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URBANA

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THE MISSISSIPPIAN-PENNSYLVANIAN UNCONFORMITY IN SOUTHERN ILLINOIS

BY

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THE MISSISSIPPIAN–PENNSYLVANIAN UNCONFORMITY IN SOUTHERN ILLINOIS[1]

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ABSTRACT

A systematic study of the Mississippian-Pennsylvanian unconformity in the southern part of the Illinois basin, using both surface and subsurface data, indicates that many factors were involved in the geologic history of the erosional surface. Criteria are presented for the recognition of the position of the unconformity in the subsurface and the rocks above and below the contact are compared and contrasted. An areal geologic map of the pre-Pennsylvanian formations shows three major features: beveling of younger formations at the edges of the Illinois basin; beveling of small structures in the basin; and long, deep, narrow channels as features of the erosional surface. Several isopach maps indicate the configuration of the channel systems and the upland surface between channels.

The geologic history of the unconformity started with uplift and withdrawal of the sea in late Chester time followed by a long period of subaerial erosion. A peneplain was formed across beveled minor structures and older Chester and Lower Mississippian formations at the structurally higher basin borders. After peneplanation and a subsequent second uplift a new cycle of erosion began that resulted in the incision of deep channels in the peneplain surface. In early Pennsylvanian time the topography was buried by detritus laid down by aggrading streams which later merged with coarse sediment advancing westward from the Appalachian geosyncline. During and after Pennsylvanian time the unconformity was warped, folded, and faulted to its present attitude.

The unconformity between the Mississippian and Pennsylvanian systems is well below ground level throughout the area covered by this paper (Fig. 1). Thus only subsurface geologic methods could be used in mapping the unconformity. There are many published descriptions of the unconformity for areas where the Mississippian-Pennsylvanian contact is exposed; in fact, almost every areal geology report covering such areas in southern Illinois, southern Indiana, and western Kentucky includes some discussion of the erosional surface, but there has been no integrated regional study of the outcrops and no detailed study of the unconformity in the subsurface. Field work in the southern part of the Eastern Interior basin has been helpful to the writer in interpreting the subsurface data.

Much information is available concerning the subsurface geology of part of the Illinois basin, both as a result of the intensive oil exploration since 1937 and from earlier drill holes bored for coal and oil. The records of many of the oil tests made with rotary drilling equipment since 1938 are accompanied by electric logs, which are very valuable in determining the position of the unconformity. The electric logs, when used with graphic logs compiled from a study of well

[1] Figs. 4, 5, and 13 on a scale of ½ inch = 1 mile are available at cost of reproduction from the Illinois State Geological Survey, Urbana.

[2] Associate geologist, Coal Division, Illinois State Geological Survey. The writer is indebted to G. H. Cady, head of the Coal Division, A. H. Bell, head of the Oil and Gas Division, and L. E. Workman, head of the Subsurface Division, of the Illinois State Geological Survey for their continued interest, and to M. M. Leighton, chief of the Survey, for his support which made this study possible. Helpful criticism of the manuscript was given by J. M. Weller, Leland Horberg, and F. J. Pettijohn, of the University of Chicago Department of Geology, and G. H. Cady, head of the Coal Division of the Illinois State Geological Survey.

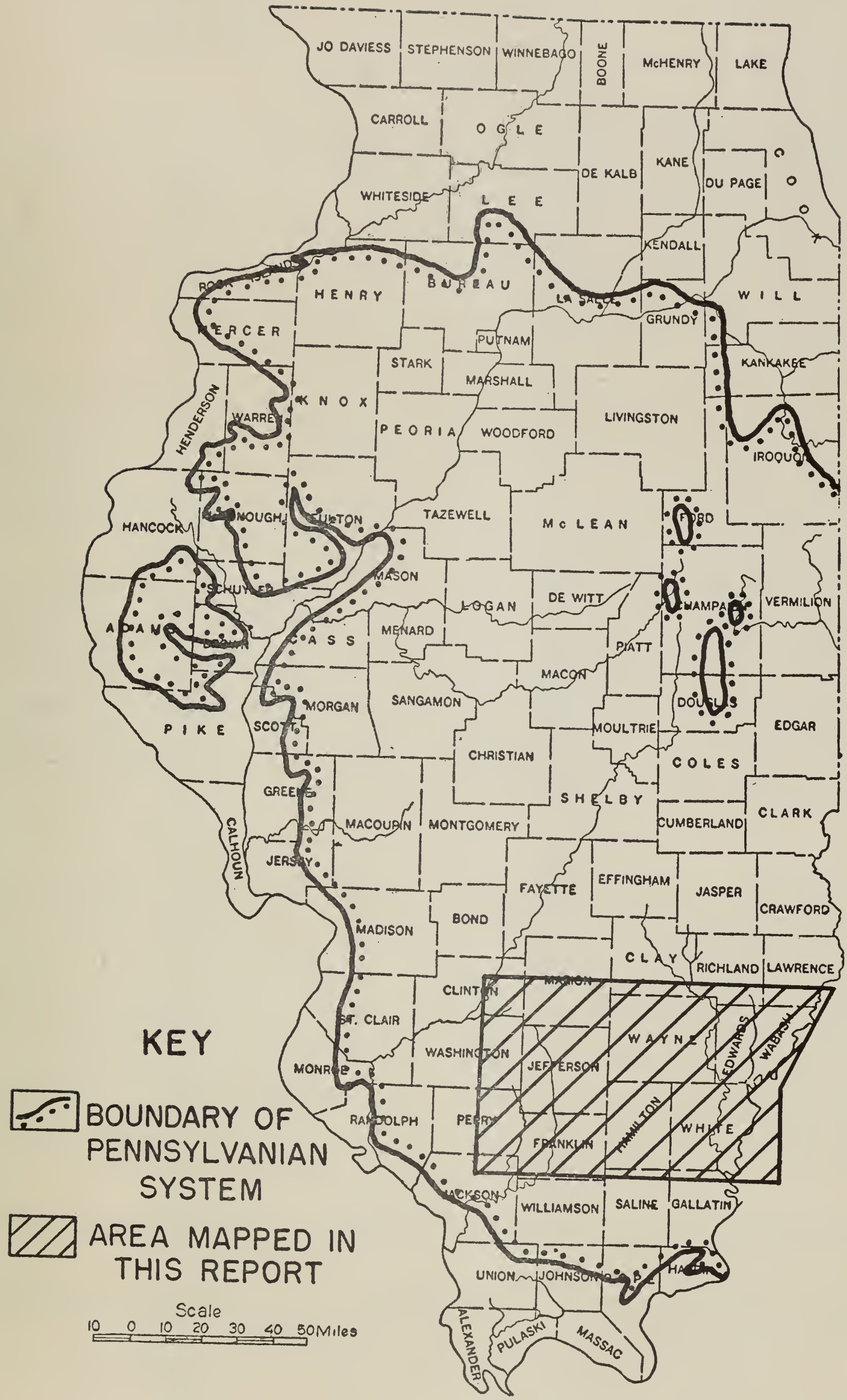


FIG. 1.—Index map of Illinois showing area mapped.

cuttings, provide a reliable basis for the interpretation of the stratigraphy.[3] Detailed lithologic logs are available for three diamond-drill borings in southern Illinois that penetrated the middle and lower parts of the Pennsylvanian system and the upper part of the Chester series. These holes are in Perry, Williamson, and White counties. The cores of the holes in Williamson and White counties are on file at the Illinois Geological Survey. These cores provide the most complete accurate record of the succession above and below the unconformity and have aided in the interpretation of other subsurface information.

Three thousand well records were examined by the writer in compiling the maps that accompany this paper; such records include electric logs, drillers' logs, sample-study logs, and drilling-time logs. Sample-study logs include those made by the writer and other members of the staff of the Illinois Geological Survey and by oil-company geologists. The greatest reliance was placed on electric logs and logs compiled from study of cuttings and drilling time collected in the field by members of the Coal Division of the Illinois Geological Survey.

The geologic section of most concern in a discussion of the Mississippian-Pennsylvanian unconformity is that part of the Chester series above the Golconda formation and that part of the Pennsylvanian system below the coal bed here called "No. 2."[4] A graphic log of a diamond-drill hole in Williamson County that penetrated to the Waltersburg formation (Fig. 2) is fairly typical of the succession in the southern part of the Illinois basin. Figure 3, a generalized section of the Chester series above the basal part of the Golconda formation, is based on many well logs from the southern part of the Illinois basin.

IDENTIFICATION OF POSITION OF UNCONFORMITY

Many criteria for the recognition of unconformities used in conventional surface geologic mapping methods are inapplicable to subsurface methods or have to be modified.[5] Of greatest value in the determination of the position of the Mississippian-Pennsylvanian contact in southern Illinois is the fact that, due to pre-Pennsylvanian erosion, the lowest Pennsylvanian beds lie on Chester beds of different ages in different places. In many places in southern Illinois the oldest Pennsylvanian beds lie on the Kinkaid formation, but in other places they lie on lower formations—the Degonia, Clore, Palestine, or Menard. Thus the determination of the position of the contact of the two systems becomes largely a problem in the stratigraphy of the Chester series. Knowledge of the characteris-

[3] Earle F. Taylor, M. William Pullen, Jr., Paul K. Sims, and J. Norman Payne, "Methods of Subsurface Study of the Pennsylvanian Strata Encountered in Rotary-Drill Holes," *Illinois Geol. Survey Rept. Inv. 93* (1944), p. 9.

[4] For discussions of this stratigraphic succession see L. E. Workman, "Subsurface Geology of the Chester Series in Illinois," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24 (1940), pp. 209–36, reprinted, *Illinois Geol. Survey Rept. Inv. 61* (1940); and J. M. Weller, "Geology and Oil Possibilities of Extreme Southern Illinois," *Illinois Geol. Survey Rept. Inv. 71* (1940), pp. 32–42.

[5] W. C. Krumbein, "Criteria for the Subsurface Recognition of Unconformities," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26 (1942), pp. 36–62.

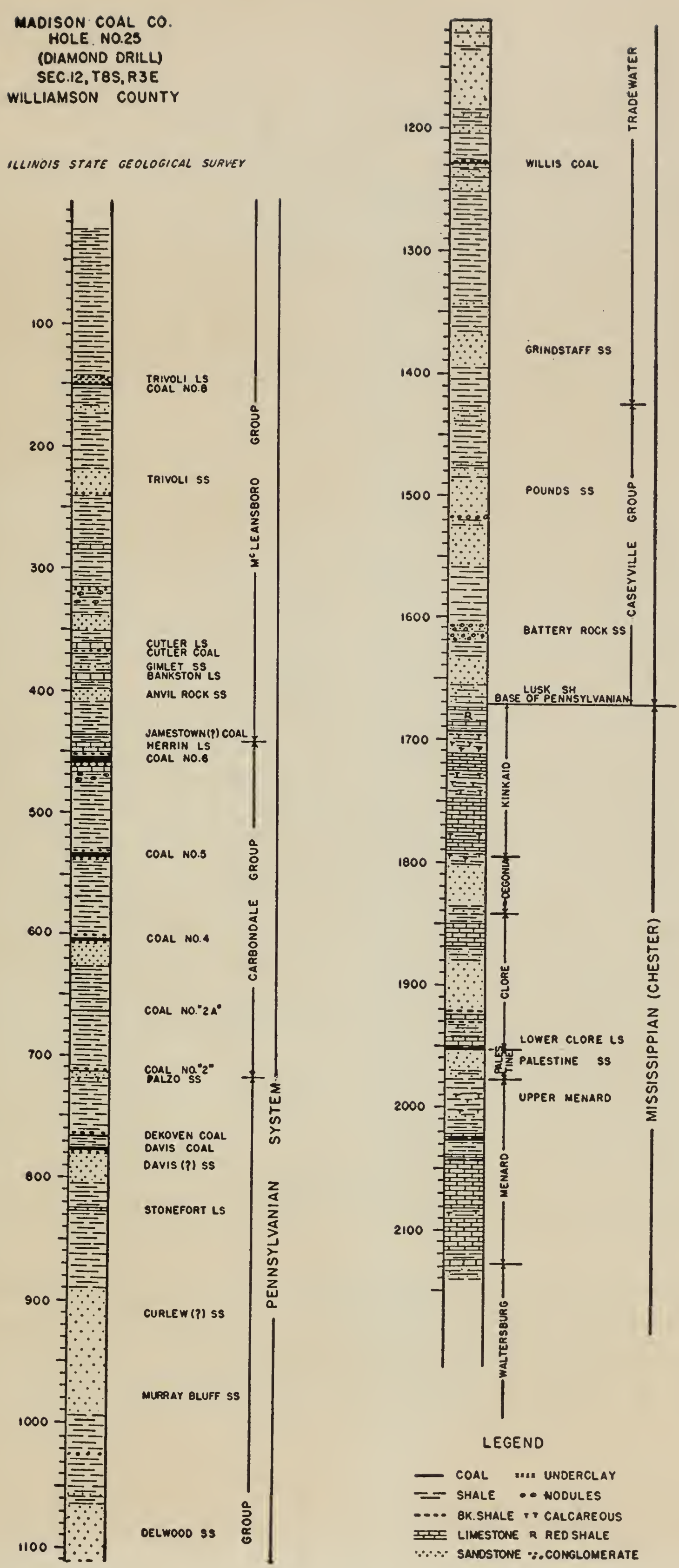


FIG. 2.—Log of Madison Coal Company Hole No. 25, Williamson County.

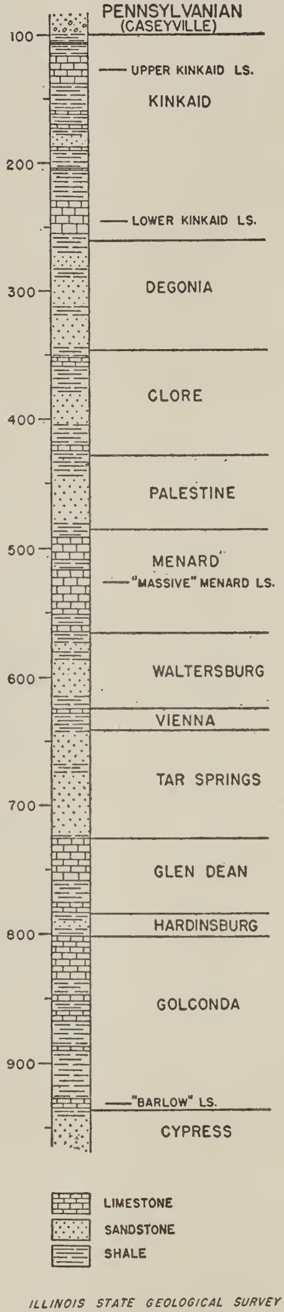


FIG. 3.—Generalized section of Chester series in Illinois.

tic sequence of formations in the Chester series ordinarily makes it possible to identify the youngest Chester beds; this makes possible the identification of the unconformity. However, the differentiation of upper Chester and Lower Pennsylvanian sediments was a major problem of the present investigation.

The chief difficulty is that many Chester beds resemble Pennsylvanian beds in lithologic character, texture, and mineralogy. This is true particularly of the shales in the Palestine and Clore formations and of the sandstones of the Palestine, Clore, and Degonia formations. In general, Chester shales are harder, less micaceous, less carbonaceous, and less silty than similar Pennsylvanian shales. The carbonaceous content in Chester shales is finer and more macerated than in Pennsylvanian shales. Although the particle-size ranges of Chester and Pennsylvanian shales are about the same, the silty material in Chester shales is commonly distributed throughout the shaly (clay mineral) components whereas silty material in Pennsylvanian shales is more likely to be separated into thin beds or laminae. Marine fossils are rare in Lower Pennsylvanian sediments except for a few zones; fossiliferous beds are many and well distributed throughout the Chester section. Red shale beds occur in several stratigraphic positions in the upper Chester but are rare in the Lower Pennsylvanian. Many Chester shales are calcareous; most Lower Pennsylvanian shales are not.

The sandstones of the Lower Pennsylvanian and the upper Chester resemble each other so closely in mineralogical content and texture that they can be differentiated only with difficulty. Thin sections of Chester and Pennsylvanian sandstones studied by the writer show slight differences. Chester sandstones are commonly very calcareous; most Pennsylvanian sandstones are only faintly calcareous. Individual quartz grains in Chester sandstones are, in general, more rounded than Lower Pennsylvanian quartz grains, but this is true mainly for grains of medium and coarse size. Chester sandstones are cemented with either calcite or secondary quartz or a combination of the two; a secondary quartz-calcite combination cement is uncommon in the sandstones in the lower part of the Pennsylvanian in Illinois, but Pennsylvanian sandstones are, in many places, cemented with calcite or quartz in combination with a clay matrix surrounding the individual detrital grains. Sideritic cement is not uncommon in Pennsylvanian sandstones but is rare in Chester sandstones. Siderite and ankerite-siderite are abundant in many forms in Pennsylvanian sediments as spherules, concretions, and veinlets, but are very uncommon in Chester rocks. However, certain zones in the Chester, notably the Waltersburg-Vienna section, contain abundant siderite spherules.

A distinguishing feature of some of the sandstones of the Lower Pennsylvanian is conglomeratic zones containing abundant rounded quartz pebbles. No such conglomeratic zones are known in upper Chester sandstones. When such conglomeratic zones can be identified from drill cuttings, the sandstone is regarded as Pennsylvanian in age.

In some drill holes and at some outcrops, a thin ferruginous silicified zone marks the contact of the two systems of rocks. This stratum is nowhere more than 4 inches thick and commonly is only 2 inches thick. It is conglomeratic in many places, containing abundant chert pebbles and, in some places, pebbles of Chester limestones and sandstones. Many of the chert pebbles resemble the chert found in the Kinkaid and Clore formations. The matrix of the rock is composed of a mixture of hematite, altered in large part to limonite, clay ironstone of undetermined mineralogical character, and abundant quartz sand particles. Carbonized plant impressions are prominent on some surfaces. This ferruginous zone is for the most part restricted to areas in which the basal Pennsylvanian overlies Kinkaid limestone, although a few wells were studied in which there is such a zone where the basal Pennsylvanian overlies the Clore limestone. The writer knows of no other occurrence of this lithologic type in the Lower Pennsylvanian excepting at the Mississippian-Pennsylvanian contact. Regardless of the restricted occurrence of this zone, wherever found it is a useful indication of the position of the unconformity.

The patterns of many of the electric logs are useful in locating the position of the Mississippian-Pennsylvanian contact. In many logs the pattern of the resistivity curve at the critical position changes abruptly from high to low resistivity. This change is believed to mark the position of the contact, a conclusion commonly substantiated by a study of the well cuttings. This criterion applies only to those shale sections which are not broken by sandstone beds, because the presence of thin sandstones almost always increases the apparent resistivity of the intervening shale beds. The self-potential curves on electric logs do not show any pronounced differences between Chester and Pennsylvanian rocks but some of them show a great amount of small variation, giving a jagged appearance for Chester shales and a smooth curve for the overlying Pennsylvanian shales. This, however, is a weak basis for determining the position of the contact. Actually the greatest value of the electric logs lies in their aid in deciphering the stratigraphy of upper Chester formations, thus providing a means for determining the approximate position of the unconformity.

It is the writer's opinion that very discriminating lithologic study, with careful attention to the minute variations in the lithologic features as already noted, is necessary to determine the Mississippian-Pennsylvanian contact. It is desirable to know the detailed lithologic character of the rocks at the outcrop, in cores, and preferably, in thin sections, before attempting to make fine lithologic distinctions on the basis of rotary drill cuttings studied under a binocular microscope. Even with this detailed lithologic study there will be many drill holes in which it is impossible to ascertain the exact depth of the contact. Under such conditions, and where the stratigraphy is doubtful, the best method is to make an intelligent guess substantiated by any information available.

In actual practice the writer first determines the uppermost Chester limestone formation that can be identified with certainty in a log. This log is then compared with a log which shows the next highest limestone formation to narrow the stratigraphic interval in which the contact must lie. In the area studied there is rarely more than 125 feet between two successive limestone formations, and thus this is the limit of error. In most places it is possible to determine the position of the unconformity with an error of not more than 20 feet. There are a few small areas in Edwards and Wabash counties where the Palestine and Degonia formations are extraordinarily thick (up to 200 feet in some drill holes) and are similar to thick basal Pennsylvanian sandstones in this area. Where one of these two is the uppermost Chester formation it is almost impossible to estimate the position of the unconformity closer than 100 feet.

Regardless of the difficulties discussed it is possible in nearly all the drill holes to determine accurately the top of the Chester series and to approximate closely the depth of the unconformity. Hence the maps constructed from the drill-hole data provide a good picture of the general configuration of the erosional surface, even though the accuracy of small details may depend on the precision with which the position of the unconformity has been ascertained in specific drill holes.

Description of Maps and Sections

Four maps delineate the features of upper Chester and Lower Pennsylvanian beds which are related to the unconformity between the two systems: a pre-Pennsylvanian areal geologic map (Fig. 4); an isopach map of the interval between the "massive" Menard[6] limestone and the base of the Pennsylvanian (Fig. 5); an isopach map of the interval between the base of the Pennsylvanian and coal No. "2" (Fig. 6); and an isopach map of the interval between the "massive" Menard limestone and coal No. "2" (Fig. 7). Approximately 3,000 drill holes are common to all maps, excepting Figure 7, for which fewer wells were used. At least one well was used for every section in which one or more wells were drilled. In some areas more wells were needed to show certain details. To some extent the southern, eastern, and western boundaries of the area mapped coincide with the limits of abundant subsurface information in that area. Many wells have been drilled north of the area mapped but, in general, the drill holes are more scattered than in the mapped area on the south. Generalized pre-Pennsylvanian maps had previously been drawn for two counties along the northern border of the area, Clay County,[7] and Lawrence County,[8] and this information was of some help in the interpretation of the maps in this investigation.

[6] The term "massive" Menard is a term commonly used by oil geologists and drillers in the Illinois basin to designate the thick lower bench of limestone in the Menard formation. See L. E. Workman, *op. cit.*, p. 213.

[7] Heinz A. Lowenstam, "Subsurface Geology of Clay County" in "Subsurface Geology and Coal Resources of the Pennsylvanian System in Certain Counties of the Illinois Basin," *Illinois Geol. Survey Rept. Inv. 148*, in press.

[8] Elwood Atherton, unpublished map, *Illinois Geol. Survey*.

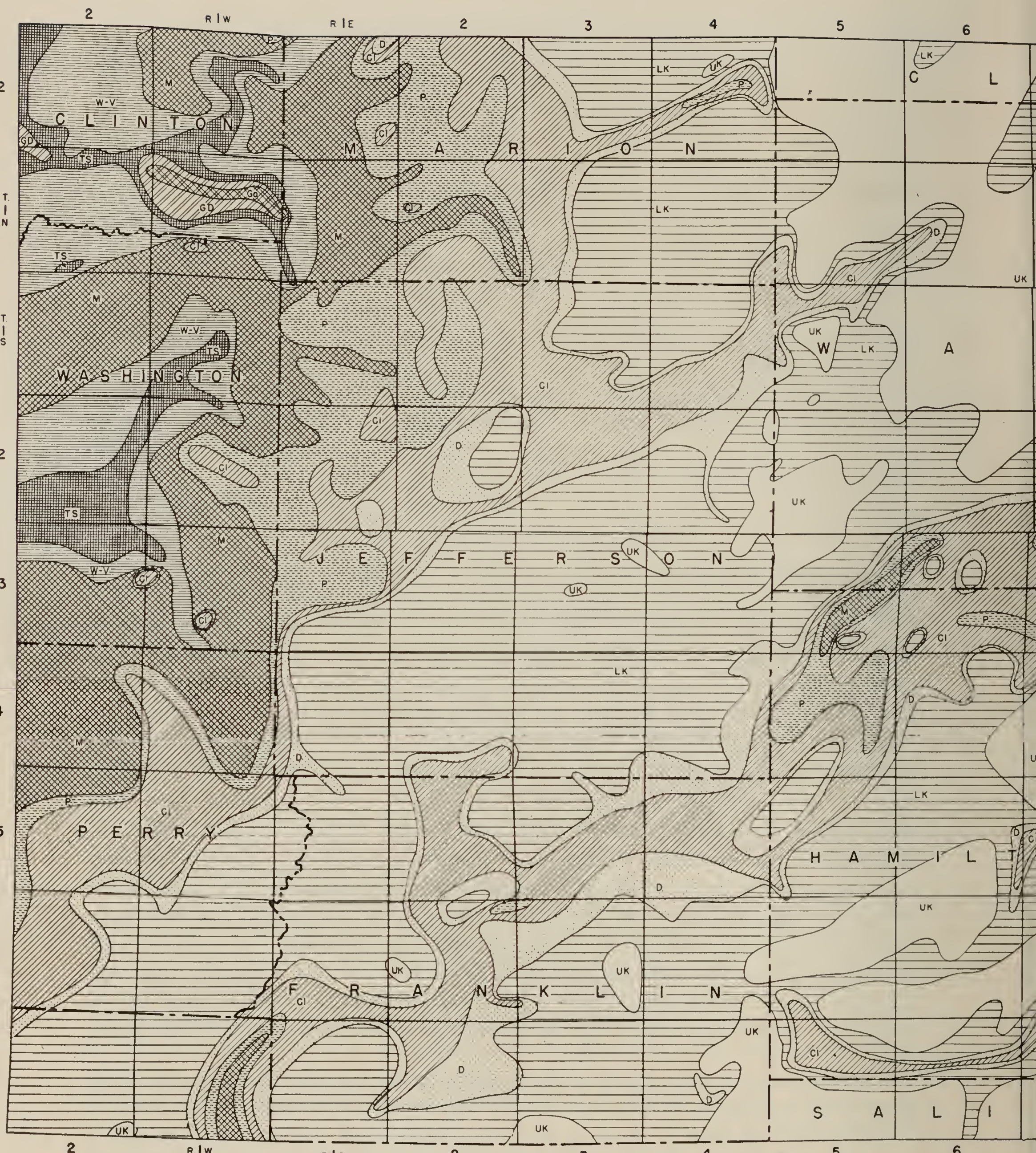
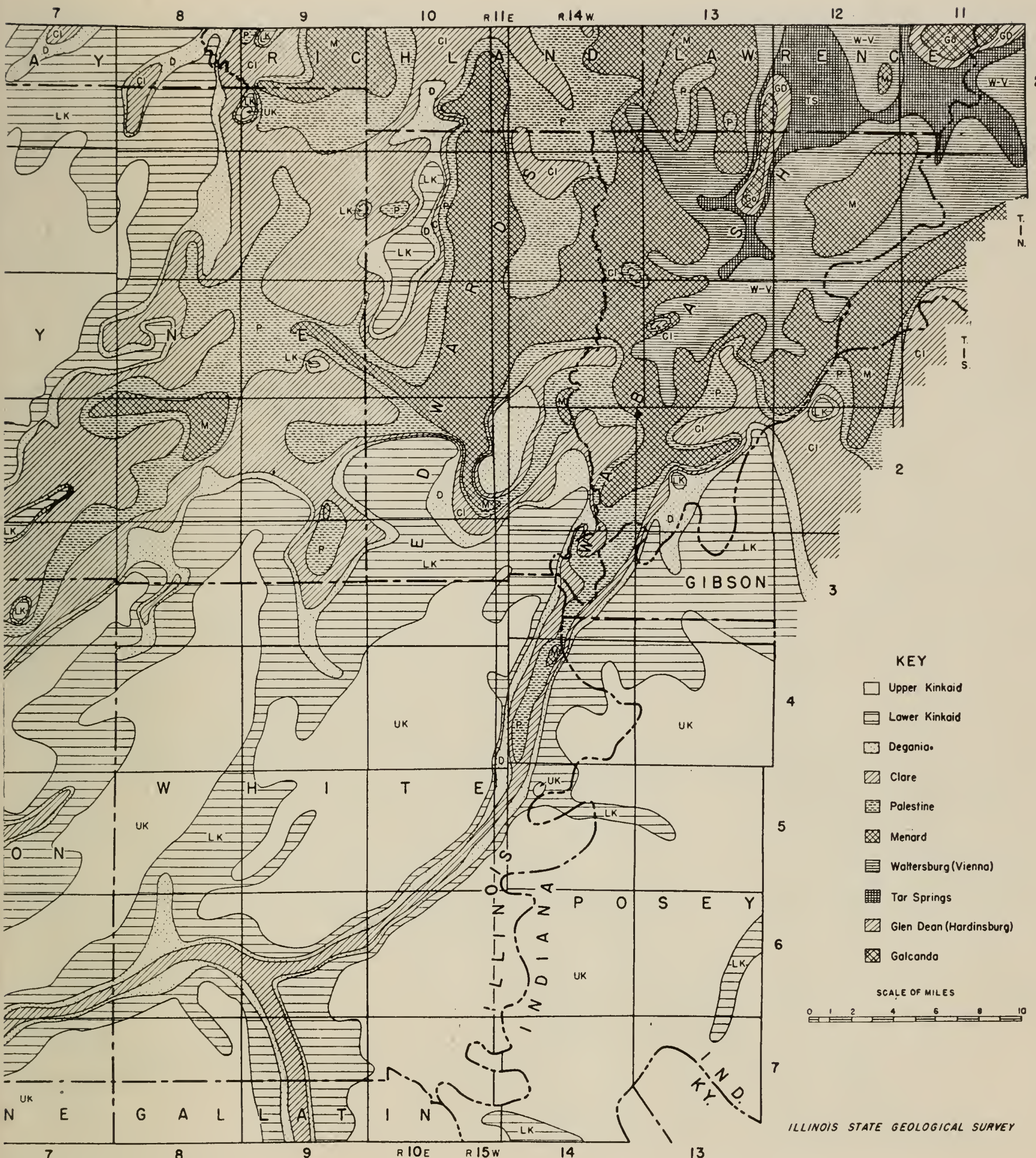
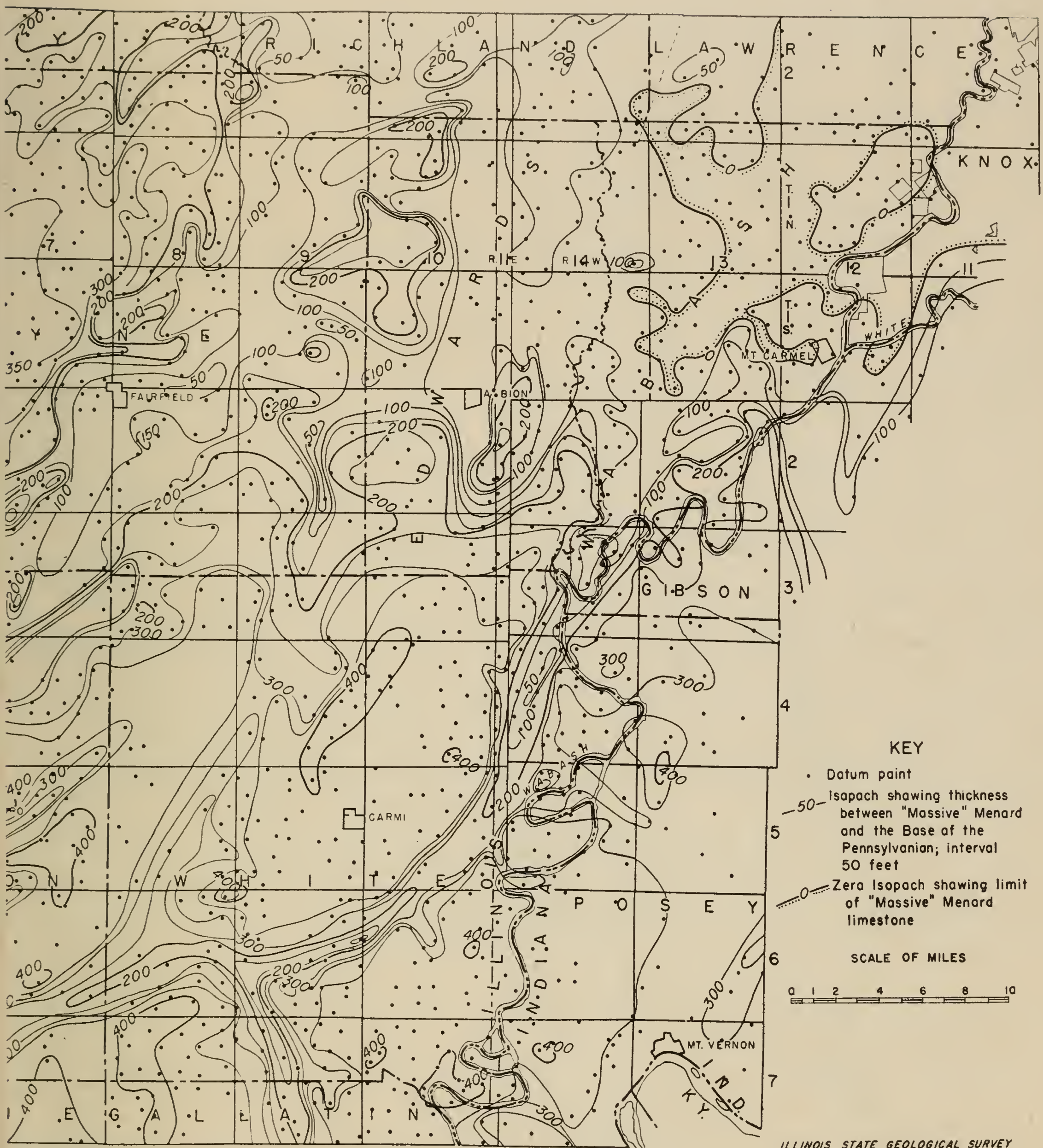


FIG. 4.—Pre-Pennsylvanian areal



geology of southern part of Illinois basin.

FIG. 5.—Isopach map of



upper part of Chester series.

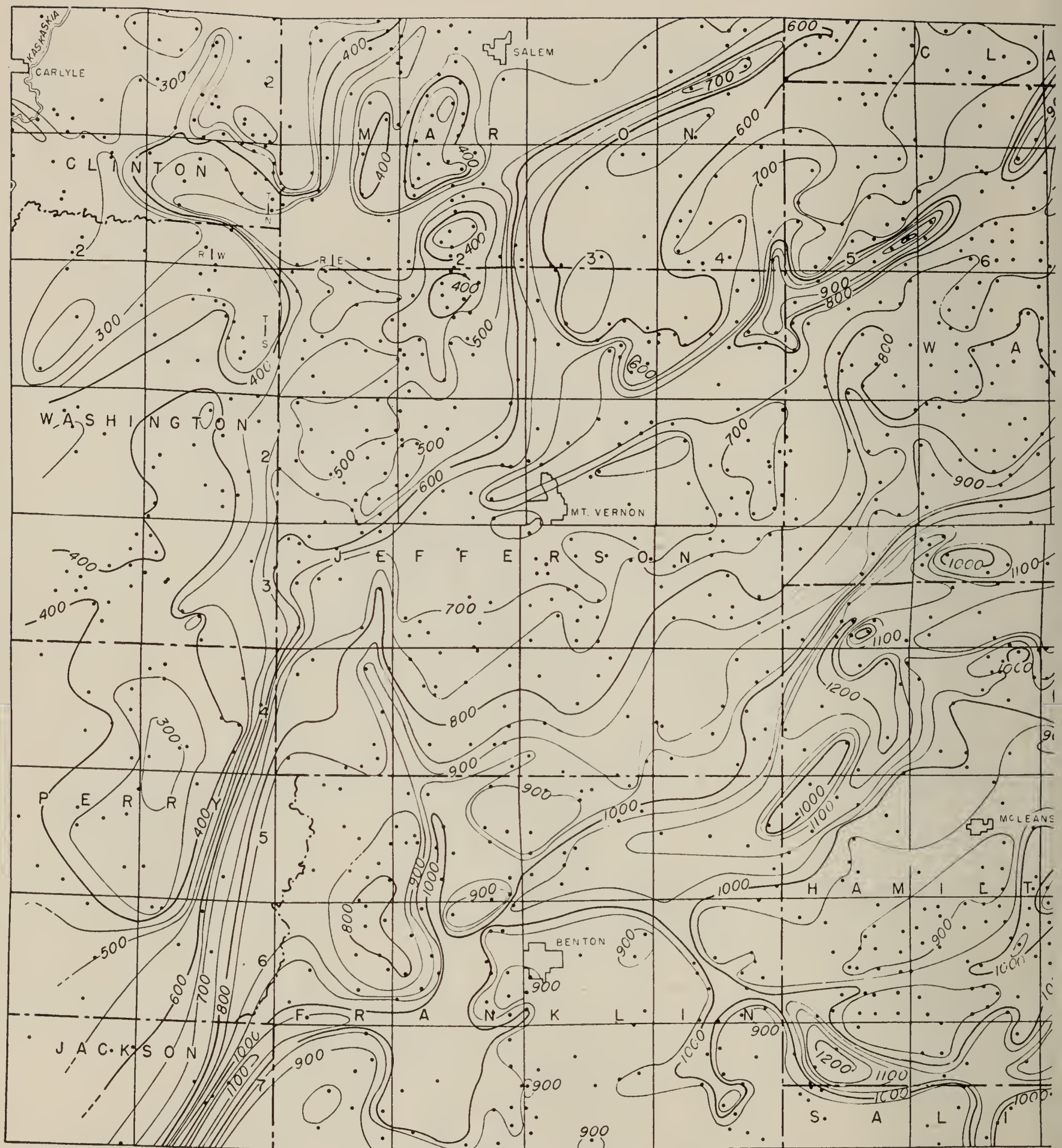
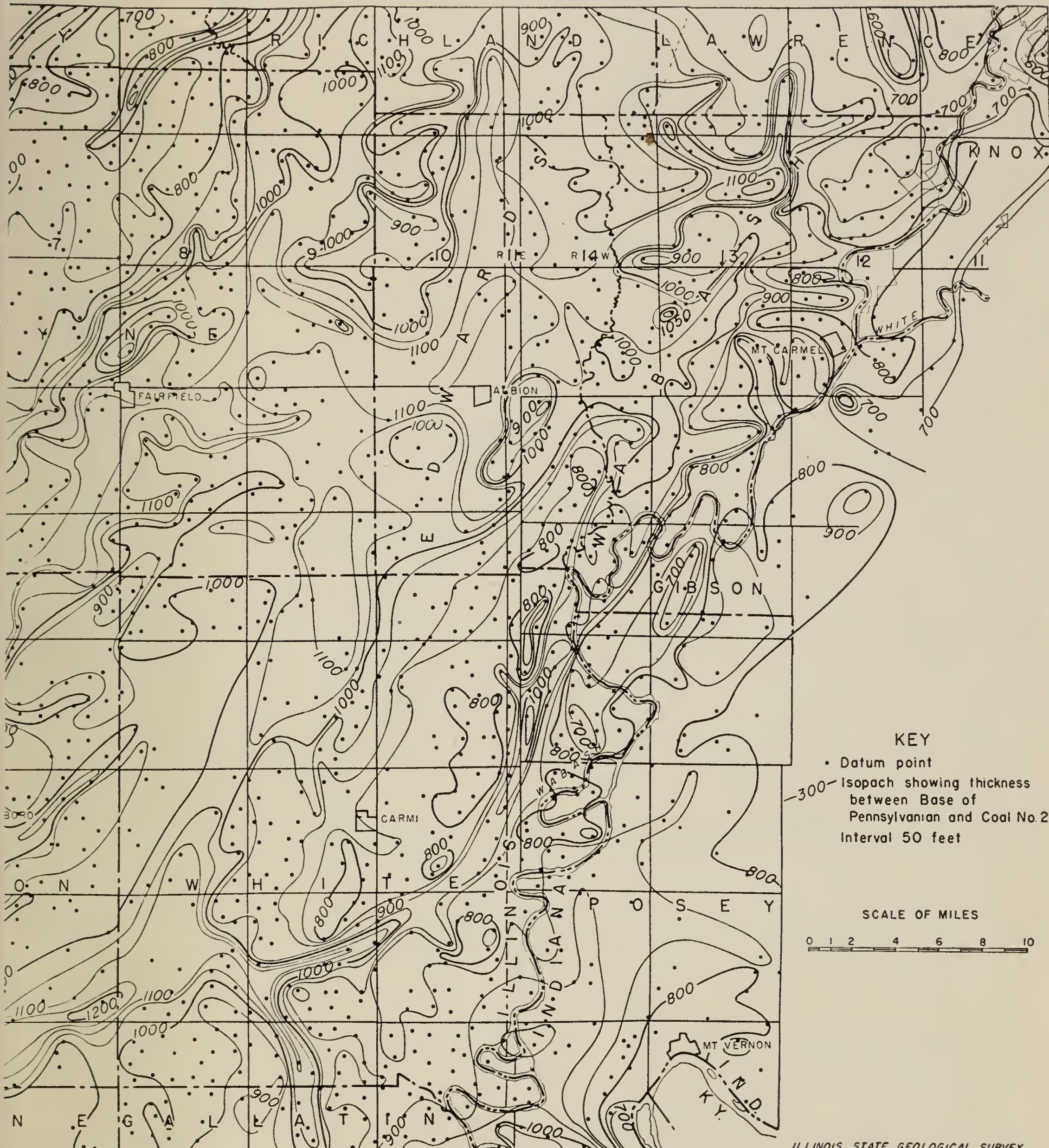


Fig. 6.—Isopach map of lower



part of Pennsylvanian series.

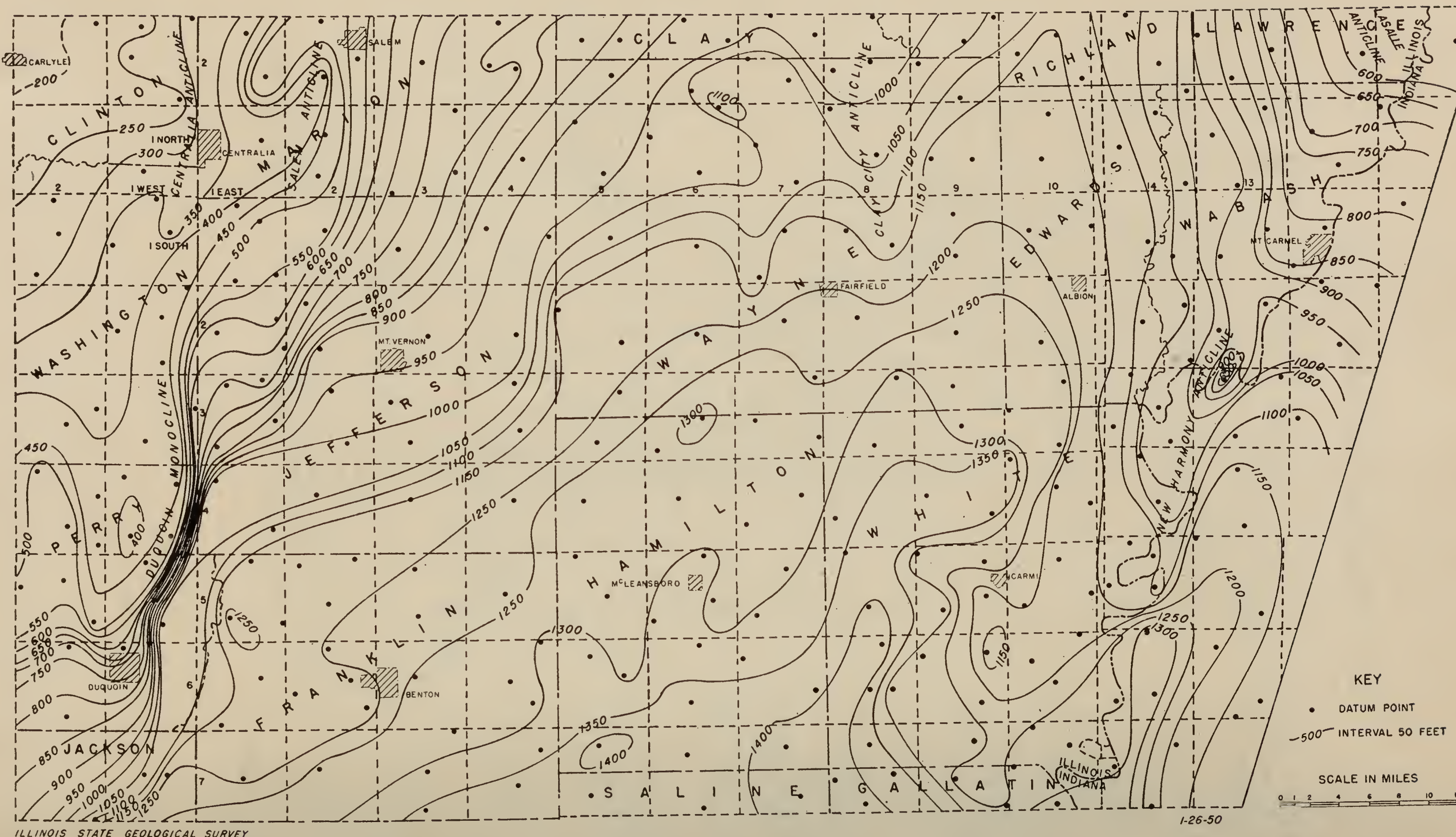


FIG. 7.—Isopach map of upper part of Chester series and lower part of Pennsylvanian system.

PRE-PENNSYLVANIAN AREAL GEOLOGIC MAP

Figure 4 shows the areal geology of the southern part of the Illinois basin as it would appear if the Pennsylvanian system were removed. The youngest formation on the map is the upper Kinkaid limestone, which is shown here as a separate unit. The lower Kinkaid as mapped here has been arbitrarily made to include all strata in the Kinkaid formation below the base of the upper Kinkaid. Other units mapped are the Degonia, Clore, Palestine, and Menard formations. The Waltersburg sandstone, which underlies the Menard, was mapped, for convenience, to include the thin Vienna limestone formation. The Tar Springs sandstone was mapped as an individual unit but the next lower unit mapped includes both the Glen Dean and Hardinsburg formations. The Golconda formation, the lowest unit mapped, occurs in only two small areas.

The map shows the youngest two formations in irregular areas commonly elongate northeast-southwest, occupying most of the southern half and the central part of the northern half of the area. The older formations are found mainly in the northwest and northeast quarters of the area but also in narrow northeast-southwest-trending belts traversing the area. The general pattern of the distribution conforms with, and reveals, the axis of the Illinois basin.

The upper Kinkaid is present in Saline, Gallatin, Hamilton, White, Wayne, and Clay counties, Illinois, and in Posey County, Indiana. There are a few outliers in Franklin and Jefferson counties. The underlying lower Kinkaid extends through a much larger but essentially concentric area, including a large part of Franklin, Jefferson, Marion, Wayne, and Hamilton counties and a small part of White County, Illinois, and Gibson County, Indiana. Formations older than the Kinkaid are much smaller in area. The Degonia sandstone forms the contact surface in narrow strips bordering the areas of lower Kinkaid. The Clore formation covers a moderately wide area in Perry, Jefferson, and Marion counties, west of the Kinkaid belt, and in eastern Wayne and Edwards counties, east of the Kinkaid. It is also at the floor of many of the channels which have been cut through the Kinkaid and Degonia formations. The Palestine formation forms the contact surface in western Jefferson and western Marion counties on the western side of the area and in small areas in southern Richland, Edwards, and Wabash counties on the eastern side of the area. In addition, the Palestine formation is exposed in some parts of the floor of the major valley cutting across Wayne and Hamilton counties. The Menard formation is present as a wide belt in Perry, Washington, and western Marion counties on the west, and in Edwards, Wabash, and Lawrence counties, Illinois, and Knox County, Indiana, on the east. It is also present in two small areas in the floor of the channel extending through Wayne and Hamilton counties. The Waltersburg-Vienna and Tar Springs formations appear at the contact surface in Washington and Clinton counties on the western side of the basin and in Wabash and Lawrence counties on the eastern side. The Glen Dean-Hardinsburg and the Golconda formations appear in two small areas, one in Clinton County and the other in Lawrence County.

Channeling in the pre-Pennsylvanian surface is a prominent feature of the areal geologic map. Many channels cut down through the Kinkaid and Degonia formations, and a few deep channels cut down to the Menard formation. The formation pattern in and adjacent to these channels resembles a normal dendritic development of tributaries and master streams. Similar channels have been described in Illinois, Indiana, and Kentucky[9] but in no place has a channel been traced for a greater distance than the length of a county.[10]

The buried erosion surface shows some relationship to certain well known structural features (Fig. 8). At the southern extremity of the LaSalle anticline, in Lawrence County, pre-Pennsylvanian erosion cut down to the Golconda limestone in two small areas bordered by wider areas of Waltersburg-Vienna. Pre-Pennsylvanian erosion cut down to the Golconda limestone also over the Centralia anticlinal structure in southeastern Clinton County. In contrast, there is no apparent relationship of the pattern of Chester formations to such structures as the DuQuoin monocline in eastern Perry County and the Clay City anticline in Wayne County.

UPPER CHESTER ISOPACH MAP

The isopach map of the thickness of upper Chester rocks above the "massive" Menard limestone provides a preliminary indication of the topography of the pre-Pennsylvanian surface. If the stratigraphic convergence between the Menard and Kinkaid formations is negligible within the limits of the area, the isopachs can be visualized as contours delineating the configuration of the erosional surface as it existed immediately prior to Pennsylvanian deposition, provided that no deformational movements accompanied the emergence. The convergence of the Menard and Kinkaid formations is about 50 feet from the southern to the northern border of the area mapped; hence, it can be judged negligible if the isopach interval is 50 feet. Emergence from the Chester sea was certainly accompanied by some deformation, hence the isopach map indicates only the general outlines of the channels and delineates very poorly the upland and regional topography.

The "massive" Menard limestone was completely eroded in Washington, Clinton, Wabash, and Lawrence counties, Illinois, and Knox County, Indiana; elsewhere it is covered by Chester beds of varying thickness up to 484 feet in Sec. 8, T. 6 S., R. 6 E., in Hamilton County, where all formations up to and including the upper Kinkaid are present. The thickness of upper Chester sediments ranges from 250 to 450 feet in the large interchannel areas in the deep part of the basin. The thickness of the formations decreases to between 50 and 150 feet in the deeper channels, where some or all of the formations above the Menard have been removed.

[9] J. Marvin Weller and A. H. Sutton, "Mississippian Border of the Eastern Interior Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 5 (1940), pp. 847–49.

[10] J. Marvin Weller, "The Geology of Edmonson County," *Kentucky Geol. Survey*, Ser. 6, Vol. 28 (1927), pp. 153–54.

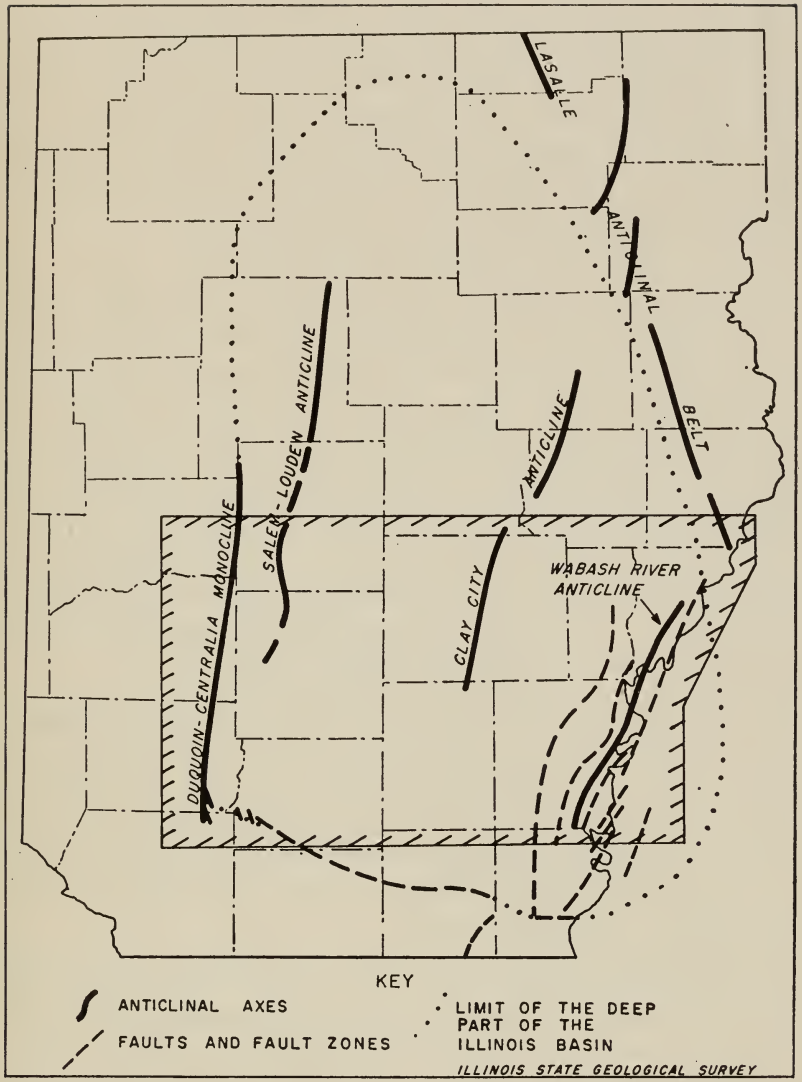


FIG. 8.—Major structural features of Illinois basin. Adapted from A. H. Bell, "Subsurface Studies of the Base of the Kinderhook-New Albany Shale in Central and Southern Illinois," *Illinois Geol. Survey Rept. Inv. 92* (1943), Fig. 3.

There is little relationship apparent between the location of major structural features and the configuration of the contours on this map excepting in the northwestern and northeastern corners of the area, where the Menard is absent over the Centralia and LaSalle anticlines.

LOWER PENNSYLVANIAN ISOPACH MAP

The isopach map of the interval between the base of the Pennsylvanian and Coal No. "2" (Fig. 6), essentially an isopach of the thickness of the Caseyville and Tradewater groups, in some respects gives a better picture of the pre-Pennsylvanian topography than the isopach map of the upper part of the Chester series. If one assumes no convergence of Tradewater and Caseyville group strata within the limits of the area, and if one assumes that there were no structural movements during the Lower Pennsylvanian, then the Lower Pennsylvanian isopachs would serve as a topographic map of the pre-Pennsylvanian surface. The thickest Lower Pennsylvanian is over the deepest pre-Pennsylvanian channels and the thinnest is over the highest interchannel areas.

However, the Lower Pennsylvanian isopachs show more regional variation than can be accounted for solely by pre-Pennsylvanian topography. The thickness of Lower Pennsylvanian rocks, exclusive of the channel areas, averages about 950 feet in Hamilton and western White counties, and decreases northward to about 600 feet, westward to about 400 feet, and eastward to about 750 feet. Thus the greatest thickness of these rocks is in the deepest part of the basin and presumably is a reflection of greater subsidence and sedimentation in that area. The thickest Lower Pennsylvanian section is present over some of the deep pre-Pennsylvanian channels. A maximum thickness of 1,240 feet is reached in Sec. 33, T. 3 S., R. 5 E., and in Sec. 36, T. 6 S., R. 7 E., both in Hamilton County. The minimum thickness of Lower Pennsylvanian strata within the limits of the area is in Sec. 36, T. 2 N., R. 1 W., in Clinton County, where such rocks are only 215 feet thick. This is over the high of the Centralia fold.

Lower Pennsylvanian isopachs show thinning over three prominent structures; the Centralia anticline, the DuQuoin monocline, and the southern end of the LaSalle anticline. In eastern Perry County the Lower Pennsylvanian thins from 850 feet east of the DuQuoin monocline to 350 feet over that structure. Lower Pennsylvanian sediments thin from 500 feet east of the Centralia anticline to 250 feet over the anticline. Over the LaSalle anticline, in southeastern Lawrence County, Lower Pennsylvanian sediments are 550 feet thick in contrast to a thickness of 800 feet west of the anticline.

The courses of pre-Pennsylvanian channels are clearly shown on the isopach maps of the upper Chester and of the Lower Pennsylvanian. The two maps are in substantial agreement on the position of the major tributaries and most details in the center of the deep part of the basin. The drainage branchwork is dominated by two channels, one through Wayne, Hamilton, and Franklin counties in a southwest direction, and the other south by southwest down the eastern side of White County and then west along the southern edge of western White County and the southern edge of Hamilton County. It is probable that the channel through White and southern Hamilton counties joins the major channel on the north in eastern Franklin County. Two smaller channels in northern Jefferson and southern Marion counties have the same southwesterly trend as the large channel through Wayne County. Figure 9 shows the location and designation numbers for the important channels. No attempt was made on this index map to show relative widths of the channels.

Channel 1 is conspicuous because of the width of the valley bottom throughout its course. No other channel is as wide, although channels 2 and 3 are as deep in several places; this channel probably was the master stream in this region. Channel 1 is notable not only for its width but for the many erosional remnants in the valley. Several hills capped by Kinkaid limestone stand in bold relief above the valley floor and are not connected with the main valley walls. There are some

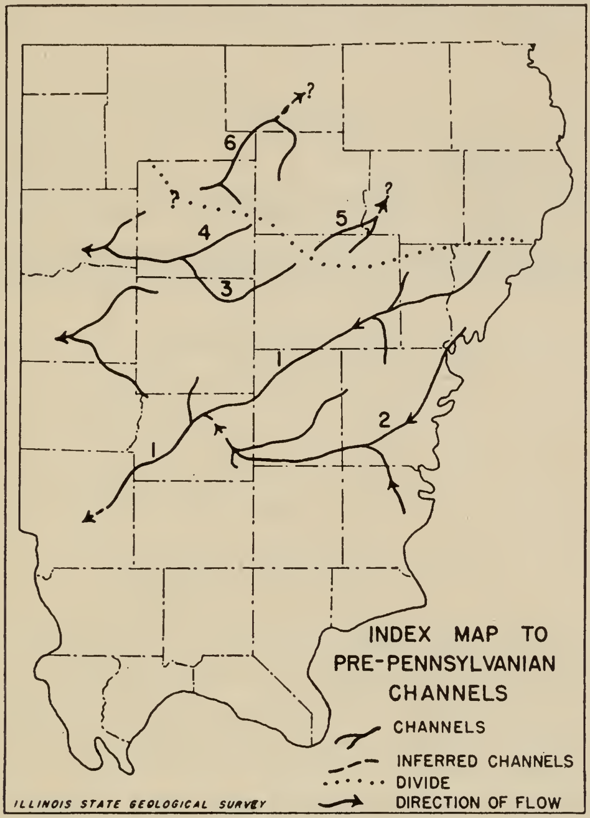


FIG. 9.—Index map of pre-Pennsylvanian channels.

small isolated hills capped by Degonia sandstone but these are very few compared to the number capped by limestone. Two types of valley profile are present (Figs. 10, 11). Channel 1 is wide, includes erosional remnants, and contains terraces at several levels. Channel 2 is V-shaped, narrow, commonly less than $\frac{3}{4}$ mile wide, and has no erosional remnants. The walls of both channels are fairly steep, in several places sloping as much as 200 feet in less than a mile. Channel 2 is uniformly fairly deep; the channel bottom, cut into the Clore formation, is about 300 feet lower than the plateau of Kinkaid limestone above it. Channel 1 is almost as deep in most places, and in certain places in Wayne County an "inner gorge," 450 feet deep, cuts into the Menard formation. Because neither the isopach maps nor the areal geologic map give an exact picture of the detailed configuration of the channels owing to insufficient well data and the inherent limitations of the maps, it is difficult to follow the deepest part of channel 1.

Here and there the lack of well data makes it impossible to do more than suggest the confluences of tributaries and main streams, but generally the positions of the tributaries can be definitely shown. Some unusual features of the channels appear on all three maps of the erosion surface (Figs. 4, 5, and 6). Channels 3

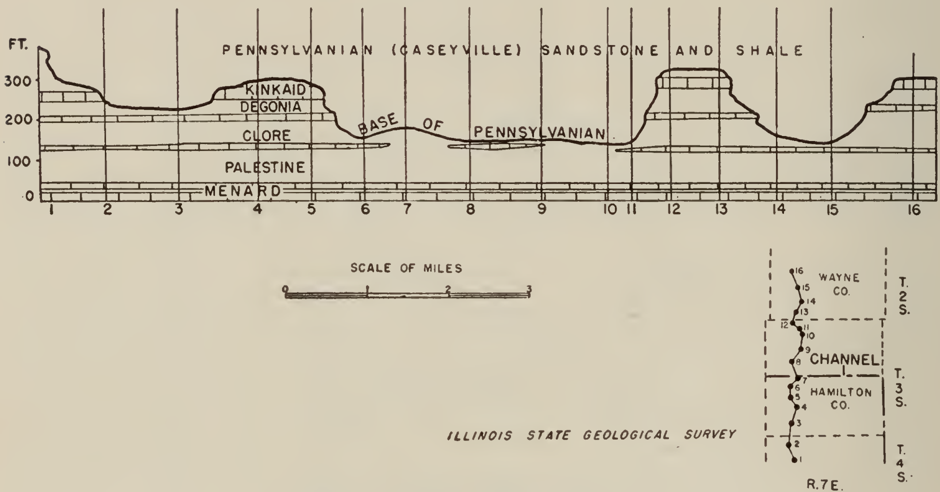


Fig. 10.—Cross section of channel 1.

and 5, although they form almost a continuous straight line, do not connect. The divide between the two channels, in the eastern part of T. 1 N., R. 6 E., in Wayne County, coincides with a dome-like structure, the Johnsonville oil pool. Other divides between channels are not so obviously associated with structures. Channel 4 terminates abruptly. Less than a mile downstream from the edge of the Kinkaid escarpment, the channel becomes deep, and is cut down to the lower part of the Clore formation. Present information does not justify indicating the connection of this channel with another trending north-south in T. 4 N., R. 5 E., in western Clay County.

The actual connection between channels 1 and 2 in southeastern Franklin County is somewhat doubtful. That channel 2 drains into channel 1 in this general area seems likely, but there are several alternatives to the route drawn on the maps. Future wells may show the exact confluence of the two major streams. The relationships of the headwaters of channels 1 and 2 in Wabash County are difficult to recognize. There is no clear indication on the maps of the position of the divide, but probably it extends across Edwards and Wabash counties.

In most of the interchannel areas the Kinkaid is the uppermost formation.

Toward the eastern and western margins of the basin successively lower limestones become the uppermost formations in interchannel areas. The Clore and Menard formations cap a larger area at the east in Edwards and Wabash counties and at the west in Perry, Washington, Jefferson, and Marion counties. There are a few outliers, such as the small hills of upper Kinkaid limestone rising above the

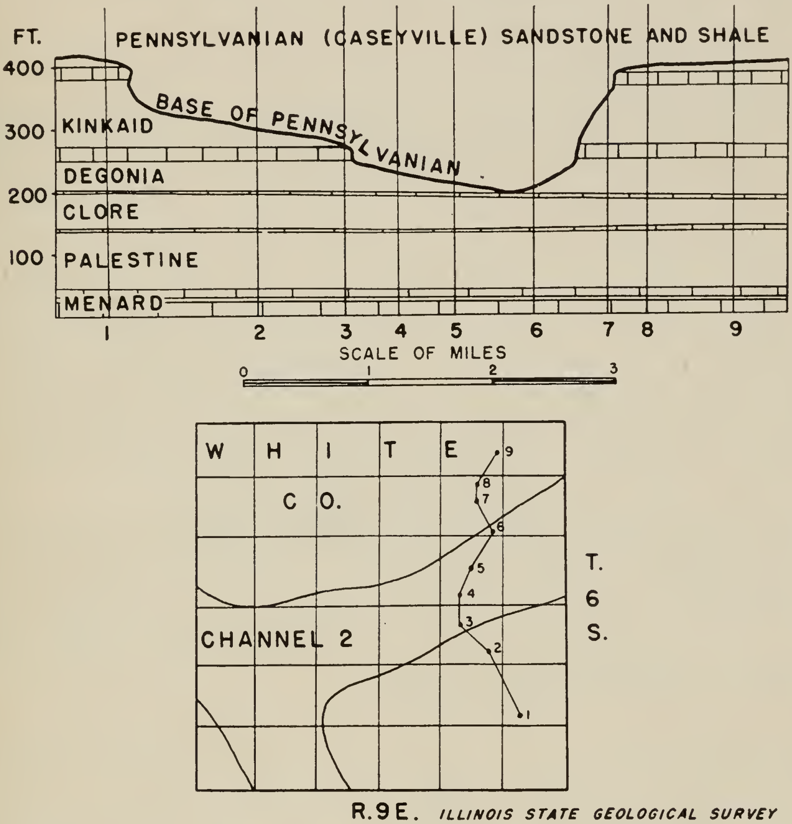


FIG. 11.—Cross section of channel 2.

relatively flat surface formed on the lower Kinkaid limestone in Jefferson and Franklin counties. The relief of the upland surface is small, not more than 100 feet in most areas, as contrasted to the over-all relief of the entire region, which is about 500 feet. The steep escarpments at the edge of the Kinkaid formation, and to a less extent at the edge of the Clore formation, form definite northward-facing cuestas. Large limestone blocks have slumped down to the base of the Kinkaid escarpment, in one area in Clay County[11] and several in Wayne and Franklin counties.

[11] D. H. Swann, "Buried Mississippian Slump Blocks in the Basal Pennsylvanian of Illinois" (abstract), *Bull. Geol. Soc. America*, Vol. 56, No. 12, Pt. 2 (1945), pp. 1204.

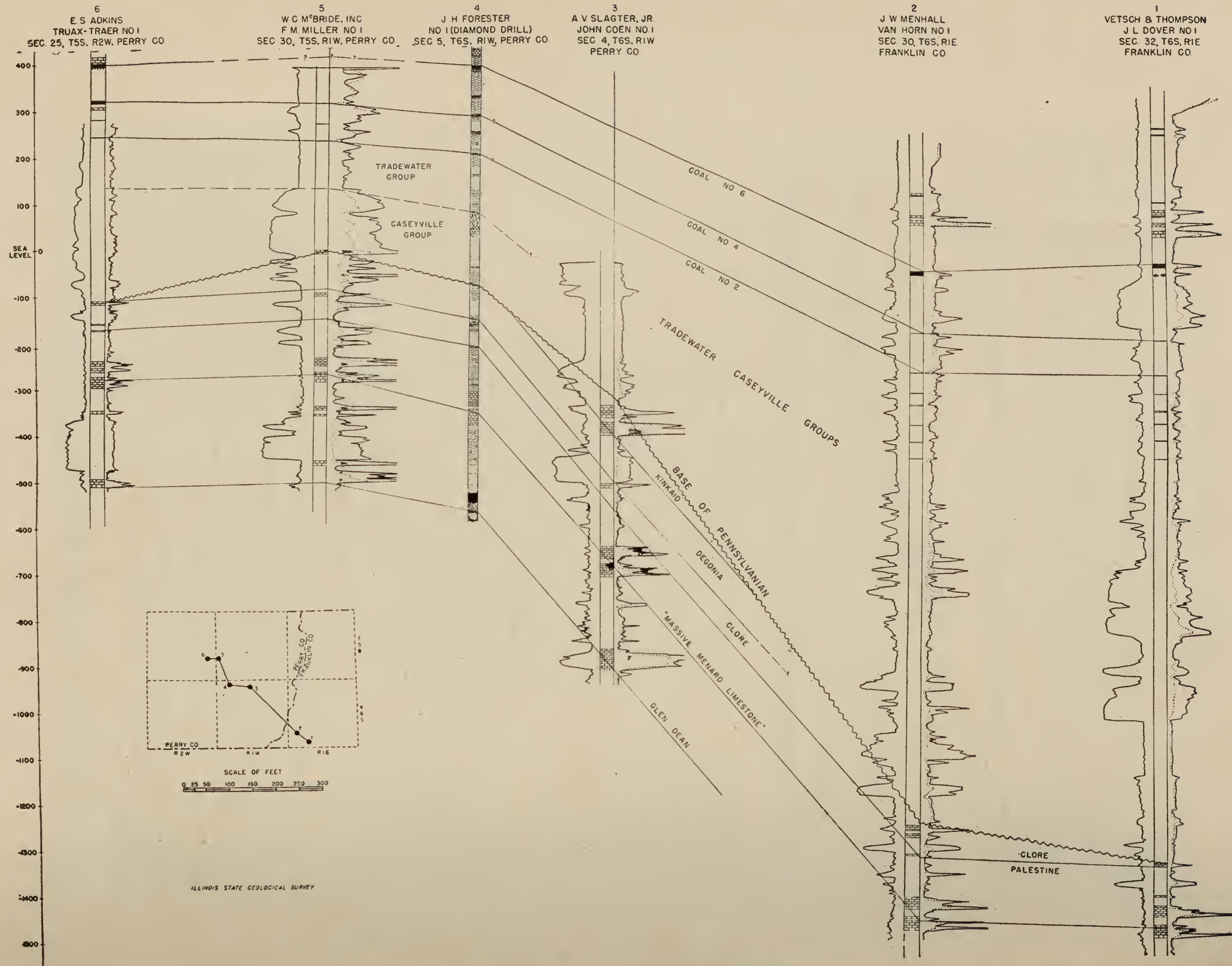


FIG. 12.—Cross section of DuQuoin monocline.

COMBINED UPPER CHESTER AND LOWER PENNSYLVANIAN ISOPACH MAP

The isopach map of the interval between the "massive" Menard limestone and Coal No. "2" (Fig. 7) is more generalized than the other two isopach maps. It shows primarily regional convergence of upper Chester and Lower Pennsylvanian sediments. The thickness of these rocks is at a maximum in northern Saline and Gallatin counties, where there is a combined thickness of more than 1,400 feet. The strata between the Menard and Coal No. "2" thin toward the north, east, and west. The thinning, however, is not uniform in all directions. The strata gradually thin northward to 900–1,000 feet in southern Clay County. Eastward thinning in the southern part of the basin, in White and Posey counties, Indiana, is relatively small, to 250–300 feet; toward the north, in Edwards and Wabash counties, the thickness decreases eastward from 1,200 feet in western Edwards County to 600–700 feet in eastern Wabash and Knox counties, Indiana. Westward thinning is gradual as far as the area of the DuQuoin monocline, where, in a distance of 2–3 miles, the formations thin from 1,200 feet to about 500 feet.

Thinning over prominent anticlines is evident from the map. Such structures include those of the Salem oil pool in southern Marion County, the Centralia oil pool in western Clinton County, the Clay City Consolidated oil pool in northern Wayne and southern Clay counties, the New Harmony Consolidated oil pool in eastern White County, and the LaSalle anticline in southeastern Lawrence County.

This isopach map shows no reflection of the pre-Pennsylvanian channels because thickening of the Pennsylvanian in the channels is compensated by thinning of the upper part of the Chester. It does show that the deeper part of the late Mississippian and early Pennsylvanian sedimentary basin was in Franklin, Hamilton, White, southern Wayne, and western Edwards counties.

"MASSIVE" MENARD STRUCTURE MAP

The general structural features of the southern part of the Illinois basin are indicated by the structure map of the "massive" Menard limestone (Fig. 13). The basin-like form is well displayed, the deeper part of the basin terminating on the west side at the DuQuoin-Centralia and Salem anticlinal belts and on the east side at the LaSalle anticline on the north and at a zone of faulting in the lower Wabash valley area on the south. The regional dip is from the periphery inward toward the axis of the Illinois basin in Hamilton, northwestern White, and southern Wayne counties. The lowest altitude of the Menard is in Sec. 36, T. 3 S., R. 3 E., White County, where it is 2,199 feet below sea-level. The highest altitude of the Menard is in Sec. 36, T. 4 S., R. 2 W., Perry County, where it is only 221 feet below sea-level.

In addition to the major structures, numerous minor structures which are commonly oil-producing are shown. Some of the more prominent are the Benton pool in south-central Franklin County, the King pool in south-central Jefferson County, Dale-Hoodville pool in southern Hamilton County, and Johnsonville

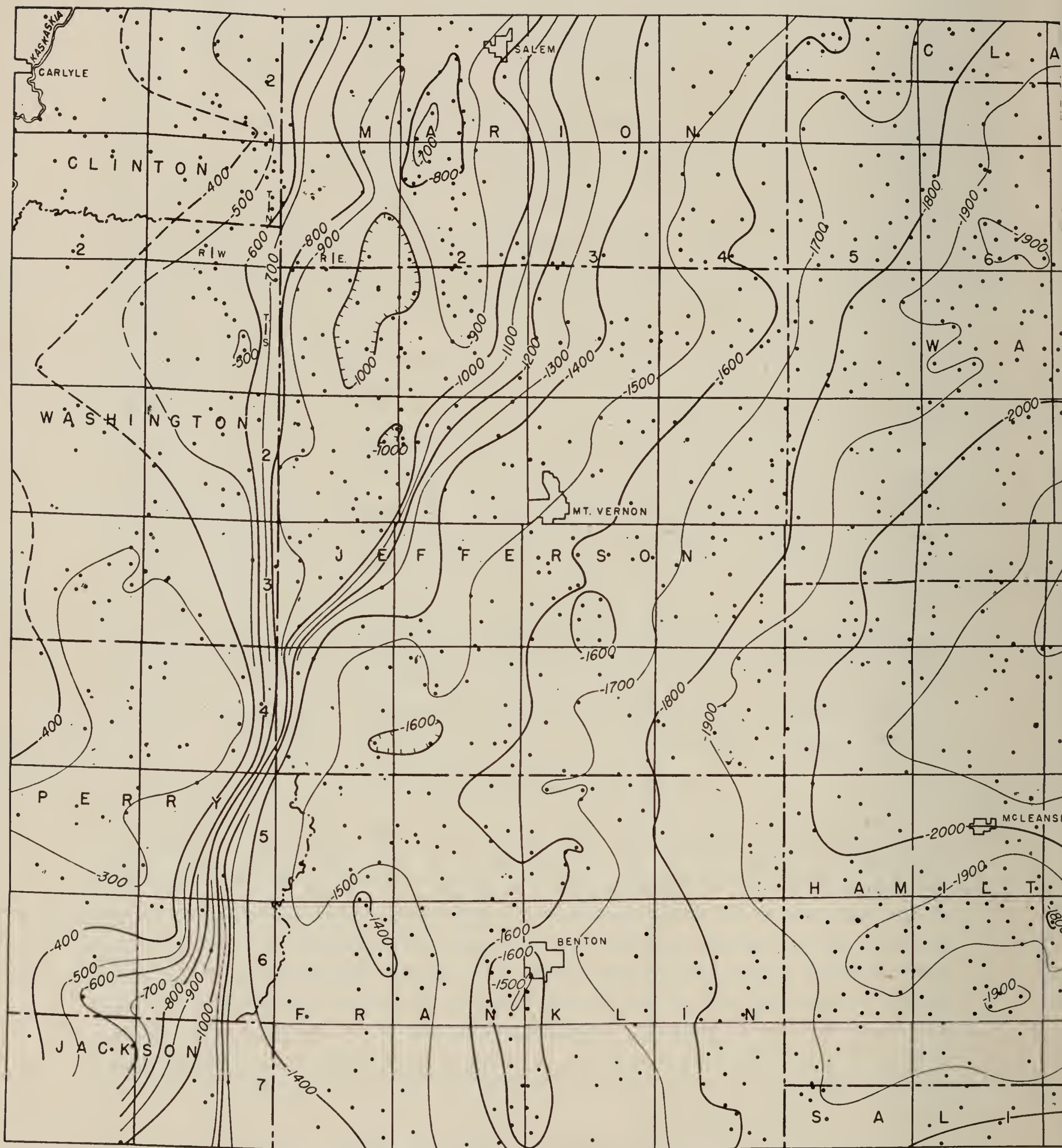
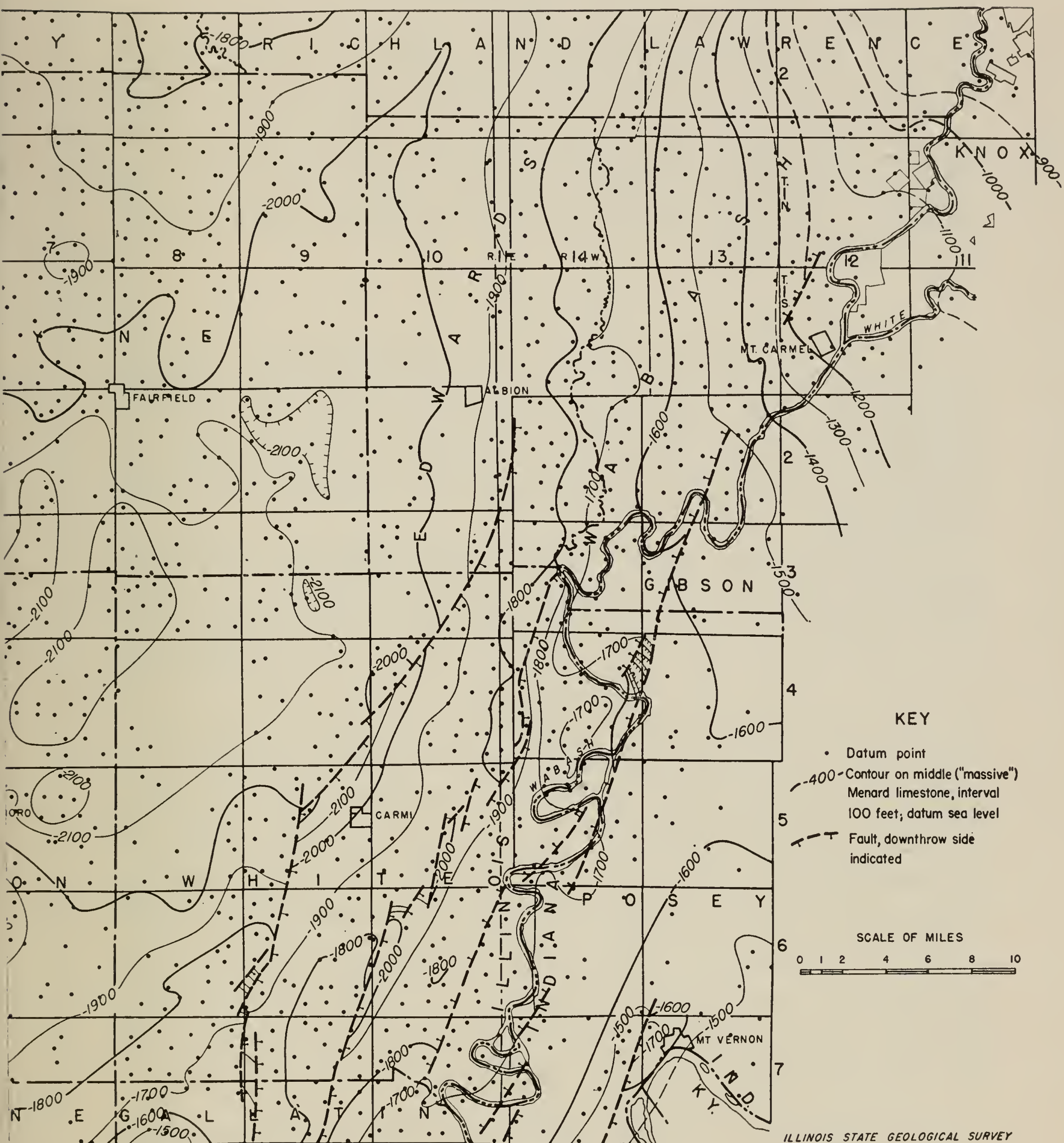


FIG. 13.—Structure of



"massive" Menard limestone.

pool in northwestern Wayne County. The Omaha dome, the northern part of which appears in T. 7 S., R. 8 E., in Gallatin County, is of interest because of igneous rocks encountered in drilling oil wells.[12] Another interesting feature of the map is the bifurcation of the DuQuoin monocline in the northeastern corner of Perry County to form two distinct anticlinal belts, the Centralia on the west and the Salem-Louden on the east, with a structural depression between them. The structure contours are generalized in eastern Wabash and eastern Lawrence counties and Knox County, Indiana, because the Menard formation has been removed in a large part of this area. The contours are also generalized in Clinton and Washington counties.

CROSS SECTIONS

Cross sections of two channels (Figs. 10, 11) have been discussed.[13] A detailed electric-log cross section of the southern end of the DuQuoin monocline (Fig. 12) is composed of five electric logs and one diamond-drill hole in which the formations were continuously cored to a depth below the Glen Dean limestone. The logs are arranged to show the present structural attitude of the beds. Although the vertical exaggeration is pronounced, the magnitude of the flexure is readily seen.

The thickness of the combined Tradewater and Caseyville groups decreases greatly over the structure, from more than 1,000 feet in the basin in Franklin County to less than 300 feet on the structural high in eastern Perry County. Thinning is less pronounced in the Carbondale group above a coal bed found over the monocline which is here correlated with Coal No. "2" in Franklin County, as shown in the cross section. The thickness of Carbondale strata above Coal No. "2" decreases from 220 feet in Franklin County to 170 feet in eastern Perry County over the monocline. Thinning of Chester beds over the structure is not apparent. It is noteworthy that conglomeratic sandstones in the Lower Pennsylvanian in the diamond-drill hole at the crest of the structure are about 150 feet thick, constituting about half of the combined thickness of the Tradewater and Caseyville groups at that place. These conglomeratic sandstones closely resemble typical Caseyville conglomeratic sandstones and are probably Caseyville in age, although some of the conglomerate may be Tradewater in age. The Tradewater-Caseyville boundary in the deep part of the basin, as represented in the easternmost two wells in the cross section (Fig. 12), is difficult to ascertain, but probably the Caseyville group is represented by not more than the basal 250–300 feet of the Pennsylvanian strata. If the conglomeratic sandstones over the monocline are all Caseyville in age, the major thinning occurs in the Tradewater group.

[12] R. M. English and R. M. Grogan, "Omaha Pool and Mica-Peridotite Intrusives, Gallatin County, Illinois," *Structure of Typical American Oil Fields*, Vol. 3, Amer. Assoc. Petrol. Geol. (1948), pp. 189–212.

[13] See pp. 561–62.

STRUCTURAL MOVEMENTS

The present structure of the southern part of the Illinois basin is the result of many positive and negative movements that affected the area at various times. In this study those movements are of concern that occurred in late Mississippian time and thereafter.

The sedimentary basin of which southern Illinois is a part began to form at least as early as early Ordovician[14] and was maintained, with minor interruptions, at least until late Pennsylvanian time. The maximum thickness of sediments deposited in this basin between the end of St. Peter time and the close of the Mississippian period is 6,000 feet. The distribution and precise thickness of St. Peter and older Paleozoic rocks in the deep part of the basin are not well known, but such rocks are probably at least 4,000–5,000 feet thick in the deeper parts of the basin. The Eastern Interior basin, of which the Illinois basin is a part, extended an unknown distance southward at the end of the Mississippian period. At the end of Chester time it was already separated from the Michigan basin by a continuation of the Cincinnati arch (the Kankakee arch),[15] and the LaSalle anticline was initiated as a positive structural trend at least as early as the beginning of the Mississippian, as evidenced by definite differences in the Lower Mississippian sediments on its two sides.[16] During Chester time the LaSalle anticline was somewhat flexed, as shown by slight thinning of sediments deposited over it. The DuQuoin monocline was not present during Chester time and the sedimentary basin extended to the borders of the Ozark uplift without interruption.

LATE MISSISSIPPIAN

Throughout Chester time the sedimentary basin in southern Illinois was slowly subsiding and receiving sediments; some areas subsided more slowly and received less sediment, as indicated on an isopach map of the thickness of the Chester series in Illinois, by Workman.[17] As differential subsidence, occasional mild compressional movements, and sedimentation continued through the Chester epoch, structures were formed and were gradually accentuated. Many of the domes and anticlinal folds which yield oil and gas in southern Illinois originated at this time. The Clay City anticline, the Wabash River anticline, the Salem-Louden anticline, and many others show slight thinning of Chester beds. Some slight thinning of upper Chester sediments is evident over the southern end of the LaSalle anticline, indicating that this structure too was present, at least in

[14] J. M. Weller and L. E. Workman, "Structural Development of Eastern Interior Basin" (abstract), Program, Amer. Assoc. Petrol. Geol., Eastern Interior Regional Meeting (1948), p. 10.

[15] George E. Ekblaw, "Kankakee Arch in Illinois," *Bull. Geol. Soc. America*, Vol. 49 (1938), pp. 1425–30.

[16] D. H. Swann, personal communication.

[17] L. E. Workman, *op. cit.*, pp. 220–21.

incipient form. The Centralia area was the only part of the present DuQuoin-Centralia monoclinal belt which was developing at this time. Emergence from the sea after Kinkaid time and cessation of sedimentation ended this period of mild deformational movements and differential subsidence.

POST-MISSISSIPPIAN—PRE-PENNSYLVANIAN

Deformational movements accompanied or followed the emergence which occurred at the end of the Mississippian period. Most of these movements followed the trends of the gentle structures formed during Chester time and emphasized them. The areal geologic map shows extensive erosion over two of the largest of these structures, the Centralia fold and the LaSalle anticline. A third, the New Harmony anticline in eastern White County, was probably uplifted also, as indicated by pre-Pennsylvanian erosion over the structure, but the relations shown on the areal geologic map are somewhat obscured by the presence of a pre-Pennsylvanian channel in this area. Many other minor structures also were either formed or accentuated at this time. The very widespread truncation of Chester and Lower Mississippian rocks throughout the Eastern Interior basin, with older beds beveled at its borders, indicates that these borders were uplifted relative to the deeper parts of the basin. Pennsylvanian rocks on the Cincinnati arch lie on formations as old as the St. Louis limestone,[18] showing that much uplift and erosion of pre-Pennsylvanian strata must have occurred over the arch. Erosion of the newly uplifted Ozarks was extensive and indicates uplift in that area.[19] Wisconsin and northern Illinois also were uplifted.[20] Two prominent fault and flexure zones originated at this time, the Cap-au-Gres fault[21] northwest of Alton, Illinois, in Calhoun and Jersey counties, and the Rattlesnake Ferry and small associated faults[22] in the Alto Pass area of Jackson and Union counties.

The extensive truncation of Mississippian beds and the beveling of structure beneath the Pennsylvanian are evidence of peneplanation. The presence of such a peneplain implies a long period of crustal stability to allow for the degradation of the land surface. This period was brought to an abrupt end by an uplift, as indicated by the deep channeling of this erosion surface in Illinois, Indiana, and Kentucky. The uplift was probably accompanied by warping which followed the structural trends initiated at the end of the Mississippian period, or earlier. Local warping may account for some of the divides between the channels incised below the peneplain. Not long after this second uplift, which rejuvenated the

[18] J. Marvin Weller and Alfred H. Bell, "Illinois Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21 (1937), p. 777.

[19] C. L. Dake, "Basal Pennsylvanian Transgression in the Ozarks," *Bull. Geol. Soc. America*, Vol. 46 (1935), pp. 697–714.

[20] J. Marvin Weller and Alfred H. Bell, *op. cit.*

[21] *Ibid.*, p. 779.

[22] George E. Ekblaw, "Post Chester, Pre-Pennsylvanian Faulting in the Alto Pass Area," *Trans. Illinois State Acad. Sci.*, Vol. 18 (1926), pp. 378–82.

streams, the entire area was lowered with respect to sea-level or base-level. This subsidence may have occurred either before or after Pennsylvanian sedimentation began, but it certainly had occurred by the time the marine Sellers limestone, midway in the Caseyville group, was deposited.

The length of time involved in the making of the unconformity surface is of some interest. The most complete transition known from Mississippian to Pennsylvanian sediments is in southern West Virginia. In this area more than 1,000 feet of Mississippian rocks of the upper Mauch Chunk series appear to be younger than any Chester beds in the Mississippi Valley area.[23] Overlying these youngest Mississippian beds is the Pocahontas group of the Lower Pennsylvanian, some of the oldest Pennsylvanian beds in the United States, which are more than 500 feet thick in this area.

No Chester rocks younger than Kinkaid are known in Illinois. If such sediments were deposited, they either were completely removed in the succeeding erosional interval, or have not been discovered. It is more likely that the Illinois basin was already exposed to erosion while very late Mississippian sediments were being deposited in the Appalachian geosyncline.

Pennsylvanian sedimentation in the Illinois basin did not begin until the lower middle Pottsville. The oldest Pennsylvanian flora known in Illinois, from the Wayside formation, closely resembles that of the Fire Creek or Beckley coals of the lower part of the New River group in the West Virginia area.[24] This would indicate that during all of Pocahontas and probably part of New River time southern Illinois was exposed to erosion.

PENNSYLVANIAN

In middle Pottsville time slow subsidence of the Eastern Interior basin began again and sedimentation was resumed. The two processes, subsidence and sedimentation, which were generally concurrent, together with the processes attending peat accumulation, under terrestrial conditions, characterized the basin throughout the Pennsylvanian. The subsidence, whether or not in response to loading, was intermittent and proceeded at variable rates. Because the deep part of the Illinois basin (Fig. 8) sank most rapidly, sedimentation here was more rapid and the accumulation was thicker than elsewhere.

Structures originating in Chester time and accentuated during the post-Mississippian-pre-Pennsylvanian interval were still further accentuated during the Pennsylvanian period. Thinning of Pennsylvanian beds is evident across most of the larger anticlinal folds in the basin. There is no evidence of emergence sufficient to have completely prevented sedimentation at the position of these structures. Stratigraphic relations of the Herrin (No. 6) coal over the Salem anti-

[23] J. Marvin Weller *et al.*, "Correlation of the Mississippian Formations of North America," *Bull. Geol. Soc. America*, Vol. 59 (1948), p. 107.

[24] C. B. Read, referred to by Harold R. Wanless, "Pennsylvanian Correlations in the Eastern Interior and Appalachian Coal Fields," *Geol. Soc. America Spec. Paper 17* (1939), p. 37.

cline indicate that the peat deposits, which were thick elsewhere, did not extend over the anticline.[25]

One new major structure, the DuQuoin monocline, began in the early Pennsylvanian. As discussed with reference to a cross section of the monocline (Fig. 12), the Chester beds show little or no thinning. The areal geologic map of the pre-Pennsylvanian surface and the upper Chester isopach map show no influence of structure in this area. The Chester beds show no difference in type of sediments on either side of the flexure, but Pennsylvanian beds show the influence of a rising structure on the rates of sedimentation. The thickest Pennsylvanian deposits are east of the monocline; these beds thin drastically on the crest of the structure and thicken again west of the monocline but not so much as on the east. There is some difference in the character of the sections east and west of the monocline. At some point in late Caseyville or early Tradewater time the area of the monocline stopped sinking as much as the deep part of the basin on the east and either sediments were deposited at a much slower rate over the newly formed structure or the structure may have been an island at various times during the Pottsville. The contrast between the very slight subsidence of the monocline and the rapid subsidence of the basin on the east was greatest during Tradewater, Carbondale, and earliest McLeansboro time and seems to have diminished later in the Pennsylvanian as suggested by the magnitude of thinning in different parts of the section.

POST-PENNSYLVANIAN

Some time during or after the late Pennsylvanian, sedimentation ceased in the Eastern Interior basin and the entire region was uplifted and warped, probably contemporaneously with a phase of the Appalachian revolution. The post-Paleozoic deformation and uplift accentuated all the Illinois basin structures much like their present form (Fig. 13). Folding of the LaSalle and DuQuoin flexures delimited the deeper part of the Illinois basin on the east and west. Extensive faulting occurred along the Shawneetown-Rough Creek, Cottage Grove, and lower Wabash Valley zones.[26] The Paleozoic formations were upturned to dip northward in Pope and Johnson counties in extreme southern Illinois, forming the present southern boundary of the Illinois basin and separating it from the southern part of the Eastern Interior basin in western Kentucky and its short extension into Eagle Valley in Saline and Gallatin counties, Illinois. At this time the Illinois part of a larger sedimentary basin became a distinct structural basin. Deep-seated igneous activity and associated emplacement of fluorspar deposits occurred in southeastern Illinois and western Kentucky.[27]

[25] Raymond Siever, "Structure of No. 6 Coal in Fayette, Marion, and Parts of Adjacent Counties," *Illinois Geol. Survey Circ. 164* (1950), p. 9.

[26] Stuart K. Clark and James S. Royds, "Structural Trends and Fault Systems in Eastern Interior Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 32 (1948), p. 1735.

[27] Edson S. Bastin, "The Fluorspar Deposits of Hardin and Pope Counties, Illinois," *Illinois Geol. Survey Bull. 58* (1931), p. 68.

The Cincinnati arch, Nashville dome, and the Ozark region were uplifted again and separated the large area of the Eastern Interior basin from the Appalachian basin on the east and the central and southern Mid-Continent region on the west.

There is no record of sedimentation in southern Illinois following the Paleozoic era until the northern tip of the Mississippi embayment reached the Cairo area and late Cretaceous and Eocene coastal plain sediments were deposited.[28] There is little or no record of the many structural movements that probably occurred during this long interval. The Appalachian region was subjected to many epeirogenic movements following the major post-Paleozoic orogeny and it is more than likely that the area of southern Illinois was affected by similar uplifts and warping movements before the subsidence and deposition in Upper Cretaceous time.

DEVELOPMENT OF PRE-PENNSYLVANIAN EROSION SURFACE

Following the deposition of the uppermost part of the Kinkaid formation or a little later, the shallow epicontinental sea withdrew from the Eastern Interior basin. The newly emerged sea floor first formed an essentially featureless coastal plain broken only by slight swells over pre-Pennsylvanian structures. The LaSalle anticline and the Centralia structure may have been slightly higher features of the surface. Southwest of the basin and beyond the present boundary of the state was the large uplifted area of the Ozark highlands. At this time shallow basin structure was already in the southern part of Illinois, with greater elevation of the borders of the sedimentary basin which had existed in Chester time. Subaerial erosion processes immediately attacked the newly emerged coastal plain and consequent streams developed, probably with a dendritic pattern. However, there is little evidence of the original pattern as later events largely obliterated it. It is probable that the present deep part of the basin was then topographically lower than the uplifted borders and initiated radial drainage into the basin from the east, west, and north, with an outlet on the south. The southward drainage would have followed the shallow basin depression which at this time continued southward an unknown distance.

The result of this subaerial erosion of the uplifted surface of southern Illinois was a peneplain. Later structural movements disturbed what were probably accordant levels excepting over relatively small areas, such as a county or group of counties, but the extensive beveling of post-Mississippian structures, the widespread truncation of Chester and older beds, and the relatively flat appearance of many of the upland areas on the isopach maps of southern Illinois provide excellent local indications of a peneplain that probably extended over a large part of the United States.[29] In many places where the Mississippian or older rocks were

[28] J. E. Lamar and A. H. Sutton, "Cretaceous and Tertiary Sediments of Kentucky, Illinois, and Missouri," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14 (1930), pp. 845–66.

[29] A. I. Levorsen, "Pennsylvanian Overlap in the United States," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 2 (1931), pp. 113–48.

never deposited the unconformity represents a time interval greater than that between the Mississippian and Pennsylvanian periods of sedimentation and the evidence for peneplanation is strong. The evidence of peneplanation is also strong in the areas where the Pennsylvanian overlies the late Mississippian. Thus, some time after the cessation of Mississippian sedimentation the greater part of the eastern half of the United States, at least, was a peneplain or panplain with isolated higher areas, such as the Ozark highlands and possibly the Cincinnati arch.

Karst topography was produced in areas where thick Mississippian and older limestones and dolomites were the dominant rocks. Such karst topography in the Ozark region has been described in detail by Dake.[30] Not all the solution features in pre-Pennsylvanian limestones lying beneath a Pennsylvanian cover can be attributed to solution before the Pennsylvanian was deposited. There is increasing evidence from the Kankakee area in northern Illinois, the Missouri filled-sink areas, and the Ozark region[31] that much of the solution took place under a Pennsylvanian cover which subsided into the sinkholes as they were formed. Pierce[32] has inferred such an origin for the configuration of the pre-Pennsylvanian surface in the Tri-State district of Kansas, Oklahoma, and Missouri. A karst topography beneath the Pennsylvanian has been described in western and northwestern Illinois.[33] In some of these areas, notably the Ozarks, the pre-Pennsylvanian unconformity represents a time interval extending through most, if not all, of Chester time and it is likely that much of the karst topography was developed before the Pennsylvanian sediments were laid down. Solution was relatively not an important process in the deep part of the basin where a section of alternating thin limestones and sandstones and shales of the upper Chester series was exposed. In this area downwasting probably took place in much the same way that the Chester formations now exposed in southern Illinois, southern Indiana, and Kentucky are being slowly weathered mainly by the action of wind, flowing water, and frost, with solution relatively subordinate.

In connection with the development of the pre-Pennsylvanian peneplain, a fossil soil horizon previously described[34] is of some interest. The thinness and spotty occurrence of the soil suggests that it may be a zone of reworked and slightly transported soil rather than a thick soil which evolved in place. The presence of such a soil horizon is another indication of a period of subaerial erosion.

The deep, youthful valleys incised into the pre-Pennsylvanian surface belong to a second cycle of subaerial erosion which was initiated by uplift of the pene-

[30] C. L. Dake, *op. cit.*

[31] J Harlen Bretz, "Origin of Filled Sink-Structures and Circle Deposits of Missouri," *Bull. Geol. Soc. America*, Vol. 61 (1950), pp. 789–834.

[32] W. G. Pierce, "Some Significant Features of the Mississippian Pennsylvanian Contact in the Tri-State District" (abstract), *Jour. Washington Acad. Sci.*, Vol. 25 (1935), pp. 572–73.

[33] J. Marvin Weller and A. H. Sutton, *op. cit.*, p. 849.

[34] See pp. 548–549.

plain. The trend of channels in southern Illinois was northeast-southwest, as is clear from the areal geologic and isopach maps (Figs. 4, 5, 6). The downstream direction is indicated by various lines of evidence. Many of the tributaries to channels 1 and 2 (Fig. 9) were connected to the main streams with acute angles whose vertices point southward or westward, indicating that downstream was in that direction. Paleographic considerations, in addition, make a southwestward drainage likely. At the close of Mississippian time the epicontinental sea withdrew from much of the North American continent.

The oldest marine strata in the Pennsylvanian of the United States are the rocks of Springer and lower Morrow age in north-central Texas and the southern Mid-Continent region, as well as the early Pennsylvanian rocks of the Marathon basin in southwest Texas. The oldest marine strata in the Appalachian basin are at about the position of the Sharon ore, correlated with the Sellers limestone of Illinois and the Morrow of Arkansas by Wanless.[35] The earliest Pennsylvanian marine invasions of the Eastern Interior and Appalachian basins therefore came nearly at the same time. Antedating these marine invasions are the marine deposits in the southwestern part of the United States. All indications are that early Pennsylvanian seas advanced into the interior of the continent from the southwest; a remnant Mississippian-Pennsylvanian sea probably lay in this direction in the intervals during which the sea retreated from the major part of the continent.[36] Thus it is probable that the drainage of the Eastern Interior basin area during the interval between the end of the Mississippian period and the resumption of sedimentation in the Pennsylvanian period was toward a remnant Mississippian sea on the southwest.

Channel 5 (Fig. 9) apparently drained northeast in contrast to the other channels. There are not enough well data to determine whether channel 6 drained northeast or southwest. Northeastward drainage may have been local reversal of the major direction of drainage or might be an indication of a major divide across the northern parts of Wabash, Edwards, Wayne, and Marion counties. The latter alternative implies that warping accompanied the uplift of the peneplaned surface, with the area north of the divide tilted slightly north. The position of these northward-draining channels is such that they extend for a short distance directly toward the LaSalle anticline. Superposition of streams over the beveled anticline would probably have produced trenches, which may be revealed by future drilling and more detailed study in this area.

Evidence of uplift of a pre-Pennsylvanian peneplain and the rejuvenation of the streams with resultant trenching of the older erosion surface is by no means restricted to southern Illinois. Such deep, incised channels are known in Indiana, Kentucky, and Missouri. Thus the rejuvenation was widespread, at least through-

[35] Harold R. Wanless, "Pennsylvanian Correlations in the Eastern Interior and Appalachian Coal Fields," *Geol. Soc. America, Spec. Paper 17* (1939), p. 64.

[36] J. Marvin Weller, "Pennsylvanian Overlap in the United States" (discussion), *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15 (1931), pp. 706–07.

out the Eastern Interior basin. There is also some evidence of such channels in Ohio, in the Appalachian basin.[37] Very detailed mapping of the pre-Pennsylvanian surface is necessary to delineate these channels as most of them are not very wide; when the erosional surface is mapped in more areas it is expected that more such channels will be described.

A rock terrace, formed on the surface of Clore limestone, in the wide part of channel 1 is indicated on the areal geologic and isopach maps. The terrace does not bevel any formations or structures and seems to be a result of the differential hardness of the Clore formation as contrasted to the soft Degonia above and the Palestine below. This terrace, therefore, is not an indication of another erosion cycle.

Small isolated hills capped by Kinkaid limestone rise prominently above the widest parts of the floor of channel 1. Most of them have been drawn on the maps as elliptical or round forms because the wells are not sufficiently closely spaced to give their detailed configuration. The most probable explanation is that they are relics of a meandering stream that was rejuvenated and cut down rapidly and left the meander cores. This would also account for the greater width of channel 1 as compared with the much narrower valleys of the other channels.

The type of erosion that took place during the second geomorphic cycle, as suggested by the isopach maps and the presence of slumped limestone blocks, was wastage and parallel retreat of slopes by sapping of weak sandstone and shale beds and undercutting of limestone beds. This erosion produced not only deep channels but prominent cuestas at the edges of the gently dipping prominent limestone beds of the Chester series.

While some erosion continued in southern Illinois, the Pottsville sea was advancing slowly over the interior of the continent with the deposition of marine sediment in such areas as the Mid-Continent region. At the same time, great thicknesses of terrestrial sediments, including peat accumulations, were laid down in the Appalachian geosyncline. In earliest Caseyville time these terrestrial sediments had overlapped farther and farther westward and northwestward, and coarse sand and rounded quartz pebbles were deposited in the southern part of the Illinois basin. The earliest Pennsylvanian sediments known in the Eastern Interior basin, the Hindostan beds[38] of southern Indiana, contain coal beds which indicate that these earliest sediments in the region were non-marine in character and possibly a westward extension of non-marine Appalachian sediments. It was not until slightly after this stage that the first known marine invasion occurred, at about the time the Sellers limestone was deposited in Illinois and the Sharon ore in Ohio.

While early Pennsylvanian sediments of Caseyville age were being laid down in the southern part of the Illinois basin, the stable land area at the north was

[37] J. E. Hyde, "Notes on the Absence of a Soil Bed at the Base of the Pennsylvanian of Southern Ohio," *Amer. Jour. Sci.*, Ser. 4, Vol. 31 (1911), p. 558.

[38] Harold R. Wanless, *op. cit.*, p. 37.

still being eroded. The oldest coal bed known in northern or western Illinois is the "sub-Babylon" coal, which is considered early Tradewater in age.[39] It was not until early Tradewater time that Pennsylvanian sediments overlapped northern Illinois. As the Mississippian and older rocks were completely overlapped by Pennsylvanian sediments, the Mississippian-Pennsylvanian unconformity was buried and preserved. Subsequent deformations modified the initial attitude of the pre-Pennsylvanian surface without destroying the irregularities produced by pre-Pennsylvanian erosion.

SEDIMENTATION ON UNCONFORMITY SURFACE

Detrital material which must have been present in the bottoms of the pre-Pennsylvanian channels and in interchannel areas was probably reworked and incorporated with other sediment to form the basal Pennsylvanian. It is difficult to decipher the precise pattern of sedimentation on the erosion surface with respect to lithologic variations over channels and uplands, because of lack of information. The writer has had access to basal Pennsylvanian cores from only six wells in the deep part of the basin, where the channels were mapped in detail. Of these cores, two are from upland areas and four are from pre-Pennsylvanian channels. From the study of these cores and rotary drill cuttings certain tentative conclusions can be drawn. Some drill holes penetrating channels show coarse sandstone and conglomerate filling the channel at one place and a few miles away, in the same channel, another drill hole shows a fill composed completely of shale and shaly siltstone. Coarse, conglomeratic sandstones, consisting primarily of coarse sand grains, rounded quartz pebbles, large granules of metamorphic and igneous quartz, and some pebbles derived from metamorphic and sedimentary quartzites are almost as common in interchannel areas as in channels. The conglomeratic material in the channels is similar to that on the uplands, although true conglomerates, as contrasted to conglomeratic sandstones, are restricted to the basal part of the channel fills.

There are several possible explanations for the distribution of the conglomeratic sandstones in the basal Pennsylvanian. One is that the channels were graded up to and over the level of the uplands. This could be accomplished by a slight lowering of the land-level, a rise in base-level, or a climatic change sometime before the first marine invasion of the area. After one event or a combination of several of these events had occurred, the streams lost their power to erode. The channels proper filled with coarse sand and gravel, and mud and silt were deposited on the flood plains. Thus a well drilled into flood-plain deposits would encounter mostly shale and siltstone and a well penetrating the channel proper would show mostly sandstone and conglomeratic sandstone. With continued aggradation the streams were graded above the level of the uplands and coarse sand and gravel was spread over much of the upland area. Imperceptibly the

[39] Robert M. Kosanke, "Pennsylvanian Spores of Illinois and Their Use in Correlation," *Illinois Geol. Survey Bull. 74* (1950), p. 64.

sediments of this aggraded plain, which now covered the unconformity surface, merged with a depositional plain of terrestrial sediments extending westward from the Appalachian geosyncline and became an integral part of it. This burial of pre-Pennsylvanian topography has a Tertiary counterpart in the well known case of the Ogallala formation invading and burying a country of hills and valleys in the Great Plains.[40]

Another possible explanation of the distribution of basal Pennsylvanian sediments is that the westward extension of a large piedmont alluvial fan in the Appalachian geosyncline spilled over into the channels and quickly filled them up to and above the level of the upland surface. The front of the fan advanced westward and northwestward from the geosyncline, encountering a drainage system in southern Illinois and Indiana at nearly right angles to it. After filling of the channels the area of southern Illinois was covered by the shifting detritus of the fan.

The sandstones of the lower part of the Pennsylvanian system in southern Illinois have long been considered to be essentially non-marine because of the absence of marine fossils and because of their association with coal beds of terrestrial origin. The possibility does exist, however, that many of these sandstones were deposited in either brackish or near-shore marine waters. Lack of marine fossils is only negative evidence and not conclusive. The sandstones do not contain thin lenticular coal streaks which might indicate terrestrial conditions, such as are common in many sandstones of the Carbondale and McLeansboro groups higher in the Pennsylvanian. Many of the basal sandstones show very prominent cross-bedding, much of it of the torrential type. The extreme regularity of some of the cross-bedding may be an indication of the marine origin of these beds. Only a thorough, detailed study of the mineralogy, textures, and field relationships of these sandstones can supply the answer to this question. If many of these sandstones should be considered marine, then different conditions must be postulated for the burial of the pre-Pennsylvanian erosion surface. Thus an initial lowering of the surface in southern Illinois caused submergence of the topography, and influx of coarse detritus from the east rapidly filled the channels. A huge delta extending westward from the Appalachian region gave rise to sediments of a mixed marine and non-marine origin and occasional peat beds which were later transformed into coal.

The buried topography of the pre-Pennsylvanian surface had some effect on the differential compaction of Pennsylvanian sediments. A comparison of the upper Chester isopachs (Fig. 5) and the Lower Pennsylvanian isopachs (Fig. 6) shows that most of the channels are deeper and isolated hills higher on the upper Chester isopach map than the same features on the Lower Pennsylvanian isopach map. This indicates that Pennsylvanian beds were compacted differentially—that beds sagged over channels and were slightly elevated over buried hills. It is likely

[40] J Harlen Bretz and Leland Horberg, "The Ogallala Formation West of the Llano Estacado," *Jour. Geol.*, Vol. 57 (1949), p. 478.

that most of this differential compaction took place in the lowest 200–300 feet of the Pennsylvanian section and above that zone the compaction effect on the buried topography is masked by deeper burial. This differential compaction due to buried topography is not to be confused with differential compaction of shales and sandstones, which has some effect on the position of thin marker beds, such as coals, all through the Pennsylvanian system in Illinois. Very commonly a coal bed bends slightly upward over a thick sand body, such as a channel sandstone within the Pennsylvanian, in areas where such a difference in elevation of the coal bed can not be attributed to structural warping.

ACCUMULATION AND MIGRATION OF OIL

Until 1937 most of the oil produced in Illinois came from the old oil fields producing in large part from Pennsylvanian formations in Lawrence, Clark, and Crawford counties. Since 1937 most of the exploration activity has centered about Chester and Lower Mississippian oil-producing formations, in particular the "McClosky oölite," part of the Ste. Genevieve formation. More recent exploration has been for oil-producing formations in the Devonian, Silurian, and Ordovician. To date the only areas that produce a large amount of oil from the Pennsylvanian are on the eastern edge of the basin—Gallatin, White, Edwards, Wabash, Lawrence, Crawford, and Clark counties. Most of the fields in the northernmost three counties are located on or near the LaSalle anticline, and the source of this oil is directly related to sedimentation conditions on or near the anticline during Pennsylvanian time.

Farther south, in Gallatin, White, and Edwards counties particularly, the presence of oil in Pennsylvanian sandstones is probably not related to such original sedimentation conditions and the sandstones can not be considered as source beds. Oil has migrated into these formations from lower source beds, probably in the lower part of the Chester series and the upper part of the Lower Mississippian. The most obvious routes of migration from source beds to reservoir beds in the Pennsylvanian are the many faults which are present in the lower Wabash River valley area (Fig. 13). Almost all the oil fields producing from Pennsylvanian formations are in close proximity to one or another of these faults, giving support to the hypothesis that the oil migrated upward to permeable Pennsylvanian sandstones. Much of the oil produced from upper Chester sandstones in this area, such as the Palestine and Degonia, probably migrated along the same fault lines.

Another route of migration of oil from source beds in the Mississippian to reservoir beds in the Pennsylvanian is the contact surface between the two systems. Most of the oil fields in Wabash County that produce from Pennsylvanian beds are not near faults. These oil-bearing Pennsylvanian sandstones are not the shoestring-type sands which are found farther north along the LaSalle anticline, but are almost invariably the basal Pennsylvanian sands which overlie the unconformity. A common term for these sands is the "Biehl" sand, which includes any sand close to the base of the Pennsylvanian. These areas producing Pennsylvanian oil closely coincide with areas on the pre-Pennsylvanian areal geologic map (Fig. 4) in which the rocks at the unconformity surface are Waltersburg or older in age. It seems, therefore, that where pre-Pennsylvanian erosion cut down close to source beds of petroleum in the lower Chester or upper part of the Lower Mississippian, the unconformity surface provided a favorable route of migration of oil to higher permeable Pennsylvanian beds.

It has been noted by Weller[41] that in Edmonson County, Kentucky, the rock-asphalt deposits, which are fossil oil accumulations, have an occurrence which is directly related to the presence of pre-Pennsylvanian channels at the contact surface between the Pennsylvanian and Mississippian systems. The richest rock asphalts are in two of the basal sandstones of the Pennsylvanian in the deeper parts of a pre-Pennsylvanian channel. Presumably the deep excavation of the channel provided the easiest migration route for oil from source beds lower in the section. Recently the writer examined oil-saturated cores of basal Pennsylvanian sandstone from a new oil pool extension in the lower Wabash River valley area. The producing sandstone, which is conglomeratic and coarse, and contains pebbles of Chester sandstones, cherts, and large granules of quartz, is the fill of a pre-Pennsylvanian channel located under the pool. The sandstone is porous and permeable and is an excellent reservoir rock. The production of oil from this conglomeratic channel-fill emphasizes the possibility that exploration of basal Pennsylvanian sands over channels in this general area may be fruitful.

SUMMARY

One of the main problems associated with the Mississippian-Pennsylvanian unconformity in southern Illinois is the identification of the contact in the subsurface. The writer believes that with a thorough study of Upper Mississippian stratigraphy and a detailed lithologic study of Chester and Lower Pennsylvanian rocks, identification of the position of the unconformity can be made in most places with minimum error. An attempt has been made to reconstruct the topography of the pre-Pennsylvanian erosion surface. From this reconstruction it is evident that two successive erosion cycles are involved in the making of the surface. The first cycle reached the peneplain stage; the second cycle did not advance beyond early youth. The evidence for the peneplain includes the beveling of formations and structures, and roughly accordant upland levels. The evidence for the second cycle of erosion is the presence of many deep channels cut into the peneplain surface.

Three explanations are here offered for the burial of the topography under basal Pennsylvanian sediments: (1) burial by aggrading streams flowing in the channels; (2) burial by a piedmont alluvial fan advancing westward from the Appalachian region; and (3) drowning and burial by marine sediments. It is

[41] J. Marvin Weller, "Geology of Edmonson County," *Kentucky Geol. Survey*, Ser. 6, Vol. 28 (1927), p. 207.

pointed out that the unconformity provides a favorable route for the migration of oil from Mississippian source beds, that exploration for oil in basal Pennsylvanian sandstones which are the fills of pre-Pennsylvanian channels has been successful, and that more exploration along these lines might be fruitful.

The geologic history of the unconformity may be summarized as follows.

1. Withdrawal of late Chester seas and the cessation of Mississippian sedimentation.

2. Uplift of the Eastern Interior basin with the structural borders of the basin raised higher than the basin.

3. A long period of subaerial erosion during which a peneplain was formed.

4. The whole area was uplifted and warped, resulting in rejuvenation of streams which cut channels into the peneplain.

5. During the period of peneplanation and the later cycle of erosion a karst topography was formed in thick limestone bedrock areas.

6. Very early in the Pennsylvanian period detritus coming from the Appalachian geosyncline merged with some locally derived sediment and buried the hills and channels completely, ushering in the period of Caseyville deposition.

7. At least as early as mid-Caseyville time, the Pottsville sea invaded the region and the Sellers limestone was deposited in southern Illinois.

8. A long period of Pennsylvanian sedimentation followed, marked by cyclic deposition and mixed marine and non-marine sedimentation in the slowly subsiding Eastern Interior basin.

9. Pennsylvanian sedimentation was brought to a close by the widespread orogenic and epeirogenic movements of the Appalachian revolution, during which the unconformity was warped and folded to essentially its present attitude.

10. Later faulting, probably pre-Cretaceous in age, cut the unconformity in southeastern Illinois and western Kentucky.

11. Post-Paleozoic erosion removed the Pennsylvanian in many areas, exhuming and then cutting below the unconformity into Chester and lower beds.