	2E	65		X	X	X	+126	174	
69. Army Corps of Engineers No. D-2 Lock and Dam 53		NE	SW	NW	18	15S	2E					X	+ 80E**		
70. Army Corps of Engineers No. DU-14 Lock and Dam 53	SE	NE	SW	NW	18	15S	2E					X	+114E		
71. Sergent No. 1 Ray Rushing		NE	NE	SW	3	16S	1W	183				X			+345
72. C.C.C. Camp No. 625		SW	SE	NW	15	16S	1W	63			X				+190
73. Illinois State Geological Survey No. 1 Sam Moses	SW	NE	NW	SW	15	16S	1W	20277		X	X (Split spoon)				+196
74. Illinois State Geological Survey No. 2 Sam Moses		NE	NW	SW	15	16S	1W	20278		X	X (Split spoon)				+195
75. Sergent No. 1 Vernon Curtis		SW	SE	NW	16	16S	1W	167				X			+210
76. Sergent No. 1 John Brennan		NW	SE	NW	17	16S	1W	132				X	+122	100	+222

Table 1. *Continued*

County Well no. Driller, farm	Location 1/4	1/4	1/4	1/4	Sec.	Twp.	Rng.	ISGS co. no.	Core	Type of Data Geophys- ical log	Chip samples	Drillers log	Elev. of base of Cretaceous (ft, datum m.s.l.)	Thickness of Cretaceous (ft)	Elev. of base of Paleocene Clayton Fm. (ft, datum m.s.l.)
Pulaski County (cont.)															
77. Cache Oil Co. No. 1 George Moses		SW	NE	SE	17	16S	1W	62			X	X	+193	44	+237
78. Miller No. 1 John Moses			SW	SE	17	16S	1W	16			X	X	+174	30	+204
79. Schneider, G. C. Droge		SE	NW	NW	18	16S	1W	15			X				+285
80. Ice Plant well, Mound City	NW	NW	NW	SE	22	16S	1W	58			X		+130	28	+158
81. Vance Oil Co. No. 1 Hudson		SE	SW	SE	23	16S	1W	59			X		+39 to + 99†		
82. Layne-Western No. 1 City of Mounds Water District			NW	NW	23	16S	1W				X		+83 to +113†		
83. Army Corps of Engineers No. U-32		NW	SE	SW	36	16S	1W					X			+ 12
84. Ice Plant well, Mound City			NW	NE	36	16S	1W	60				X	+ 15	25	+ 40
85. Halliday, Mound City well		NW	NE	NE	36	16S	1W	61				X	- 30		
86. Vick Oil Co. No. 1 Boyd		NW	NE	SW	5	16S	1E	11			X	X	- 2	262	+260
87. Vick Oil Co. No. 1 Roberts		NW	SW	SW	5	16S	1E	6			X	X	+ 13	202	+215
88. Army Corps of Engineers No. MD-54		SE	NW	NW	10	16S	1E					X			+230
89. Sergent, Mound City Warehouse Co.					30	16S	1E	73		X			+ 8	68	+ 76
Massac County															
90. Ditterline No. 1A Thomas Ivan & Edna West		SE	SE	NW	1	14S	3E	20218		X	X				
91. Glen Kahle et al. No. 1 Harvick	SW	SW	SW	SW	23	14S	3E	1396			X			0	
92. Ditterline No. 1 Henry Schmidt		SE	SW	SE	23	14S	3E	20219			X				
93. Sergent No. 1 Armon Barnett		NW	NW	NW	28	14S	3E	20277				X	+258*		
94. Beanland, Philip Barnett		NW	NW	NW	28	14S	3E	20259				X	+293*		
95. Sergent No. 1 Robert Harmonl		SW	SW	SE	28	14S	3E	20278				X	+260*		
96. Sergent No. 1 William Brooks		SW	SW	SW	29	14S	3E	20252				X	+370*		
97. Sergent No. 1 Terry Lewis		NW	SW	NE	29	14S	3E	20250				X	+280*		
98. Sergent No. 1 Paul Fisher		NW	NW	NE	30	14S	3E	20282				X	+350*		
99. Sergent No. 1 John Neil		NW	NW	NE	31	14S	3E	20284				X	+360*		
100. Sergent No. 1 Arthur Meyers		SW	NW	NE	33	14S	3E	20285				X	+360*		
101. Sergent, Ronnie Stubblefield		SE	SE	SW	33	14S	3E	20251				X	+372*		
102. Sergent, Howard Stubblefield		NW	SW	SW	33	14S	3E	20286				X	+410*		
103. Fred Foss No. 1 Foss		SE	SE	SE	1	14S	4E	2		X	X	X			
104. Clark No. 1 William Croft		SE	SW	SE	5	14S	4E	39			X	X		0	

Table 1. *Continued*

County Well no. Driller, farm	Location 1/4	1/4	1/4	1/4	Sec.	Twp.	Rng.	ISGS co. no.	Type of Data Core	Geophys- ical log	Chip samples	Drillers log	Elev. of base of Cretaceous (ft, datum m.s.l.)	Thickness of Cretaceous (ft)	Elev. of base of Paleocene Clayton Fm. (ft, datum m.s.l.)
Massac County (cont.)															
105. Clark No. 1 C. O. Cummings		NW	NW	SW	9	14S	4E	41			X	X		0	
106. Richey No. 1 Floyd Wiley		SW	NE	NE	17	14S	4E	12		X		X			
107. Richey No. 1 Terry Korte		SE	NW	SE	25	14S	4E	20292				X	+307*		
108. Richey No. 1 United Baptist Church		NE	NE	NE	36	14S	4E	78				X	+382	128	
109. Richey No. 1 Brian Bremer		NW	SE	SE	19	14S	5E	20237				X	+374*		
110. Fitch Brothers No. 1 Pullen and Farmer		NE	NE	NE	20	14S	5E	22			X	X	+352		
111. Richey No. 1 Wilson Kruger	NE	NE	NW	NE	29	14S	5E	29				X	+411*		
112. Campbell No. 1 Teckenbrock		SW	NW	NW	29	14S	5E	10				X	+405*		
113. Richey No. 1 Ralph Logeman	SE	SE	SW	NW	30	14S	5E	142				X	+407	54	
114. Richey, Raymond Roethe		NW	NW	NE	31	14S	5E	27				X	+319*		
115. Richey No. 1 James Weaver	SE	SE	SE	NE	32	14S	5E	138				X	<+ 78**		
116. Sergent No. 1 Jack Mathews		NE	NE	NE	1	15S	3E	192				X	+270*		
117. Richey No. 1 Truman Windhorst		SW	NW	SW	1	15S	3E	20234				X	+210*		
118. Sergent No. 1 Charles Brewer		NW	NW	NW	3	15S	3E	20294				X	+290*		
119. Sergent No. 1 Paul Myres		SE	SE	SW	3	15S	3E	20295				X	+295*		
120. Sergent No. 1 Cecil Becker		SW	NW	NW	4	15S	3E	20249				X	+325*		
121. Sergent No. 1 Lavell Neill	SW	NE	NE	NE	5	15S	3E	132				X	+316*		
122. Sergent, Delbert Goines		NE	SE	SE	6	15S	3E	129				X	+300	115	
123. Sergent, Delbert Goines	SW	NE	NE	NE	7	15S	3E	179		X			+310*		
124. Richey No. 1 John McCuan		NE	SE	NW	8	15S	3E	20297				X	+239*		
125. Layne Western No. 1 Joppa, Illinois Compressor Station No. 7			SW	SE	10	15S	3E	20884			X	X	⩽+247	⩾20	
126. Layne Western No. 2 Joppa Illinois Compressor Station No. 7			SW	SE	10	15S	3E	20885			X	X	⩽+250	⩾30	
127. Wittig No. 17 School District	NE	NE	NE	SE	10	15S	3E	15			X	X	+ 75**?	122**?	
128. Layne Western No. 4 Electric Energy, Inc.		NW	SW	SW	14	15S	3E	1			X	X	+175	80	
129. Smith Cunningham No. 1 A. J. Bunchman		SW	SW	NE	14	15S	3E	30				X	+206	99	
130. Layne Western No. 2 Electric Energy, Inc.			NW	SW	14	15S	3E	50			X	X	+211	65	
131. Layne Western No. 3 Electric Energy Plant		SW	SW	NW	14	15S	3E	51			X	X	+210	45	
132. Smith Cunningham No. 1 M. G. Roberts		SW	SW	NE	14	15S	3E	31			X	X	+200	100	

Table 1. *Continued*

County Well no. Driller, farm	Location 1/4	1/4	1/4	1/4	Sec.	Twp.	Rng.	ISGS co. no.	Core	Type of Data Geophys- ical log	Chip samples	Drillers log	Elev. of base of Cretaceous (ft, datum m.s.l.)	Thickness of Cretaceous (ft)	Elev. of base of Paleocene Clayton Fm. (ft, datum m.s.l.)
Massac County (cont.)															
133. Layne Western No. 1 Electric Energy, Inc.		SE	NE	SE	15	15S	3E	53			X	X	+216	47	
134. Layne Western No. 1A Missouri Portland Cement Co.			NW	SW	15	15S	3E	23				X	+219	48	
135. Layne Western No. 1 Missouri Portland Cement Co.		SW	SW	NW	15	15S	3E				X		⩾ +192		
136. Missouri Portland Cement Co., in Ohio River Boring "A"	NE	SW	NW	SE	16	15S	3E				X		+167	55	
137. Smith Cunningham No. 1 Joppa Colored School	SW	NE	NE	NW	23	15S	3E	54			X	X	+210	95	
138. Linker No. 2 Fort Massac Water District	NE	NE	NE	SE	24	15S	3E	175			X	X	+185	87	
139. Richey No. 1 Jerry Baird		NW	SE	SE	2	15S	4E	20299				X	+257*		
140. Smith Cunningham, Joe Weinke	NE	SE	NE	NE	4	15S	4E	56			X	X			
141. Richey No. 1 Roy Hinners			SW	SW	12	15S	4E	72				X	+210	190	
142. Richey No. 1 John Sweney	SE	SE	SW	SW	12	15S	4E	166				X	+270	145	
143. Richey, J. L. Brenningmeyer		NW	SE	SW	14	15S	4E	20302				X	+239		
144. C. L. Owens No. 1 Sommers		SW	SW	SE	18	15S	4E	119			X		⩾ +203		
145. Searles, Ray Sullivan		NW	SE	NE	20	15S	4E	59				X	+173		
146. Hepp No. 1-A AEP Service Corp.	NW	SW	NE	SW	28	15S	4E	20247			X		+ 90	168	
147. Hepp No. 1 AEP Service Corp.	SE	NE	NW	SE	28	15S	4E	20232			X	X	+ 95	148	
148. Hepp No. 2 AEP Service Corp.			NW	SE	28	15S	4E	20233			X	X	+ 62	191	
149. Gwin, Allied Chemical Co.	NW	SE	SE	NW	34	15S	4E	168			X	X	+105	186	
150. Layne Western No. 1 General Chemical Corp.		SE	NW	NW	34	15S	4E				X		+ 78	207	
151. Layne Western No. 3 General Chemical Corp.		NE	SE	NW	34	15S	4E				X		+ 95	191	
152. Layne Western, General Chemical Corp. Plant Sanitary Well		SE	NE	NW	34	15S	4E				X		+ 90	192	
153. Richey No. 1 William Hook	NE	NE	SW	NW	2	15S	5E	134				X	+354	168	
154. Geer, Melvin Brockman		NW	NW	NW	3	15S	5E	143				X	+315	135	
155. Richey No. 1 Truman Logeman		NW	SW	SW	5	15S	5E	20240				X	+318	47	
156. Richey No. 1 C. O. Babb		NE	NE	NW	7	15S	5E	20224				X	+326	74	
157. Richey No. 1 Frank Forthman		SW	SW	SW	7	15S	5E	20242				X	+304	70	
158. Richey No. 1 Windell Bremer		SE	SE	SE	9	15S	5E	71				X	+272	144	

Table 1. *Continued*

County Well no. Driller, farm	Location 1/4	1/4	1/4	1/4	Sec.	Twp.	Rng.	ISGS co. no.	Core	Type of Data Geophys-ical log	Chip samples	Drillers log	Elev. of base of Cretaceous (ft, datum m.s.l.)	Thickness of Cretaceous (ft)	Elev. of base of Paleocene Clayton Fm. (ft, datum m.s.l.)
Massac County (cont.)															
159. Richey No. 1 William Meddagh		SE	SW	SE	18	15S	5E	20238				X	+150	200	
160. Sergent No. 1 Lloyd Covgill		NE	NW	SW	20	15S	5E	177				X	+195	175	
161. Metropolis Nat'l. Well Co. No. 5 St. John's E and R Church			SW	SE	27	15S	5E	13				X	+212	112	
162. Brady (Wittig) No. 2 Metropolis Country Club	NE	NE	NW	NE	30	15S	5E	21			X	X	+135	245	
163. Henners No. 1 Fred Moller		NW	NW	SW	35	15S	5E	4			X		⩾+167		
164. Richey No. 1 Robert Brewer		NE	NE	SE	7	15S	6E	198				X	+300	200	
165. Sergent No. 1 Charles Geitman		SE	SE	SE	8	15S	6E	193				X	+370		
166. Jennings, Louis Faughn		NE	NE	NE	19	15S	6E	144				X	+305	130	
167. Wittig, Luke Webb	SW	SW	SW	NW	32	15S	6E	20			X		+320	55	
168. Luth, Metropolis City Well		SW	NE	NE	11	16S	4E	66			X	X	+ 51	224	
169. Thorne, Metropolis City Well					11	16S	4E	68				X	+ 33	252	
170. Layne Western No. 5 Metropolis					11	16S	4E				X		⩽ - 80**	⩾320**	
171. Sergent No. 1 Sherman Taylor		SE	SE	NW	1	16S	5E	20307				X	+205		
172. Marshall No. 1 Harry McGhee		NE	NE	NE	3	16S	5E	69			X	X	+166	162	
173. Fondaw, Claud Hoyer		NE	SE	SE	1	16S	6E	20216				X	+386	35	
174. Tennessee Valley Authority No. L-A Paducah Dam Site		NW	SW	NW	15	16S	6E					X	+251		
175. Tennessee Valley Authority No. L-1 Paducah Dam Site		NE	NW	SW	15	16S	6E					X	+236		
176. Fondaw, Robert Summons		SE	SE	NE	17	16S	6E	20226				X	+183	119	
177. Tennessee Valley Authority No. L-3 Paducah Dam Site		NE	NW	NW	22	16S	6E	20311				X		⩾153	
178. Tennessee Valley Authority No. L-4 Paducah Dam Site	SW	NW	SE	NW	22	16S	6E	20312				X	+134	⩾131	
179. Tennessee Valley Authority No. L-5 Paducah Dam Site		SW	NE	SW	22	16S	6E	20313				X	+181		
180. Tennessee Valley Authority No. L-6 Paducah Dam Site	SE	SW	SE	SW	22	16S	6E	20314				X	+126	⩾100	
181. Tennessee Valley Authority No. L-8 Paducah Dam Site	SE	SE	SE	NW	27	16S	6E					X	+154		
182. Tennessee Valley Authority No. L-12 Paducah Dam Site		NW	SW	NE	34	16S	6E					X	+153		

Table 1. *Continued*

County Well no. Driller, farm	Location 1/4	1/4	1/4	1/4	Sec.	Twp.	Rng.	ISGS co. no.	Core	Type of Data Geophys- ical log	Chip samples	Drillers log	Elev. of base of Cretaceous (ft, datum m.s.l.)	Thickness of Cretaceous (ft)	Elev. of base of Paleocene Clayton Fm. (ft, datum m.s.l.)
Pope County															
183. Haverstick, C.C.C. Camp Hamberg		NW	NW	SE	14	14S	5E	125				X	+496		
184. Edleman No. 6 Compton Mine		SE	NW	SW	26	14S	6E	130	X				+308*		
185. Jennings No. 1 Robert Worten		SW	SW	SW	29	14S	6E	271				X	+557*		
186. Sergent No. 1 Arthur Owens		SW	NE	NE	1	15S	6E	279				X	+435*		
187. Gwin No. 1 Vernon Pederson		NE	SE	NW	7	15S	7E	235				X	+406*		
188. Jennings No. 1 Tony W. Harris		SE	SE	SW	32	15S	7E	266				X	+400*		
189. Fitch Bros. No. 1 J. H. Lewis		NW	NE	NE	32	15S	7E	185			X	X	+319	21	
190. Jennings No. 1 Bryant Estate		NE	SE	SW	33	15S	7E	265				X	+330*		
191. Tharp No. 1 Millard Woolridge		SW	SW	SW	3	16S	7E	196			X	X	+293*		
192. Tennessee Valley Authority No. L-1 Upper Smithland Dam Site			SW	SW	3	16S	7E					X	+268*		
193. Tennessee Valley Authority No. L-2 Upper Smithland Dam Site			SE	SW	3	16S	7E					X	+253*		
194. Rigney & Dodson Oil Co. No. 1 J. H. Lewis		SW	SW	NE	18	16S	7E	158		X	X	X	+287*		
195. Tennessee Valley Authority No. L-A Lower Smithland Dam Site		NW	NE	NW	16	16S	7E					X	+317	58	
196. Tennessee Valley Authority No. L-1 Lower Smithland Dam Site	SE	NW	SW	NE	16	16S	7E					X	+298*		
197. Tennessee Valley Authority No. L-2A Lower Smithland Dam Site	SE	SE	SW	NE	16	16S	7E					X	+237*		
198. Tennessee Valley Authority No. L-3A Lower Smithland Dam Site		NW	NE	SE	16	16S	7E					X	+221*		

E Estimated. ? Datum is questionable.

* Point used as supportive evidence for the configuration of mapping surface although the Cretaceous was absent, or there were insufficient data to determine the presence of the Cretaceous.

** Anomalous datum, point not contoured. † 30 to 60 feet of samples missing near base of Cretaceous.

Table 2. Outcrops used to supply data in compiling maps of sub-cretaceous geology, configuration of base of Cretaceous, and structure of base of Paleocene Clayton Formation (figs. 4, 5, 6, 8)

	Location 1/4	1/4	1/4	1/4	Sec.	Twp.	Rng.	Paleozoic bedrock formation	Elev. of base of Cretaceous (ft, datum m.s.l.)	Elev. of base of Paleocene (ft, datum m.s.l.)
Alexander County										
a.	SW	SE	NE	NW	34	15S	3W	Thebes Sandstone Member of Scales Shale	~+400	
b.	NE	NW	SE	SE	28	15S	3W	Girardeau Limestone	~+400	
c.	SW	NW	SW	NE	28	15S	3W	Girardeau Limestone	~+400	
d.	NW	SW	SE	SW	21	15S	3W	St. Clair Limestone	~+400	
Pulaski County										
e.	SW	NE	NW	NE	13	15S	1E			+380
f.	NW	SW	SW	NE	13	15S	1E			+375
g.	SE	NW	SW	SW	13	15S	1E			+380
h.		SE	SE	NW	2	15S	2E	Salem Limestone	+310	

TABLE 3. Composite stratigraphic section — Sam Moses' pit

Sam Moses' pit is located on the north side of the County Highway 6 in the northwest corner of the town of Mounds, Pulaski County, Illinois (S½NW SW, Sec. 15, T. 16 S., R. 1 W.)

The upper part of the stratigraphic section, including the top few feet of the Wilcox Formation, consists of outcrop descriptions from the pit. The lower part of the section consists of descriptions of split spoon samples taken every 10 feet from two test holes drilled in the floor of the pit.

	Thickness (feet)
Quaternary System	
Pleistocene Series	
Wisconsinan Stage	
Woodfordian Substage	
Peoria Loess	
Silt, massive; Modern Soil at top; light brown to light brownish gray with depth; nodular calcareous concretions in lower part.	12
Altonian Substage	
Roxana Silt	
Silt, massive; Farmdale Soil in top; light brownish to grayish red; clayey; becomes more brownish red at base, indicating a transition to the underlying silt.	7
Illinoian Stage	
Loveland Silt	
Silt, blocky; Sangamon Soil at top; reddish brown; clayey; dark brown clay skins coat the blocky fractures; scattered chert pebbles increase in abundance toward base, indicating colluvial deposition that incorporates material from the underlying gravel.	6

	Thickness (feet)
Tertiary System	
Pliocene-Pleistocene Series	
Mounds Gravel	
Gravel, pebbles are predominantly chert with some sandstone and siltstone, subangular to subrounded, dominantly coated with a glossy, moderate yellow-brown to brown patina, most are 0.75 to 1.5 in. in diameter; a few sandstone boulders occur, the largest one observed was 3 ft in diameter; a few ellipsoidal to ovoidal milky quartz pebbles up to 0.75 in. in diameter are present; matrix is reddish brown to orangish brown silt and clay in various proportions; sand and silt lenses locally up to 4 ft thick near the top of the section, usually clayey, reddish brown, and some cross-bedding; a lens of light-gray clay up to 8 in. thick occurs in about the middle of the pit face over a distance of about 200 ft; iron hydroxides form liesegang-like cemented zones in various places in the gravel and sand lenses; occasionally very low angle and broad cross-bedding can be recognized in the gravel; the contact with the underlying sand is erosional as indicated by the abrupt change of material and the presence of reworked subangular to subrounded cobbles of iron hydroxide-cemented chert pebble conglomerate lying on the sharp contact.	20
Eocene Series	
Wilcox Formation	
Sand, fine- to coarse-grained; clean to moderately silty and clayey, often micaceous; in places the top 6 ft is heavily iron-stained to reddish brown; generally, the sand is white, light gray to yellowish gray or pale yellow-orange; upper contact with Mounds is very irregular with up to 6 ft of relief in pit area; contains some iron concretions 1 to 2 in. in diameter, some are elongated vertically resembling fossil burrows; heavy minerals apparent in places up to ~ 1 percent; generally horizontally bedded; some cross-bedded units average 6 in. thick; occasionally contains up to 10 percent pebbles, consisting of up to 0.5 in. diameter ellipsoidal to ovoidal, milky to pink to reddish brown, translucent quartz pebbles and up to 1 in. in diameter ellipsoidal to variably shaped, subangular, medium to dark gray, polished chert pebbles; grayish-orange (buff) clay balls up to 2 in. in diameter are also present; occasional clay beds range from minute laminae up to 6 ft thick locally within the pit area; they are very light yellowish to pinkish gray with some areas of stronger pinkish coloration.	40
Paleocene Series	
Porters Creek Formation	
Clay, light olive to medium gray, mottled with yellowish orange areas; plastic; non-calcareous.	10
Clay, massive; medium dark to dark gray; possibly bioturbated; firm; non-calcareous; slightly silty and micaceous; occasional sublaminar partings or lenses of silt as close as 0.25 to 0.5 in. apart; lower 40 ft contains scattered glauconite pellets, very thin lenses of very fine sand, and fine sand-sized disc-shaped amber crystals of siderite; clay is darker gray in lower 40 ft and has more abundant sublaminar mottled zones of slightly lighter gray.	90
Clayton Formation	
Clay, very dark greenish gray; slightly silty and micaceous, especially in thin laminations and lighter colored mottled areas; scattered glauconite pellets; moderately calcareous and fossiliferous; becomes sandy, more silty, and micaceous and non-calcareous with depth; clay becomes moderately light olive gray with mottled patches of dusky yellow and some sand beds with depth.	16
Cretaceous System	
Gulfian Series	
Owl Creek Formation	
Clay and sand, alternating beds, dominantly clay; clay is dark gray, silty, sandy, micaceous, beds up to 1 in. thick; sand is clayey to clean, moderate gray to very light gray, micaceous, beds up to 0.5 in. thick; glauconite pellets occur in both clay and sand; non-calcareous.	+14

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David L. Zierath, B.S., Assistant Chemist I
Sheri L. Crosswhite, B.A., Special Research Assistant
Kerry M. Riley, B.S., Special Research Assistant

Topographic mapping in cooperation with the United States Geological Survey.