Sturgis Formation (Upper Pennsylvanian), a New Map Unit in the Western Kentucky Coal Field

GEOLOGICAL SURVEY BULLETIN 1394-B

Work done in cooperation with the Kentucky Geological Survey

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By THOMAS M. KEHN

CONTRIBUTIONS TO STRATIGRAPHY

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A clarification and revision of the stratigraphic terminology and a description of the rocks of Late Pennsylvanian age

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STURGIS FORMATION (UPPER PENNSYLVANIAN), A NEW MAP UNIT IN THE WESTERN KENTUCKY COAL FIELD

By THOMAS M. KEHN

ABSTRACT

The Sturgis Formation is a new rock-stratigraphic unit which includes all Upper Pennsylvanian strata in the western Kentucky coal field. Geologic investigations reveal that the strata previously assigned to the Lisman and Henshaw Formations cannot be distinguished or mapped on the basis of lithologic differences; these names are abandoned. The Sturgis Formation consists of interbedded sandstone, siltstone, shale, limestone, and coal. It has a thickness of about 2,075 feet in a fault block in the Sturgis, Ky., area. The Providence Limestone, Anvil Rock Sandstone, Madisonville Limestone, and Carthage Limestone, all former members of the Lisman Formation, are retained as members of the Sturgis Formation. The Sturgis overlies the Carbondale Formation, and the contact between the formations is placed at the top of the No. 11 coal bed.

INTRODUCTION

Detailed geologic investigations in the Kentucky part of the Dekoven 7½-minute quadrangle and the Bordley and Sturgis 7½-minute quadrangles and reconnaissance studies in the Dixon 7½-minute quadrangle of the western Kentucky coal field reveal that the Lisman and Henshaw Formations of Late Pennsylvanian age are composed of similar lithologies and cannot be distinguished or mapped on the basis of lithologic differences. Therefore the rocks formerly assigned to these two units are here assigned to the Sturgis Formation, a new stratigraphic unit, and the names Lisman and Henshaw are abandoned. The Providence Limestone, Anvil Rock Sandstone, Madisonville Limestone, and Carthage Limestone, all former members of the Lisman Formation, are retained as members of the Sturgis Formation. A summary of the nomenclature is given in figure 1.

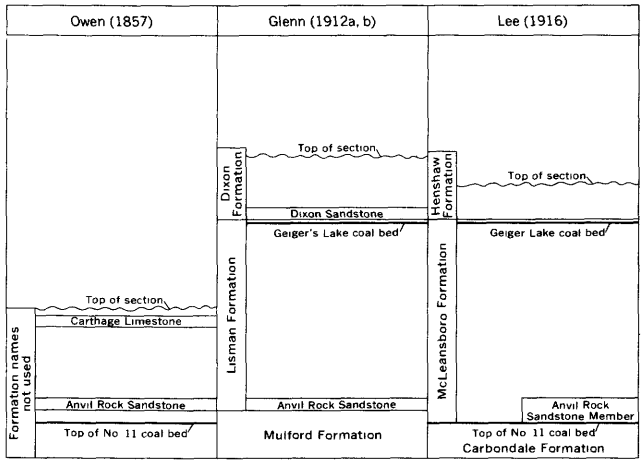


FIGURE 1.—Correlation chart showing the

This report is based in large measure on the areal geological mapping of Kentucky being conducted by the U.S. Geological Survey in cooperation with the Kentucky Geological Survey. The writer is grateful to the Peabody Coal Co. for releasing heretofore unpublished data on cores from the lower part of test holes drilled at the type locality of the Sturgis Formation.

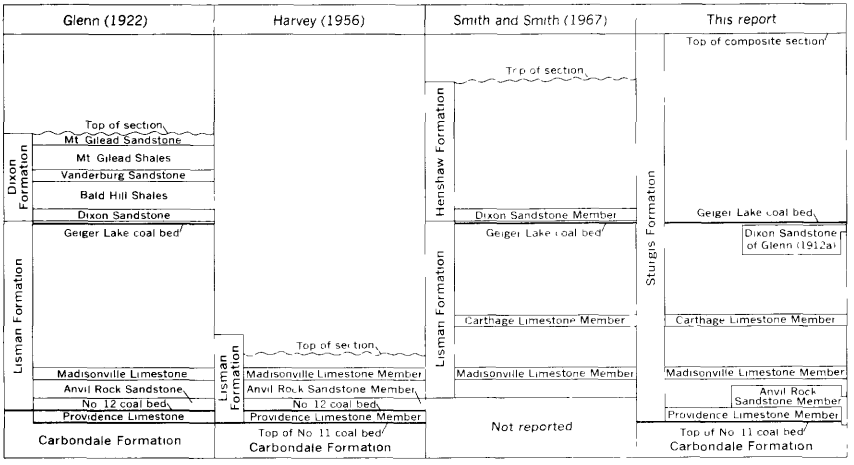
PREVIOUS NOMENCLATURE

LISMAN FORMATION

The name Lisman Formation was assigned by Glenn (1912a, p. 26) to a stratigraphic sequence of Upper Pennsylvania rocks consisting chiefly of soft, partly calcareous shale and some sandstone and thin limestone beds between the base of Owen's (1857) Anvil Rock Sandstone below and the base of a sandstone, the Dixon Sandstone of Glenn (1912a), at the top (fig. 1). Harvey (1956, p. 64) redefined the lower boundary as the top of the No. 11 coal bed of the Carbondale Formation, and this is now accepted as the base of the Sturgis Formation.

In the Kentucky part of the Shawneetown 15-minute quadrangle, rocks stratigraphically equivalent to the Lisman were identified by Lee (1916) as the McLeansboro Formation on the basis of correlation with the Pennsylvanian coal-bearing sequence in Illinois. The term McLeansboro Formation did not find wide acceptance in Kentucky and was eventually abandoned (Harvey, 1956, p. 64) in favor of the Lisman Formation.

A number of subunits of the Lisman Formation were recognized by earlier workers. Of these the Providence Limestone, Anvil Rock



nomenclature of this report and of earlier reports.

Sandstone, Madisonville Limestone, and Carthage Limestone are retained as members of the Sturgis Formation.

HENSHAW FORMATION

The Henshaw Formation was named by Lee (1916, p. 43) for rocks exposed in the vicinity of Henshaw, Union County, Ky., and included all strata of Pennsylvanian age above the base of a massive sandstone which occurs a few feet above the Geiger Lake coal bed. Lee (1916, p. 43) described the unit as consisting of interbedded sandstone, shale, and coal. Earlier, in nearby Webster County, Glenn (1912a) had designated a sequence, almost the homotaxial equivalent of the Henshaw, as the Dixon Formation and named the basal sandstone the Dixon Sandstone. But because the "Dixon" was preoccupied, the entire unit was renamed the Henshaw Formation by Lee. As reported by Glenn (1912b, p. 57) and as used by Glenn (1922) and Smith and Smith (1967), the Dixon Sandstone occurs only a few feet above the Geiger Lake coal bed in the Henshaw area.

Seemingly the massive sandstone above the Geiger Lake would be equivalent to Glenn's Dixon Sandstone, but this is not so. Geologic mapping and subsurface studies in the area between Dixon, Ky., the type locality of the Dixon Sandstone, and Henshaw, Ky. (fig. 2) show that the Geiger Lake coal bed of Lee is 60 to 70 feet above the Dixon Sandstone of Glenn.

Smith and Smith (1967, p. 11), who were unaware of the miscorrelation, proposed the term "Dixon Sandstone Member of the Henshaw Formation" to include the Dixon Sandstone of Glenn

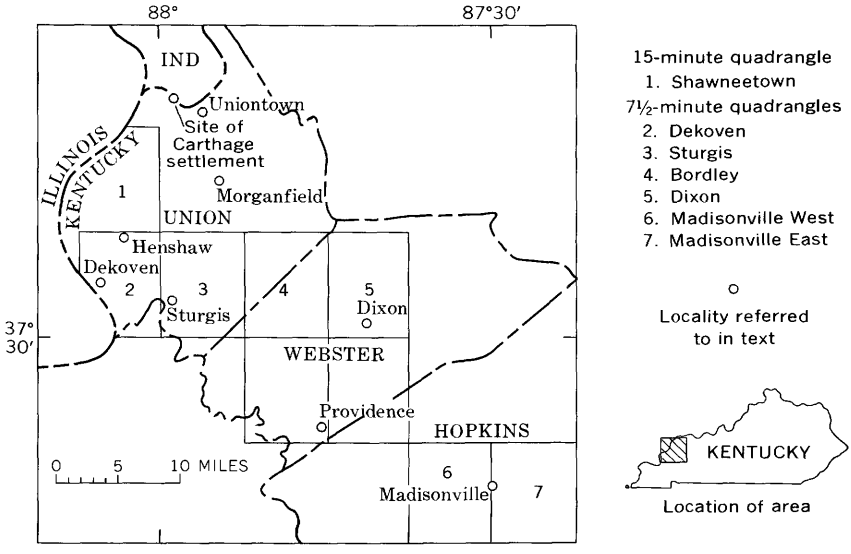


FIGURE 2.—Index map of part of the western Kentucky coal field showing localities and quadrangles referred to in this report.

and the massive sandstone above the Geiger Lake coal bed as described by Lee. From Dixon the sandstone appears to extend westward at least as far as the east boundary of the Bordley quadrangle (fig. 2); it has not been identified in the Henshaw area. Its extent in other directions is not known. Because of the foregoing and because the term "Dixon" is preoccupied, the Dixon Sandstone Member of Smith and Smith is not proposed as a member of the Sturgis Formation.

STURGIS FORMATION

Subsurface and outcrop data show that rocks previously assigned to the Lisman and Henshaw Formations consist of the same lithic types in equal proportion and similar stratigraphic distribution; hence, no criteria for differentiating the two units for mapping purposes could be found. Therefore, the two formations have been combined to form a new unit, the Sturgis Formation.

The Sturgis Formation is largely concealed by loess, alluvium, and colluvium, and no outcrop adequate for a type locality was found. Hence, the type area and composite section (fig. 3) of the formation is designated as two core holes drilled by the Peabody Coal Co. and stratigraphic test hole 1801 drilled by Cities Service Oil Co. at Camp Breckinridge about 3 miles northeast of hole

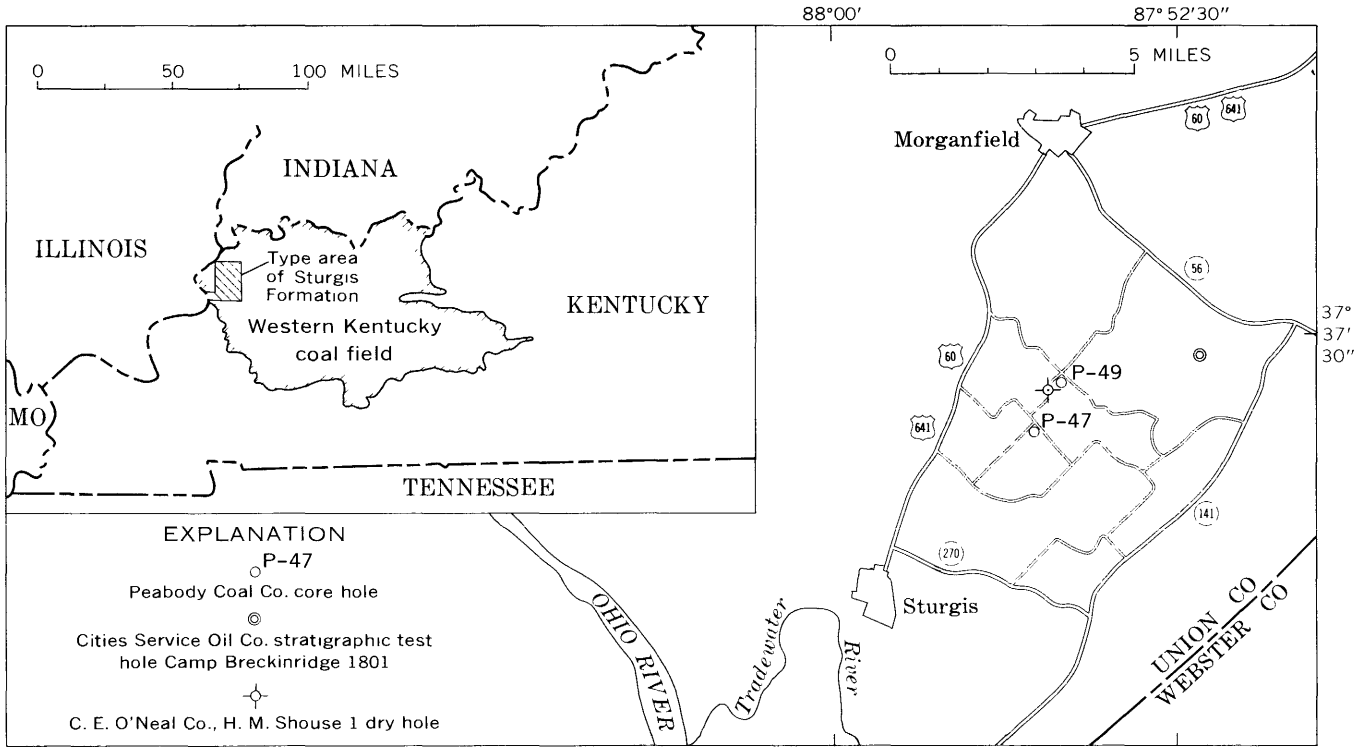


FIGURE 3.—Index map of the western Kentucky coal field and the type area of the Sturgis Formation showing the locations of the composite section core holes, oil test hole, and stratigraphic test hole.

P–49. The core holes, designated P–47 and P–49, are about 5 miles northeast of Sturgis, Union County, Ky., and are in the northeast part of the Sturgis quadrangle in Carter Coordinate section 21, N–19, and section 20, N–19. Hole P–49 is about 1 mile northeast of hole P–47 and is about 800 feet northeast of an oil test hole, C. E. O'Neal Co. H. M. Shouse 1 dry hole in Carter Coordinate section 20, N–19. (See page B11 for additional location data.)

Representative core samples from holes P–47 and P–49 are on file at the core library of the Illinois State Geological Survey, Urbana, Ill. Of the total section represented by the cores, Smith and Smith (1967, p. 14–25 and pl. 1) described 1,588 feet which they assigned to the Henshaw and Lisman Formations but here is reassigned to the Sturgis Formation. They correlated these rocks with the electric log of the C. E. O'Neal Co. H. M. Shouse 1 dry hole. Sixty feet of section below that described by Smith and Smith and also belonging to the Sturgis has been subsequently described by W. H. Smith (written commun., 1972) of the Illinois State Geological Survey. About 2,075 feet of the Sturgis Formation in a fault block in the Bordley 7½-minute quadrangle includes about 460 feet of stratigraphically higher strata than were described from cores P–47 and P–49. Four hundred and thirty-five feet of these younger strata was penetrated by the Cities Service Oil Co. stratigraphic test hole Camp Breckinridge 1801, about 3 miles east-northeast of hole P–49 and about 8 miles northeast of Sturgis, Ky. These strata and an additional 25 feet of younger strata poorly exposed in a nearby outcrop are proposed as a reference section. Descriptions of samples from the test hole and electric-log data are on file at the Kentucky Geological Survey in Henderson, Ky.

A modified description of the measured core sections P–47 and P–49 and a generalized description of the 460 feet of stratigraphically higher strata penetrated by Cities Service Oil Co. test hole 1801 is presented on page B11 of this report. The stratigraphic relations of these sections are shown in figure 4.

As determined from surface and subsurface investigations, the Sturgis Formation is composed of interbedded sandstone, siltstone, shale, limestone, and coal. Sandstone, the dominant rock type, makes up 30 to 50 percent of the formation. The sandstone is commonly light to dark gray, weathering to yellowish brown, and is fine to medium grained; locally, near the bottom of some channel-fill deposits, it is coarse grained and conglomeratic. Beds of sandstone are thin to very thick and massive; crossbedding, cut-and-fill structure, and channel deposits are common; some channel deposits are as much as 60 feet thick at places. Most of

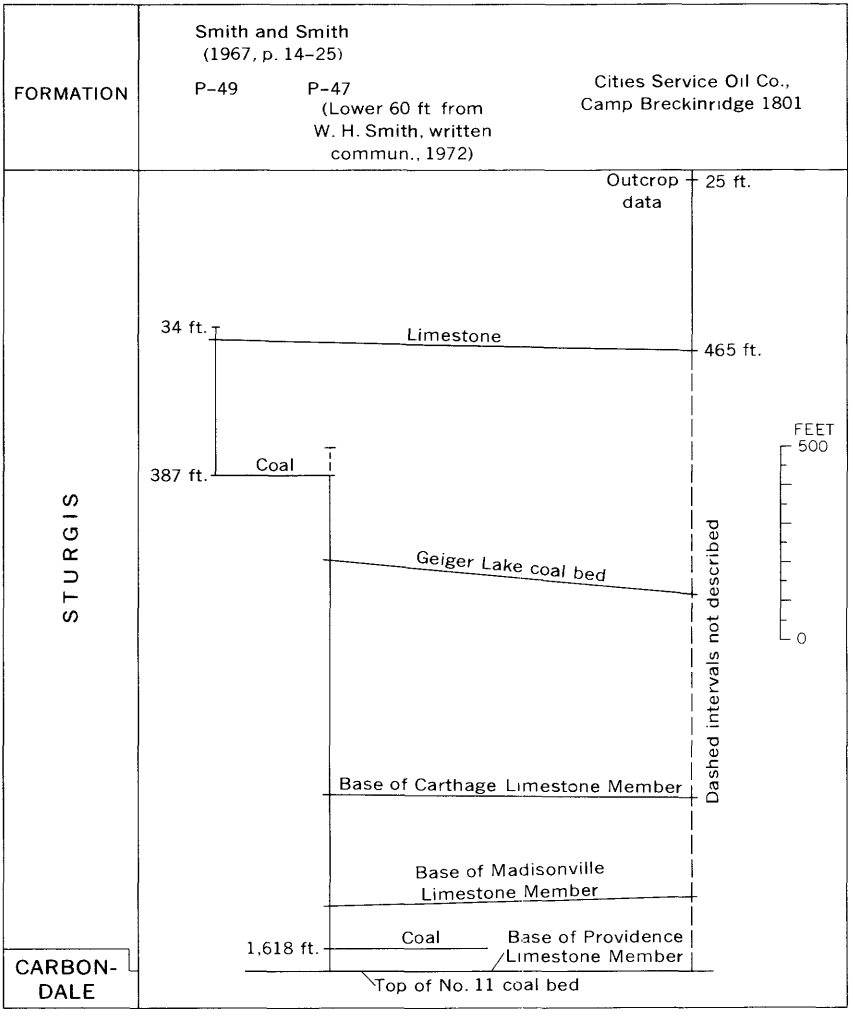


FIGURE 4.—Correlation of measured core sections P–47 and P–49 and of the rocks penetrated by the Cities Service Oil Co. stratigraphic test hole Camp Breckinridge 1801.

the sandstone is friable to moderately indurated, but locally it is well indurated and forms conspicuous cliffs as much as 20 feet high. In the west-central part of the western Kentucky coal field most hills are commonly capped by sandstone of the Sturgis Formation.

Siltstone makes up about 30 to 40 percent of the Sturgis. When fresh, the rock is light to dark gray; it weathers to yellowish brown or grayish brown. Most siltstone is in even to wavy beds

½ to 4 inches thick, but locally the beds appear contorted. The siltstone is limy and fossiliferous where it grades into or is interbedded with limestone. The siltstone is generally interbedded with or grades laterally into sandstone and shale.

Shale makes up about 20 to 30 percent of the Sturgis. Most of the shale is medium gray to black and weathers to yellowish brown or yellowish gray. It is poorly to well laminated and generally is very micaceous on bedding surfaces. The shale is carbonaceous and contains plant fossil fragments where associated with coal beds or coaly zones. Marine fossils, chiefly brachiopods and crinoids, are common only where the shale is interbedded with limestone. White to medium-gray clayey shale is generally present below coal beds and coaly zones and locally is interbedded with limestone.

Limestone makes up less than 5 percent of the formation. The limestone is generally light to dark gray and weathers light gray to yellowish brown. It ranges from very fine to coarse grained but is mostly very fine to fine grained and generally is reported as "dense" on drill-hole logs. The limestone is mostly in even to wavy beds ½ to 12 inches thick, but beds as much as 10 feet thick are locally present in the Carthage Limestone Member. Fossils, chiefly brachiopods and crinoid fragments, are common in many limestone beds.

Coal is generally a minor constituent of the Sturgis Formation. Most coal is thin, ranging from very thin laminations to beds 18 inches thick. However, the Nos. 12, 13, and 14 coal beds are locally very thick, and the No. 14 coal bed is reported to be more than 12 feet thick in some drill-hole logs.

The thickness of the Sturgis Formation represented by the sections at the type locality is 1,678 feet and at the reference section is 2,075 feet. In the Sturgis quadrangle, approximately 1 mile west of the reference section and in the same fault block, the formation is at least 2,650 feet thick (Kehn, unpub. data). The total thickness of the formation is not known because the upper part has everywhere been removed by erosion.

PROVIDENCE LIMESTONE MEMBER

The Providence Limestone Member was named by Glenn (1922, p. 98) from exposures at Providence, Ky. He described it as occurring between the No. 11 and No. 12 coal beds and as consisting of an argillaceous, impure, and irregularly bedded limestone that locally contains a shale parting a few inches to a few feet thick. Recent studies of numerous drill-hole records in the western Kentucky coal field have shown that Glenn's No. 12 coal bed at Providence is actually the No. 13 coal bed; therefore the Provi-

dence includes all limestone beds between the No. 11 and No. 13 coal beds.

In core hole P–47 the Providence Limestone Member comprises about 33 feet of strata, extending from the base of the limestone bed above the No. 11 coal bed to the top of the limestone bed a few feet below the No. 13 coal bed. In the Providence area, Kentucky, and elsewhere in the western Kentucky coal field, the member includes as many as four limestone beds separated by light- to dark-gray clayey shale and, locally, thin lenses of sandstone. At places, the No. 12 coal bed, which is generally thin and locally discontinuous, occurs just above the lowest limestone bed. The Providence Limestone Member is poorly exposed except in highwalls of strip mines on the No. 11 coal bed.

ANVIL ROCK SANDSTONE MEMBER

The Anvil Rock Sandstone was named by Owen (1856, p. 45) for a massive-bedded sandstone exposed in a bluff known as Anvil Rock west of Dekoven, Ky. The unit was later formally given the rank of member and assigned to the Lisman Formation by Harvey (1956, p. 65). It consists of reddish-brown to yellowish-brown crossbedded fine- to coarse-grained sandstone that contains a few white quartz pebbles as much as ¼ inch in diameter. At Anvil Rock the sandstone rests unconformably on the No. 11 coal bed, and the lower 2 to 3 feet consists of a residuum of shale chips and coarse sand in an "earthy" limonitic matrix. The Anvil Rock Sandstone Member has a maximum thickness of about 110 feet in the Dekoven quadrangle where it was deposited in a channel that had a steep west bank and a gentle east bank. Channel-fill sandstone deposits of the Anvil Rock Sandstone Member have been reported by Harvey (1956), Hopkins (1958), and Potter and Simon (1961). Hopkins (1958) recognized a thin widespread "sheet phase" of the Anvil Rock in southern Illinois and parts of southern Indiana and western Kentucky. In the Dekoven quadrangle Kehn (1973) restricts the name Anvil Rock Sandstone Member to the channel-fill deposit entirely within the bounds of the quadrangle; other relatively thin, lenticular sandstones in about the same stratigraphic interval may or may not be time-stratigraphic or homotaxial equivalents.

MADISONVILLE LIMESTONE MEMBER

The Madisonville Limestone Member was named by Norwood (1878, p. 319–320) for exposures in Madisonville, Hopkins County, Ky. He reported about 4 feet of massive light-brown to light-gray fossiliferous limestone about 80 feet above the No. 11 coal bed. The

name was adopted by the U.S. Geological Survey (Harvey, 1956) as the Madisonville Limestone Member of the Lisman Formation.

In the type area the member includes limestone, claystone, shale, sandstone, and coal (Kehn, 1963 and 1964). The limestone is light to medium gray, very finely to coarsely crystalline, and locally fossiliferous (mostly brachiopods and crinoid plates). Weathered surfaces are light brown to light gray. Claystone is light to medium gray and locally contains small nodules of hematite. Shale is light gray to black and is locally coaly. Sandstone is fine to medium grained, micaceous, and thin to thick bedded. In the vicinity of Madisonville the member is about 200 feet above the base of the Sturgis Formation, rather than 80 feet as reported by Norwood, is as much as 50 feet thick, and contains as many as four limestone beds that range in thickness from 0 to 5 feet (Kehn, 1963 and 1964). In core hole P–47 only one bed of limestone is present. The Madisonville Limestone Member is generally poorly exposed owing to a cover by surficial deposits. Best exposures are in highwalls of strip mines on the No. 14 coal bed.

CARTHAGE LIMESTONE MEMBER

The Carthage Limestone was named by Owen (1856, p. 60–61) for exposures on the bank of the Ohio River at the site of Carthage settlement, about 1 mile below Uniontown, Union County, Ky. The unit was proposed as the Carthage Limestone Member of the Lisman Formation by Smith and Smith (1967).

The member generally ranges from 2 to 5 feet in thickness, but in some drill-hole logs it is reported to be as much as 10 feet thick. It commonly consists of one bed, but on a few logs it is reported as two limestone beds. The limestone is regionally persistent but locally is absent owing to nondeposition or erosion. Owing to weathering and thinness, the bed is seldom seen on outcrop. In core hole P–47 the member is about 465 feet above the base of the Sturgis Formation.

CONTACTS

The Sturgis Formation overlies the Carbondale Formation (Middle Pennsylvanian) with which it intergrades. The Carbondale, as is the Sturgis, is composed of interbedded sandstone, siltstone, shale, limestone, and coal, but in general limestone beds of the Carbondale are fewer and thinner and have smaller areal extent, and coal beds are more numerous and thicker and have greater areal extent.

The zone of intergradation between the two units is wide and

because of poor exposure is difficult to locate. Hence, for convenience of mapping, the contact is placed at the base of the Providence Limestone Member, which at some places rests directly on the No. 11 coal bed of the Carbondale Formation but at other places is as much as 5 feet above the No. 11. The Providence and the No. 11 coal bed in close proximity form a zone that is easily recognized. Recognition is further facilitated by the presence of a persistent thin shale parting, commonly referred to as the blue band, in the lower half of the No. 11 coal bed.

The upper limit of the Sturgis Formation is not defined because the upper part of the formation has everywhere been removed by erosion.

LOCATION OF DRILL HOLES
(fig. 3)

Hole P–47, 200 ft from N. line and 2,300 ft from W. line of Carter Coordinate section 21, N–19, or 9,350 ft from north boundary and 14,650 ft from east boundary of the Sturgis 7½-minute quadrangle, Union County, Ky. Surface elevation 375 ft above mean sea level.

Hole P–49, 1,800 ft from N. line and 600 ft from E. line of Carter Coordinate section 20, N–19, or 4,900 ft from north boundary and 12,700 ft from east boundary of Sturgis 7½-minute quadrangle, Union County, Ky. Surface elevation 410 ft above mean sea level.

Oil test hole—C. E. O'Neal Co. H. M. Shouse 1 dry hole, 2,300 ft from N. line and 1,100 ft from E. line of Carter Coordinate section 20, N–19, or 5,450 ft from north boundary and 13,200 ft from east boundary of Sturgis 7½-minute quadrangle, Union County, Ky. Surface elevation 413 ft above mean sea level. Electric-log datum 415 ft above mean sea level.

Stratigraphic test hole—Cities Service Oil Co. stratigraphic test hole Camp Breckinridge 1801, 700 ft from S. line and 600 ft from W. line of Carter Coordinate section 12, N–20, or 2,150 ft from north boundary and 3,150 ft from west boundary of Bordley 7½-minute quadrangle, Union and Webster Counties, Ky. Surface elevation 520 ft above mean sea level. Driller's log and mechanical electric-log datum 526 ft above mean sea level.

SECTIONS OF THE STURGIS FORMATION

UPPER SECTION

This section includes 460 feet of strata younger than that described from core holes P–47 and P–49. Lithologies are based on descriptions of samples from Cities Service Oil Co. stratigraphic test hole Camp Breckinridge 1801 and on outcrop data.

Pennsylvanian System—Sturgis Formation (in part):	*Depth (feet)*
Surface, includes loess, soil, and weathered bedrock	0–5
Sandstone and siltstone, micaceous, weathered; very poorly exposed; reported as siltstone in sample log	5–65
Siltstone and sandstone, micaceous	65–119

Pennsylvanian System—Sturgis Formation (in part)—Continued	Depth (feet)
Limestone, brown, dense	119–121
Shale, medium-gray	121–133
Limestone, brown, dense	133–137
Shale, dark-gray to brown	137–146
Sandstone, light-gray, very fine grained, micaceous	146–158
Shale, dark-gray, silty, locally carbonaceous	158–185
Coal and carbonaceous shale	185–186
Sandstone, light-gray, very fine grained, silty and shaly	186–197
Shale and siltstone, light- to dark-gray, micaceous, sandy; shale locally coaly	197–226
Sandstone, light-gray, very fine grained, micaceous; includes some thin beds of shale and siltstone	226–260
Shale, medium-gray to black, coaly. Coal prospect pits about 1,500 feet southeast of well site caved, estimated thickness 2 ft. Probably correlative to coal, near base, of this unit	260–270
Limestone, tan, finely crystalline, dense	270–275
Shale and siltstone, light- to dark-gray, micaceous; thin bed of limestone reported in middle of unit	275–315
Limestone, brown, dense	315–320
Shale and siltstone, light- to dark-gray	320–340
Sandstone, white, very fine grained	340–345
Shale and siltstone, light- to dark-gray, micaceous; shale contains siderite pellets	345–375
Coal and carbonaceous shale	375–400
Shale and siltstone, light- to dark-gray, micaceous	400–425
Sandstone, light-gray, very fine grained	425–438
Siltstone and shale, medium-gray to black, carbonaceous at base	438–460
Limestone, light-gray, dense (stratigraphically equivalent to limestone at about 31 to 34 ft in core hole P–49 (Smith and Smith, 1967, p. 14; fig. 4, this report))	460–465

MIDDLE SECTION

A modified log description of about 1,618 feet of the Sturgis Formation penetrated by holes P–47 and P–49 of the Peabody Coal Co. has been made from the detailed log descriptions by Smith and Smith (1967, p. 14–25). The description from 0 to 387 feet is from the core description of hole P–49, and that from 387 to 1,618 feet is from the core description of hole P–47.

Pennsylvanian System—Sturgis Formation (in part):	Depth (feet)
No data, started to core at depth of 30 ft	0–30
Shale, medium-gray, slightly silty, calcareous, ostracodes, carbonized plant fragments	30–31
Limestone, medium-gray at top and light-olive-gray at base, dense; about 1 ft silty fossiliferous medium-gray shale 3 in. below top; unit is stratigraphically equivalent to that	

Pennsylvanian System—Sturgis Formation (in part)—Continued	Depth (feet)
between depths of 435 and 440 ft (labeled 465 ft on fig. 4) in the Cities Service test hole	31–34
Claystone, medium-gray, slightly silty, relatively hard but crumbly; scattered limestone nodules as much as 2 in. thick; carbonaceous shale near top and base	34–39
Limestone, light-olive-gray to medium-gray; argillaceous, dense; contains greenish-gray clay matrix	39–49
Claystone, light-greenish-gray, very soft, crumbly; abundant limestone nodules	49–56
Siltstone, light-greenish-gray, slightly argillaceous; calcareous nodule zone 3 ft below top	56–63
Sandstone, light-gray, fine-grained, in beds mostly 6 in. to 2 ft thick; bottom 10 ft coarser and contains carbonaceous micaceous laminae on bedding planes; in sharp contact with 4-in.-thick coal bed at base	63–93
Claystone, medium-gray, very friable	93–95
Siltstone, medium-light-gray; about 50 percent interbedded light-gray sandstone	95–98
Sandstone, light-gray, fine- to medium-grained, in beds as much as 2 ft thick; thin irregular coaly laminae and scattered coaly bands as much as ¾ in. thick	98–152
Claystone, medium-gray, silty; small dark limestone nodules in lower part; 7-in.-thick coal bed at top	152–156
Siltstone, medium-gray, argillaceous, hackly fracture; scattered limestone nodules	156–164
Sandstone, light-gray, fine-grained, interbedded with about 30 percent siltstone similar to above	164–167
Shale, medium-dark-gray, clayey to silty; brownish-orange sideritic veinlets and crack fillings	167–169
Shale, brownish-orange, silty, poorly bedded; sideritic veinlets and crack fillings	169–170
Sandstone, light-gray, thinly laminated; scattered calcareous nodules	170–171
Siltstone, medium-gray, fairly well laminated	171–172
Claystone, medium-gray, very soft; abundant small limestone pellets, granular siderite, and scattered dark sideritic masses	172–176
Siltstone, medium-gray, slight greenish-gray cast, poorly bedded; argillaceous; limestone nodules	176–183
Sandstone, light-gray, fine-grained, and about 30 percent interlaminated siltstone, as above	183–185
Shale, medium-gray, thinly laminated; medium-gray siltstone at base	185–188
Limestone, light-olive-gray to medium-dark-gray; greenish-gray claystone matrix; massively bedded, hard, dense; fossiliferous, contains brachiopods, pelecypods, crinoids	188–193
Shale, medium-dark-gray, very silty, well-laminated	193–194
Siltstone, medium-dark-gray; contains laminae and lenses of fine-grained, light-gray sandstone	194–200

Pennsylvanian System—Sturgis Formation (in part)—Continued	Depth (feet)
Siltstone, medium-gray; thinly interbedded and interlaminated with medium-dark-gray shale; scattered interlaminations of fine-grained, light-gray sandstone	200–220
Shale, medium-gray; interbedded with shaly siltstone and scattered interlaminations of fine-grained, light-gray sandstone	220–244
Shale, medium- to dark-gray, fissile	244–255
Limestone, medium-gray, very fossiliferous, contains brachiopods, crinoids, and 50 percent interbedded dark-gray shale	255–258
Claystone, medium-gray, very crumbly; small limestone nodules in lower 1 ft	258–262
Limestone, medium-gray, brecciated; traversed by calcite veinlets	262–263
Claystone, medium-gray, few limestone and sideritic nodules, poorly bedded; bottom 3 in. contains argillaceous limestone and siderite nodules	263–270
Shale, medium-gray, fissile; several dark-gray carbonaceous laminae in bottom 1 ft with 1½-in.-thick coal bed at base	270–281
Claystone, medium-dark-gray, hard, pyritic, slightly silty; contains poorly preserved plant rootlets at top	281–283
Claystone, greenish-gray; top 1 ft limy—almost a very argillaceous limestone; contains small granules and scattered nodules of light- to medium-gray limestone	283–287
Siltstone, medium-gray, argillaceous; contains nodules, masses, and veinlets of brownish-gray limestone and siderite	287–290
Sandstone, light-gray, fine-grained, and 35 percent thinly laminated shale	290–295
Shale, medium- to dark-gray; few siderite nodules; thin beds of fine-grained sandstone	295–329
Limestone, medium-gray, shaly, very fossiliferous with brachiopods, crinoids, corals	329–331
Shale, black, fissile, hard; 4-in.-thick coal bed at base	331–333
Shale, medium- to dark-gray; abundant carbonized plant stem impressions; silty toward base	333–335
Sandstone, light-gray, fine-grained, and interbedded with about 10 percent siltstone; contains coal shale in lowest 1 ft	335–345
Siltstone, medium-gray; interlaminations of sandstone	345–350
Shale, medium-dark-gray, laminated; scattered siderite nodules and lenses	350–370
Shale, medium-dark-gray, very fissile; abundant siderite bands and nodules	370–386
Shale, medium-dark-gray; very fossiliferous, contains numerous pectinaceans. Coal bed, 2½ in. thick, at base is stratigraphic equivalent of 2¾-in.-thick coal at depth of 67 ft 9½ in. of core P–47, described by Smith and Smith (1967, p. 17)	386–387

Pennsylvanian System—Sturgis Formation (in part)—Continued	Depth (feet)
Claystone and shale, medium-gray, carbonaceous, very silty in part	387–389
Limestone interbedded with about 30 percent shale; limestone, light-olive-gray to yellowish-gray, is light brownish gray in middle and at base; dense; abundant ostracodes throughout. Shale, medium-gray, silty, very clayey, calcareous	389–392
Claystone, medium-gray, calcareous; silty in lower part	392–395
Siltstone, light-gray, very calcareous throughout, thinly laminated; thin partings of shale	395–400
Shale, medium-gray, very silty in top 1 ft, becomes slightly silty with depth, well-laminated; carbonized plant fragments	400–410
Shale, medium-dark-gray, smooth, fissile	410–411
Coal, bright, banded	411–412
Shale, medium-dark-gray, clayey to silty, scattered carbonized plant impressions	412–415
Siltstone, light- to medium-gray	415–416
Shale, medium-gray; conspicuous carbonized plant impressions, numerous ostracodes; thin coal laminae in top 1 ft	416–427
Siltstone, light-gray, and about 20 percent thin interlaminations of silty medium- and dark-gray shale	427–431
Sandstone, light-gray, fine-grained, thick-bedded, cross-bedded in zones; abundant coarse mica and carbonaceous debris on bedding planes; a few ½- to 3-in.-thick beds of siltstone in top 5 ft; ½-in.-thick coal bed at base	431–450
Sandstone, medium- to fine-grained; abundant coarse mica	450–454
Sandstone, fine-grained; top 1 ft contains a few sideritic lenses and pebbles; ½-in.-thick coaly band 1 ft above base; several ¼-in.-thick shale lenses scattered throughout	454–472
Sandstone, light-gray, fine-grained, very thinly and irregularly interlaminated with about 15 percent medium-dark-gray shale and siltstone	472–481
Shale, medium-dark-gray, hard; thin interlaminations of light-gray siltstone	481–488
Shale, dark-gray; numerous fossils including brachiopods and pelecypods; contains three 1-in.-thick fossiliferous limestone lenses	488–492
Shale, dark-gray, fissile	492–495
Claystone, medium-gray, highly calcareous; contains abundant pellets and small nodules of very light gray limestone; 2½-in.-thick light-gray limestone bed at top	495–505
Siltstone, light-gray, calcareous, thinly laminated with about 15 percent medium-gray shale	505–511
Shale, medium-gray, interlaminated with siltstone	511–525
Shale, dark-gray, clayey, laminated, thin lenses and nodules of siderite; lower 3 ft contains scattered pelecypods and ostracodes	525–530

Pennsylvanian System—Sturgis Formation (in part)—Continued	Depth (feet)
Coal, bright, banded	530–531
Claystone, medium-dark-gray, very crumbly; calcareous and contains limestone pellets	531–534
Siltstone, light-gray, clayey and calcareous, moderately hard, some interbedded shale in lower part	534–539
Claystone, light-gray, silty, faintly laminated; siderite in veinlets; 3-in.-thick carbonaceous shale bed at base	539–541
Siltstone, light-gray, and 10 to 20 percent interlaminated medium-gray shale; siderite nodules and veinlets	541–553
Sandstone, light-gray, fine-grained; top 5 ft thick bedded; lower part thin bedded and interbedded with siltstone	553–562
Siltstone, medium-gray	562–570
Shale, medium-dark-gray, silty at top; moderately hard, well laminated, siderite streaks in lower part; lower 2 ft contains scattered pelecypods, ostracodes, and fish scales; 8½-in.-thick coal bed at base	570–574
Shale, medium-dark-gray, with interlaminations of siltstone	574–576
Siltstone, medium-gray, and interbedded fine-grained, light-gray sandstone	576–581
Shale, medium-gray, medium-gray siltstone, and light-gray sandstone; irregularly and thinly interbedded in about equal amounts	581–586
Siltstone, medium-gray, and light-gray sandstone, irregularly interbedded	586–597
Shale, medium-dark-gray, slightly silty, relatively hard, well-laminated	597–602
Limestone, abundant white pellets and irregular limestone masses in dark-gray claystone matrix; fossiliferous	602–603
Claystone, medium-gray, crumbly; white limestone nodules at base	603–604
Siltstone, light-gray, rather soft; argillaceous; calcareous in top 3 ft, well bedded, thinly laminated; lower part contains about 50 percent fine-grained, light-gray sandstone	604–624
Siltstone, medium-gray, with about 10 percent thin interlaminations of light-gray, fine-grained sandstone	624–631
Siltstone, medium-gray, and thinly interlaminated light-gray sandstone, in about equal proportions	631–657
Sandstone, fine-grained, in beds 3 to 8 in. thick; sharp contact with underlying coal	657–665
Coal (Geiger Lake coal bed), bright, somewhat bony to shaly	665–666
Claystone, medium-gray, moderately hard; few carbonized plant impressions; small white limestone nodules in lower part	666–669
Limestone, light-gray, hard, dense; sublithographic to finely crystalline texture; contains a few clay bands in lowest 10 in.	669–672

Pennsylvanian System—Sturgis Formation (in part)—Continued	Depth (feet)
Claystone, medium-gray with greenish cast, very crumbly; weak shaly bedding; contains much siderite as granules and veinlets	672–675
Shale, medium-gray, slightly silty, relatively hard; contains a few thin beds of siltstone	675–684
Shale, medium-dark-gray, well-laminated	684–694
Shale, medium-gray, slightly silty throughout, well-laminated, uniform; from 704 to 708 ft silty beds as much as 8 in. thick, contain slump structures	694–728
Shale, dark-gray to black; sideritic bands; marine fossils; 1¾-in.-thick coal bed and coaly shale, 7 in. above base, and 1½-in.-thick coal bed and coaly shale at base	728–733
Claystone, medium-gray, very smooth, slickensides; abundant well-preserved plant impressions	733–734
Siltstone, medium-gray; contains poorly preserved root impressions and coprolites	734-735
Siltstone, medium-gray, in fairly uniform beds ½ to 2 in. thick	735–738
Sandstone, light-gray, fine-grained, in beds as much as 2 ft thick; some laminae of medium-gray shale or siltstone	738–770
Siltstone, medium-gray, shaly; several 1- to 3-in.-thick sandstone beds, a few sandstone- and shale-pebble conglomerate beds that contain coaly bands	770–774
Shale, medium-gray, relatively clayey, fairly soft; bedding inclined about 30°; angular unconformity at base	774–776
Sandstone, light- to medium-gray, fine-grained; 1-in.-thick zone at base contains pebbles and lenses of shale	776–777
Shale, medium-dark-gray to black, carbonaceous	777–778
Coal, bright, banded	778–779
Shale, medium-gray, hard, clayey, moderately laminated; 19-in.-thick coal bed and coaly shale at base	779–783
Sandstone, dark-gray, fine-grained; carbonaceous, argillaceous, light-gray and calcareous in bottom 4 in	783–784
Claystone, very faintly laminated, silty; abundant pellets and irregular masses of light- to dark-gray limestone as much as 1 in. in diameter	784–787
Siltstone, very argillaceous, calcareous; pellets and irregular masses of light- to dark-gray limestone constitute about 10 percent of unit	787–790
Coal, bony; 5 in. of medium-gray to black shale at top	790–791
Claystone, medium-gray, very calcareous, crumbly; at base, 6 in. of very argillaceous light-gray limestone containing darker gray nodules	791–798
Claystone, silty; moderately soft, faintly laminated; moderately abundant granular siderite and some finely disseminated pyrite	798–804
Limestone, light-gray, very impure; very silty in lower part, shaly near top	804–805

Pennsylvanian System—Sturgis Formation (in part)—Continued	Depth (feet)
Sandstone, light-gray, very fine grained, calcareous, and irregular thin beds of medium-gray siltstone	805–808
Shale, siltstone, and sandstone, interlaminated; medium-gray shale is about 50 percent of unit	808–812
Siltstone, medium-dark-gray, shaly; contains moderately abundant plant impressions, carbonaceous debris, and coal bands in bottom 8 in.	812–814
Claystone, medium-gray, silty, poorly bedded	814–815
Siltstone, medium-dark-gray, and shale, medium-dark-gray; interbedded and interlaminated	815–824
Shale, medium-dark-gray, silty at top, becomes more clayey with depth, relatively hard, well-laminated; widely scattered pelecypods	824–856
Limestone, light-olive-gray, dense, hard, highly fossiliferous; siltstone conglomerate at base	856–857
Siltstone, medium-gray, and medium-gray shale, thinly interlaminated; contains abundant granular siderite; bottom 1½ ft interlaminated with about 50 percent light-gray sandstone	857–861
Sandstone, light-gray, fine-grained, in beds 8 to 12 in. thick; a few shale laminae	861–874
Shale, dark-gray; bottom 2 ft is well laminated; top part contains about 10 percent light-gray siltstone	874–882
Limestone, light-olive-gray, fossiliferous, crinoidal, somewhat sandy; a single bed in sharp contact with shale below	882–885
Shale, dark-gray, well-laminated; contains thin interlaminations of light-gray siltstone; 50 percent siltstone in lower 1 ft; 8-in.-thick fossiliferous shale and siderite nodule and shale-pebble conglomerate about 6 ft below top	885–897
Sandstone, light-gray, fine-grained, irregularly interbedded with about 25 percent siltstone	897–909
Siltstone, medium-gray, in beds 6 in. to 2 ft thick	909–914
Siltstone, similar to above; beds of shale 4 in. to 1 ft thick	914–924
Shale, medium-dark-gray; medium-gray siltstone in 4- to 18-in.-thick beds make up about 25 percent of unit	924–944
Shale, medium-dark-gray, and 10 to 20 percent interlaminated light-gray siltstone	944–1,015
Shale, grayish-black, smooth, hard, fissile; few siderite nodules; fossiliferous, contains pectinaceans and ostracodes	1,015–1,021
Shale, dark-gray; abundant shell fragments	1,021–1,023
Claystone, light-gray, crumbly; contains small limestone pellets in lower 1 ft; 6 in. bright banded coal at top of unit (Lisman coal bed)	1,023–1,025
Limestone, medium-gray to grayish-yellow with darker gray pellets and nodules; 50 percent light-gray claystone in top 8 in.	1,025–1,027
Claystone, medium-gray, crumbly; contains limestone pellets and nodules; grades into very clayey, calcareous, sideritic, medium-gray siltstone	1,027–1,030

Pennsylvanian System—Sturgis Formation (in part)—Continued	Depth (feet)
Sandstone, light-gray, very fine grained, calcareous; about 10 percent siltstone	1,030–1,033
Sandstone, siltstone, and shale, irregularly interbedded; sandstone, light-gray, very fine grained; siltstone, medium-gray; shale, medium-dark-gray; upper part is principally sandstone and siltstone	1,033–1,064
Shale, medium-dark-gray, very silty, and about 20 percent laminae of siltstone and light-gray sandstone	1,064–1,101
Claystone, medium-gray, crumbly, and grainy; a few very small limestone pellets; 3-in. medium-gray shale at base; 2-in. bright coal at top	1,101–1,107
Limestone, grayish-yellow; about 50 percent shale in lower 4 in	1,107–1,108
Shale, medium-gray, silty, relatively soft; contains several thin beds of siltstone and light-gray, calcareous, fine-grained sandstone	1,108–1,111
Shale, medium-dark-gray, clayey, fissile; a few siderite bands	1,111–1,113
Shale, siltstone, and sandstone, interlaminated; mostly medium-dark-gray shale with lenses and thin beds of light-gray, very fine grained sandstone and medium-gray siltstone	1,113–1,134
Shale, dark-gray, clayey, fissile	1,134–1,136
Coal (No. 18 coal bed), bright, banded; shaly zone 2 to 4 in. below top	1,136–1,137
Claystone, medium-gray, chippy, and crumbly	1,137–1,138
Shale, medium-gray, silty, with laminae and thin beds of siltstone; top 1 ft very soft and clayey; contains siderite bands and lenses	1,138–1,146
Shale, medium-dark-gray, slightly silty, fissile, strongly jointed; a conspicuous 2-in.-thick fossiliferous clay or ironstone band containing crinoids and shell fossils 11 in. above base; a few minute fossils were observed in the shale above and below the more fossiliferous band	1,146–1,153
Coal, bright, banded	1,153–1,154
Claystone, medium-gray, silty; scattered limestone nodules; about 8 in. of very argillaceous medium-gray and grayish-yellow limestone 1 ft below top	1,154–1,157
Siltstone, medium-gray; laminae and a few thin beds of light-gray, very fine grained sandstone; top 5 ft contains a few shaly zones and is argillaceous and soft near top	1,157–1,176
Sandstone, light-gray, fine-grained, in beds mostly 2 to 6 in. thick; minor amounts of shale in streaks and thin laminae; contains a ¾-in.-thick coaly band at 1,183 ft and carbonaceous and coaly laminae in a 3-in.-thick zone at 1,197 ft	1,176–1,205
Shale, medium-gray, silty, well-laminated; no fossils observed; sharp contact with limestone below	1,205–1,206
Limestone (Carthage Limestone Member), light-olive-gray, very dense, wavy bedding; fossiliferous, abundant con-	

Pennsylvanian System—Sturgis Formation (in part)—Continued	Depth (feet)
spicuous crinoid stem segments; top 3 in. a conglomerate of shells and siderite nodules in a dark-gray shale matrix	1,206–1,213
Shale, dark-gray, dense, fissile	1,213–1,215
Coal (No. 17 coal bed), bright, banded; coal fragments as much as ½ in. thick were recovered. Driller's log reports 12 in. of coal	1,215–1,216
Claystone, medium-gray, crumbly; limestone pellets and nodules as much as 1 in. in diameter in basal 1 ft	1,216–1,219
Claystone, siltstone, and limestone; top 4 in., a 4-in.-thick zone near the middle, and the bottom 3 in. are medium-gray to grayish-yellow nodular limestone containing a lacelike network of calcite crack fillings with about 25 percent claystone matrix; remainder of unit is claystone and siltstone with minor amounts of limestone	1,219–1,224
Sandstone and siltstone, light-gray, and shale, medium-gray, interbedded and interlaminated; upper 6 ft is about 50 percent sandstone and 50 percent siltstone; lower part is 30 percent sandstone and 70 percent shale	1,224–1,234
Shale, medium-gray; silty at top, abundant laminae of light-gray siltstone; becomes finer and more fissile downward	1,234–1,241
Shale, medium-dark-gray, relatively smooth, thinly laminated; siderite bands and nodules	1,241–1,244
Shale, dark-gray, very thinly laminated; contains scattered pelecypods and ostracodes	1,244–1,250
Coal (No. 16 coal bed), somewhat shaly, bright, banded; no underclay or seat earth at base of coal	1,250–1,251
Sandstone, light-gray, very fine grained, thinly interlaminated with about 50 percent medium-gray siltstone and medium-dark-gray shale	1,251–1,262
Siltstone, medium-gray, and medium-dark-gray shale; about 5 to 10 percent light-gray sandstone laminae; more shaly in lower part	1,262–1,284
Shale, medium-dark-gray, silty in upper part, well-laminated; becomes finer grained and darker downward; scattered fossils in lower part	1,284–1,315
Shale, medium-dark-gray to black; dense; small fossils, some pyritized; very limy at top	1,315–1,324
Shale, medium-dark-gray, silty; sparingly fossiliferous	1,324–1,331
Claystone, medium-gray, crumbly; small limestone pellets	1,331–1,332
Limestone and claystone, medium-gray; claystone contains nodules and nodular beds of medium-dark-gray limestone as much as 2 in. thick and grayish-yellow lacelike crack fillings	1,332–1,334
Shale, medium-gray, clayey, laminated; no fossils observed; some siderite nodules	1,334–1,337
Shale, medium-gray, clayey, laminated; abundant finely disseminated carbonaceous debris	1,337–1,338
Claystone, medium-dark-gray, silty, relatively hard; suggestive of underclay but *Stigmaria* not observed	1,338–1,339

Pennsylvanian System—Sturgis Formation (in part)—Continued	Depth (feet)
Shale, medium-gray, and about 25 percent laminae of light-gray siltstone and very fine grained sandstone	1,339–1,352
Siltstone, medium-gray; approaches a very silty claystone	1,352–1,353
Shale and siltstone, medium-gray, and light-gray sandstone; irregularly interbedded and interlaminated; some contorted bedding	1,353–1,356
Sandstone, light-gray, calcareous, conglomeratic; shale and siderite in irregular tongues and lenses; contorted bedding; upper part contains a few brachiopods and fossil fragments	1,356–1,359
Sandstone, light-gray, medium-gray siltstone, and about 25 percent shale, very irregularly interbedded and contorted; numerous siderite nodules	1,359–1,369
Shale, medium-gray; siderite bands and lenses	1,369–1,384
Limestone, medium-gray, fine-grained, dense; abundant carbonized plant fragments; no fossils discernible; sharp contacts at top and bottom	1,384–1,386
Shale, medium-gray; in middle part is medium dark gray and less silty and contains siderite nodules; bottom 10 to 15 ft is slightly darker, more thinly laminated, and clayey, with a few small pelecypods; 15 percent of top 10 ft is light-gray siltstone laminae	1,386–1,445
Limestone, medium-dark-gray, very argillaceous; very fossiliferous, contains brachiopods, corals; 6-in. laminated, hard, fossiliferous black shale in middle of unit	1,445–1,446
Claystone and coal (No. 15 coal bed), bright, banded; contains shale lenses and marine fossils in top 2 in.; 18-in. silty, medium-gray, claystone at base	1,446–1,448
Siltstone, very argillaceous, soft, crumbly; contains nodules of freshwater limestone; no discernible bedding in top 2 ft	1,448–1,452
Shale, medium-dark-gray, and medium-gray siltstone, interlaminated; a few nodules of limestone	1,452–1,454
Shale, medium-dark-gray, silty; a few laminae of light-gray sandstone	1,454–1,467
Sandstone, light-gray, medium- to fine-grained; in beds ¼ in. to 2 ft thick parted by dark, shaly laminae; sharp angular unconformity at base with some carbonaceous debris	1,467–1,488
Shale, medium-dark-gray, slightly silty, hard, well-laminated; less silty and thinner laminated in lower part, fossils in bottom 3 ft	1,488–1,492
Limestone (Madisonville Limestone Member), medium-gray; a single massive bed; dense; abundant fossils; calcite-filled vertical fractures	1,492–1,497
Claystone, medium-gray, relatively hard, finely disseminated pyrite and siderite granules; very carbonaceous in top 2 in.	1,497–1,498
Siltstone, medium-gray, interlaminated with about 25 percent sandstone	1,498–1,500

Pennsylvanian System—Sturgis Formation (in part)—Continued	Depth (feet)
Sandstone, light-gray, fine-grained; shaly laminae	1,500–1,506
Sandstone, light-gray and medium-gray; shale and siltstone, regularly interlaminated	1,506–1,512
Sandstone, light-gray above, medium-gray below	1,512–1,514
Siltstone, medium-gray	1,514–1,524
Shale, medium-gray, medium-dark-gray; silty in top 3 ft; clayey, well laminated in bottom 4 ft; some fossils at base	1,524–1,532
Shale, dark-gray, laminated; a few brachiopods	1,532–1,534
Coal, bright, banded, 2 in. thick at top, and slightly silty, medium-gray claystone; *Stigmaria* present	1,534–1,536
Claystone, medium-gray, crumbly, silty	1,536–1,538
Sandstone, light-gray, fine-grained, interbedded with 50 percent medium-gray coarse siltstone	1,538–1,558
Shale, medium-gray, relatively hard, silty	1,558–1,564
Shale, medium-gray, silty, and 50 percent siltstone, medium-gray; bottom 4 ft mostly shale; slightly fossiliferous and nonsilty at base	1,564–1,588
Shale, dark-gray to grayish-black with sideritic bands and lenses; very fossiliferous—brachiopods, gastropods, crinoids observed. Shale, medium-dark-gray, clayey, well-laminated; sparingly fossiliferous; 2½-in. bright-banded coal at base (Wheatcroft coal bed)	1,588–1,618

LOWER SECTION

Supplemental log of core from the base of the coal bed at 1,618 feet to base of the Providence Limestone Member in Peabody Coal Co. hole P–47. The modified description below is from a detailed description by William H. Smith (written commun., 1972) of the Illinois State Geological Survey, Urbana, Ill.

Pennsylvanian System—Sturgis Formation (in part):	Depth (feet)
Claystone, medium-gray, firm; contains *Stigmaria*, carbonaceous in top 2 in. Underclay of the Wheatcroft coal bed at depth of 1,618 ft	1,618–1,622
Claystone, medium-gray, silty, hard; contains pyritic dolomitic nodules	1,622–1,626
Claystone, medium-gray, and light-gray sandstone, very fine grained, interlaminated in about equal proportions	1,626–1,634
Shale, medium-dark-gray, very silty at top, becomes clayey, laminated in bottom 2 ft; numerous carbonized plant impressions	1,634–1,640
Coal (No. 13 coal bed), shaly; core very badly broken	1,640–1,641
Claystone (underclay), medium-gray, fairly soft; contains *Stigmaria*	1,641–1,644
Claystone, similar to overlying unit, contains nodules of limestone similar to underlying unit	1,644–1,645

Pennsylvanian System—Sturgis Formation (in part)—Continued	Depth (feet)
Providence Limestone Member (33 ft):	
Limestone and claystone; limestone, medium-gray, dense; some clay partings; fossiliferous; 1 ft 10 in. hard, calcareous, fossiliferous, greenish-gray claystone at base, containing numerous nodules and lenticular beds of limestone	1,645–1,648
Siltstone, medium-gray; nodules of limestone	1,648–1,651
Sandstone, light-gray, very fine grained; laminae and thin beds of siltstone	1,651–1,655
Shale, medium-dark-gray, silty, with about 25 percent siltstone and sandstone	1,655–1,661
Claystone, medium-gray; numerous carbonized plant remains and thin bands of carbonaceous shale	1,661–1,663
Sandstone, light-gray, medium-grained; in beds as much as 1 ft thick	1,663–1,671
Shale, medium-dark-gray; siltstone laminae in top 1 ft, lower part clayey, laminated; contains some fossil shells and siderite bands	1,671–1,674
Claystone, shale, and coal; claystone, medium-gray, calcareous, abundant fossil shells; shale, grayish-black, very soft, clayey, coaly, 3 in. thick at top of unit; No. 12 coal bed is ½ in. thick, 5 in. above base	1,674–1,675
Limestone, medium-gray, slight brownish cast, very dense, a single thick bed; contains fossil shells; 5½-in. calcareous, very fossiliferous, grayish-black claystone at base of unit. Basal part of claystone, contains coaly streaks and is in contact with top of the No. 11 coal bed of the Carbondale Formation	1,675–1,678

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