CHANNEL-FILL SANDSTONES IN THE MIDDLE PENNSYLVANIAN ROCKS OF INDIANA

by
S. A. FRIEDMAN

Indiana Department of Conservation
GEOLOGICAL SURVEY
Report of Progress No. 23

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Harold W. Handley, Governor

DEPARTMENT OF CONSERVATION
E. Kenneth Marlin, Director

GEOLOGICAL SURVEY
John B. Patton, State Geologist
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CHANNEL- FILL SANDSTONES IN THE MIDDLE PENNSYLVANIAN ROCKS OF INDIANA

By S. A. Friedman

ABSTRACT

Data from coal-test boreholes and outcrops show that channel-fill sandstones occur at 32 localities in western Indiana in the Brazil, Staunton, Linton, Petersburg, and Dugger Formations of middle Pennsylvanian age. These sandstones average 40 feet thick, 3 miles long, and a quarter of a mile wide at the top and commonly trend southwestward down the regional dip. At least nine different coal beds are cutout or replaced locally by these channel-fill sandstones.

Four classes of channel-fill sandstones are recognized in Indiana. Channel-fill sandstones of class 1 form a dendritic pattern and trend and thicken downdip; those of class 2 also form a dendritic pattern and trend downdip without thickening; channel sandstones of class 3 do not form a dendritic pattern but also trend downdip; and those of class 4 do not trend downdip; instead, they are parallel to the regional strike, and they do not have a dendritic pattern.

The channel-fill sandstones are light brown or red brown, thick bedded and crossbedded, medium grained to coarse grained, and micaceous. Their bases rest disconformably on underlying strata, and they represent the lowest stratigraphic unit in a cyclothem. Paleotopography, influenced by differential compaction of sandstone and shale, underlying structure, and a southwesterly regional slope determined the geographic distribution and orientation of the channel-fill sandstones.

The periodic lowering of sea level during middle Pennsylvanian time probably exposed the Cincinnati Arch and thus permitted consequent subaerial streams to erode the channels and fill them mostly with sand on at least six different occasions. Possibly most of the channel-fill sandstones were derived from the Pottsville (lower and middle? Pennsylvanian) and the Chester rocks that were presumably on the arch.

The Coxville Sandstone, first referred to by G. H. Ashley in 1899, is herein proposed as a member at or near the base of the Linton Formation of the Allegheny Series (middle Pennsylvanian) in Indiana. The Palzo Sandstone of Illinois probably is correlative with the Coxville Sandstone Member.

INTRODUCTION

PURPOSE AND SCOPE OF STUDY

The main objectives of this report are (1) to show the geographic and stratigraphic distribution of some of the channel-fill sandstones in the Allegheny Series (middle Pennsylvanian) in Indiana, (2) to show how these sandstones can be recognized by means of a working geometric classification, and (3) to discuss their tectonic relations, genesis, and economic significance. Except for some field descriptions, the petrography of the channel sandstones was not studied.

The author collected data on channel sandstones from outcrops and coal-test boreholes while he worked on coal resources studies in parts of Parke, Vermillion, and Vigo Counties from 1953 to 1958 inclusive. Other geologists of the Coal Section provided data from Clay, Knox, Daviess, Pike, Spencer, and Warrick Counties. Although channel-fill sandstones occur in the other coal-bearing counties in Indiana, they have not been studied and thus are not included in this report.

ACKNOWLEDGMENTS

The author wishes to thank Mr. T. J. Nolan, district geologist of the Ohio Oil Co., Terre Haute, and his staff; Mr. A. G. Gossard, vice president, and Mr. Robert Mitchell, engineer, of the Snow Hill Coal Corp., Terre Haute; and Mr. Ivan Craggs, Public Service Co. of Indiana, for the many courtesies that they have extended and for the drilling data that they have made available. The author also is grateful to various landowners and farmers for their cooperation during the field exploration part of the channel sandstone project.

PREVIOUS RESEARCH

Ashley (1899, p. 80-82, 300-301, 362, 385-386) first described channel-fill sandstones in the middle Pennsylvanian rocks in Indiana. Since Ashley's time little attention has been paid to these sandstones until recent coal resources investigations pointed them out. For example, Wier (1952 and 1953) mapped a channel sandstone of middle Pennsylvanian age in Vigo County and one in Pike County. Important information on channel-fill sandstones of middle Pennsylvanian age in the Eastern Interior Basin was presented by Ekblaw (1931), Weller (1930, 1931, and 1956), Wanless (1931, 1955, and 1957), Mueller and Wanless (1957), Rusnak (1957a and 1957b), Siever (1957), Potter and Glass (1958), Hopkins (1958), and Friedman

(1956, 1957a, 1957b, and 1958).

DESCRIPTION OF CHANNEL SANDSTONES

STRUCTURAL AND STRATIGRAPHIC SETTING

A map of the "Coal Fields of the United States" that was prepared by Campbell (1917) and revised by Averitt (1942) includes an eastern and an interior coal province. In the present report the eastern coal province is referred to as the Appalachian Basin, and the divisions of the interior coal province are referred to as the Western Interior, Eastern Interior, and Michigan Basins (fig. 1). The author prefers to use Eastern Interior Basin to indicate the present extent of Pennsylvanian rocks and thus to follow the usage of Wanless (1955). The term Illinois Basin of some authors, for example Cady (195 1), is synonymous with the Eastern Interior Basin of Wanless. These basins are considered, furthermore, as struc-

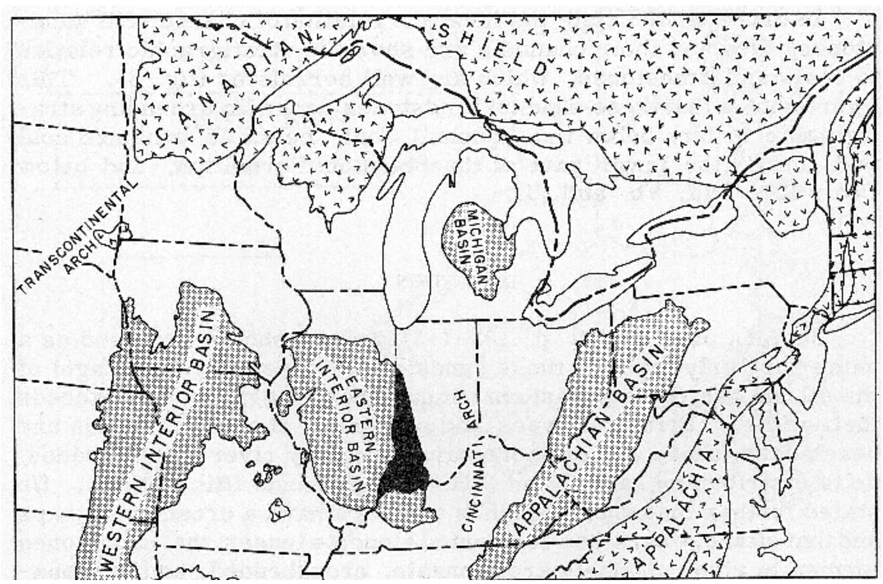


Figure 1. --Index map showing area studied (black) in relation to present extent of Pennsylvanian basins (stippled) and source areas (checked). Modified from Tectonic Map of the United States, 1944, American Association of Petroleum Geologists.

tural basins that are remnants of former larger sedimentary basins, and they all are bounded by the present outcrop of strata of Pennsylvanian age. That part of the Eastern Interior Basin that is in Indiana (fig. 1) contains the thickest accumulation of coal in this basin (Wanless, 1955, p. 1798), and it is considered to be in large part a structural shelf. Strata of Pennsylvanian age dip southwestward or westward in this shelf area at about 25 feet per mile. The channel-fill sandstones that were studied lie in this area and their surfaces conform to this dip. Undoubtedly they also are present in Illinois in that part of the Basin where maximum subsidence took place and the Pennsylvanian sedimentary rocks are thickest.

These channel-fill sandstones occur at 32 localities in western Indiana (fig. 2). Where channel fragments are too close to show as separate lines on this map, they were connected. Thus only 23 channels are numbered. The "X" in Vigo County (fig. 2) represents channel-fill sandstones oriented nearly perpendicular to each other and in different stratigraphic positions. Channel-fill sandstones are present in the Brazil, Staunton, Linton, Petersburg, and Dugger Formations of middle Pennsylvanian age.

In order to facilitate the local correlation of channel-fill sandstones, they and their channels are shown in stratigraphic relation to coals and limestones, which are well correlated (fig. 3). This figure shows that these channel sandstones occur (in ascending stratigraphic order) below the Minshall Coal, below an unnamed coal that lies in the lower part of the Staunton Formation, and below Coals IIIa, IVa, Vb, and VII.

DEFINITION

John L. Rich (1923, p. 103-113) defined shoestring sand as a name popularly given to those sandstones (of Pennsylvanian age) of the oil and gas pools of eastern Kansas whose length greatly exceeds their width. Principal types and origins of shoestring sands are beach bars, shore and offshore bars, ordinary river channel sands, delta distributary sands, and tidal channel sands (Rich, 1923). He stated further that shore beaches and bars have a crescentic shape and that off shore bars are segmented elongate lenses; that sandstones formed in river channels are elongate, crossbedded, and carbonaceous and show meander curves; and that those in tidal channels are elongate but shorter than sandstones formed in delta channels and contain more branches and meander curves.

Credit is due Rich for this pioneering basic differentiation of shoestring sands (sandstones) that is still valid, although subsequent authors have added petrographic criteria and other descriptive terms.

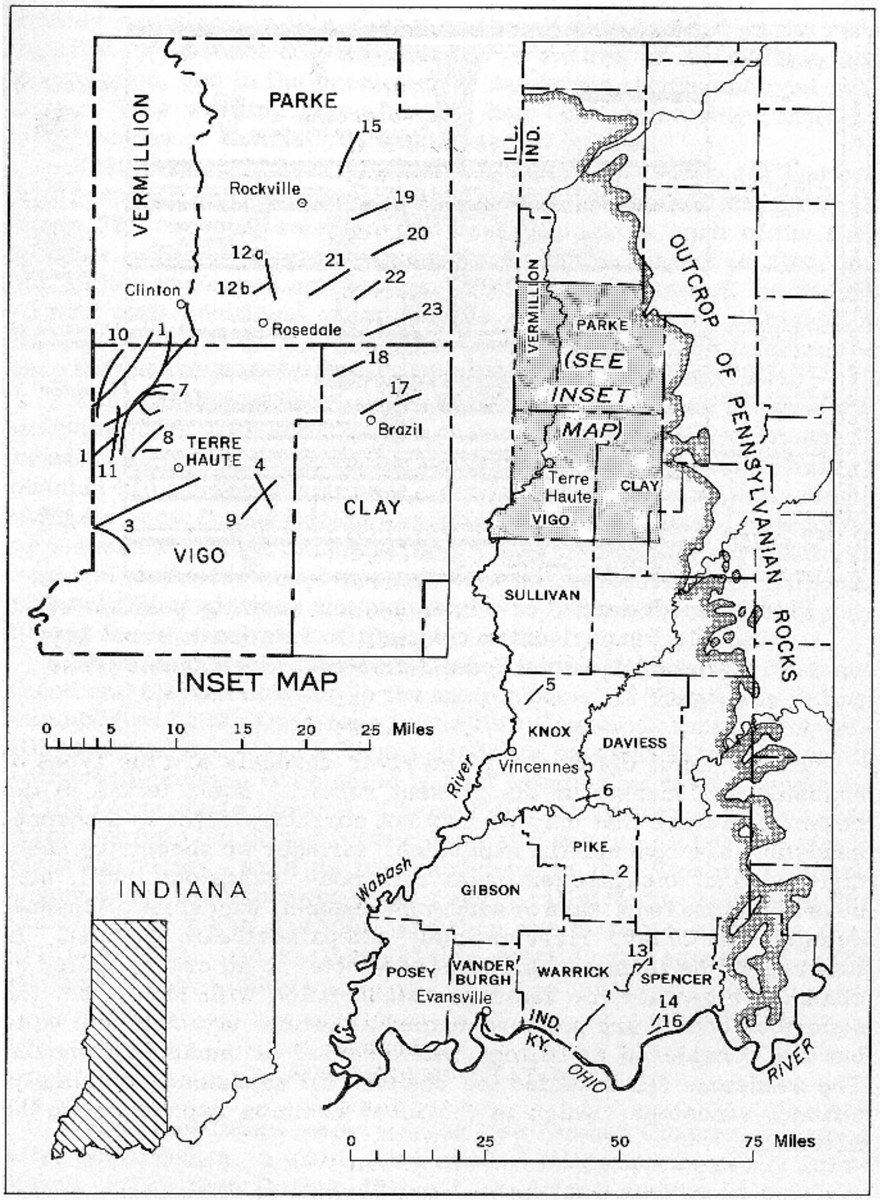


Figure 2. - -Index map showing generalized outcrop of Pennsylvanian rocks and location of some middle Pennsylvanian channels. Numbers correspond to those in text and in figure 3.

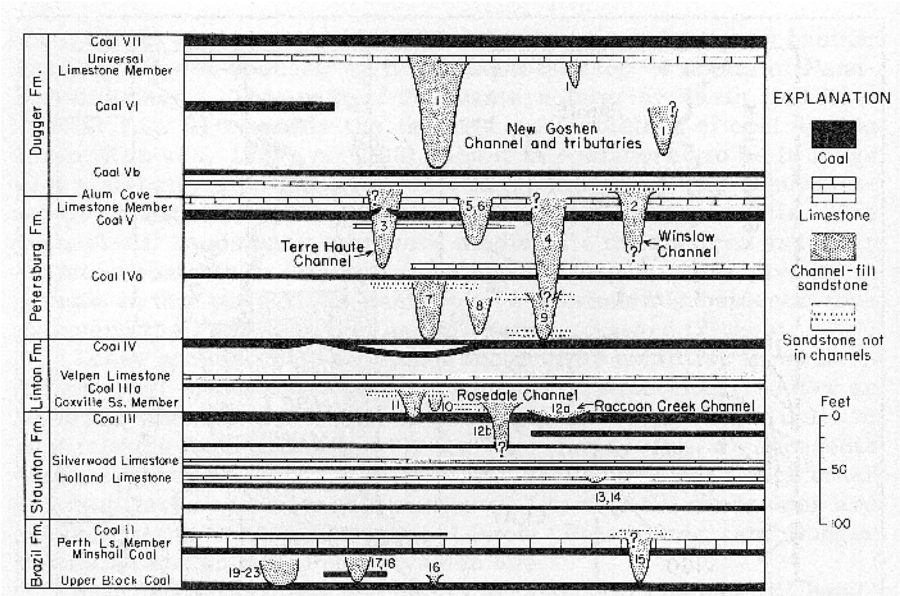


Figure 3. --Extended columnar section showing position of middle Pennsylvanian channels in relation to some key coal and limestone beds. Numbers correspond to those in figure 2.

Rich's delta distributary and river channels are the types of sandstones discussed in the present report. Some terms in the recent literature that may or may not correctly refer to a channel sandstone are channel-fill sandstone, stringer or shoestring sand, digitate sand, elongate lenticular sand body, sandstone lentil, sinuous sandstone lens, sand or sandstone channel, sandstone or channel cutout, coal cutout, river channel, and paleostream channel. In this report the term channel is used to refer to an eroded valley or channel, a geomorphic feature, that is filled with sandstone; the sandstone bodies are not here named as formal stratigraphic units but are considered as fillings within named or unnamed channels. The sandstone fill is called the channel-fill sandstone, or simply, channel sandstone, which is the most common expression in the literature.

CLASSIFICATION

A fourfold working classification of Pennsylvanian channel-fill sandstones has been outlined previously by the author (1957b). It is further explained in this report so that it may be used in the recognition of channel-fill sandstones, in studies of their origin and correlation, and in the prediction of sandstone trends and coal cutouts. This working classification has been determined from 50 occurrences of channel-fill sandstones in Indiana.

Thirty-two of these channel-fill sandstones crop out and are well-exposed and (or) they are well documented by drilling data. Of these 32, one was selected that best illustrates each of the four classes. The other channel sandstones can be classified also, but the author preferred not to do so in this report; instead, he wishes to wait until additional stratigraphic and petrographic information on the sandstone bodies has been accumulated. Such information may indicate a genetic significance for this classification.

The working classification is based on the three dimensional orientation or geometric pattern of some channel-fill sandstones in relation to the dip and strike of the enclosing strata. Thus, a channel-fill sandstone may have a dendritic pattern or may be a single elongate body; it may thicken along its length in the downdip direction or possess a uniform thickness; and it may trend either normal to the regional strike (downdip) or parallel to the regional strike. Although channel-fill sandstones are correlative in different places, they may belong to the same or to different classes.

Channel-fill sandstones of class 1 forma dendritic pattern and trend and thicken downdip in the main channel. This class is best exemplified by the sandstone in the New Goshen Channel. Channel-fill sandstones of class 2 forma dendritic pattern but trend downdip without thickening. This class is best exemplified by the sandstone in the Terre Haute Channel. Channel-fill sandstones of class 3 also trend downdip but do not form a dendritic pattern. They are single elongate bodies, such as the sandstone in the Winslow Channel. Channel-fill sandstones of class 4 are parallel to the regional strike instead of trending downdip, and they are elongate without a dendritic pattern. An example of this class is the sandstone in the Raccoon Creek Channel.

STRATIGRAPHIC RELATIONS

New Goshen Channel sandstone.-The New Goshen Channel is named after New Goshen, a small town about 5 miles northwest of Terre Haute. The New Goshen Channel sandstone occurs in southern Vermillion County and northwestern Vigo County (figs. 2 and 4), where it has been mapped from more than 60 records of coal-test boreholes and 10 outcrops (Friedman, 1957a). It is 7 miles long in its main channel. An isopach map (fig. 4) shows that it attains a

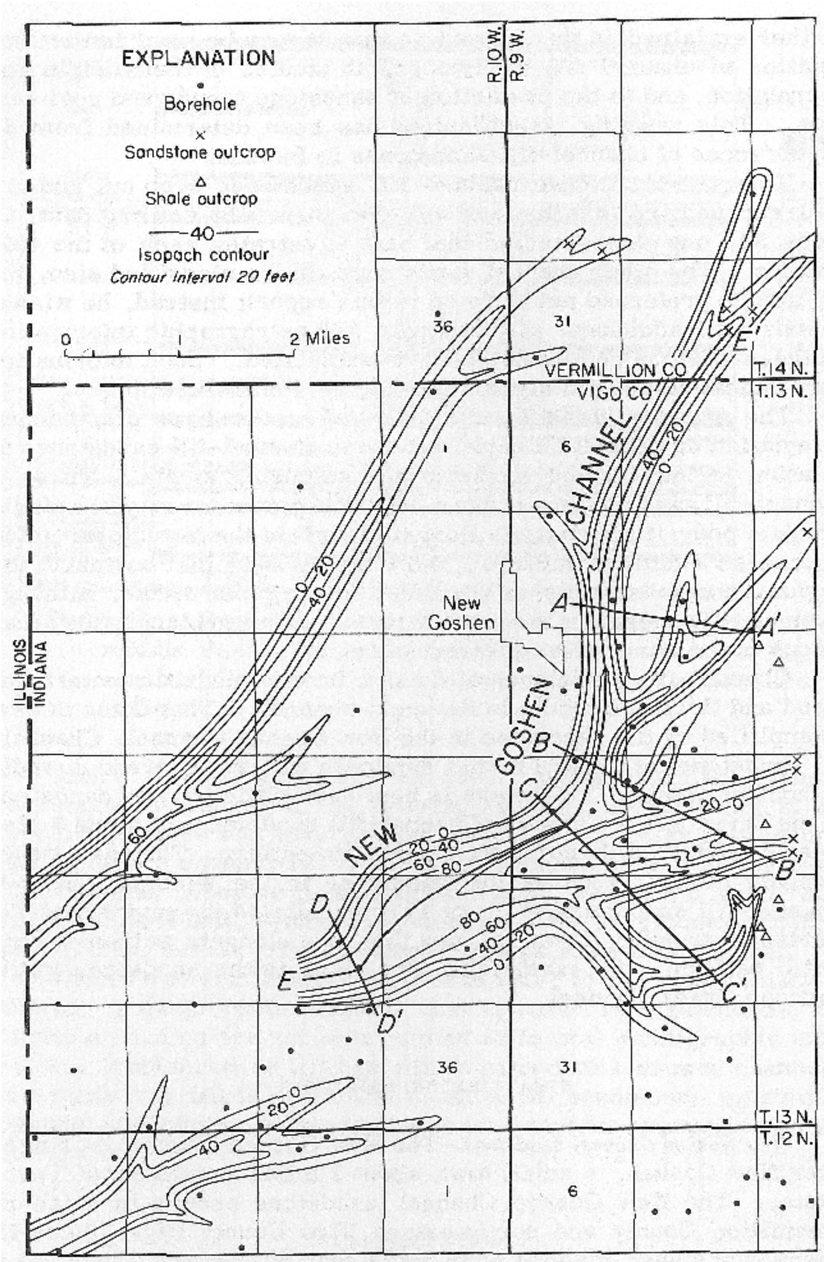


Figure 4. --Isopach map of the sandstone fill in the New Goshen Channel and two tributary channels (figs. 2 and 3, no. 1). Lines A-A', B-B ', C-C ', and D-D ' indicate cross sections shown in figure 5. Line E-E ' indicates the axial section shown in figure 6.

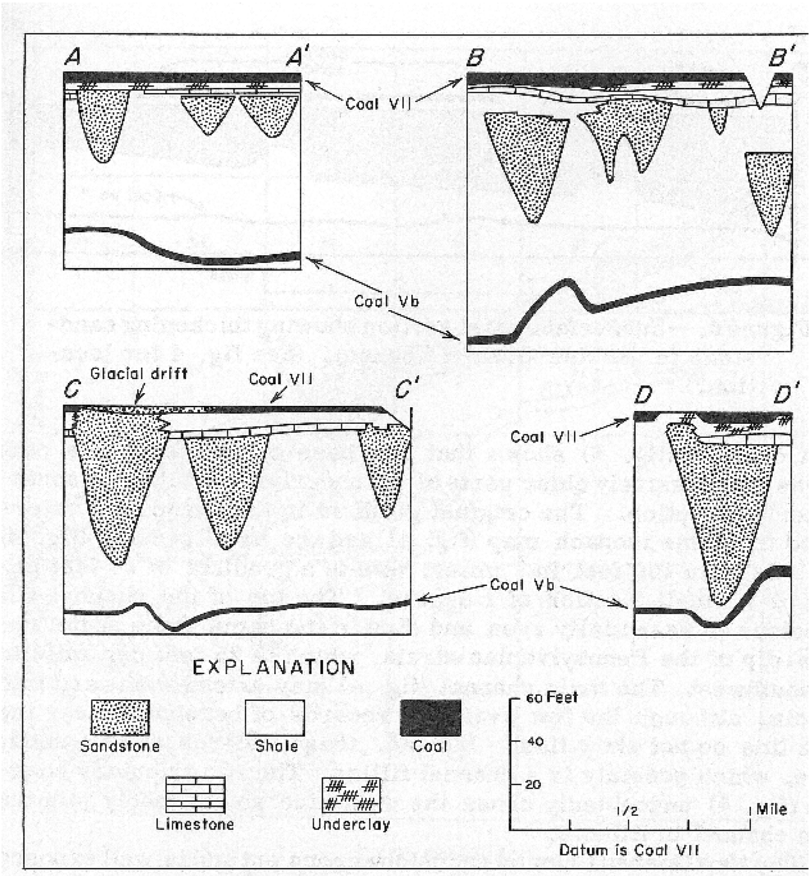


Figure 5. --Cross sections showing the sandstone in the New Goshen Channel and its tributaries in stratigraphic relation to Coal VII, the Universal Limestone Member, and Coal Vb. (See fig. 4 for locations.)

maximum thickness of more than 80 feet in sec. 26, T. 13 , R. 10 W., and a maximum width of 5,000feet at the top at one place and that it thins to 40 feet and narrows to 700 feet at the north and east edges of the area studied.

Cross sections of the New Goshen Channel (fig. 5) show that the sandstone in the main channel and its tributaries are lens shaped and have bases that are convex downward. Some sandy shale occurs in each channel. Logs of coal-test boreholes indicate that each channel-fill sandstone has a sharp unconformable basal contact with gray shale of the U-shaped eroded channels. An axial section of the

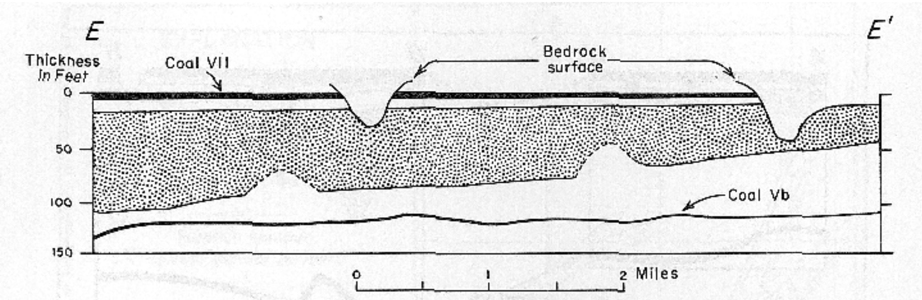


Figure 6. --Subsurface axial section showing thickening sandstone in the New Goshen Channel. (See fig. 4 for location.)

main channel (fig. 6) shows that the base of the sandstone cuts across progressively older parts of the underlying strata in a southwesterly direction. The original gradient in the channel as determined from the isopach map (fig. 4) and the axial section (fig. 6) was less than 100 feet in 7 miles; this is a gradient of 14 feet per mile or a small fraction of 1 degree. The top of the channel-fill sandstone is essentially even and dips in the same plane as the regional dip of the Pennsylvanian strata, which is 25 feet per mile to the southwest. The main channel (fig. 4) may extend westward into Illinois, although the few available records of boreholes near the state line do not show this. Instead, these records show a sandy shale, which possibly i-s a channel filling. The two tributary channels (fig. 4) undoubtedly cross the state line and probably join the main channel in Illinois.

The New Goshen Channel sandstone crops out and is well exposed in an almost vertical massive bluff, in the SE¼NE¼ sec. 29, T. 13 N., R. 9 W., Vigo County (fig. 4), where it is light brown and locally stained red, probably by iron oxides. Furthermore, it is thick bedded, crossbedded to the southwest (pl. 1A), medium grained, micaceous, and, in some places, calcareous. Thin glacial drift overlies this sandstone outcrop. Elsewhere the sandstone in the New Goshen Channel is overlain by the Universal Limestone Member or, where the limestone is absent, by shale or the underclay of Coal VII, all of which are in the Dugger Formation (fig. 5).

Terre Haute Channel sandstone.-The Terre Haute Channel is so named because the city of Terre Haute is situated over its northeastern part. It lies entirely below the surface in west-central Vigo County (figs. 2 and 7), where it has been studied and mapped from records of more than 100 coal-test boreholes (Friedman, 1956). The Terre Haute Channel is 7 miles long, and its sandstone filling is about a

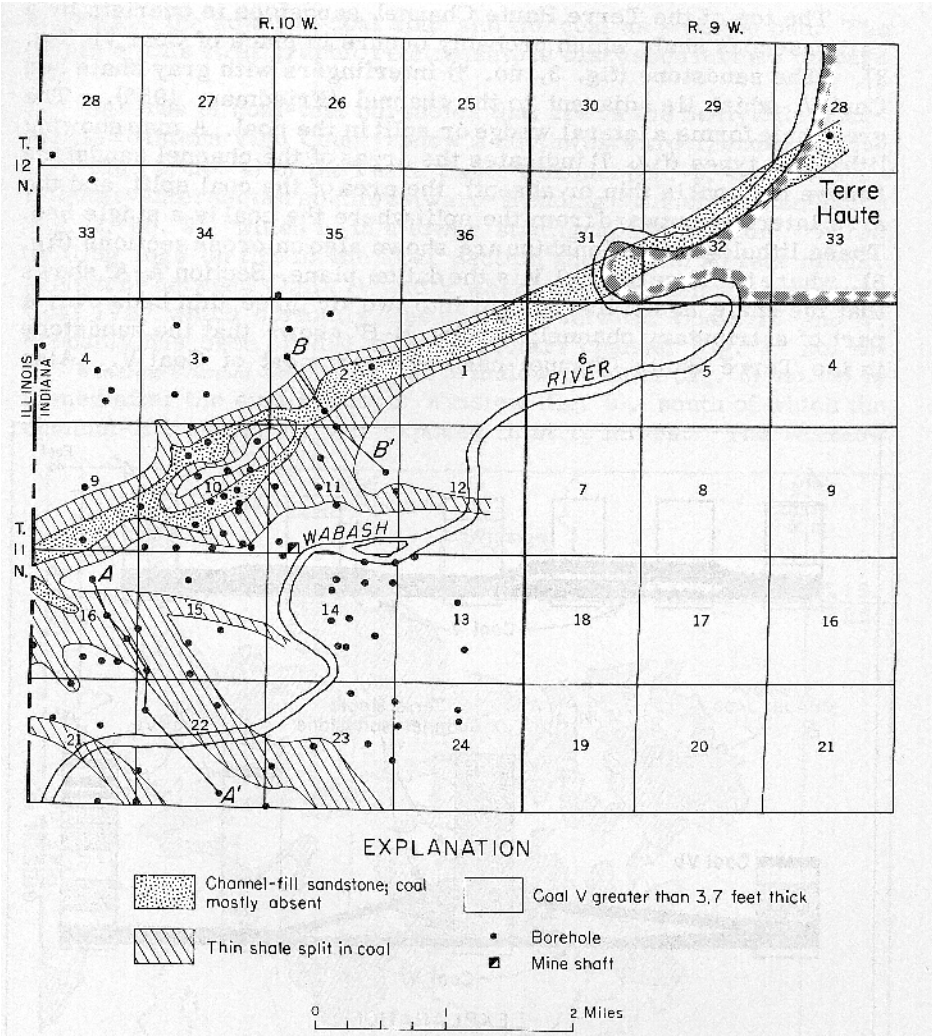


Figure 7. --Distribution of rock types in the Terre Haute Channel. Note coal island in section 10. (See fig. 2, no. 3.)

quarter of a mile wide at the top and 40 feet thick throughout its length. This uniformity of sandstone thickness is inferred from the only two boreholes that penetrated the base of the sandstone; one borehole is in the SE¼ SW¼ sec. 2, and one is in the south-central part of sec. 9, T. 11 N., R. 10 W. (fig. 7). A third datum point probably would substantiate this assumption.

The top of the Terre Haute Channel sandstone is overlain by a carbonaceous shale which probably occurs in place of Coal Vb (fig. 3). The sandstone (fig. 3, no. 3) interfingers with gray shale and Coal V, which lie adjacent to the channel (Friedman, 1956). The gray shale forms a lateral wedge or split in the coal. A map showing lithologic types (fig. 7) indicates the areas of the channel sandstone (where the coal is thin or absent), the area of the coal split, and the area laterally outward from the split where the coal is a single bed. These lithologic relationships are shown also on cross sections (fig. 8), where the base of Coal V is the datum plane. Section A-A' shows that the shale has split the coal into two or three thin beds over a part of a tributary channel; section B-BI shows that the sandstone in the Terre Haute Channel has replaced most of Coal V. Also

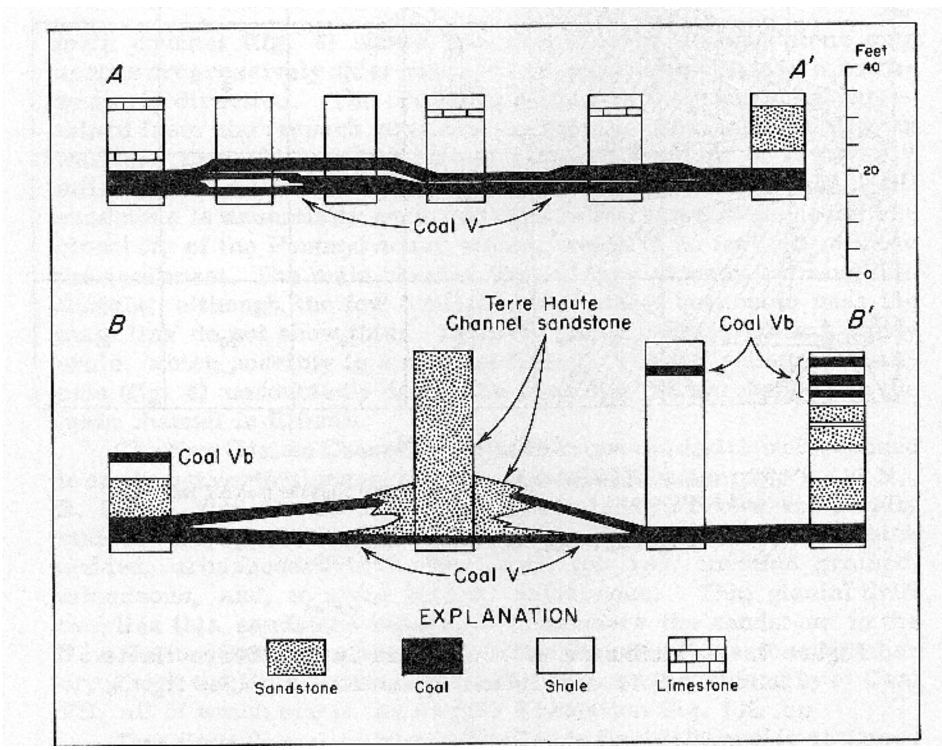


Figure 8. --Cross sections showing subsurface lithologic relationships of the sandstone and associated rocks in the Terre Haute Channel. Lines of cross sections A-A' and B-B' are in figure 7.

shown are the adjacent coal split and the coal as a single bed. The origin of this stratigraphic relationship is discussed further on page 36.

Records of coal-test boreholes that are in the Seelyville Quadrangle (eastern Vigo County) show a northwestward-trending tributary (fig. 2, no. 4) of the Terre Haute Channel (fig. 2, no. 3). This tributary intersects a southwestward-trending channel-fill sandstone (fig. 2,,no. 9), which is in a lower stratigraphic position. A few drilling logs on file in the Coal Section show 70 to 90 feet of only sandstone between Coals IV and V where the two channels intersect. Coal IVa, which normally lies midway between Coals IV and V, probably has been eroded in the tributary channel (fig. 3, no. 4).

Winslow Channel sandstone.-The Winslow Channel (fig. 3, no. 2) is named after the small town of Winslow (fig. 9), south of which the channel-fill sandstone was exposed in strip mines. The Winslow

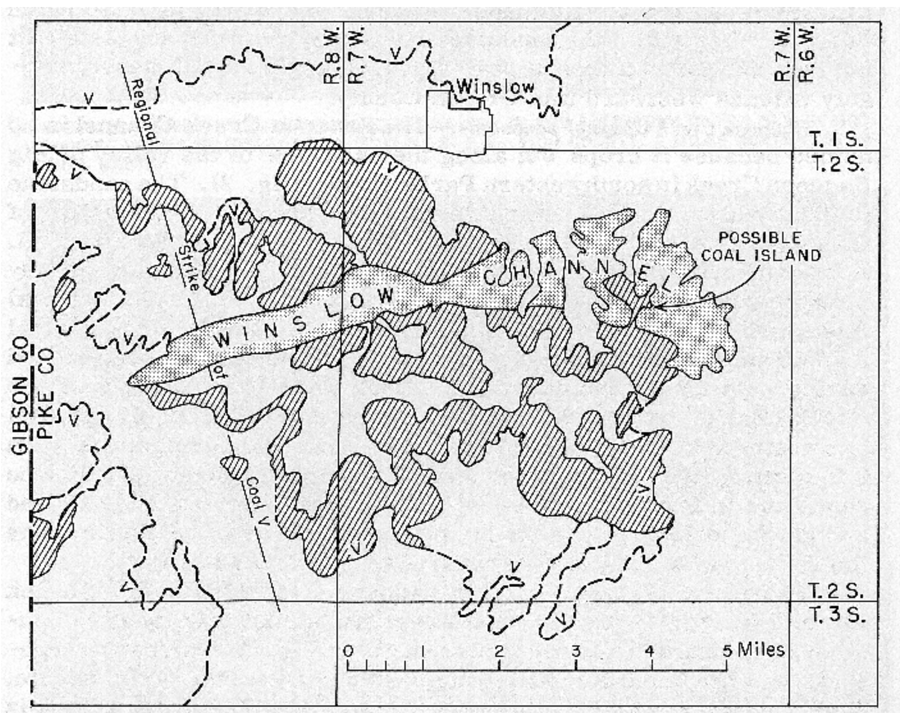


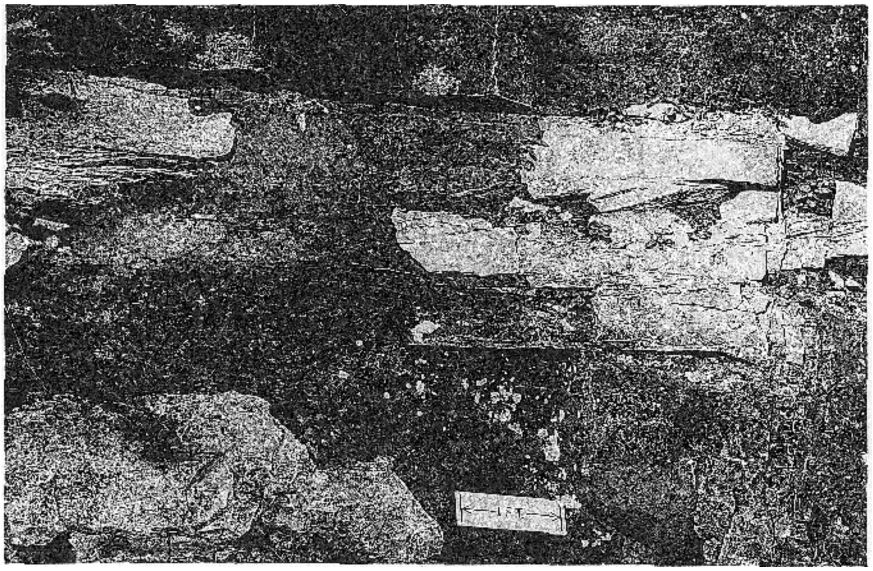
Figure 9. --Distribution of the Winslow channel-fill sandstone (stippled) and the mined areas of Coal V (lined). The labeled side of the coal boundary is within the area of Coal V. (See fig. 2, no. 2.) After Wier, 1953.

Channel sandstone trends south- southwestward for 7 miles across central Pike County (fig. 2, no. 2) and averages 2, 600 feet in width at the top. Scant data suggest that it is as much as 50 feet thick.

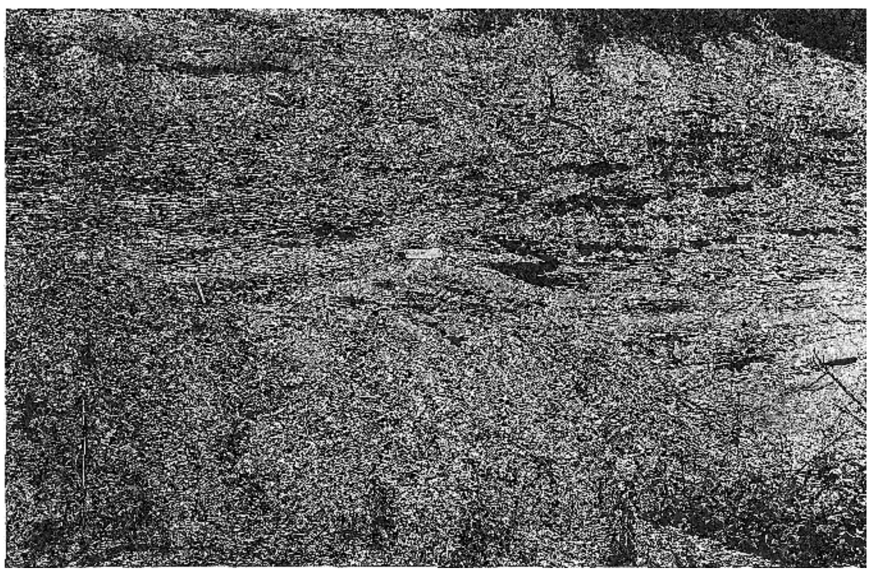
Measured sections on file in the Coal Section indicate that this sandstone is gray or tan, medium grained to coarse grained, thin bedded to thick bedded, crossbedded, and micaceous. In places the top of the sandstone has been eroded and is covered by residual soil and lacustrine beds of Pleistocene age. Data from coal-test boreholes and outcrops indicate that a blanket sandstone, which averages 10 feet thick, occurs outward from and is laterally contiguous with the upper part of the channel-fill sandstone. Local shallow channels occur within the blanket sandstone, and one such channel that has a disconformity exposed at its base (pl. 1B) lies at the south edge of a strip-mined area. The Winslow Channel sandstone has cut out Coal V extensively (fig. 9). Mines terminate abruptly where the sandstone has replaced the coal. At least one nearly isolated patch of Coal V lies within the sandstone body; this condition suggests that the coal was formed from a peat island. The Winslow Channel probably extends westward into Gibson County.

Raccoon Creek Channel 8andstone.- The Raccoon Creek Channel is so named because it crops out along the east side of the valley of Big Raccoon Creek in southwestern Parke County (fig. 2). The sandstone is exposed continuously f rom this valley northward into the valley of Rock Run in secs. 16, 15, 10, and 3, T. 14 N., R. 8 W. (fig. 10). A stratigraphic test hole, bored by the Indiana Geological Survey near the center of section 15, showed that the sandstone (3 feet thick) lies about 100 feet below the upland surface; it is overlain by glacial drift at this place. Apparently most of the sandstone had been eroded during post Pennsylvanian time. This sandstone in the Raccoon Creek Channel extends for 3 miles northwestward, roughly parallel to the strike of Coal III. It is almost a mile wide and ranges from 0 to more than 50 feet in thickness. Consolidated strata overlie the sandstone in few places; in most places such beds have been eroded and glacial drift overlies the sandstone. Shale and Coal IlIa overlie the sandstone in the northwest parts of sections 3 and 9 (fig. 10).

The elongate trend of this sandstone in the Raccoon Creek Channel is roughly parallel to the regional strike; this trend is considered uncommon for a consequent river channel unless it represents a large meander filling or possibly a coastal plain stream. Field investigation of the present outcrop pattern indicates that it is not a meander filling, however. The base of the Raccoon Creek Channel sandstone contains very thin coal lenses and stringers as well as casts of tree trunks and branches that show leaf bases of *L epidodendron aculeatuin.* The most striking characteristic of this sandstone is deltaic crossbedding (pl. 2A), which exhibits bottomset,

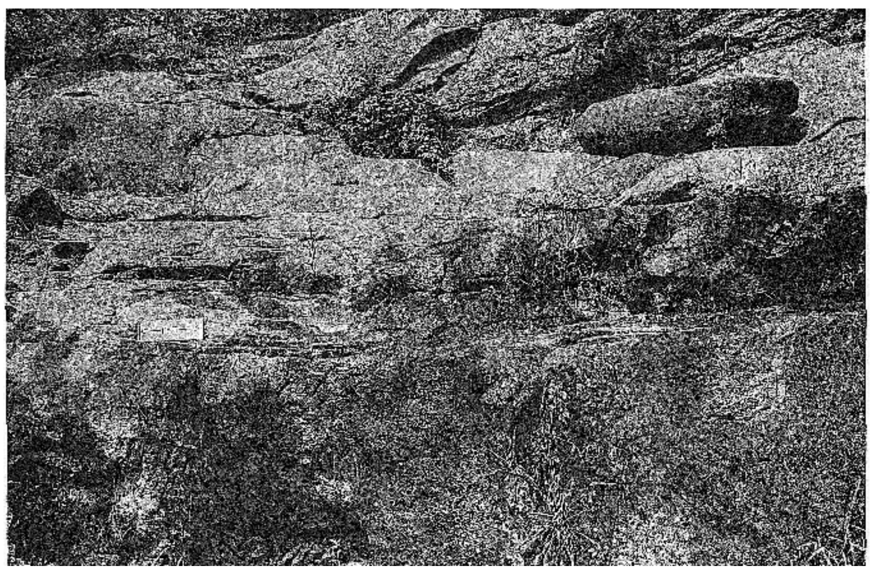


.4. SOUTH-SOUTHWESTWARD-TRENDING CROSSBEDDING IN THE SANDSTONE IN THE NEW GOSHEN CHANNEL IN THE SE¼ NE¼, SEC. 20, T. 13 N., R. 9 W., VIGO COUNTY, 3 MILES NORTHWEST OF TERRE HAUTE.



B. DISCONFORMITY (INDICATED BY HAMMER AND SCALE) AT THE BASE OF A SMALL CHANNEL IN A BLANKET SANDSTONE EXPOSED IN A BLUFF ON THE NORTH SIDE OF A MINE ROAD IN THE SE¼ SEC. 16, T. 2 S., R. 7 W., PIKE COUNTY, 3½ MILES SOUTHEAST OF WINSLOW.

A. CROSSBEDDING DIPS NORTHWESTWARD IN THE COXVILLE SANDSTONE MEMBER IN A RAVINE IN THE SE¼ SEC. 15, T. 14 N., R. 8 W., PARKE COUNTY.



B. MASSIVE THICK-BEDDED ORTHOQUARTZITIC COXVILLE SANDSTONE MEMBER IN THE ROSEDALE CHANNEL IN A QUARRY IN THE SW¼ SEC. 15, T. 14 N., R. 8 W., PARKE COUNTY.

COXVILLE SANDSTONE MEMBER

foreset, and rarely topset units; these dip mostly northwestward but range from west-northwestward to westward. The base of this sandstone is wavy and exhibits a sharp disconformable contact with the underlying Coal 111. This coal ranges from 0. 5 foot to 4 feet in thickness, and the variation is presumed due to erosion by the water that deposited the sandstone.

As much as 60 years ago six drift mines, now abandoned, had been opened in 2 to 4 feet of Coal III, directly below the sandstone in the SW-41 see. 15 (figs. 10 and 11). The coal, except for a fragment of it, is absent in the abandoned sandstone quarry that is shown on both of these figures. The upper part of the sandstone in this quarry belongs to the Raccoon Creek Channel, which is part of a deltaic distributary, but the lower part has a fluviatile origin (see p. 39) and fills the Rosedale Channel (fig. 10).

Rosedale Channel sandstone.-The Rosedale Channel (fig. 10) is named after the town of Rosedale, Parke County, which is about 2 miles southeast of Coxville. The statement by Ashley (1899, p. 386) that this channel trends southwestward is confirmed. It continues southwestward from the outcrop in the quarry in section 15, below the valley of Big Raccoon Creek, into the upland in sections 21 and 22, south of Coxville. Thus it also trends normal to the strike and downdip (fig. 10). A stratigraphic test hole was bored by the Indiana Geological Survey near the center of section 21 (fig. 10) because the author presumed that this channel sandstone had a straight course southwestward from the quarry. The borehole indicated the absence of this sandstone, however, and pointed out the difficulty of successful subsurface channel exploration. Nevertheless, generalized data from abandoned underground mines in Coal III show that sandstone in places forms the roof in mines south and southwest but not north of Coxville; this condition suggests that the sandstone thickens and fills a channel southwest of Coxville. According to a former employee of one of these mines, a water-bearing "sand" that formed the roof fell into a mine entry and later was found to have completely cut out Coal III for a horizontal distance of 200 feet. Probably this sand is the Rosedale Channel sandstone. This channel is drawn (fig. 10) so that its western extent coincides with the location of the sand cutout. Thus the channel is at least 2 miles long. The base of the Rosedale Channel sandstone is probably convex downward (fig. 11).

The cross section (fig. 11) shows that the Rosedale Channel has cut out strata, including Coal III and two minor thin coals below it, in the area of the quarry in section 15. The channel is a quarter of a mile wide at the quarry floor. The position of the base of the channel is inferred because it is concealed below the quarry floor. It is estimated that the sandstone is 45 feet thick below the quarry floor. The Rosedale Channel sandstone is about 30 feet thick from the quarry floor to the top of its confining channel walls. Thus its total thickness probably is 75 feet.

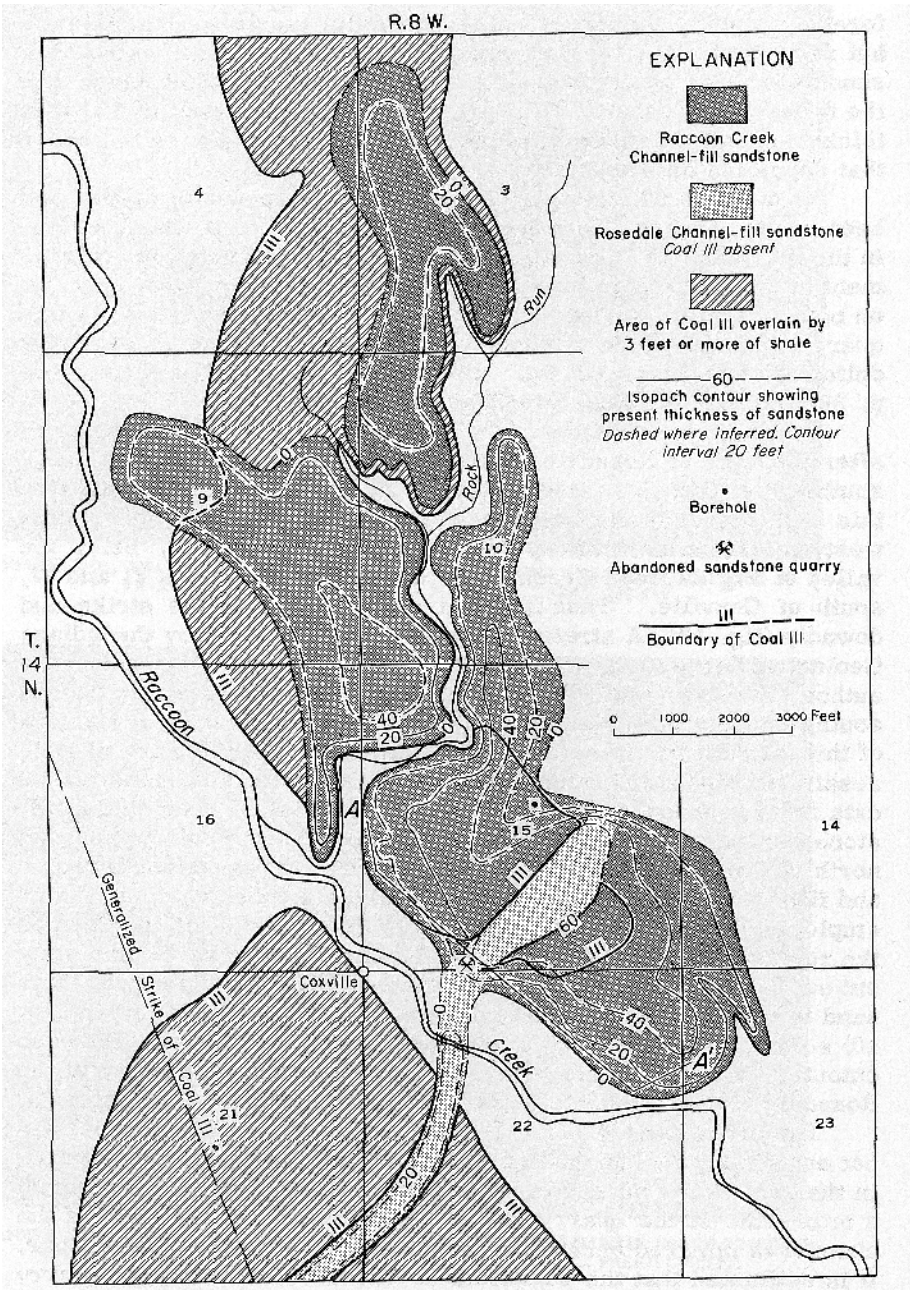


Figure 10. --Map showing distribution and thickness of the Raccoon Creek and Rosedale channel-fill sandstones, located in figure 2 as nos. 12a and 12b, and the extent of Coal Ill.

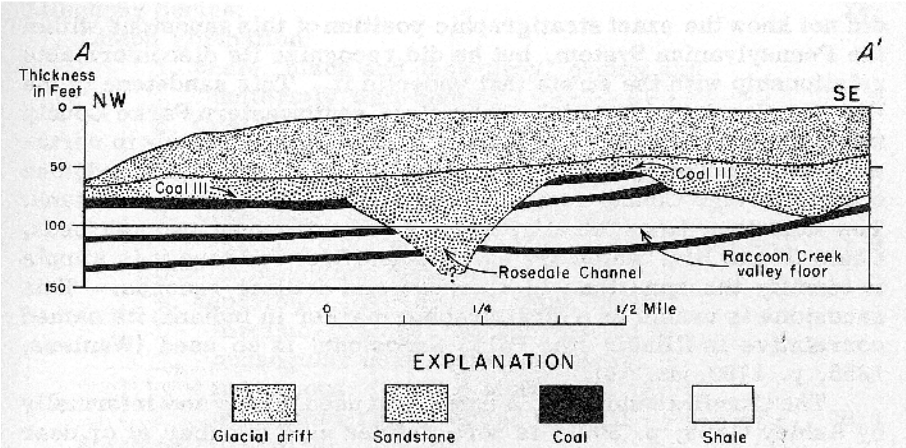


Figure ll. --Cross section showing the Coxville Sandstone Member, the Rosedale Channel, and a tributary channel. Line of cross section A-A' is in figure 10.

An exposure of the Rosedale Channel sandstone in the abandoned quarry in section 15 (fig. 10) exhibits tanto light -gray thick- bedded massive sandstone (pl. 2B), which is an orthoquartzite. The sandstone bedding appears horizontal, but close observation reveals slight cross- stratification, which dips gently South-southwestward (the downdip direction) of perpendicular to the strike of the strata.

This slight cross- stratification may be explained by the flume experiments on sand stratification by McKee (1957, p. 133), who stated that “where a stream deposits sediment in a channel bottom, as the result either of increase in a stream load or decrease in stream velocity, the layering tends to be essentially horizontal so that it conforms to the flat-bottomed profile of scour in a stream-cut channel.”

COXVILLE SANDSTONE MEMBER

The sandstone in the Raccoon Creek Channel was first described by Hobbs (1872, p. 350) as "millstone grit." Hopkins (1896, p. 231) stated that the age of this sandstone was "Upper Coal Measures" and also that the sandstone overlies (Coal III) northwest and Southeast of a quarry in this sandstone in the SW¼ sec. 15, T. 14 N., R. 8 W. (fig. 10). Ashley (1899, p. 300-301, 385-386) also described this sandstone and referred to it as the “Coxville sandstone.” He did not know the exact stratigraphic position of this sandstone within the Pennsylvanian System, but he did recognize its disconformable relationship with the strata that underlie it. This sandstone in the Raccoon Creek and Rosedale Channels in southwestern Parke County (figs. 2, 3, and 10 and pl. 2) also occurs in other channels in northwestern Vigo County (fig. 12). A thin blanket phase of this sandstone occurs in Vigo County and is widespread in southwestern Indiana. The sandstone has a stratigraphic position between two key beds, Coals III and IIIa, which are easily identified, and thus it is simple to identify the sandstone in outcrops and drilling records. This sandstone is usable as a stratigraphic marker in Indiana; its named correlative in Illinois (the Palzo Sandstone) is so used (Wanless, 1955, p. 1789, no. 16).

The Coxville Sandstone, a name first used locally and informally by Ashley (1899, p. 300), is here defined as a member at or near the base of the Linton Formation (Allegheny Series) in Indiana. This sandstone crops out extensively north and east of Coxville (fig. 10), a village in Parke County after which it is named. Coxville lies approximately 15 miles north-northeast of Terre Haute. The Coxville Sandstone Member is conformably overlain (in ascending order) by underclay, Coal IIIa, dark-gray and black shale that is evenly and uniformly thin to medium bedded and carbonaceous, and a thin limestone. The Coxville Sandstone Member, furthermore, is underlain disconformably by shale above Coal III, by Coal III, or, where this coal has been completely eroded, by underclay or gray shale. The Coxville Sandstone is as muchas 60 feet thick in its outcrop in the abandoned sandstone quarry (figs. 10 and pl. 2B). Where the Coxville Sandstone Member is absent owing to nondeposition, unnamed shale or underclay lies in its place.

The following detailed section is a composite section from the type locality, which is the sides of a southward- trending valley in the NE¼ sec. 16, T. 14 N., R. 8 W., Parke County (fig. 10). The Coxville Sandstone Member (unit 4) fills part of a deltaic channel and has replaced the upper part of Coal III (unit 2).

Allegheny Series:	Ft
Linton Formation:	
7. Shale, black and dark-gray, evenly and uniformly thin-bedded - - - - - - - - - - - - - - - -	4.0
6. Coal IIIa, black, banded, bituminous; contains 0. 1 ft of clay, 0. 5 ft above the base -	1.8
5. Underclay, gray; bedding absent; plastic; covered -	2.0
Coxville Sandstone Member:	
4. Sandstone, light-brown, thick-bedded, medium-grained; has subrounded to subangular quartz grains; unit is micaceous, forms a bluff, and disconformably overlies Coal III - - - - - - - -	20.0
Staunton Formation:	
3. Coal III, black, banded, bituminous; contains a clay parting in the lower part, where coal is more than 2 ft thick; ranges from 0. 5 to 2. 8 ft in thickness -	2.8
2. Underclay, dark blue-gray, nonplastic, covered -	2.0
1. Shale, tan-gray, thin- to medium-bedded, covered - - - - - - - - - - - - - - - - - - -	20.0
Base of measured composite section.	
Total Staunton and Linton Formations measured -	52.6

The following reference section of the Coxville Sandstone Member was measured in the well-exposed westward-facing high wall of an abandoned quarry in the SE¼ SW¼ sec. 15, T. 14 N., R. 8 W. (fig. 10); the quarry is 1, 000 feet southeast of a place where a north-eastward-trending road turns northwest at a bluff on the east side of the valley of Big Raccoon Creek. At the top of the quarry wall, some of the sandstone and all of Coal IIIa and its underclay are absent, probably owing to erosion. The base of the sandstone lies concealed at an estimated 45 feet below the quarry floor.

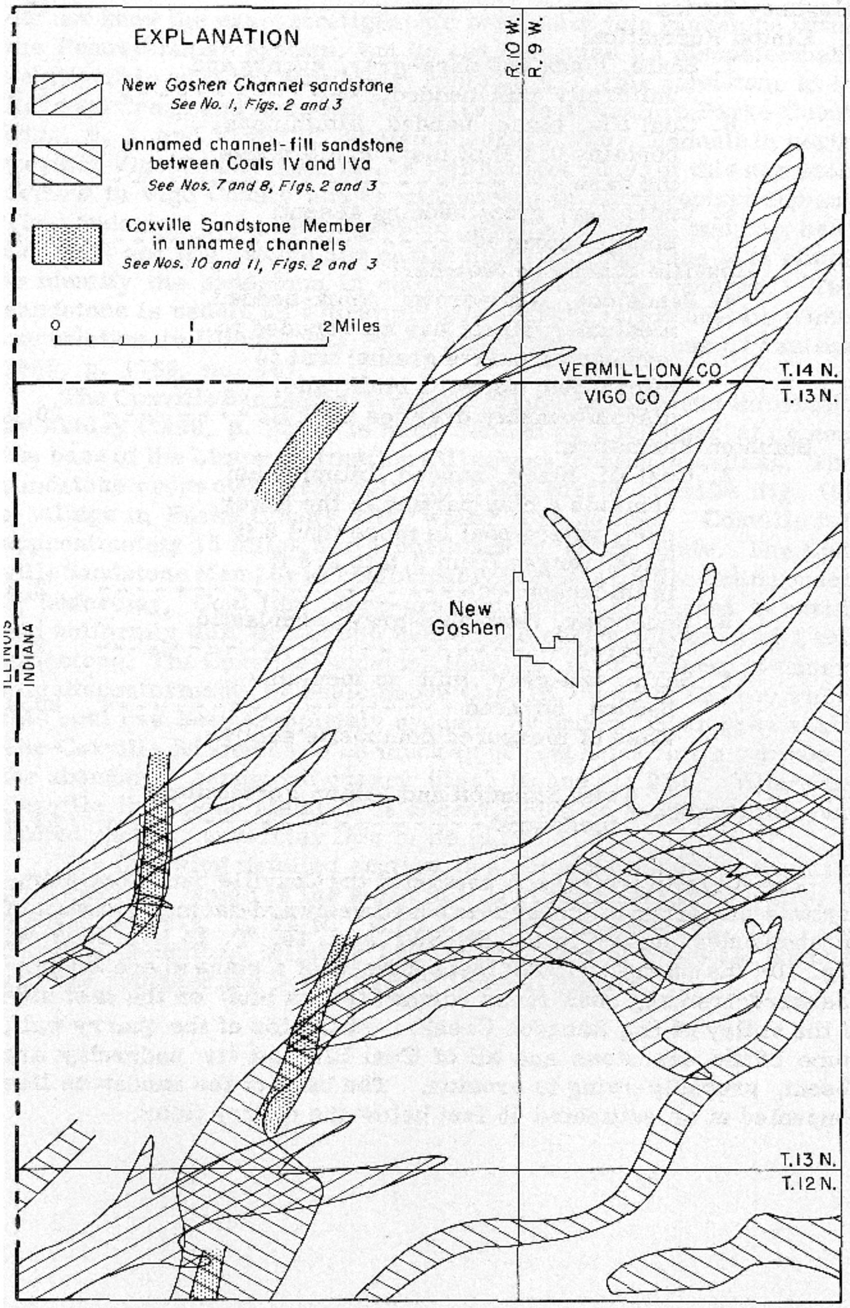


Figure 12. - - Map showing subsurface distribution of channel-fill sandstones which lie in three different stratigraphic positions.

	Ft
Allegheny Series:	
Linton Formation:	
Coxville Sandstone Member:	
1. Sandstone, light gray-tan, thick-bedded, massive; as much as 15 ft thick without a bedding plane; in places faintly crossbedded at very low angles; mostly medium grained (0. 25 mm); contains subangular to subrounded white quartz grains and some siliceous cement, but is friable and weathers medium tan to buff. The sandstone contains a weathered red-black coal lens, 0. 5 ft thick and 3 ft long in the quarry wall, about 5 ft from the base of the section -	60
Total Coxville Sandstone Member measured -	60

Inasmuch as the above outcrop is the only one that shows the river channel phase of the Coxville Sandstone Member, a subsurface occurrence of the channel-fill sandstone (fig. 12) is described herein in a second reference section. The upper 10 feet of the sandstone (unit 6) probably belongs to a nonchannel sheet phase, however. The occurrence of the limestone (unit 4) between Coals III and IIIa is rare and is not understood, but it is reported in the driller's log. Perhaps it is a "fresh-water" or an "underclay" limestone. This section, a part of a driller's log of a coal-test borehole from the files of the Indiana Geological Survey, is in the NW¼ NW¼ SE¼ sec. 26 (600 feet east of the center of the section) T. 13 N. , R. 10 W., Vigo County, Ind., New Goshen Quadrangle, 2. 8 miles southwest from New Goshen (fig. 4).

	Depth from land surface to base of unit (ft)	Thickness (ft)
1. Shale, black - - - - - - - - - - - - - - - - - -	455	3
2. Coal III -	456	1
3. Underclay - - - - - - - - - - - - - - - - - - -	460	4
4. Limestone - - - - - - - - - - - - - - - - - - -	464	4
5. Shale, brown - - - - - - - - - - - - - - - - -	474	10

Allegheny Series--continued Linton Formation--continued	Depth from land surface to base of unit (ft)	Thickness (ft)
Coxville Sandstone Member:		
6. Sandstone - - - - - - - - - - - - - - - - - -	518	44
Staunton Formation:		
7. Coal III -	521	3
Base of section.		
Total Staunton and Linton Formations shown -		69

When sufficient data become available for study, geologists probably will recognize that the Coxville Sandstone Member forms a widespread, complex channel sandstone system in Indiana, just as its correlative does in Illinois (Wanless, 1955, p. 1789, key bed no. 16).

The Coxville Sandstone Member of the Linton Formation is here correlated in stratigraphic position and age with the Palzo (or Isabel) Sandstone of the Carbondale Group in Illinois and the Sebree Sandstone of the Carbondale Formation in western Kentucky (table 1).

CORRELATION

Table 1 shows the correlation of certain middle Pennsylvanian sandstones in Indiana, Illinois, and Kentucky, most of which fill channels; only some of the channels and some of the sandstones have names.

The New Goshen Channel sandstone occupies part of the stratigraphic interval between Coals Vb and VII (fig. 7); thus it is equivalent in position to a thick sandstone that lies below Coal VII in Sullivan and Knox Counties, Ind. It is also in part equal in stratigraphic position and age to the Anvil Rock or Copperas Creek Sandstones of Illinois. Hopkins (1958) showed that the Anvil Rock Sandstone is present in Gibson and Posey Counties, Ind. Wanless (1955, p. 1787, table 3) correlated the Anvil Rock Sandstone from western Illinois to Kentucky.

An unnamed blanket sandstone occurs between Coals Vb and VI in some places in Indiana (Wier, 1953), and it may be correlative with the upper part of the Vermilionville (or Cuba) Sandstone of Illinois. The Cuba Sandstone of Wanless (1955, p. 1791) occurs as as a channel filling between Illinois Coals 5 and 6, and it locally cuts out Coal 5. Thus it is also possible that the unnamed sandstone in

Table I.-Correlation of some middle Pennsylvanian sandstones of Indiana, Illinois, and Kentucky (in stratigraphic sequence)

Indiana	Illinois	Kentucky
Unnamed sandstone in the New Goshen Channel (Anvil Rock Sandstone of Hopkins) in Gibson and Posey Counties	Anvil Rock Sandstone (Copperas Creek Sandstone)	Anvil Rock Sandstone
Unnamed sandstone between Coals Vb and VI	Vermilionville Sandstone (Cuba Sandstone)	
Unnamed sandstone in the Terre Haute and Winslow Channels	Unnamed sandstone	
Unnamed sandstone between Coals IVa and V	Unnamed sandstone	
Unnamed sandstone between Coals IV and IVa	Pleasantview Sandstone	
Coxville Sandstone Member (fills Raccoon Creek and Rosedale Channels)	Palzo Sandstone (Isabel Sandstone)	Sebree Sandstone

the Terre Haute and Winslow Channels, which locally replaces Coal V in Indiana, may be equal in age to the lower part of the Cuba Sandstone. On the other hand, Wanless (1955, p. 1772) stated that a channel sandstone position occurs in Illinois between Coals 5 and 5a, which are respectively Coals V and Vb in Indiana. Therefore it is likely that this sandstone is different from the Cuba Sandstone, and thus it is shown on table I as an unnamed sandstone that probably is equal in age and stratigraphic position to the unnamed sandstone in the Terre Haute and Winslow Channels. This latter correlation is preferred by the present author because the sandstone in the Terre Haute and Winslow Channels does not extend above the base of Coal Vb.

An unnamed sandstone occurs between Coals IVa and V in Indiana and between Coals 4 and 5, their respective correlatives in Illinois, where it fills channels (Wanless, 1955, p. 1772). It is not known to fill channels in Indiana, however. These two sandstones are correlated simply as unnamed sandstones on table 1.

The present author has traced a sandstone, which fills channels between Indiana Coals IV and IVa, westward into eastern Illinois, where it also occupies channels, between Illinois Coals 2a and 4, the respective correlatives of Indiana Coals IV and IVa. This unnamed channel-fill sandstone, therefore, is herein tentatively correlated with the Pleasantview Sandstone of Illinois, where Wanless (1955, p. 1787, table 3) lists its distribution. Its channels in Vigo County, Ind., are shown in figure 12 and are numbers 7, 8, and 9 in figures 2 and 3.

The Coxville Sandstone Member of the Linton Formation is correlated with the Palzo (or Isabel) Sandstone of Illinois, because these sandstones occupy similar stratigraphic positions and fill prominent channels in Indiana and Illinois respectively.

The base of the Staunton Formation contains a sandstone unit which in places is underlain by a channel (figs. 2 and 3, no. 15) in Parke County. This channel-fill sandstone has cut down into a coal believed to be the Minshall Coal, has replaced this coal in places, and contains only irregular lenses and chunks of coal at its base. Subparallel channel-fill sandstones in southeastern Parke County (figs. 2 and 3, nos. 19-23) in places have cut out the Upper Block Coal (H. C. Hutchison, 1958, oral communication), lie at the same stratigraphic position in the top of the Brazil Formation, and thus are correlative. They appear to be part of a channel system whose present segmented nature is due to post- Pennsylvanian erosion. Channels 17 and 18 (figs. 2 and 3) appear to be correlative with channels 19-23, because they lie in the same stratigraphic position; however, they have cut out a "rider" coal that lies above the Upper Block Coal but have not cut out the Upper Block (H. C. Hutchison, 1958, oral communication).

Channels 13 and 14 (figs. 2 and 3) in Warrick and Spencer Counties trend southwestward and contain sandstone that occurs in place of the Holland Limestone (H. C. Hutchison, 1958, oral communication). Correlatives of these channels are not known. Channel 16 (figs. 2 and 3) in Spencer County trends southwestward and occurs below the Buffaloville Coal, which may be correlative with the Minshall Coal in Parke County (H. C. Hutchison, 1958, oral communication). This channel has no known correlatives.

These channels in Parke, Clay, Warrick, and Spencer Counties are known only from outcrops; subsurface data are not available to permit tracing them elsewhere. It is certain, however, that they do exist elsewhere. They are included here to show their stratigraphic position.

GENESIS OF CHANNELS AND SANDSTONE FILLINGS

Basal disconformities commonly occur beneath channel-fill sandstones. The disconformities may be shown by sharp, fairly steep contacts, as in a sandstone that fills a channel eroded in a shale; or they may lie below shallow scour channels that occur within blanket sandstone units, and thus they are not sharp or conspicuous in outcrops. Channel-fill sandstones with basal disconformities fit well within the concept of cyclothems as the lowermost or first cyclic unit.

Paleostream channels probably were eroded on sloping land surfaces. The paleostreams that eroded these channels or valleys must have headed on a divide. It is not certain whether this divide was a hilly or mountainous elongate region, parallel to the east coast of the United States, or whether it was a broad linear ridge (the Cincinnati Arch), which was much closer to the channels of the Eastern Interior Basin. On the other hand, both of these regions may have affected the origin of the channels. Sources for the channel sandstone fillings may have been local, from older strata within the Eastern Interior Basin, and (or) from such strata that possibly were formerly on the Cincinnati Arch. To some extent Appalachia also may have directly contributed sedimentary material to the channel fillings.

BASAL DISCONFORNUTY

Theoretically a basal disconformity should occur beneath all channel-fill sandstones. In fact disconformities that have been recognized within the strata of Pennsylvanian age occur at the bases of channel-fill sandstones and rarely elsewhere (Weller, 195 6, p. 29). For example, Wanless (1981, p. 193) recognized basal disconformities beneath channel sandstones in 13 ofthe first 15 described cyclic formations of Pennsylvanian age in Illinois.

In Indiana 30 channel-fill sandstones have basal disconformities, as determined or inferred from outcrops or drilling records. The basal disconformity that is best shown by logs of coal-test boreholes occurs at the base of the New Goshen Channel sandstone (fig. 5). This sandstone thickens downdip at the expense of an underlying shale (fig. 6). This basal disconformity is the easiest kind to determine because of the sharp lithologic break between the channel-fill sandstone and the underlying shale and the abrupt thickening of the sandstone. Where one channel-fill sandstone disconformably overlies another (figs. 2 and 3, nos. 4 and 9), however, the erosional base of the upper one is difficult to)ick because the sandstones commonly are indistinguishable.

A disconformity would be difficult to recognize, also, between two shale beds which are similar in color, composition, and grain size. This difficulty possibly explains why a continuous regional disconformity, if one exists, has not been recognized definitely within the strata of Pennsylvanian age in Indiana. Nevertheless, separate ones are indicated at two positions in the middle Pennsylvanian strata of Indiana on a stratigraphic column by Wier (1957, p. 11, fig. 1).

POSITION IN THE PENNSYLVANIAN CYCLOTHEM

The position of the channel sandstone and its basal unconformity in cyclical Pennsylvanian sedimentation in the Eastern Interior Basin has been described in detail (Weller, 1930, 193 1, and 1956; Wanless, 1931 and 1957; and Weller in Wanless and Weller, 1932). A channel sandstone is the lowest stratigraphic unit in an ideal or complete cyclothem, and the valley that it fills was eroded down through strata which had formed during the previous cycle or cycles. The disconformities at the base of two successive channel sandstones serve as the boundaries of a cyclothem. Cyclothems thus bounded by channel sandstones occur in Indiana, but they are paid little attention as a rule, because, just as in Illinois, some are too thin or too indistinct to warrant recognition as separate formations (Weller in Weller, Henbest, and Dunbar, 1942, p. 10; Wanless, 1955, p. 1806-1807).

The top of a coal bed, rather than cyclothemic boundaries, is commonly used to delimit subsurface Pennsylvanian formations in Indiana. In outcrops, tops of coal beds and associated disconformities are used to distinguish these formations. The disconformity known or assumed to be at the base of a channel sandstone is used as a formational boundary where coal beds are absent, in subsurface mapping as well as in outcrop mapping.

EROSIONAL AND DEPOSITIONAL ENVIRONMENTS

Wanless and Shepard (1936), Weller (1956), Wheeler and Murray (1957), and Potter and Glass (1958) have discussed in detail theories that explain the periodic transgression and regression by shallow seas over the low-lying plain of the Eastern Interior Basin during Pennsylvanian time; also explained were subsidence, uplift, or tilting of the basin. Siever (1957) made petrographic and stratigraphic studies of Pennsylvanian sheet and channel sandstones and pointed out that available data do not permit adequate interpretation of their depositional environments, but he preferred shallow marine deposition of sand bodies (Siever, 1957, p. 247).

The original extent of the Pennsylvanian rocks in Indiana is unknown because of post- Pennsylvanian erosion. However, these rocks, especially the middle Pennsylvanian, probably covered an area including the Cincinnati Arch between the Eastern Interior and the Appalachian Basins (fig. 1 and Weller, 1957a, p. 328-329).

Weller (1930, p. 116; 1956, p. 17) indicated that the channels containing the Pennsylvanian sandstones were eroded by streams on an upraised alluvial coastal plain, which Potter and Glass (1958, p. 49) suggested was coupled with a shallow marginal shelf. This plain sloped westward and southwestward from Appalachia and the Canadian Shield respectively (fig. 1). It is here theorized that the Cincinnati Arch periodically interrupted the westerly slope of this plain and diverted some streams southward along the east side of the arch in Ohio and Kentucky. Thus it is further suggested that the Cincinnati Arch was a divide during channel cutting and filling. At other times it was submerged or formed islands. Weller (1957b. p. 326) indicated that this arch never was subjected to deep or rapid erosion nor contributed large amounts of detrital sediments. Weller's hypothesis applies to the total volume of Pennsylvanian rocks, and it permits the possibility that periodically some channels were eroded and were filled by streams that had a southwesterly trend on the west flank of the arch (Friedman, 1958, p. 1567). Furthermore, Weller's terms "deep or rapid erosion" and "large amounts of detrital sediments" are relative to the total erosion and total amount of Pennsylvanian detrital sediments; merely moderate erosion and moderate amounts of detrital sediments would have been sufficient to account for the channel cutting and filling in Indiana.

Marine or estuarine waters of Pennsylvanian age may well have deposited sandstone in some of the channels that were eroded by subaerial streams. Some channels may have been filled by sand that was dumped into them from the side (Weller, 1956, p. 29), perhaps by longshore currents. Also, some of the channels may have been cut below sea level (Wanless and Shepard, 1936, p. 1202).

Hopkins (1958, p. 41) carefully weighed the problem of the filling of a Pennsylvanian channel system. He stated:

> Alluviation of Anvil Rock channels is considered a result of sea level change.... With a relative rise in sea level a graded stream would first deposit its load near the mouth and a wave of aggradation would extend upstream. A continual rise in sea level would give the same results, and the channels would be filled by either stream alluviation or marine deposition, depending on the balance of deposition of alluvial material and the rate of rise in sea level. In the absence of marine fossils separation of these two environments would be difficult.

Hopkins (1958, p. 42) favored the hypotheses that the channels (at the base of the Anvil Rock Sandstone in Illinois and in Indiana) have a dominant subaerial origin and that deposition by valley alluviation combined with marine filling of the channels is the most probable explanation of channel fill based on stratigraphic and petrographic relationships. Hopkins' explanation is presented herein because it deals with a sandstone in the same basin and of probable equivalent age as the New Goshen Channel sandstone in Indiana. This explanation also may well apply to some of the other channel deposits in Indiana.

In Indiana most of the evidence available and examined by the author tends to indicate fluviatile channel cutting and filling. The down channel direction is southwestward in most of the channels examined in Indiana, as indicated by the dominant southwesterly trend of the crossbedding of the channel sandstones. Northeastward trending crossbedding was not observed. The subsurface parts of the New Goshen Channel exhibit a southwesterly gradient; this indicates that the down channel direction is also southwesterly. Crossbedding in the only prominent outcrop of the New Goshen Channel sandstone occurs in a tributary channel and is southwesterly. Crossbedding in the well-exposed Raccoon Creek Channel sandstone is dominantly northwesterly (down channel), and crossbedding in the outcropping Rosedale Channel sandstone is gently inclined southwestward (the down channel direction). Inasmuch as sand transportation is down channel in modern as well as ancient (fossil) stream beds, it is assumed that streams deposited the channel sands of this study after having cut the channels.

An examination of the criteria of geometric shape and pattern established by John L. Rich (1923 and 1926) for the recognition of tidal, delta distributary, and consequent (fluviatile) channel deposits of Pennsylvanian age in Kansas also suggests to the present author that the Indiana channels are nonmarine in origin and are filled in large part with fluviatile deposits. None of the channel fillings examined in Indiana showed marine fossils; only plant material was fossilized. This too may indicate nonmarine origin of the channel sandstones.

Although the genesis of channels and their sandstone fillings is still open to question, the writer favors the "working hypothesis" that the channels were eroded by subaerial streams and in large part were filled by these same streams (with the exception of the Raccoon Creek Channel). (See p. 38-40.) Nevertheless, it appears quite possible that the upper parts of some channel fillings of middle Pennsylvanian age were deposited in estuaries or tidal channels (Hopkins, 1958; Rusnak, 1957a and 1957b).

Consequent stream channels.-When the Eastern Interior Basin was emergent, it drained to the southwest (Weller, 1957a, p. 327), which is the direction of the linear orientation (trend) of most of the channel-fill sandstones in Indiana. During emergent times in this basin, these channels were parts of a southwestward -trending drainage system. Possibly a drainage system in the Michigan Basin was connected with one in the Eastern Interior Basin across a structural sag in northwestern Indiana, and a drainage system in the northern Appalachian Basin was connected with the one in the Eastern Interior across Kentucky (Friedman, 1959, p. 1606).

Presumably consequent streams were formed during Pennsylvanian time by headward erosion and (or) by extending themselves seaward. Stream gradients were low, but tributary gradients were higher. The streams or rivers probably incised channels in incompletely consolidated or indurated strata.

Vegetation probably closely followed the seaward migration of the shoreline during regression. Some *Lepidodendron* branch casts occur near the base of some of the channel-fill sandstones of this study, indicating that these ancient trees grew on river flood-plain banks. Fragments of trees that fell into the channels and were buried rapidly by sand are now lenses or laminae of coal in some of the channel-fill sandstones. Vertebrate or invertebrate fossils are absent from the channel sandstones. It seems likely, however, that at least mollusks lived in or near the streams in the humid climate that must have prevailed, but conditions were adverse for their fossilization.

Quartz pebbles have not been found in the middle Pennsylvanian channel sandstones in Indiana. These sandstones range from fine to coarse grained, and small amounts of silt and clay size quartz particles are present also. Most of the sandstones are medium grained, however. The colors tan, buff, brown, orange, and red in the sandstones undoubtedly are due to coatings of iron oxides on the sand grains. Deltaic (or foreset) crossbedding in the sandstones is common (pls. 1A and 2A) and indicates deposition by rapidly flowing streams. The fragmentary occurrence of the channel -fill sandstones (fig. 2) appears puzzling, but in places it may be due to post-Pennsylvanian erosion. The New Goshen Channel (fig. 4) appears to terminate abruptly in section 26 where it is filled with sandy shale instead of sandstone. This sandy shale may have originated as follows: A paleostream entered a deep pool in the New Goshen Channel, lost its speed and carrying power, and subsequently deposited most of its load of sand. Finer particles were carried farther downstream from the pool and deposited as sandy mud (now sandy shale).

Most of the middle Pennsylvanian channels in Indiana contain no recognizable flood-plain deposits. Perhaps such deposits exist without the obvious characteristics that have been recognized in outcrops. Recognition of subsurface flood-plain deposits is difficult. Perhaps streams eroded their channels rapidly and, shortly afterwards, filled them with detrital sediment. Thus flood plains would have had no time to form. In the valley occupied by the Terre Haute Channel a flood plain very likely was formed, however.

The Terre Haute Channel sandstone has an unusual stratigraphic relationship with a gray shale and Coal V. This shale splits the coal into two or three beds (fig. 8). Both the shale and coal lie contiguous with the sides of the channel-fill sandstone (figs. 7 and 8), which has replaced them. A study (Friedman, 1956) of a map of the abandoned underground Dresser Mine and 100 borehole records from this area suggests a hypothesis for the origin of the sand-stone-shale-coal relationship as illustrated by a sequence of cross sections (fig. 13).

It is assumed that in late Petersburg (middle Pennsylvanian) time a consequent stream formed a course on a newly exposed southwestward- sloping surface that was underlain by serniindurated strata. The stream had essentially finished downcutting its channel (fig. 13A) when conditions that were favorable to the accumulation of peat in a swamp or "coal forest" developed (fig. 13B). The stream persisted in its course through the swamp, meandered somewhat, cut laterally only slightly and with difficulty into the peat that formed its banks, and deposited mud with some silt on its flood plain (fig. 13C); at the same time peat was accumulating in adjacent areas. Thus the mud overlay the peat disconformably. Sand and some silt were deposited in the main channel, and tributary streams deposited smaller amounts of mud and very little sand. The swamp vegetation encroached upon the mud-covered flood plains (fig. 13D), and peat later formed over the mud. In this manner alternate deposition of peat and mud resulted in the intertonguing of these sediments (fig. 13E). This intertonguing is the best evidence in favor of the contemporaneous deposition of the sand, mud, and peat. A

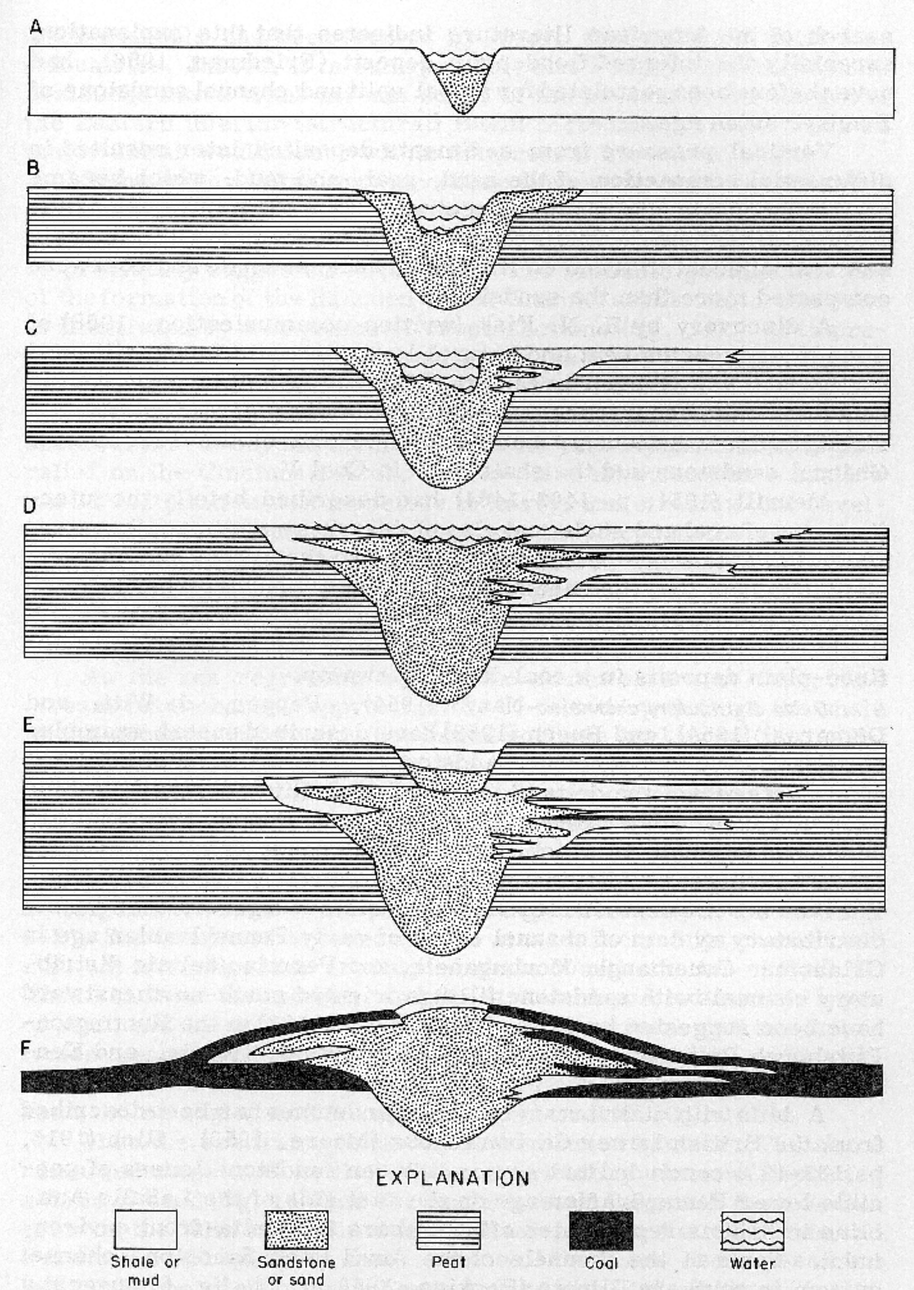


Figure 13. --Sequence of sections showing hypothetical development of the sandstone- coal- shale relationship in the Terre Haute Channel.

search of the American literature indicates that this explanation, especially the inferred flood-plain deposit (Friedman, 1956), had never before been postulated for a coal split and channel sandstone of Pennsylvanian age.

Vertical pressure from sediments deposited later resulted in differential compaction of the sand, peat, and mud, which became sandstone, coal, and shale respectively (fig. 13F). The top of the channel sandstone is thus relatively higher than part of the shale and coal adjacent to it and on its flanks, because shale and coal were compacted more than the sandstone.

A discovery by H. N. Fisk (written communication, 1958) of thick interfingering peat and natural levee deposits (mud, silt, and sand) in the New Orleans area of the Mississippi deltaic plain represents the only occurrence known to the author of sediments in a stratigraphic relationship comparable to that of the Terre Haute Channel sandstone and the shale split in Coal V.

Merrill (1951, p. 1463-1464) had described briefly the interfingering of coal and shale and clay of Allegheny age in southeastern Ohio. Channel sandstones occur adjacent to the area of the coal and shale tongues, but the sandstones were not found interbedded with the coal and shale. Reexamination of this interfingering may result in the interpretation that some of the clay and shale strata were flood-plain deposits in a coal-forming swamp.

Delta distributary channels.-Nanz *(1954*), Pepper, de Witt, and Demarest (1954), and Busch (1959) have described superb examples of delta distributary channel sandstones. The deltaic plain of Nanz represents part of the delta of the Rio Grande River during Oligocene time in Texas. The "Red Bedford Delta" of Pepper and others is composed of shale in which distributary channel sandstones were formed during early Mississippian time in northern and central Ohio. The Booch Delta described by Busch consists of a generalized deltaic distributary system of channel sands of early Pennsylvanian age in Oklahoma. Conernaugh, Monongahela, and Permian deltaic distributary channels with sandstone fillings oriented north-northeastward have been suggested by Arkle (1959, p. 122-123) in the Huntington-Pittsburgh Basin of Pennsylvania, Ohio, West Virginia, and Kentucky.

A delta with distributary channel sandstones has been described from the British Lower Carboniferous (Moore, 1959). Rich (1916, p. 133-137) concluded that some oil-laden sandstone lenses of possible lower Pennsylvanian age on the east side of the LaSalle Anticline in Illinois represented offshore bars in a delta-front environment. Some of the channels of the Anvil Rock Sandstone channel system in southern Illinois (Hopkins, 1958, p. 11, fig. 6) suggest a distributary pattern; however, Hopkins considered that all the Anvil

Rock channels had been formed by rivers that were not delta distributaries. Indeed, it is quite possible that Pennsylvanian channels coalesced into a trunk stream south of the present south margin of the Eastern Interior (structural) Basin (Friedman, 1959). Thus no major deltas would occur within the present structural basin.

Some minor deltas may have been formed during transgression of Pennsylvanian seas in Indiana. The Coxville Sandstone in the Raccoon Creek Channel (fig. 10) probably is part of a small delta, as previously suggested on page 21. The probable geologic history of the formation of the Raccoon Creek Channel sandstone in this delta is illustrated by a sequence of cross sections (fig. 14). It is presumed that a sedimentation cycle began as a plain emerged from a sea (Weller, 1930, p. 116) in late Staunton (middle Pennsylvanian) time in western Indiana. The plain had low hummocks and sloped southwestward; beyond the horizon to the east lay an area of higher relief on the Cincinnati Arch, and to the west stretched a shallow sea. Precipitation was moderate to heavy, and streams that developed dendritic tributary patterns while they eroded the plain were formed. One of the streams eroded a southwestward-trending channel in some of the shale (fig. 14A) that probably was present above Coal III in the area of the abandoned quarry in section 15 near Coxville (fig. 10).

As the sea regressed beyond the southwestern horizon, this stream cut a channel approximately 80 feet deep through the shale into a sequence of strata that includes three coal beds (fig. 14B). The stream meandered slightly and widened its channel. Later sea level was stable; to the northeast, there was a constant source of sand. This situation resulted in a gentler stream gradient and filling of the channel with sand (fig. 14C), whose crossbedding was inclined gently southwestward. The stream left the channel, meandered onto an original low area of the plain, and deposited a layer of sand (fig. 14D). Sea level was lowered and the stream incised its channel and also cut laterally, thus eroding the shale down to the top of Coal III. Then sea level was stable, and the stream deposited another layer of sand; sea level went down again, and the stream and two tributaries meandered and eroded the surface nearly flat (fig. 14E). Another drop in sea level resulted in erosion of the unconsolidated sand, some shale, and the upper part of Coal III (fig. 14F).

Then the sea transgressed upon the eroded surface. The shore remained close to Coxville, where distributary streams deposited a delta of sand (fig. 14G and H). Scale trees of the genus *Lepidodendron* grew on the delta and in time fell into some of the distributaries and were covered rapidly by sand. Some of the trees decomposed but left sandstone casts of branches or trunks with leaf cushions *(Lepidodendron aculeatuin);* at the same time others were preserved and later

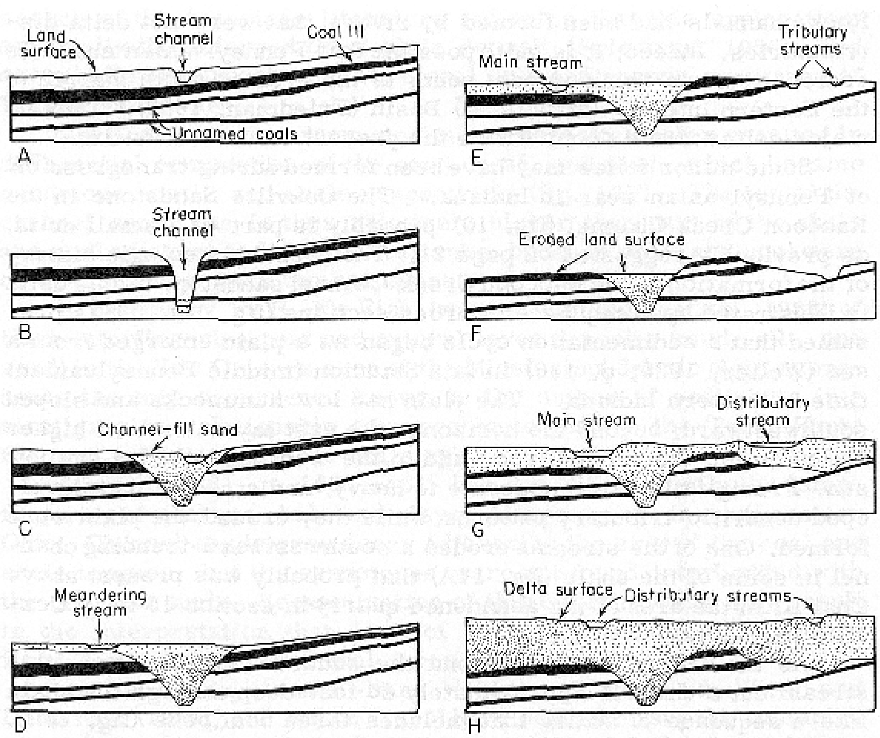


Figure 14. --Sequence of sections showing hypothetical development of the Coxville Sandstone Member near Coxville.

were compressed and coalified in crossbedded sandstone as coal stringers and lenses.

Abundant deltaic crossbedding in the sand formed units of topset, foreset, and bottomset beds. The delta was fan shaped so that the dip of the crossbedding probably ranged from northwestward to southeastward. The main stream flowed southwestward. Post-Pennsylvanian erosion of the delta has left only that part with crossbedding that dips mostly northwestward (figs. 10 and 11).

A similar but more complete explanation of a deltaic sandstone that overlies a consequent stream channel-fill sandstone is given by Pepper and others (1954, p. 33, 64-70).

TECTONIC RELATIONS AND SOURCE AREAS

Appalachia and the Canadian Shield.-Weller (1930, 1931, and 1956) indicated that Appalachia was the main source for the sediments of

Pennsylvanian age (including the channel sandstones) in the Eastern Interior Basin (fig. 1).

Levorsen (1931, p. 148) stated that a study of Pennsylvanian overlap indicated that the general major source for Pennsylvanian sediments in the Eastern Interior Basin was the Canadian Shield (fig. 1) rather than Appalachia.

In a comprehensive petrographic and stratigraphic study of the middle and upper Pennsylvanian sandstones in this basin, Siever (1957, p. 247) concluded that the major source areas for both the channel and nonchannel (sheet) sandstones were the southeastern part of the Canadian Shield and an uplifted part of the "Appalachian mobile belt" (presumably Appalachia) to the northeast and east. The present author concurs with these authorities on the source areas for all the Pennsylvanian sedimentary rocks except those rocks that fill the middle Pennsylvanian channels.

The total distribution and projection of the channel-fill sandstones studied may show the source direction of sandstone fillings. A projection of the Terre Haute Channel northeastward in the direction of western Pennsylvania leads to the northern part of Appalachia (fig. 1). Upon superficial examination it would appear that possibly that area was the source for the river as well as for the detrital sediments that formed this channel-fill sandstone. The Winslow Channel sandstone also could be projected eastward toward West Virginia so that Appalachia also may have been its source. Directed projections for the sandstones in the Rosedale and New Goshen Channels also may appear to suggest northeastern and north-northeastern sources respectively, possibly but not necessarily, as distant as northern Appalachia and the Canadian Shield.

Cincinnati Arch.-Neither Appalachia nor the Canadian Shield may have been the principal sources for these channel sandstones, however. Most likely some of the channels mark courses of rivers originating in some region other than Appalachia (Weller, 1956, p. 29). The present study suggests that the area of origin is closer than Appalachia. Probably it is the Cincinnati Arch (Friedman, 1958) as shown by the following reasoning. Had these rivers extended eastward hundreds of miles to Appalachia, they surely would have eroded valleys similar in magnitude to the principal bedrock valleys of the late Tertiary Teays drainage system (Wayne, 1956, p. 33, fig. 9). This is the only known example of an ancient continuous valley system that is in large part buried and that heads in the Blue Ridge area and extends across north-central Indiana. It is suggested that a Pennsylvanian valley system would have resembled the Teays if it had originated in Appalachia. In this state the Teays Valley ranges from 2 to 4 miles in width at the base and from 4 to 8 miles at the top. It is wider in Illinois (Horberg, 1950, p. 68-69). None of the channel-fill sandstones studied approach the Teays Valley in magnitude, however. These sandstones range from 500 feet to 1 mile in width at the top.

The two largest channel-fill sandstones, in the Terre Haute (fig. 7) and the New Goshen Channels (fig. 4), are 7 miles long and broaden downdip from 700 feet in their outcrop areas to 5, 000 feet in their subsurface areas. In the New Goshen Channel the sandstone thickens southwestward (downdip) from 40 feet along outcrop areas to 90 feet in subsurface areas (fig. 5). Its tributaries are enclosed by shale and terminate abruptly where they head. Thus, the Terre Haute and New Goshen Channels and their sandstone fillings are progressively narrower and thinner upstream (northeastward), and they probably did not extend more than 25 miles farther northeastward. This conclusion precludes any possibility that they could have extended 500 miles or more into the Blue Ridge or Appalachian areas, as did the Teays Valley, or, on the other hand, into the Canadian Shield area.

Field observations by the author of some of the Allegheny rocks of western Pennsylvania also suggest that the Indiana channels did not extend far enough northeastward to reach this region.

Dutcher, Ferm, Flint, and Williams (1959, p. 61-114) have shown convincingly that the Pennsylvanian strata in the northern part of the Appalachian Basin exhibit marine facies which grade southeastward into continental facies. Thus if one seeks a continental, upland source in western Pennsylvania for the Indiana channel-fill sandstones, one finds this marine facies. Consequently, the idea of the Indiana channels heading in western Pennsylvania appears absurd. An upland source is required closer to the east side of the Eastern Interior Basin.

The Cincinnati Arch (fig. 1) is the most likely source, inasmuch as it was undergoing uplift and widespread erosion at the close of Paleozoic time (Weller, 1957a, p. 2134). As used herein, this arch is confined to its extent from Cincinnati, Ohio, north-northwestward across Indiana, and not west of central northern Indiana.

Theoretically, then, during middle Pennsylvanian time, at least, sea level was periodically lowered and raised in the Eastern Interior Basin. Each major regression of the sea led to the start of a sedimentary cycle and was coincident with the exposure of the Cincinnati Arch. Consequent streams were formed on the coastal plain on the west side of the arch, which was a part of the regional slope (fig. 15A). As the sea regressed, littoral marine sand and mud formed a thin blanket deposit on the coastal plain. Hopkins (19 5 8, p. 3 8 - 3 9) described in detail the depositional environment of a blanket sand thus formed. As regression continued, stream gradients were steepened. The blanket deposit was eroded completely from an

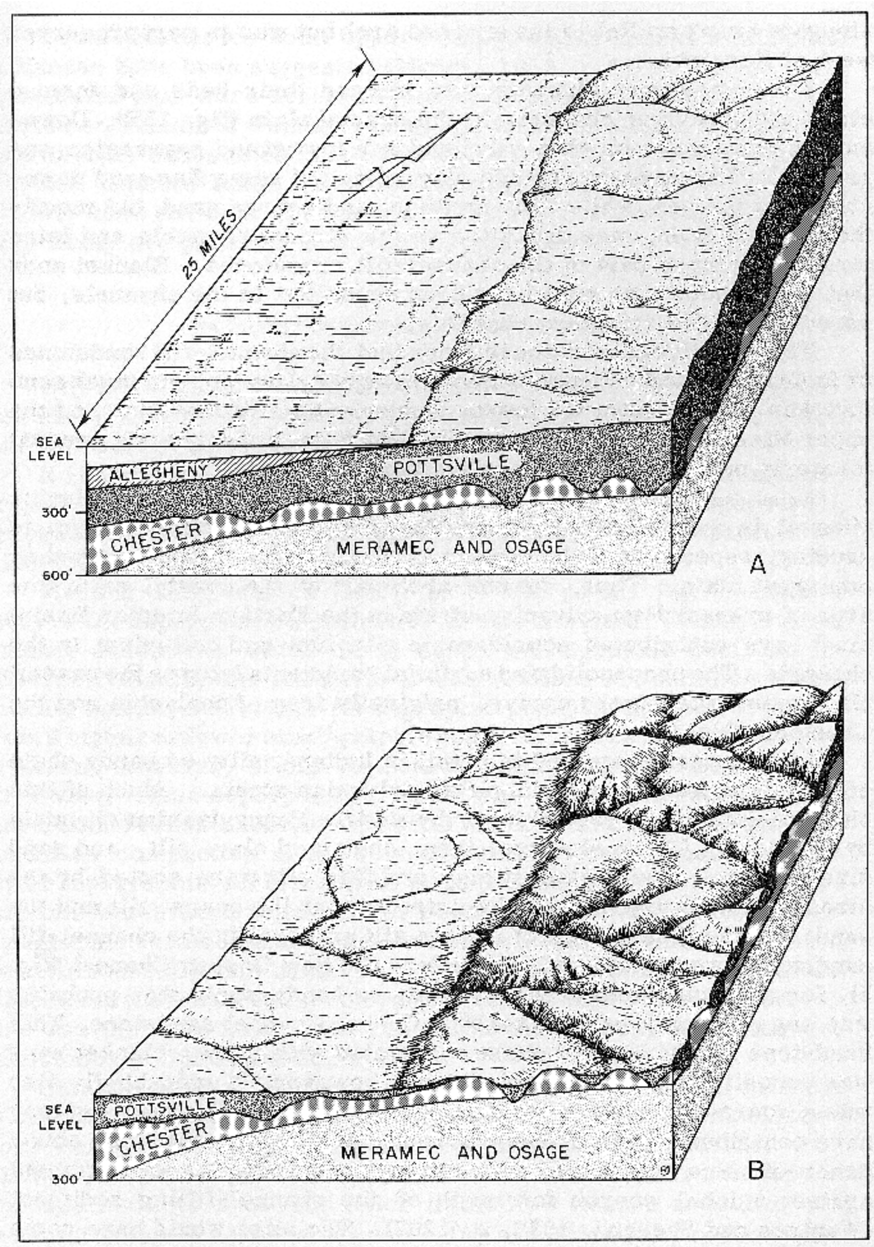


Figure 15. --Block diagrams showing stream dissection of a hypothetical part of the Cincinnati Arch during middle Pennsylvanian time. A. Shortly after exposure; B. Long after exposure.

elongate area parallel to the exposed arch but was in part preserved west of this area.

The consequent streams then incised their beds and formed steep- sided valleys (channels) in the coastal plain (fig. 15 B). Down-cutting was maximum when sea level was lowest and regression was greatest. The streams carried clay, silt, and some fine sand downstream to the sea, while fine, medium, and coarse sand, but mostly the medium sand, was deposited in the stream channels and later formed the large part of the channel-fill sandstones. Blanket sand that was eroded also may have been deposited in the channels, but especially in the tributary channels.

The tentative conclusion is made that the channel-fill sandstones in Indiana of middle Pennsylvanian (Allegheny) age contain much sand that was eroded from the lower Pennsylvanian (Pottsville) and the upper Mississippian (Chester) rocks which presumably were present formerly on the west flank of the Cincinnati Arch.

Local Sources- The alluvium and colluvium in a stream valley or channel is derived mostly from the material that the stream is eroding, especially if the stream is dissecting a newly exposed or emergent plain. Thus, the non-arch part of the coastal plain (the area of present Pennsylvanian strata in the Eastern Interior Basin) must have contributed considerable alluvium and colluvium to the channels. The unconsolidated surficial sediments lying on the coastal plain most likely were derived originally from Appalachia and the Canadian Shield.

In the areas examined in detail in Indiana, silty or sandy shale constitute most of the middle Pennsylvanian strata. Much of this shale probably was eroded from the middle Pennsylvanian channels by streams. These streams, then, contained clay, silt, and sand size grains. The grains of clay and fine silt were sorted by the streams and carried farther downstream than the coarse silt and the sand, and thus the amount of coarse silt and sand in the channel-fill sandstones was increased. Therefore the New Goshen Channel (fig. 5), for example, was eroded in silty or sandy shale that probably was one of the sources for the New Goshen Channel sandstone. This sandstone has no blanket phase associated with it. If a blanket sand was deposited before channel cutting, however, it undoubtedly also was a source for part of the channel filling. Such blanket sand may have contributed much mica to the channel-filling sands. The abundance of mica in channel deposits has been used as an argument against a local source for much of the channel-filling sediment (Wanless and Shepard, 1936, p. 1202). The mica would have come from distant metamorphic or igneous terranes instead of the herein suggested blanket sand. The New Goshen Channel also may contain a minor amount of flood-plain deposits, which have not been recognized.

Local sources for some upper Pennsylvanian channel sandstones in Kansas have been suggested (Mudge, 1956, p. 676). Basal conglomerates that were derived from local areas containing earlier formed sediments of Pennsylvanian age occur in middle Pennsylvanian channel sandstones in Illinois (Siever, 1957, p. 230) and in the Western Interior Basin in eastern Kansas (Mudge, 1956, p. 670), but they have not been recognized in Indiana. Such conglomerates very likely are present, however, in this State.

FACTORS CONTROLLING PALEOLOCATION

Why are channel sandstones located where they are ? This question needs answering, because the answer may contain useful ideas that will permit predictions of channel trends.

It is presumed that the paleostreams became situated in topographic depressions on newly exposed surfaces. These topographic depressions probably originated from differential compaction or underlying structural control.

Mueller and Wanless (1957, p. 87-88; p. 88, fig. 7) made a study of the superposition pattern of middle and upper Pennsylvanian channel sandstones which lie in seven stratigraphic positions in Jefferson County, Ill. All kinds of intersections are common where channel sandstones of one stratigraphic position crossed over one from a higher or lower stratigraphic position. A lack of superposition is shown, however, if one expects coinciding channel boundaries; otherwise, some superposition is shown. The writers concluded that channel sandstones had subaerial relief after deposition and that continued compaction of the adjacent shales after burial produced lower topographic surfaces than were produced on the sandstones. Streams which were formed later would have flowed on these lower topographic surfaces and would have eroded valleys which still later were filled mostly with sand. The present author assumes from these statements that differential compaction rather than underlying structure was the main factor that controlled the location of the channel sandstones in Jefferson County.

Detailed study of structure contours (drawn on coals) in relation to channel sandstones in Vigo County indicate that paleochannel locations were controlled to some extent by underlying structure. For example, three channel-fill sandstones in some places are superimposed and intersect each other in the New Goshen area (fig. 12) as shown by coal-test borehole data. The sandstones are not in physical contact with each other because they lie in three separate stratigraphic positions. The New Goshen Channel sandstone (figs. 2 and 3, no. 1) is in the highest position; below it is an unnamed channel sand stone, which lies between Indiana Coals IV and IVa (figs. 2 and 3, nos. 7, 8, and 9; table 1); the Coxville Sandstone Member, in an unnamed channel (figs. 2 and 3, nos. 10 and 11), is in the lowest

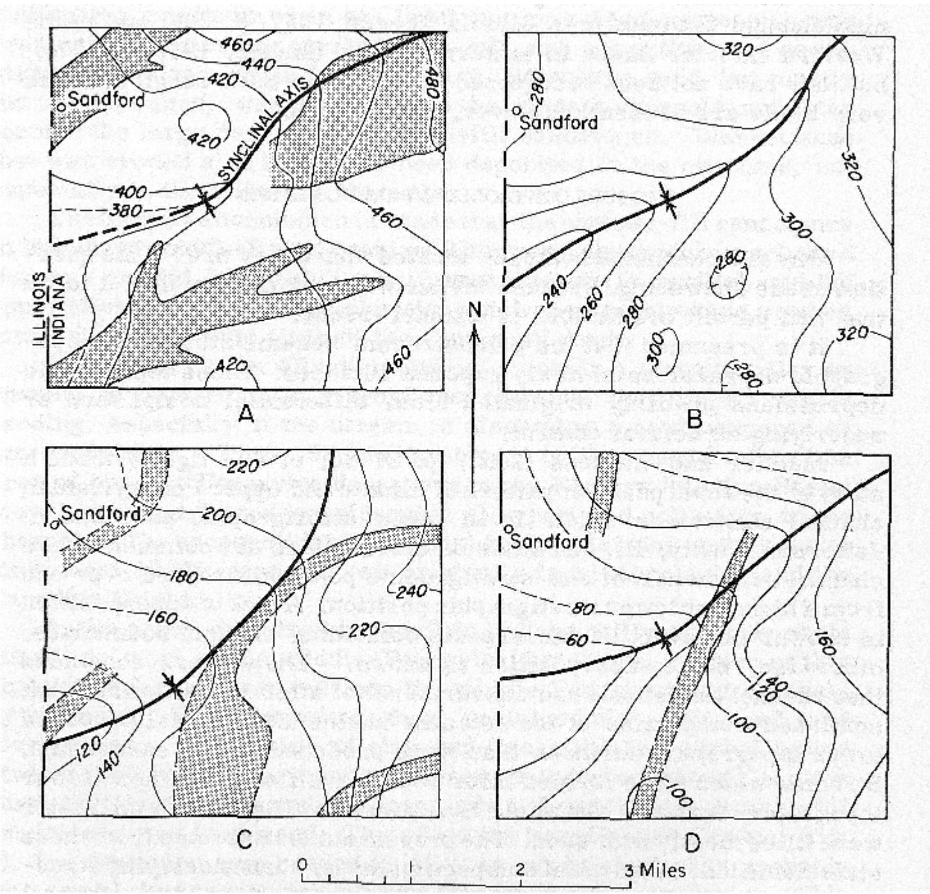


Figure 16. --Maps showing subsurface distribution of some channel-fill sandstones (stippled) in a syncline in parts of Ts. 12 and 13 N., R. 10 W., northwestern Vigo County. A. New Goshen Channel and tributary channels (fig. 2, no. 1); structure contours on Coal VII. B. Structure contours on Coal V. C. Sandstone between Coals IV and IVa in unnamed channels (fig. 2, nos. 7 and 8); structure contours on Coal IV. D. Unnamed channels at base of Coxville Sandstone Member (fig. 2, nos. 10 and 11); structure contours on Coal III. Contour interval is 20 feet.

position. All three channel- fill sandstones tend to parallel each other (fig. 12), a situation that is explained by a structure contour study.

Contours drawn on the top of Coals VII, V, IV, and III in the New Goshen area show certain structural similarities (fig. 16A, B, C, and D). A syncline persists in the strata from Coal III to Coal VII as shown by the subparallel trend of the synclinal axes. Comparison of the channel sandstones (fig. 16A, C, and D) and the syncline indicates that in most places the sandstones lie within the syncline; this suggests at least local structural control of the paleolocation of the channels and sandstone fillings. Such structural control has been suggested for a channel sandstone of Mesozoic age (Johnson and Thordarson, 1959, p. 123). It is not known exactly when the syncline in the New Goshen area first began to form and subside; however, by Coal III time, it was present.

Probably the syncline subsided periodically and influenced sedimentation and erosion in the following manner: After Coal III had formed, the syncline continued to subside, and a local trough that later became a stream channel on the land surface was formed. Sand filled this channel, which now is a Coxville Sandstone channel (fig. 16D). Later, after Coal IV had formed, the same syncline was still subsiding, and after the land surface was exposed, a stream eroded a channel there, which then was filled with sand that later became sandstone (fig. 16C). Subsidence in this same area continued after Coal V had formed (fig. 16B), and later the New Goshen Channel sandstone was formed (fig. 16A). The effect of differential compaction was nullified where each channel sandstone lies within the syncline, as shown by the coal contours.

Thus factors that caused the paleolocation of channel-fill sandstones were subsiding synclinal troughs, topographic depressions produced by differential compaction of sandstone and shale, and undoubtedly some original irregular depressions on emergent coastal plains. All these factors were superimposed upon a southwestward-trending regional slope.

ECONOMIC SIGNIFICANCE OF CHANNEL SANDSTONES

Channel sandstones have played a significantly useful role in the economy of the United States because some of them have contained oil, gas, uranium, and fresh water. Some channel-fill sandstones may be used as a source for glass sand if they are sufficiently low in impurities. Some sandstone- filled channels are not beneficial to the economy because they have been cut into coal deposits.

ADVERSE EFFECT ON COAL DEPOSITS

Some of the most important commercial coal beds in Indiana abruptly terminate against channel-fill sandstones. Coal III is cut out by the Coxville Sandstone Member in the Rosedale Channel (figs. 2 and 3, no. 12b, and fig. 11) near Coxville (fig. 10) to the extent that reserves of this coal are nil. In the Raccoon Creek Channel (figs. 2 and 3, no. 12a, and fig. 11) the Coxville Sandstone (fig. 10) has cut out all but the lower 6 inches to a foot of Coal III. In western Vigo County Coal III is only 3 feet or less thick in an area between the recently abandoned Talleydale Mine and the Green Valley Mine, both underground mines of the Snow Hill Coal Corp. Analysis of coal-test borehole data shows that the Coxville Sandstone, underlain by channels (fig. 2, nos. 10 and 11), has replaced the upper 3 feet of Coal III, which is commonly 6 feet thick in this area.

The Upper Block Coal has been cut out by a channel-fill sandstone (fig. 2, no. 23) approximately 8 miles north of Brazil, Ind. (H. C. Hutchison, 1958, oral communication). The Winslow Channel sandstone (figs. 2 and 3, no. 2, and fig. 9) has cut out Coal V in part of central Pike County (Wier, 1953). Numerous coal mines lie along the north and south sides of this channel-fill sandstone, and thus the limiting effect of the sandstone on coal mining is clearly indicated. Various publications by Geological Surveys of other States, especially some of those of Illinois, show clearly that channel cutouts have had adverse effects on coal mining.

The best example in Indiana of a channel that interferred with a mining operation is the Terre Haute Channel at the place where it passes through the area of the abandoned underground Dresser Mine. This mine produced 10½ million tons of Coal V, and, to be sure, it was a successful mine. Had the channel and its tributaries not been present, an additional 1 million tons of coal could have been mined, however. Four small tunnels and one tunnel 1,000 feet long had to be excavated through channel tributaries to connect different parts of the mine; this was expensive. Geological recognition of the Terre Haute Channel could have simplified the engineering problems of this mining operation.

Thus one of the most important uses of maps of channels and their sandstone fillings is to permit prediction of channel trends and coal cutouts.

OIL AND GAS POSSIBILITIES

Oil and gas have been found in channel sandstones that were formed in river, delta, and tidal environments in different parts of the United States as reported by Rich(1916, 1923, and 1926), Charles (1927), Landes (1951), Pepper and others (1953 and 1954), Nanz (1954), Curry and Curry (1954), Wanless (1955), Mundt (1956), Hopkins (1958), and Busch (1959). The oil- and gas -bearing channel sandstones range in age from Silurian to Tertiary.

Oil and (or) gar. production from channel sandstones of Pennsylvanian age has been reported f rom Kansas (Rich, 19 23 and 19 2 6), Oklahoma (Charles, 1927; Busch, 1959), Illinois (Lee, 1915; Rich, 1916; Hopkins, 1958), Illinois and Kentucky (Wanless, 1955), and Montana (Mundt, 1956). The present author did not check the Appalachian or Michigan Basins for oil and gas production from Pennsylvanian channel sandstones but probably there has been some.

According to Wanless (1955, p. 1812-1814), a high proportion of the oil of Pennsylvanian age present originally in the Eastern Interior Basin has been discovered already. This assertion implies that it would be unwise to search f or new Pennsylvanian discoveries; however, the author feels that many oil-bearing channel-fill sandstones of Pennsylvanian age still remain undiscovered and should be searched for. Very likely average daily production from these sandstones would not be very high, but wells would tend to produce for a long time. Lee (1915, p. 77, 93-101) reported that some oil and gas were produced from "sandstones deposited in channels" in western Illinois of early and middle Pennsylvanian age.

Channel sandstones of middle and late Pennsylvanian age probably contain undiscovered oil and gas in Indiana, Illinois, and Kentucky. Hopkins (1958, p. 45) reported gas production from a channel phase of the Anvil Rock Sandstone in White County, Ill. Wanless (1955, p. 1812) stated that further exploration might be carried on for channel sandstone reservoirs by using the distribution of the channel sandstone valleys (channels) as a guide. Upper Pennsylvanian channels have not been recognized yet in Indiana. Middle Pennsylvanian channel sandstone segments in only six stratigraphic positions (fig. 3) are recognized in this report. Possibly two more remain to be recognized in the lower part of the Staunton Formation. Furthermore, the segments have not been connected to show channel systems. Thus additional mapping must be done on the channel-fill sandstones in Indiana in order to use them as guides for oil and gas exploration.

URANIUM POTENTIAL

Channel sandstones contain uranium deposits in the Colorado Plateau and are Triassic in age (Davidson, 1956; Masters, 1955; Miller, 1955; Mitcham and Evensen, 1955; and Wright, 1955) and to a small extent Eocene (Isachsen, Mitcham, and Wood, 1955). Sandstones of Pennsylvanian age that are fluvial, if not of channel origin, and that contain uranium deposits occur in the Hermit Shale of the Colorado Plateau (Isachsen, Mitcham, and Wood, 1955, p. 128) and in conglomerate in the lower part of the Pottsville Formation near Mauch Chunk, Pa. (Wherry, 1912, p. 574-580).

Although minable uranium deposits have not been found in rocks of the Pennsylvanian System of the Eastern Interior Basin, uranium or equivalent uranium in small amounts is present in many of the carbonaceous shales or has been obtained from ash from coals (Snider, 1954; Ostrom, Hopkins, White, and McVicker, 1955). This uranium or equivalent uranium is at least 10 times less than the minimum of 0.1 percent $U_3 0_8$ for which prices have been quoted by the U. S. Atomic Energy Commission.

The shale that overlies Coal V contains uranium (Snider, 1954, p. 20), and carbonaceous shales that overlie Coal IIIa and two unnamed coals in the middle part of the Staunton Formation (fig. 3) contain equivalent uranium (possibly thorium or potassium instead of uranium) in low concentrations (R. F. Blakely, 1955, written communication). Chemical analyses have not been performed to determine which of these rare elements caused the radioactivity of the carbonaceous shales.

Deul (1955, p. 1549) concentrated uranium-rich fractions of a black shale by grinding the shale for many hours in the laboratory. Thus, erosion of the uraniferous Pennsylvanian black shales by channel-cutting streams could have released uranium-rich compounds. These streams, then, could have concentrated and deposited the uranium along with sand at certain places in the channels. (The geochemistry of this deposition of uranium is not within the scope of this report, and the reader is referred to the various references given on uranium.)

Thus channel-fill sandstones that have replaced carbonaceous shales may contain uranium deposits. Such deposits possibly occur at certain undetermined places in some of the channel-fill sandstones of Pennsylvanian age in Indiana, but none have been discovered. Much exploration remains to be done to find radioactive sedimentary strata. If and when they are found, chemical analyses would have to be made to determine whether the radioactivity of the strata is due to potassium, thorium, or actually uranium. It must be determined also if a potential uranium deposit would be large enough to mine at a profit.

FRESH-WATER AQUIFERS

Subsurface channel sandstones as deep as 300 feet may serve as excellent fresh-water aquifers, if the sand does not contain much shale and silt and if the water is not heavily mineralized. Water may enter the sandstones at subsurface outcrops that lie beneath glacial drift and stream alluvium. The New Goshen Channel sandstone (fig. 4) was recommended for exploration as a fresh-water source by Steen and Uhl (1959) after these geologists examined data shown on a copy of figure 4 in the SE¼ sec. 18. However, channel-fill sandstones near abandoned mines or those deeper than 300 feet may contain water which is unsuitable because of high "mineral" or acid content. Channel sandstones at depths of 200 feet or more also may contain abundant salt water. Fresh or salt water from these sandstones could be used in water input wells in oilfields.

SUMMARY

1. Channel-fill sandstones are divided into four classes based on their three-dimensional shape and pattern:

class 1. Channels forma dendritic pattern, and the sandstone trends and thickens downdip.

class 2. Channels forma dendritic pattern, and the sandstone trends but does not thicken downdip.

class 3. Channels do not forma dendritic pattern, and the elongate sandstone body trends downdip.

class 4. Channels do not forma dendritic pattern, and the elongate sandstone body trends parallel to the strike.

2. (a) The New Goshen Channel sandstone is the type example of class 1; (b) the Terre Haute Channel sandstone is the type example of class 2; (c) the Winslow Channel sandstone is the type example of class 3; and (d) class 4 is an anomolous class owing to the occurence of a delta distributary channel-fill sandstone overlying a consequent channel sandstone at the same place. Both channels are filled with the Coxville Sandstone Member. A channel sandstone in one stratigraphic position but at different places may belong to more than one class.

3. Three of these type examples of channel sandstones were deposited in consequent river channels, and one was deposited in a delta distributary channel.

4. Channel-fill sandstones are recognized in this report in six different stratigraphic positions in the middle Pennsylvanian rocks of Indiana. They occur below the Minshall Coal, below an unnamed coal in the lower part of the Staunton Formation, and below Coals IIIa, IVa, Vb, and VII.

5. These channel-fill sandstones of middle Pennsylvanian (Allegheny) age probably did not originate some 500 miles eastward in the ancient highland area of Appalachia. Instead, both channels and their sandstone fillings originated on the west flank of the Cincinnati Arch. The Allegheny sandstones are multicyclic and were derived from Pottsville and Chester sandstones that very likely once were on the arch.

6. The Cincinnati Arch must have been exposed periodically, at least 6 times during Allegheny time; this periodic exposure permitted channel cutting and filling at six stratigraphic positions.

7. Factors which determined the geographic position and orientation of the channel-fill sandstones and which influenced the paleotopography are subsiding synclinal troughs, depressions produced by differential compaction of sandstone and shale, and possibly some other original irregularities on the newly exposed land surfaces. These factors were superimposed on a southwestward-trending regional slope.

8. Anomolous anticlines which do not persist vertically in the strata may overlie some channel sandstones. These anticlines are due to differential compaction of the sandstones and the shaly strata and coal adjacent to the sandstones.

9. The channel-fill sandstones commonly have cut down into or have completely replaced coal beds. Recognition of these sandstones would reduce engineering problems in coal mines and permit prediction of channel trends and coal cutouts.

10. Deposits of oil, gas, uranium, and fresh water were not discovered from the records of the channel-fill sandstones studied, but deposits of these resources may occur in these and other channel sandstones in Indiana as well as in Illinois and western Kentucky.

PROBLEMS DESERVING FURTHER STUDY

The systematic mapping and sampling of channel-fill sandstones in the lower, middle, and upper Pennsylvanian strata in Indiana should be undertaken in order to better understand their (a) stratigraphic position and distribution, (b) relation to coal deposits, especially where channels have been cut into coal beds, (c) petrology, (d) possible uranium content, (e) fresh-water potentiality, and (f) possible use as a source of high-silica sand.

2. Approximately 50 oil pools in Indiana produce from Pennsylvanian sandstones. How many of these pools are in mappable channel-fill sandstones? And what formations are they in? Could the resultant maps of channel sandstones be used as a guide for further petroleum exploration?

3. A shale sequence that lies adjacent to the New Goshen Channel sandstone should be examined by petrographic methods to determine whether this shale might have been a source for some of this sandstone.

4. The channel-fill sandstones in Indiana should be mapped carefully westward into eastern Illinois in order to correlate them with those in Illinois and to aid in the general correlation of the Pennsylvanian strata, especially in the state-line area where such knowledge is vague.

5. Channel sandstones in the northern part of the Appalachian Basin should be studied especially to aid in correlation with those in Indiana. Such correlation would (a) shed light on the tectonic significance of the Cincinnati Arch during Pennsylvanian time, (b) clarify problems dealing with the origin and source of the channel-fill sandstones in the eastern part of the Eastern Interior Basin, and (c) possibly explain the absence of Pennsylvanian strata between the Appalachian and the Eastern Interior Basins.

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