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Shape and Distribution Patterns of Pennsylvanian Sand Bodies in Illinois

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ABSTRACT

Pennsylvanian sandstones occur as sheets or as one of several types of elongate sand bodies—belts, dendroids, and pods. This report presents detailed local and regional maps of sandstone thickness delineating these various types.

Thickness of sandstone was mapped for three intervals of the Pennsylvanian sequence in Illinois - from the Davis Coal Member to the Colchester (No. 2) Coal Member, from the Summum (No. 4) Coal Member to the Harrisburg (No. 5) Coal Member, and from the No. 5 Coal Member to the Herrin (No. 6) Coal Member. The maps were supplemented by basin-wide maps showing the percentage of sandstone in the interval from the base of the Pennsylvanian System to the No. 2 Coal and from the No. 2 Coal to the Shoal Creek Limestone Member.

The similarity of the detailed and regional maps of Pennsylvanian sandstones indicate that they have common, recurring patterns of distribution throughout the state. Knowledge of such distribution patterns, shown on the maps, is helpful when contouring Pennsylvanian sand bodies. Where cross-bedding can be obtained, its orientation helps to predict the trend of elongate Pennsylvanian sand bodies.

INTRODUCTION

Much of the previous research on Pennsylvanian sediments of Illinois has had two principal objectives, to delineate economically valuable coal resources and to expand insight into the stratigraphic sequence. Subsurface and outcrop mapping have contributed importantly to both objectives. Because of their economic interest and because they have great lateral continuity, thus forming key beds of the sequence, the limestones, coals, and black shales have been the chief objects of study. Statewide correlations are based primarily on rocks of these lithologies. In recent years, however, the associated sandstones and shales have received increasing attention.

This paper delineates shapes of sand bodies and patterns of distribution, or map patterns, of the Pennsylvanian sandstones of Illinois. The thick sandstones, with erosional unconformities at their base and differential compaction on their flanks, are the most variable and discontinuous of all the Pennsylvanian sediments and constitute the most disruptive element in the Pennsylvanian sequence in Illinois. Hence, knowledge of their shapes and map patterns contributes importantly to understanding the entire stratigraphic section and has direct practical significance.

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GENERAL

Pennsylvanian sediments cover approximately 67 percent or 37,500 square miles of the state. Their maximum thickness of almost 3000 feet occurs in the southern part of the state. As the result of both thinning and overlap, the total section thins westward and northward, thus defining a depositional shelf area that lies to the west and north of the more rapidly subsiding and now structurally deeper portion of the Illinois Basin (fig. 1).

A chart of stratigraphic nomenclature is shown in figure 2.

Shale is predominant in the sequence, sandstone is subordinate, and limestone and coal are present in much lesser amounts. The presence of ordered sequences or cycles is a characteristic lithologic feature of the Pennsylvanian sediments in Illinois (Weller, 1930). More than fifty such sequences have been recognized.

The mineralogical composition of Pennsylvanian sandstones in the state is related to stratigraphic position (Siever, 1957, p. 235; Potter and Glass, 1958, table 6). The sandstones of the Caseyville Formation and the basal Babylon Sandstone Member of the Abbott Formation in western Illinois are relatively mature and consist principally of quartz with minor amounts of matrix, feldspar, mica, and rock fragments. Petrographically they are orthoquartzites and protoquartzites. The sandstones of the Abbott Formation have intermediate properties and are chiefly protoquartzites. Sandstones above the Abbott are subgraywackes, have more mica, feldspar, matrix, and the grains are less well rounded than in the sandstones of the Caseyville Formation. Because of overlap and the thinning of the underlying units, it is possible for the subgraywacke sandstones of the Kewanee and McLeansboro Groups to occur near the base of the Pennsylvanian System in western and northern Illinois.

Udden (1912) described at some length the sandstones of the Peoria region, and Rich (1916) early discussed problems of shape and origin of the sand bodies. Ekblaw (1931) described a channel of the Pleasantview Sandstone Member in western Illinois, and Willman and Payne (1942, p. 90, 127-128) referred to Pennsylvanian channels in northern Illinois. Pryor (1956, fig. 11 and fig. 12) mapped thicknesses of sandstones of the McLeansboro Group in White County. Wanless (1957, p. 53-55) described channel and sheet sandstones and outlined several channels from closely spaced outcrop data in western Illinois. Mueller and Wanless (1957) showed subsurface map patterns of sandstones in Jefferson County, Illinois. Rusnak (1957) studied the Pleasantview Sandstone Member in western Illinois. Hopkins (1958, fig. 4) and Potter and Simon (1961, fig. 4) mapped the Anvil Rock Sandstone Member in southern and west-central Illinois. Andresen (1961) mapped the Trivoli and Inglefield Sandstone Members in southern Illinois.

ELONGATE AND SHEET SAND BODIES

Conditions for the study of the shape and distribution patterns of sand bodies vary widely across the state. Areas in western and northern Illinois provide good places to observe sandstones in outcrop, partly because there is relatively little sandstone in the section and partly because there are many thin marker beds in the sequence. Nevertheless, because subsurface information is meager, map patterns usually cannot be well demonstrated.

In central and much of southern Illinois, in areas where the basin subsided more rapidly (fig. 1), subsurface information is abundant so that both map patterns and cross-sections can be well established for the sequence above the Davis Coal Member. Because of the absence of traceable coal beds and limestones below the Davis Coal, the lower subsurface sandstones cannot be identified and mapped with certainty. Outcrops are sparse in most of central and southern Illinois, but along the southern Pennsylvanian boundary the steeper northward regional dip into the basin and abundant sandstones provide many outcrops for the sequence below the Herrin (No. 6) Coal Member.

Both outcrops and subsurface observation indicate that the sand bodies of the Pennsylvanian sequence of Illinois have recurring shapes and distribution patterns. Two recognizable types of sand bodies are present: elongate sand bodies that are thick, commonly lenticular, and sometimes discontinuous; and sheet sand bodies that are thin and relatively widespread. Table 1 gives some outcrop localities of both types.

Elongate Sand Bodies

Elongate sand bodies almost invariably have an erosional unconformity at their base. As seen in outcrop or in underground mining operations, the basal contact is usually abrupt and well defined. Electric logs can demonstrate the unconformity only where underlying marker beds are progressively replaced by sandstone.

Thickness usually ranges from 20 to 125 feet. Sections thicker than 125 feet nearly always represent sandstones of two or more cycles that have been superimposed.

Elongate sand bodies contain fine and fine-to-medium sand and less commonly, medium and coarse sand, especially in the Caseyville Formation where they also contain quartz granules and pebbles. Although exceptions exist, most elongate sand bodies become finer grained from bottom to top. Conglomerates of locally derived pebbles and cobbles of shale, coal, and limestone may be present, particularly near the base of the sand body. Both finely divided and coarse plant debris also may be present. A few marine fossils, although rare, have been reported. Cross-bedding is usually present, and small-scale scouring (cut-and-fill) and ripple marks also occur.

TABLE 1 - EXPOSURES OF PENNSYLVANIAN ELONGATE AND SHEET SANDSTONES IN ILLINOIS

Unit	Type	Location ¼ Sec., T., R., County	Quadrangle Map and Reference
Mattoon	Elongate	NW SE SE 21-2S-9E, Wayne	Albion
Bond, McWain	Elongate	SE SW NW 25-9N-5W, Montgomery	Mount Olive
Modesto, Gimlet	Elongate	NW 12-8N-6E, Peoria	Glasford (Wanless, 1957, p. 116)
Modesto, Trivoli	Elongate	SW SW NW 5-19N-12W, Vermilion	Fithian
Modesto	Sheet	SW NE NW 31-20N-11W, Vermilion	Danville, NW
Carbondale, Copperas Creek	Sheet	NE NE SE 2-12N-9E, Marshall	Lacon
Carbondale, Copperas Creek	Sheet	SW SE SE 24-16N-6E, Bureau	Buda (MacClintock and Willman, 1959)
Carbondale, Copperas Creek	Elongate	SE SW NW 5-29N-4E, Livingston	Streator (Willman and Payne, 1942)
Carbondale, Pleasantview	Elongate	SE SW SE 23-12N-11W, Greene	Roodhouse
Carbondale, Pleasantview	Sheet	SW NE 25-6N-3E, Fulton	Havana (Wanless, 1957, p. 95)
Carbondale, Pleasantview	Elongate	Cen. 31-2N-1E, Schuyler	Beardstown (Wanless, 1957, Geol. sec. 5)
Carbondale, Pleasantview	Elongate	SE SW SW 14-13N-12W, Scott	Winchester

TABLE 1 - EXPOSURES OF PENNSYLVANIAN ELONGATE AND SHEET SANDSTONES IN ILLINOIS - continued

Unit	Type	Location ¼ Sec., T., R., County	Quadrangle Map and Reference
Carbondale, Vermilion	Sheet	NW NE SW 23-33N-4E, LaSalle	Marseilles (Willman and Payne 1942, fig. 71)
Carbondale, Vermilionville	Sheet	NW SW SW 10-31N-3E, LaSalle	Streator (Willman and Payne, 1942, p. 295)
Carbondale, Vermilionville	Belt	SW SW SW 29-32N-3E, LaSalle	Streator (Willman and Payne, 1942)
Carbondale, Vermilionville	Belt	SE SW NE 23-32N-2E, LaSalle	Streator (Willman and Payne, 1942)
Carbondale, Vermilionville	Belt	SE NW SW 13-8N-7E, Peoria	Peoria (Udden, 1912)
Carbondale, Vermilionville	Belt	SW NE NW 1-7N-7E, Peoria	Peoria (Udden, 1912)
Carbondale, Vermilionville	Elongate	NE NE SE 13-33N-4E, LaSalle	Marseilles (Willman and Payne, 1942)
Carbondale	Sheet	SW SW NW 4-10N-2E, Knox	Galesburg
Spoon, Vergennes	Sheet	NW SW NW 19-7S-2W, Jackson	Murphysboro (Shaw and Savage, 1912)
Spoon	Elongate	NW SE SE 9-1N-6W, Adams	Camp Point

TABLE 1 - EXPOSURES OF PENNSYLVANIAN ELONGATE AND SHEET SANDSTONES IN ILLINOIS - continued

Unit	Type	Location ¼ Sec., T., R., County	Quadrangle Map and Reference
Spoon	Elongate	SE NW NW 30-9S-1W, Jackson	Carbondale (Lamar, 1925)
Spoon	Elongate	SW SW SE 6-16N-5W, Rock Island	Muscatine
Spoon	Sheet	NE SE SW 10-10S-6E, Saline	Harrisburg
Abbott, Babylon	Sheet	SE 2-5N-1E, Fulton	Vermont (Wanless, 1957, Geol. sec. 34)
Abbott, Babylon	Elongate	NE SW SW 31-17N-1W, Rock Island	Milan (Savage and Udden, 1921)
Abbott, Bernadotte	Elongate	NW SE SE 30-5N-4W, McDonough	Colchester
Abbott, Finnie	Sheet	NE SW NE 7-11S-5E, Pope	Harrisburg (Kosanke et al., 1960, Geol. sec. 3)
Abbott, Grindstaff	Elongate	SE NE SE 35-11S-3E, Johnson	Marion
Abbott, Grindstaff	Elongate	Cen. 19-11S-5E, Pope	Harrisburg (Kosanke et al., 1960, Geol. sec. 3)
Abbott	Sheet	SW SE NE 3-17N-5W, Rock Island	Eddington (Savage and Udden, 1921)
Caseyville, Pounds	Belt	SE NW NE 18-11S-10E, Hardin	Saline Mines (Baxter et al., in press)
Caseyville, Battery Rock	Belt	SW NW NE 10-11S-9E, Hardin	Saline Mines (Baxter et al., in press

TABLE 1 - EXPOSURES OF PENNSYLVANIAN ELONGATE AND SHEET SANDSTONES IN ILLINOIS - continued

Unit	Type	Location ¼ Sec., T., R., County	Quadrangle Map and Reference
Caseyville, Battery Rock	Belt	NE SE NE 28-11S-1E, Union	Carbondale (Lamar, 1925)
Caseyville	Sheet	SW NW NW 11-11S-9E, Hardin	Saline Mines (Baxter et al., in press
Caseyville	Belt	Cen. 2-10S-3W, Jackson	Alto Pass (Weller, 1940)
Caseyville	Sheet	SW NW SE 8-12S-6E, Pope	Brownfield (Weller, 1939b)
Caseyville	Belt	SW NE NW 32-6S-5W, Randolph	Campbell Hill (Weller, 1939a)
Caseyville	Belt	NE NE NW 21-7S-5W, Randolph	Campbell Hill (Weller, 1939a)

Elongate sand bodies commonly have one of three map patterns, termed belts, dendroids, and pods (fig. 3). Belts may range in width from 3 to 35 miles, contain "islands" in which no permeable sandstone occurs, have weakly meandering outlines, and may include tributaries and distributaries. Belt map patterns usually have good continuity.

The simple fluvial or dentritic map patterns (dendroids) are weakly to strongly meandering and also have tributaries and distributaries. Widths range from less than 100 feet to 2 or 3 miles. With increasing width they grade into the belt map pattern. The wide belt map patterns are believed to result from either the lateral migration of a dendroid or the lateral coalescence of several. Dendroid map patterns usually have fair to good continuity.

The apparently isolated lenses or pods of smaller elongate sand bodies appear to show most of the properties of elongate sand bodies except that they are disconnected. Some such isolated pods may be the result of an ancient stream or delta distributary channel having been filled here and there with silt and mud instead of sand. Other pods may possibly have had a marine origin.

Elongate sand bodies that have either pod or dendroid map patterns typically have lenticular cross sections (fig. 4). Belt sandstones, because of their width, tend to have top and bottom surfaces that are parallel, except along their boundaries.

Most Pennsylvanian sandstones have pod and dendroid map patterns but some also have belt map patterns. Belt sand bodies are better developed in the portion of the basin that subsided more rapidly, particularly in the Caseyville and Abbott Formations. Although the absence of reliable marker beds precludes accurate subsurface mapping, observation of outcrops indicates that the Pounds, Battery Rock, and Finnie Sandstone Members in southern Illinois are good examples of belt sandstones. The Trivoli, Inglefield, and Mt. Carmel Sandstone Members higher in the section are also good examples, as subsurface mapping in the southern part of the basin has shown.

Sheet Sand Bodies

Sheet sand bodies are rarely more than 20 feet thick. They are relatively widespread but may pass laterally into siltstone and shale. Usually they are thin-bedded, fine-grained, and have ripple marks as their chief sedimentary structure. Vertical size variation is not as pronounced in sheet sand bodies as it is in the elongate. Carbonaceous debris may be present and, very rarely, some marine invertebrates.

Commonly the basal contact of the sheet sand body is conformable with underlying strata. Where a sheet overlies an elongate sand body it normally is gradational at the contact, grading from the coarser sandstone below to the sandy shales and siltstones of the sheet above. More generally, sheet sand bodies occur by themselves where they commonly have conformable and transitional contacts with underlying shales. Cross section is typically planar (fig. 4).

CROSS-BEDDING

Cross-bedding is probably the most prominent sedimentary structure in Pennsylvanian sandstones. The cross-bedding of most elongate sand bodies is conspicuous at outcrops and in cores and can be observed in sand bodies encountered in underground mining operations. Figure 5 shows a typical example of the cross-bedding of thick, elongate sand bodies.

Direction of the maximum dip of cross-bedding is a useful guide to the trend of elongate Pennsylvanian sand bodies in Illinois because cross-bedding generally has relatively uniform direction in single outcrops, and individual sand bodies also show consistent orientation of cross-bedding.

An example of the consistent orientation of cross-bedding in a dendroid sand body is shown in figure 6, a map of the Palzo Sandstone Member in an abandoned strip mine in the DeKoven and Davis Coal Members, near Mitchellsville, Saline County, Illinois. Here the Palzo Sandstone is approximately 60 feet thick, has an unconformity at its base, and is abundantly cross-bedded. This pattern of cross-bedding orientation is typical of the majority of the dendroid and belt bodies. Comparison with plate 1 shows that the trend of the sand body in Saline County parallels the average direction of cross-bedding shown in figure 6.

SAND BODY SHAPE

Three detailed maps of small areas, illustrating several types of elongate sand bodies, provide insight into the local and regional patterns of sand distribution. Although all the maps show sandstones of the Kewanee and McLeansboro Groups, their shapes and patterns are typical of the entire Pennsylvanian section.

Electric logs were the principal source of information for both the local and regional subsurface maps. Sandstone was defined on electric logs by counting the footage of self potential 10 millivolts to the left of the shale base line.

Figure 7 shows thickness of sand and cross section of the Anvil Rock Sandstone in Edwards County, Illinois. The sand body was delineated using data from 391 wells. One feature of the map is the abrupt boundaries of the sand body. Thickness of permeable sand can increase from 0 to more than 80 feet in a horizontal distance of less than 1400 feet. Other features that occur on many maps of elongate sand bodies are the tributary or distributary appendages to the principal sand body such as those shown in the northeast corner of the map. The maximum thickness of the sandstone in the mapped area is 133 feet where both the Herrin (No. 6) Coal Member and the underlying Briar Hill (No. 5A) Coal Member have been replaced by Anvil Rock Sandstone. Differential compaction of sandstone and shale is reflected in the structure of the overlying Danville (No. 7) Coal Member.

Figure 8 shows another example of an elongate sand body between the Harrisburg (No. 5) Coal and the Summum (No. 4) Coal Member in portions of Clay and Jasper Counties, Illinois. This map exhibits a striking meandering pattern and unusually sharp boundaries. Maximum thickness of the sand is 78 feet.

The cross section shown in figure 8 indicates that the sand body has a flat base that lies close to, but does not erode, the underlying No. 4 Coal. Channel erosion at the base of the sandstone cannot be demonstrated in subsurface in this area because no marker beds are present between the No. 4 and No. 5 Coals, nevertheless, this sandstone is assigned confidently to a channel origin for the following reasons.

Observations at outcrops indicate that thick sections of Pennsylvanian sandstones almost invariably have erosional and unconformable basal contacts. Unless a subsurface marker bed is eroded, however, the wide spacing of even the most dense subsurface control may mask this fact. Thus, strict adherence to the idea that the flat base of a sandstone (determined in subsurface) precludes a channel origin is erroneous. The meandering pattern of distribution also contradicts the idea that a flat-bottomed sandstone must represent an offshore or beach-like origin (Rich, 1916, p. 133, 134). Another factor that may contribute to the apparent flat bottoms of Pennsylvanian channel sandstones (as seen in subsurface) is the possibility that erosion was inhibited by an unconsolidated, leathery peat bed prior to lithification of the coal (Wanless, 1954, p. 158-161). Unlike the coal above the Anvil Rock Sandstone (fig. 7) the coal beds overlying the sandstone of the St. David Cyclothem (fig. 8) do not show appreciable compaction over the sand body.

Figure 9 shows the thickness of the Trivoli Sandstone in portions of Hamilton, Wayne, and White Counties, Illinois, based on data from 775 drill holes. The Trivoli sand body, a good example of a belt, has an average width of 9 miles, abrupt borders, and meandering map patterns. It is as much as 115 feet thick. In T. 4 S., R. 7 E., there is a small tributary or distributary to the principal belt sandstone, and within the area of the main sand body is an example of a small "island" in which no permeable sandstone is present.

The cross section of figure 9 shows the sandstones in the interval between the Danville (No. 7) Coal and the Shoal Creek Limestone Member. The Trivoli Sandstone replaces the West Franklin Limestone Member at the east end of the cross section. Another belt sandstone, the overlying Inglefield (Andresen, 1961, p. 8) is also present and locally erodes the Chapel (No. 8) Coal Member. Above the Inglefield Sandstone Member, the overlying Shoal Creek Limestone is also locally eroded by the Mt. Carmel Sandstone. In part because the interval between No. 7 Coal and the Shoal Creek Limestone thins rapidly to the west, compactional highs over the Trivoli and Inglefield Sandstones are not well expressed in the cross section.

These three detailed maps of local sand thickness and cross sections are representative of the majority of Pennsylvanian sandstones in the state. Studies such as these suggest the following generalizations:

1) Elongate sand bodies may have very sharp boundaries. Thickness of sandstone may commonly range from 0 to 60 feet or more, as noted in 660- and 1320-foot drill-hole spacing. Observations at outcrops and in mines indicates that basal contacts of elongate sand bodies are unconformable.

2) Weakly to strongly meandering patterns of distribution are typical, but some relatively straight patterns may also occur.

3) If sufficiently wide, elongate sand bodies may contain "islands" that are without permeable sandstone.

4) Small tributaries or distributaries exist.

5) Because of the relatively wide spacing of even the most dense subsurface control, a sandstone which clearly has an erosional and unconformable base in outcrop may appear in subsurface to have a flat base.

6) Lenticular cross sections are typical of pod and dendroid sand bodies.

THREE REGIONAL MAPS OF SANDSTONE THICKNESS

The sandstones of three stratigraphic intervals were mapped over much of southern and central Illinois. Commonly one to three drill hole records per section, if available, were used.

Interval from the Davis Coal to the Colchester (No. 2) Coal

Figure 10 shows two electric logs that include the interval between the Davis Coal and the Colchester (No. 2) Coal in Gallatin County. The Palzo Sandstone, well developed in the Farrar No. 1 Rister well (fig. 10), is the principal sandstone of the interval. Because the DeKoven Coal Member is not consistently well developed northward in the basin, it was not possible to limit the map to the Palzo Sandstone, and therefore, the Davis Coal was selected as the base of the interval and the sandstone below the DeKoven Coal, which generally has only minor thickness, was included in the mapped unit. A poorly developed, unnamed coal also occurs below the Palzo Sandstone in the interval between the DeKoven Coal and the No. 2 Coal. Plate 1 shows the sandstone thickness in the interval from the Davis Coal to the No. 2 Coal in southern and southwestern Illinois.

In the northeastern portion of the mapped area, in parts of Edwards, Wabash, and White Counties, is a southwestward trending belt sandstone, 10 to 12 miles wide, that is commonly more than 60 feet thick. In the vicinity of Carmi, White County, a dendroid sand body generally less than 2 miles wide marks the continuation of this trend. The sand body extends southwestward towards Harrisburg and the outcrop in T. 10 S., R. 4 E., Williamson County. Thick sandstone also occurs westward through southern Wayne County, northeastern Hamilton County, and southeastern Jefferson County into Franklin County. Sandstone thicker than 40 feet ranges from 2 to 4 miles in width. The trend continues in a south and southeastern direction across Franklin and Williamson Counties, where its width is generally less than 2 miles, and it joins the principal dendroid of White County in T. 9 S., R. 4 and 5 E. Another system extending southward from the belt sand body in Edwards County occurs along the Wabash River in White and Gallatin Counties and trends southwestward across central Gallatin and Saline Counties toward the outcrop. The abandoned strip mine in the Davis and DeKoven Coals near Mitchellsville, Saline County, displays excellent exposures (fig. 6) of the thick Palzo Sandstone mapped in subsurface southeast of Harrisburg (plate 1).

In southwestern Illinois in Washington, Perry, and Randolph Counties, an elongate sand body, believed to be the Palzo Sandstone, trends southwestward from T. 1 S., R. 1 W. in Washington County, to T. 5 S., R. 5 W. in Randolph County. This sand body has a weakly meandering map pattern. West of the DuQuoin Monocline (fig. 1) this dendroid sand body is the only sandstone recognizable on electric logs in the interval. East of the DuQuoin Monocline a thin but fairly persistent sheet sand generally is present in addition to the elongate sand bodies. A similar absence of sheet sand bodies west of the DuQuoin Monocline was observed by Hopkins (1958, fig. 4) and by Potter and Simon (1961, fig. 4) for the Anvil Rock Sandstone.

Areas of thick sandstone occur in outcrop east of R. 3 E. in Williamson County. Although drill-hole data near the outcrop are not abundant enough to permit detailed mapping, the apparent confluence of three dendroid systems is indicated. In outcrop, as in subsurface, the Palzo Sandstone is the principal sandstone of the interval. The poorly developed, thin, unnamed coal in the interval between the

DeKoven and No. 2 Coals has been eroded locally at the base of the Palzo Sandstone. Where thick, the Palzo Sandstone commonly rests directly on the DeKoven Coal, but at no place in Williamson, Saline, or Gallatin Counties is the DeKoven Coal known to be eroded at the base of the Palzo Sandstone.

Interval from the Summum (No. 4) Coal to the Harrisburg (No. 5) Coal

The thickness of sandstone between the Summum (No. 4) Coal Member and the Harrisburg (No. 5) Coal Member is shown on plate 2. Figure 11 shows two electric logs that include the interval. Because of the good definition of its bounding marker beds, the sandstone of this interval (the St. David Cyclothem) can be mapped over a wide area of the basin. Locally, however, the No. 5 Coal is absent under a stratigraphically higher sandstone. In south central Douglas County, along the west flank of the LaSalle Anticline, the interval has been removed by post-Pennsylvanian — pre-Pleistocene erosion.

The sandstone of the St. David Cyclothem contains clearly defined elongate sand bodies with relatively simple meandering map patterns. One of them extends southward from Douglas County into southeastern Shelby County where it joins an east-west dendroid system. From southeastern Shelby County, sandstone thicker than 40 feet extends southeastward with a well defined meandering map pattern into northeastern Wabash County, enters Indiana, then reappears in Illinois in southern Wabash County, and extends southwestward as a narrow sand body toward the outcrop. Locally, thicknesses of more than 80 feet occur. What may be a distributary extends from Edwards County southwestward toward Franklin County.

The position of the south-southeast trending dendroid from southeastern Shelby County to Wabash County appears to have been determined, at least in part, by the LaSalle Anticlinal Belt (fig. 1). Uplifting of this anticlinal belt during the deposition of the interval from No. 4 Coal to No. 5 Coal is shown by the thinning of the interval over the anticlinal structures of the belt.

In T. 8 S., R. 7 E., the sand body that trends southwestward from Albion is joined by one that extends with a complex meander pattern across Gallatin County.

Another dendroid, less well defined, extends in a general southwesterly direction from Edwards County into Franklin and Jackson Counties. This dendroid system may connect, with complex pattern, across Franklin and Hamilton Counties with the dendroids of Saline County.

West of the third principal meridian, especially in Clinton and Washington Counties, there is some sandstone that is rarely more than 40 feet thick. Although it cannot be demonstrated conclusively, this sandstone probably forms an interconnected system that entered the basin from the northwest.

Because the interval between the No. 4 and No. 5 Coals does not contain much sandstone, contrast in development of sheet sandstone on the shelf areas and in the more rapidly subsiding basin to the east is less pronounced than in other sandstones that have been discussed.

Interval from the Harrisburg (No. 5) Coal to the Herrin (No. 6) Coal

The interval between the No. 5 and No. 6 Coals contains two sandstones, the Vermilionville Sandstone Member below the Herrin (No. 6) Coal being the principal one and the other, an unnamed sandstone that occurs between the No. 5 Coal and the Briar Hill (No. 5A) Coal Members. The unnamed sandstone is not as extensive as the Vermilionville, but because the No. 5A Coal cannot be recognized with confidence over the entire map area of plate 3, it was not feasible to map the Vermilionville Sandstone only. Figure 12 shows two electric logs that include the interval. The Vermilionville sandstone is well developed in the Moran and Buchanan No. 1 Woolard log shown in figure 12. Locally, the interval has been replaced by stratigraphically higher sandstones, principally the Anvil Rock Sandstone.

The outcrop area in southwestern Illinois (Randolph and Perry Counties) and in southern Illinois (most of Williamson County) contains little or no sandstone in the interval between the No. 5 Coal and No. 6 Coal. Nevertheless, thick Anvil Rock Sandstone may be present in a few places. East of Williamson County, however, thick sandstone occurs in the interval at the outcrop. In Saline County the No. 5 Coal has been locally eroded in T. 9 S., R. 6 E. (Smith and Lennon, pl. 3 in Smith, 1957). These contrasts in abundance of sandstone along the outcrop reflect similar contrasts found in the subsurface.

A major belt sandstone is present in the northern part of Wabash County. A complex system that may in part be a delta distributary extends westward into Wayne County, turns southward through Hamilton County, and intersects the outcrop southwest of Harrisburg in Saline County. What may be distributaries extend westward into Jefferson and Franklin Counties. Another system, less well defined and with a complex map pattern, extends across Gallatin County into Saline County; complex distributaries may be present. To some extent map patterns in Saline and Gallatin Counties are complex because the sandstone below the Briar Hill (No. 5A) Coal is well developed in the area. In Lawrence and Crawford Counties there is a southwest trending dendroid sand body that joins the principal belt sand body in northwestern Wabash County. This small dendroid also crosses the LaSalle Anticlinal belt in northwestern Lawrence County.

Elsewhere in the mapped area there is relatively little sandstone in the interval. West of the third principal meridian sand thicker than 20 feet is unusual. Northward into Marion, Clay, Richland, Fayette, Effingham, and Jasper Counties the sandstone, rarely more than 25 feet thick, is defined by an irregular map pattern.

The Vermilionville Sandstone, where it is thick, commonly has eroded the No. 5A Coal. The No. 5 Coal is only rarely eroded by either the Vermilionville Sandstone or the sandstone between the Briar Hill Coal and No. 5 Coal. No. 5 Coal is, however, locally replaced by Anvil Rock Sandstone in southwestern Illinois.

In summary, these three regional maps suggest the following generalizations:

1) Elongate sand bodies tend to be oriented toward the south, southwest, or west; few trend toward the southeast.

2) The shelf area west of the DuQuoin Monocline has less sandstone than the basin to the east which subsided more rapidly.

3) When electric logs are used for subsurface mapping, elongate sand bodies are most readily recognized. Sheet sand bodies are less readily recognized on such records particularly in areas in which such sand bodies have low permeability. On the western shelf area of generally less sandstone, sheet sandstones if present are not usually recognized on electric logs and only occasional elongate pod and dendroid sand bodies are mapped. This agrees with findings by Hopkins (1958, fig. 4) and Potter and Simon (1960, fig. 4) for the Anvil Rock Sandstone.

4) Elongate sand bodies may have both tributary and distributary map patterns.

5) Each sandstone regionally appears to have been the response to an integrated pattern of sand dispersal across the basin. In some cases, detailed mapping is required to demonstrate an integrated map pattern. Even detailed local mapping, however, may fail to demonstrate the connection between some elongate sand bodies. In part, this reflects the fact that a channel may contain pods of sandstone, the remainder being filled with shale and siltstone.

REGIONAL DISTRIBUTION PATTERNS

Regional distribution patterns of Pennsylvanian sandstones are displayed by 1) diagrammatic map patterns of individual sandstones and 2) two maps showing the percentage of sandstone present in thick intervals.

Simplified Map Patterns

The map patterns of plates 1, 2, and 3 and previous studies by Hopkins (1958), Potter and Simon (1961), and Andresen (1961) suggest that there are several common, recurring regional patterns of sand deposition in the basin. Three of these patterns, obtained by representing either a dendroid or belt sandstone by a single line drawn through the area of thickest sandstone, are shown in figure 13.

Figure 13A displays a clearly defined dendritic pattern similar to that Andresen (1961, fig. 7) showed for the Trivoli Sandstone. Not all Pennsylvanian sandstones, however, have such regional dendritic map patterns.

The map pattern of figure 13B is more complex and probably the most common, exhibiting bifurcations, braids, and relatively long, straight segments. Complexity is increased by the fact that even though the pattern is one of a single stratigraphic unit, such as the Finnie Sandstone, the different dendroid and belt sand bodies may not have developed simultaneously. Neither in outcrop nor subsurface has it generally been possible to distinguish their relative ages. The Anvil Rock, Palzo, and Vermilionville Sandstones appear to have patterns at least partly similar to that of figure 13B.

Figure 13C shows a map pattern somewhat similar to that of the sandstone of the St. David Cyclothem (pl. 2) and includes a delta distributary system. Although plate 2 does not display a clearly defined distributary system, additional subsurface mapping may demonstrate the existence of more delta distributaries in the basin.

Some Pennsylvanian sandstones display only one of these patterns. Others, especially if they could be mapped in detail (one or more datum points per section) across the entire basin rather than only in its central and southern parts, doubtless would reveal two or possibly even three of these patterns. Although they cannot be mapped easily in subsurface, the Pennsylvanian sandstones below the Davis Coal appear to have similar map patterns.

Many of the sand bodies in the southern and central part of the basin in Illinois trend southwestward. Elsewhere in the basin, as for example in western and northern Illinois, map patterns oriented westward and even northwestward probably occur.

Maps Showing Percentage of Sandstone

The regional pattern of Pennsylvanian sandstones across the basin is shown by figures 14 and 15. These maps show the percentage of sandstone in the interval from the base of the Pennsylvanian System to the Colchester (No. 2) Coal (Coal IIIa in Indiana and the Schultztown Coal in Kentucky) and in the interval from No. 2 Coal to the Shoal Creek Limestone (Carthage Limestone in Kentucky). For the lower interval 430 logs were used and for the upper interval 215 logs.

Table 2 shows a basin-wide summary of directions of cross-bedding for the sandstones of the two intervals, indicating that in both intervals the dominant direction was to the southwest, 219 and 227 degrees respectively. Sand entered the basin from the east, northeast, north, northwest, and west and was transported southwestward beyond the present southern outcrop. The maps of figures 14 and 15 reflect this pattern of sand transport.

TABLE 2 - BASIN WIDE CROSS-BEDDING OF PENNSYLVANIAN SANDSTONES*

Compass Direction	No. 2 Coal to Shoal Creek Limestone Number of Observations	Base of Pennsylvanian System to No. 2 Coal Number of Observations
1-40^{o}	38	47
41-80	28	45
81-120	45	39
121-160	87	129
161-200	102	227
201-240	92	311
241-280	98	210
281-320	82	114
321-360	70	52
Total	642	1174
Average Direction	227^{o}	219^{o}

*Simplified from Potter (1962, table 2).

The map of the lower interval (fig. 14) shows a pronounced centripetal pattern along the eastern, northern, and western margins of the basin. In part, these marginal trends are a reflection of the erosional channels at the base of the Pennsylvanian System. The lower interval shows the high sand content, more than 60 percent, of the more rapidly subsiding and now structurally deeper portion of the basin. In contrast there is little sandstone on the western and northern shelf areas.

The map of the upper interval (fig. 15) indicates much less sandstone; in only a few wells does more than 40 percent sandstone occur. Although the area covered is not as large, there appears to be less sandstone in the interval on the western and northern shelf areas.

Each map (figs. 14, 15) represents the summation of a series of more than ten pulses of sand input into the basin, each with patterns such as those shown in figure 13.

CONTOURING PENNSYLVANIAN SAND BODIES

Because sand bodies are more variable in thickness and occurrence than other types of sediments in the Pennsylvanian System in Illinois, they present the most difficult problems in mapping.

Figure 16 shows an idealized map pattern of a typical dendroid sand body. This pattern appears to be widely duplicated throughout the state. The width of such a pattern may range from less than a few hundred feet to several miles. Tributaries and distributaries, bifurcations, and "islands" of no sandstone may be present. Sharp contacts along dendroid boundaries are common and have been observed at outcrops and in underground mines. Using densely spaced drill holes in 10-acre or 660-foot spacings, transitions of thickness from more than 60 feet to less than 10 feet of sandstone were found to occur between adjacent drill hole locations.

Contouring thickness of sandstone on the basis of arithmetic spacing between control points generally yields poor estimates of both channel width and location. Detailed and regional mapping indicate that the method used in figure 17 more closely approximates sand body size and position. The hypothetical example in this figure was contoured by determining the rate of change of thickness of the sand along the margin of the sand body in an area of dense control and then by extrapolating that rate of change into areas of more open control. Unless the data preclude it, both width of the dendroid and rate of change of sand thickness, as determined in areas of dense control, should be used as a guide in areas of open control.

Boundaries may be relatively straight over short distances, but more commonly they are weakly to strongly meandering. Although sandstone is the most common, siltstone and shale also may occur, and their presence may result in a discontinuous pattern of isolated, elongate pods of sandstone.

Over any small area, from a few square miles to several townships, detailed subsurface mapping of sandstone thickness will nearly always define a definite trend and pattern. This pattern is the basis for more accurate prediction of sandstone occurrence and thickness. Near the outcrop, and where it can be observed underground, direction of cross-bedding also can serve as a helpful guide in contouring sandstone thickness, because Pennsylvanian sand bodies tend to be elongate parallel to the direction of maximum dip of their cross-bedding.

CONCLUSIONS

Both local and regional mapping show that Pennsylvanian sandstones have recurring patterns of distribution. Pennsylvanian sand bodies occur either as thin sheets or as one of several thick elongate types.

Sheet sand bodies are relatively widespread, tend to have conformable basal contacts, to lack abundant cross-bedding, and generally to be planar in cross section. Because of conformability and continuity, they present few problems in contouring.

The three types of elongate sand bodies—belts, dendroids, and pods—have unconformable basal contacts and commonly have sharp map boundaries. Thickness ranges from 20 feet to as much as 125 feet or more. The elongate sand bodies disrupt the stratigraphic continuity of the sequence and offer challenging problems of contouring. The typical dendroid sand body has a lenticular cross section and a weakly to strongly meandering map pattern. Tributaries and distributaries also are present. Belt sand bodies are similar in all but width and cross section. Their cross section, because of width, tends to be planar. Belt sand bodies may be as wide as 20 miles or more. Both dendroid and belt sand bodies have abundant cross-bedding and tend to be elongate parallel to direction of cross-bedding. Pods are isolated, elongate sand bodies of limited size.

Regionally, map patterns may show: 1) a predominant dendritic outline, 2) a complex of braids as well as tributaries and distributaries, and 3) strongly meandering form with or without delta distributaries. Well defined delta distributaries are doubtless present but do not appear to be as common as the other patterns in the area mapped. If mapped over a sufficiently broad area, combinations of these patterns may occur.

Although some of the sandstones in the state may have map patterns that are oriented toward the west or even the northwest, most are oriented toward the south or southwest. Basin-wide orientation of cross-bedding also indicates a dominant southwestward direction of transport. Maps showing the percentage of sandstone for two thick intervals, each including as many as ten major pulses of sand deposition, also reflect this paleoslope. These maps, as well as isolith maps of individual sandstones, show that sand deposition was better developed in the more rapidly subsiding basin than on the western and northern shelf areas.

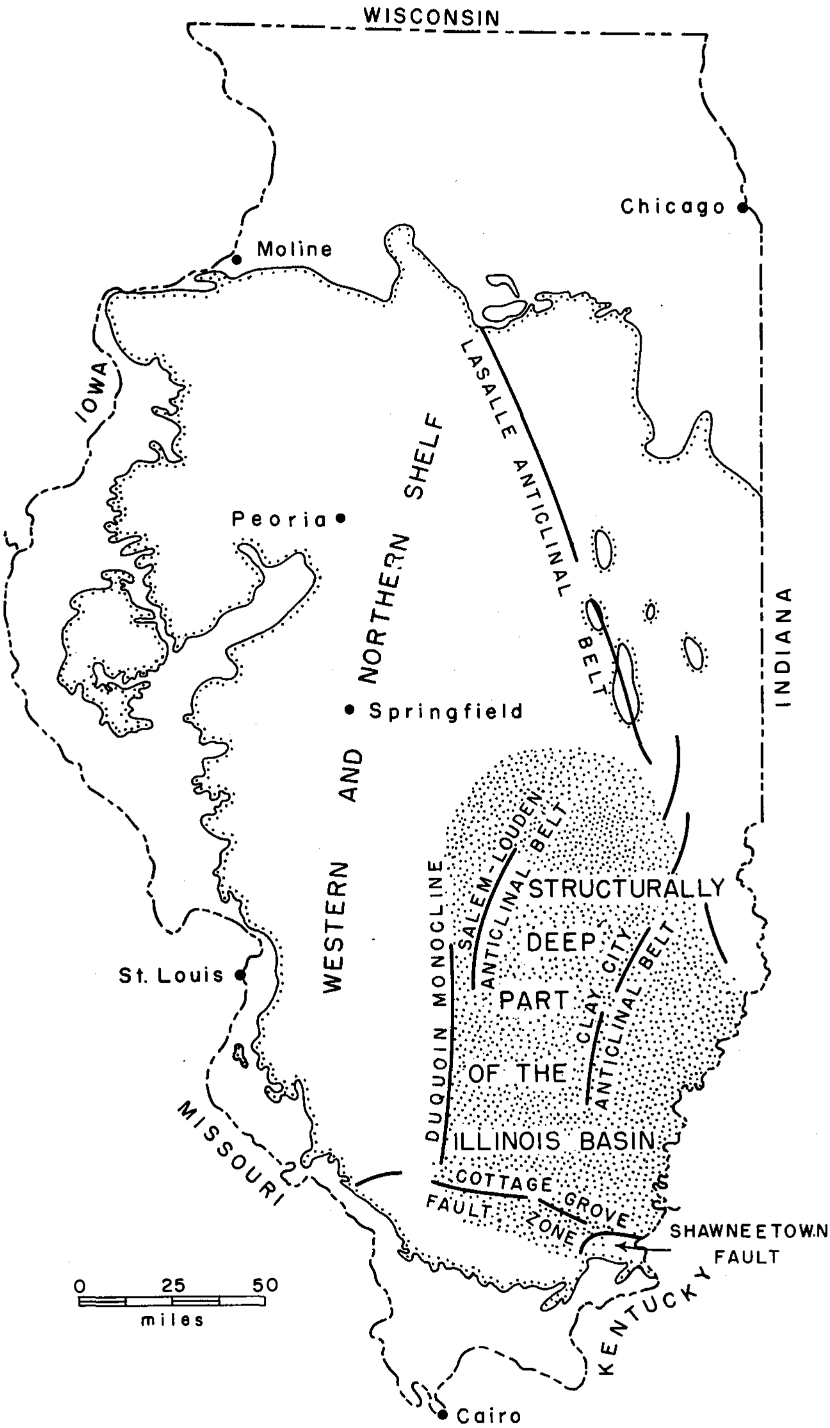

Fig. 1 - Regional map showing major structural features and structurally deeper part of the Illinois Basin.

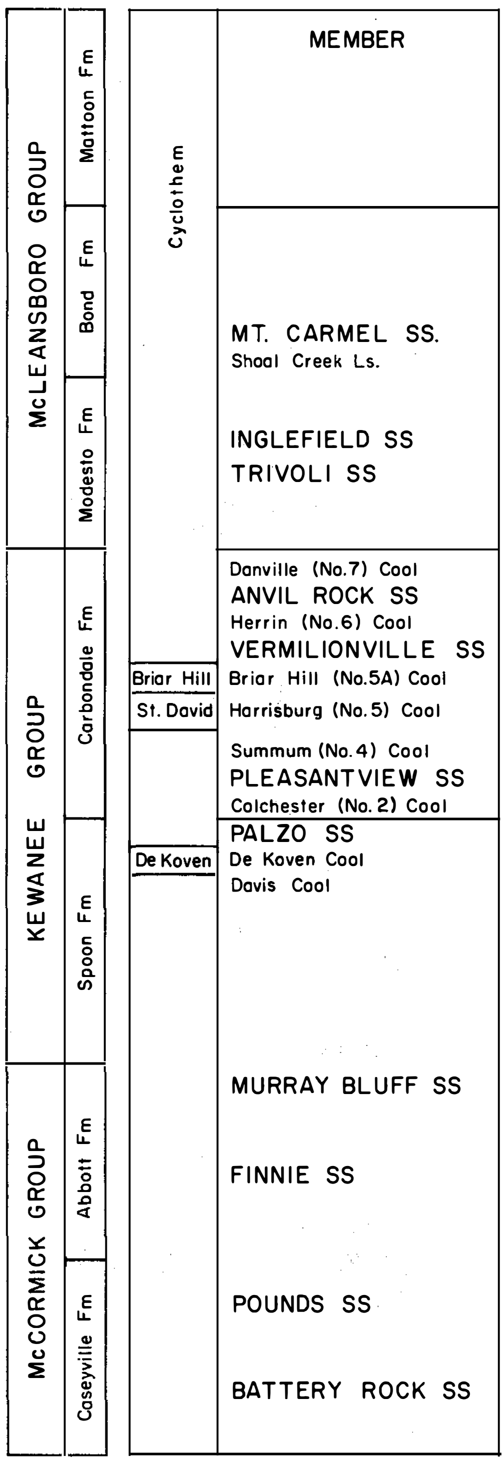

Fig. 2 - Nomenclature of Pennsylvanian units used in this report.

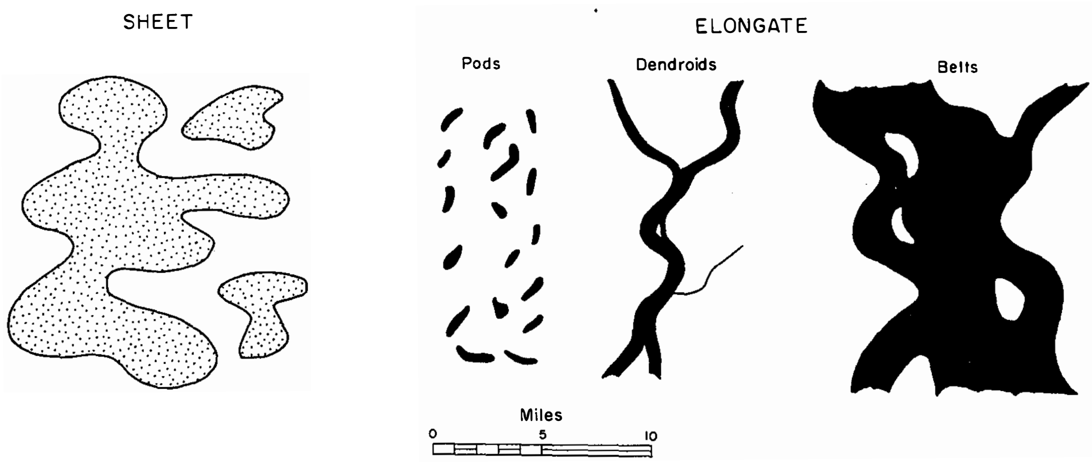

Fig. 3 - Common distribution patterns of Pennsylvanian sheet and elongate sand bodies.

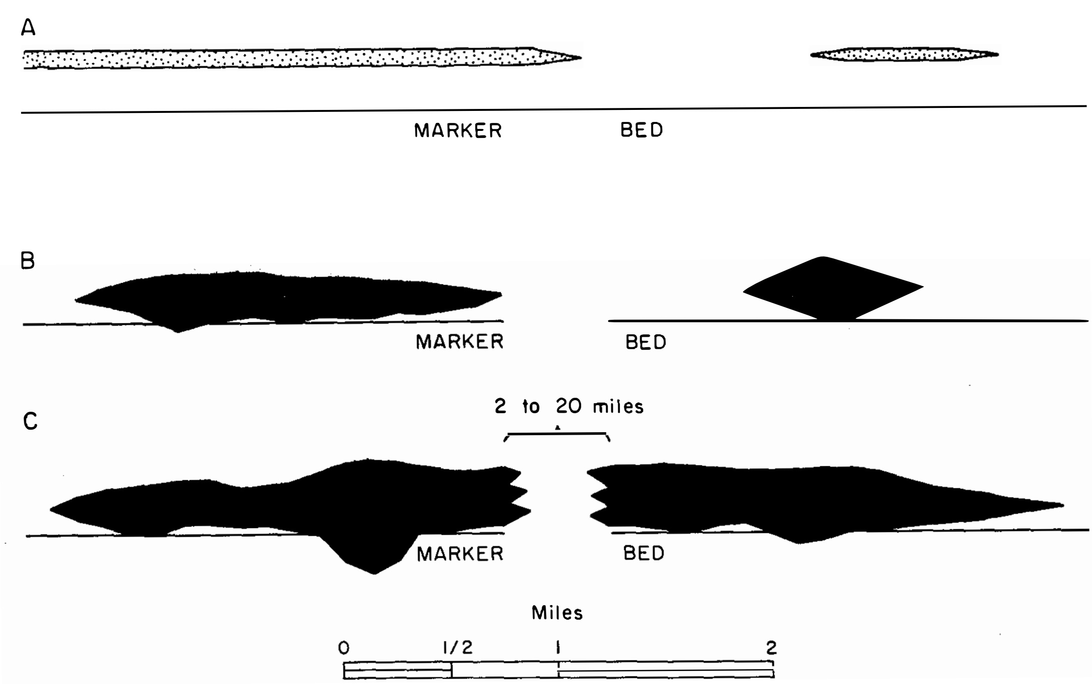

Fig. 4 - Diagrammatic cross sections of (A) sheet, (B) dendroid, and (C) belt sand bodies.

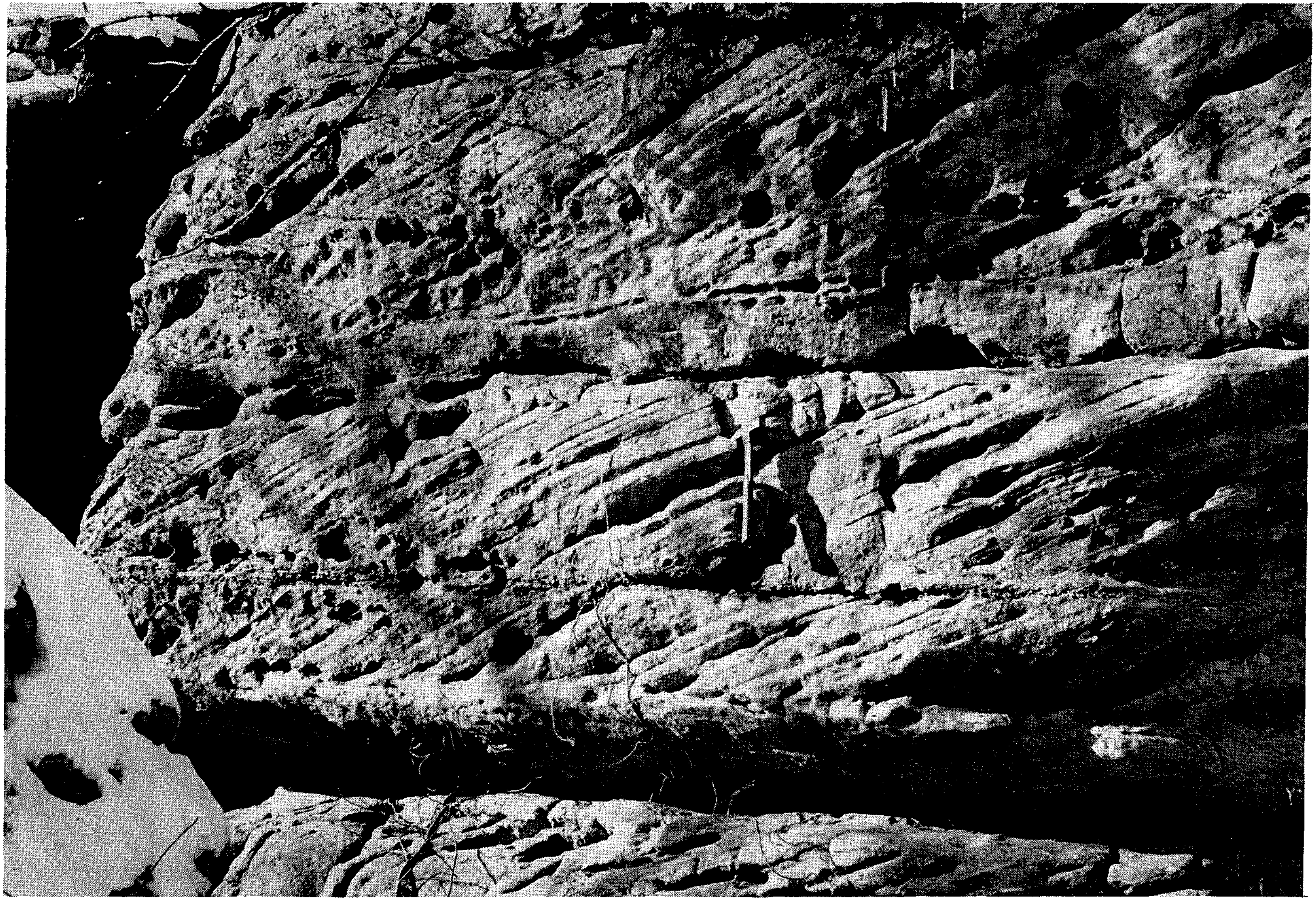

Fig. 5 - Cross-bedding in the Battery Rock Sandstone in the SE¼ SE¼ NW¼ sec. 1, T. 11 S., R. 7 E., Hardin County, Illinois.

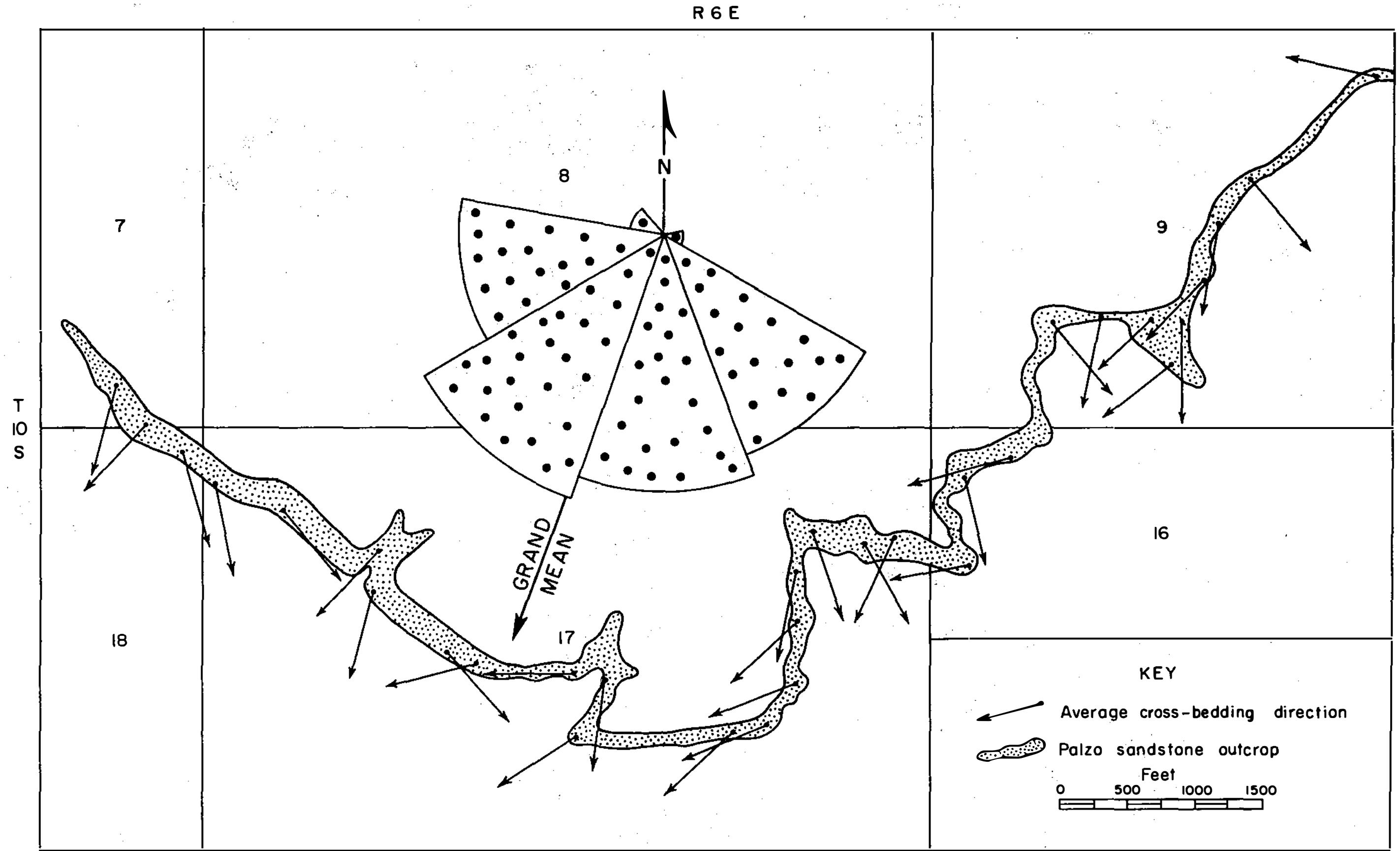

Fig. 6 - Direction of cross-bedding (60 measurements) in Palzo Sandstone in T. 10 S., R. 6 E., Saline County, Illinois.

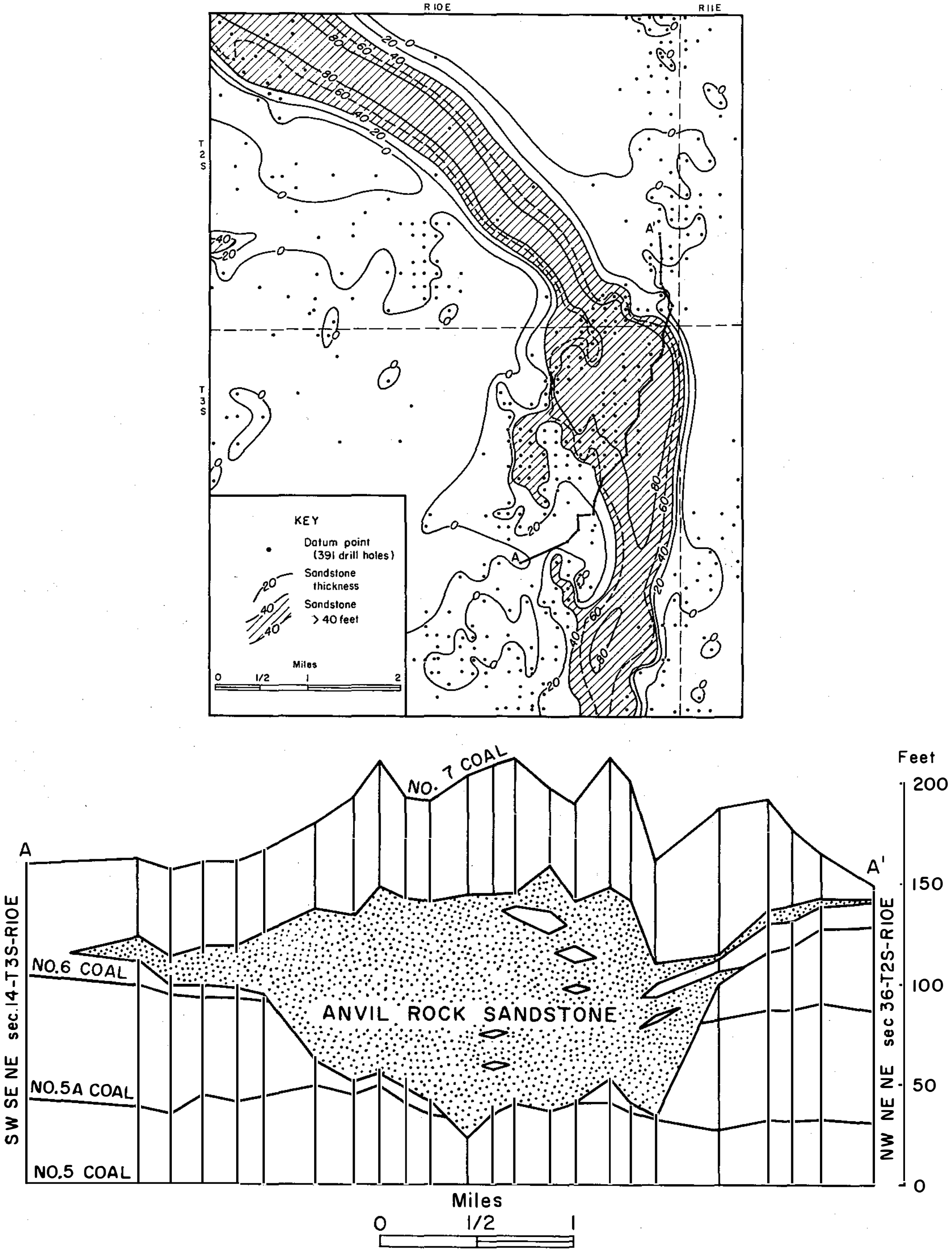

Fig. 7 - Thickness of the Anvil Rock Sandstone and cross section in Edwards County, Illinois.

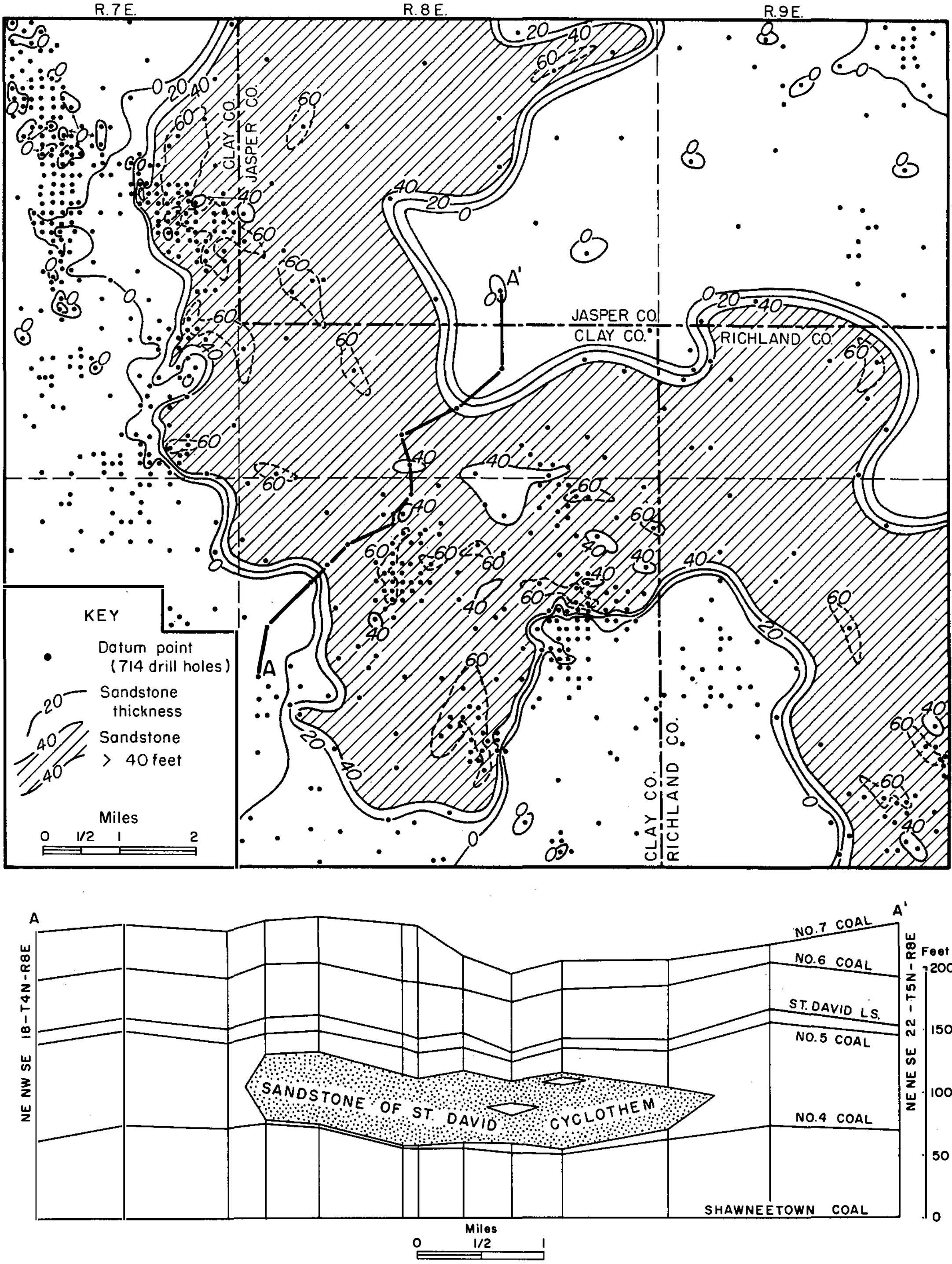

Fig. 8 - Thickness of the sandstone of the St. David Cyclothem and cross section in portions of Clay and Jasper Counties, Illinois.

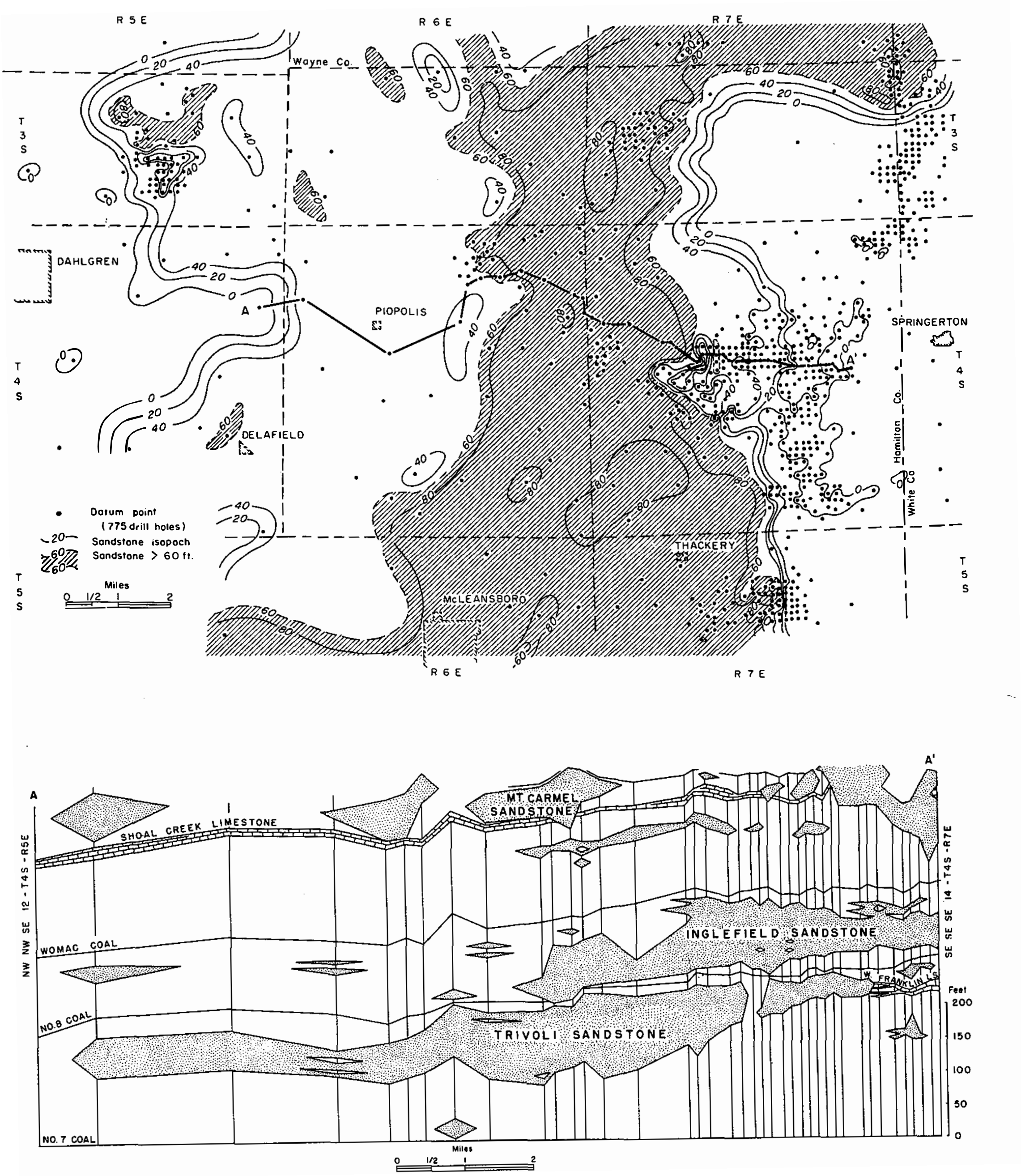

Fig. 9 - Thickness of the Trivoli Sandstone and cross section in portions of Hamilton, Wayne, and White Counties, Illinois.

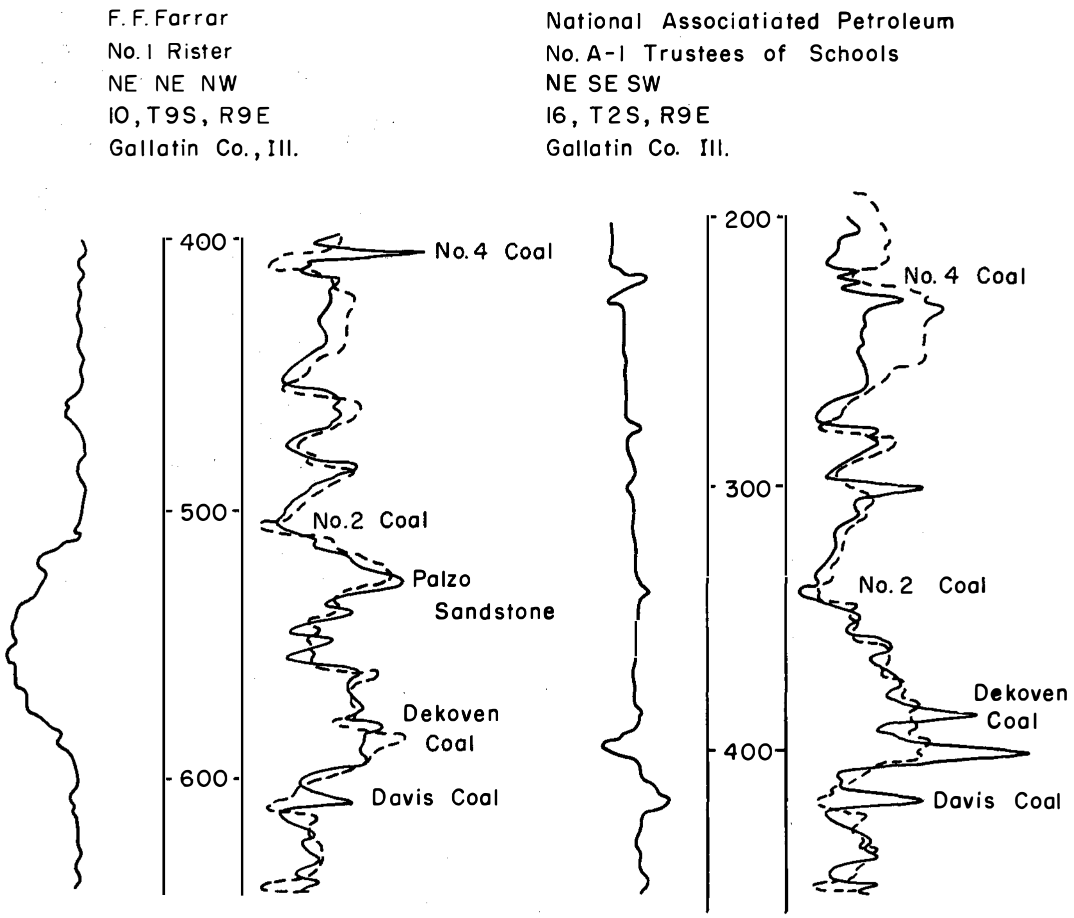

Fig. 10 - Two representative electric logs including the interval from the Davis Coal to the Colchester (No. 2) Coal in Gallatin County, Illinois.

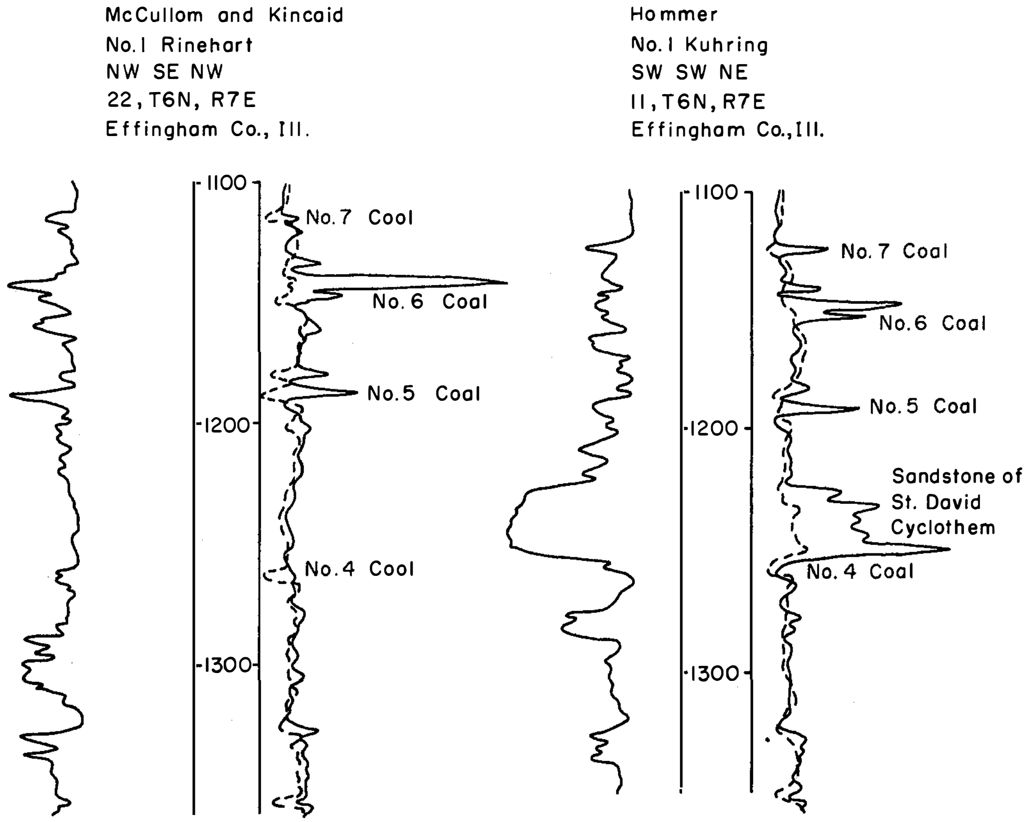

Fig. 11 - Two representative electric logs including the interval between the Summum (No. 4) and Harrisburg (No. 5) Coals in Effingham County, Illinois.

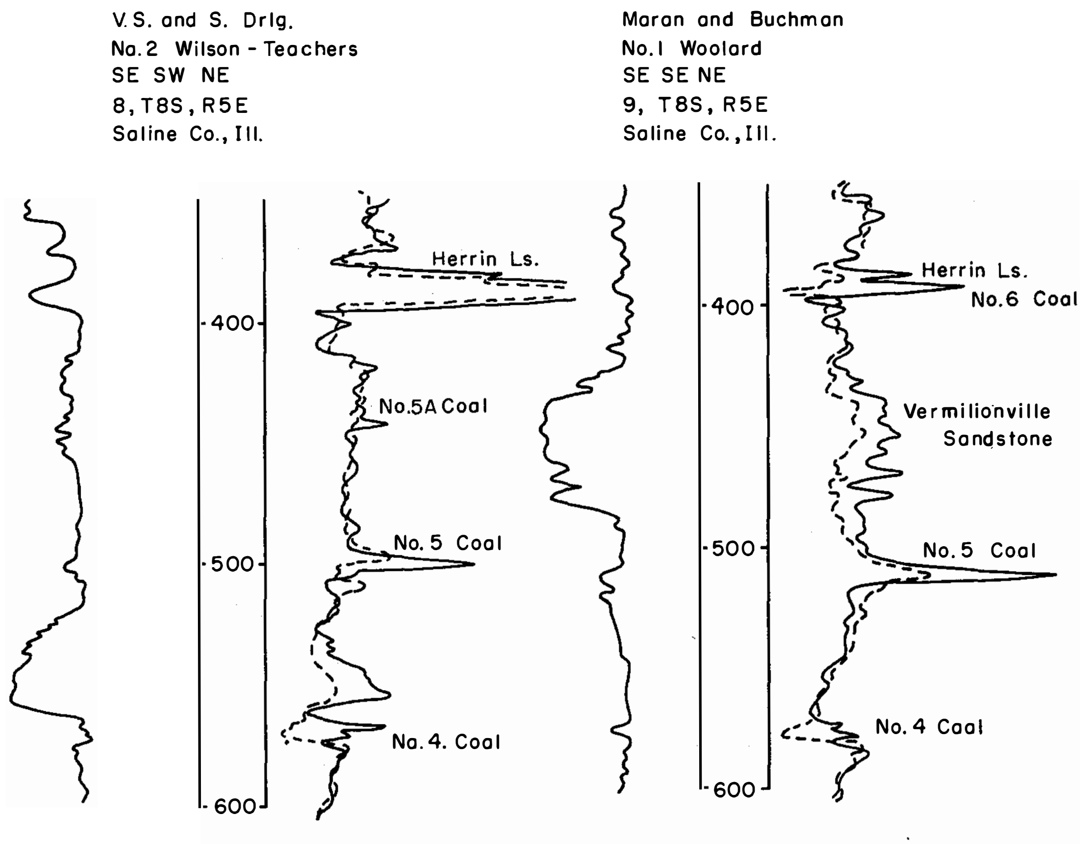

Fig. 12 - Two representative electric logs including the interval between the Harrisburg (No. 5) and Herrin (No. 6) Coals in Saline County, Illinois.

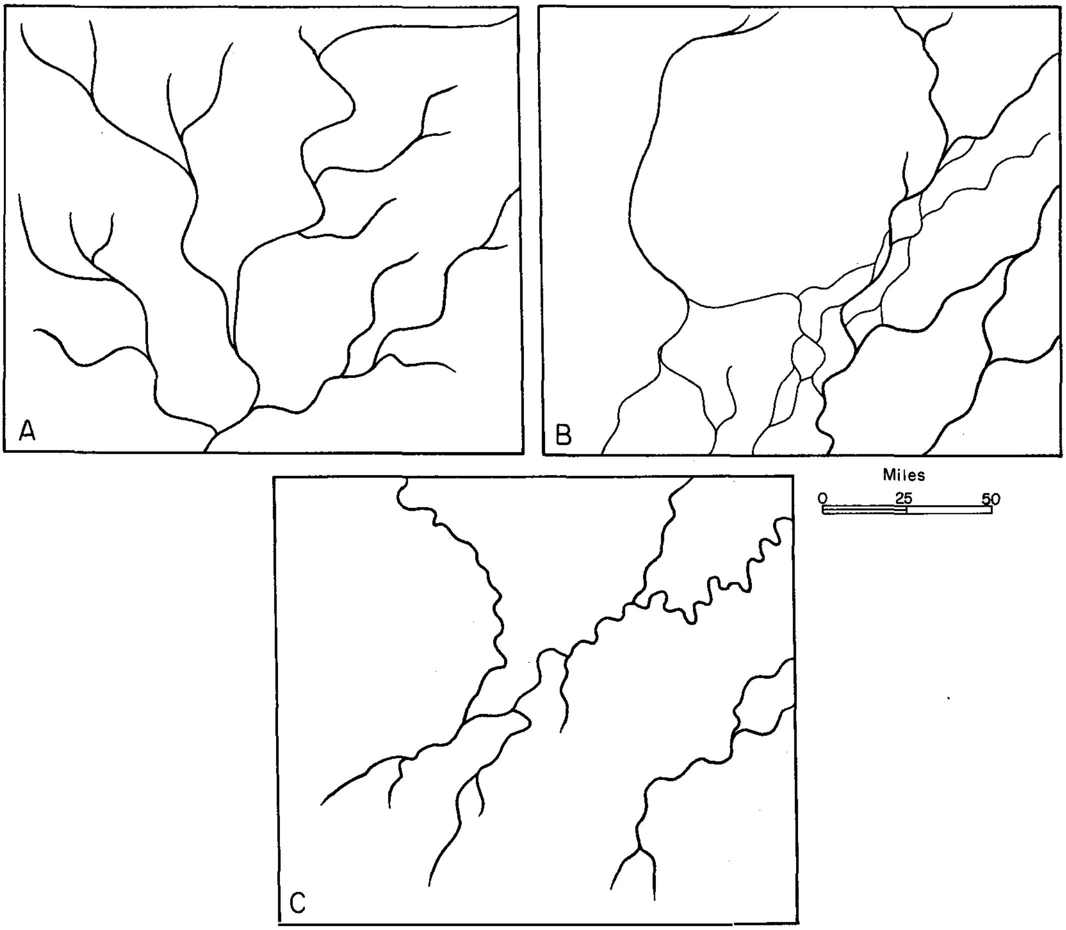

Fig. 13 - Three generalized patterns of Pennsylvanian elongate sand deposition in the Illinois Basin, (A) dendritic, (B) complex, and (C) deltaic.

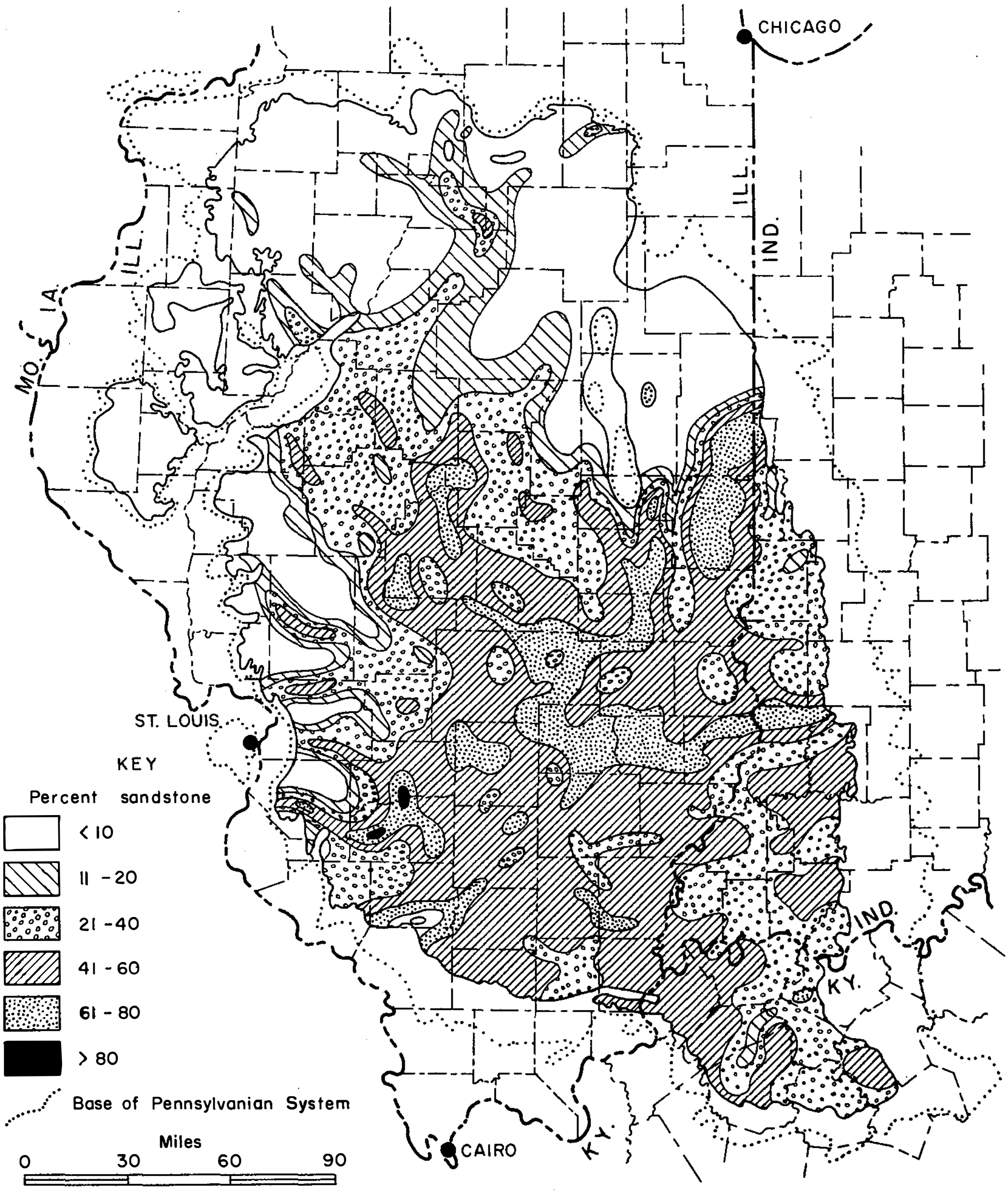

Fig. 14 - Percentage of sandstone in the interval from the base of the Pennsylvanian System to the Colchester (No. 2) Coal.

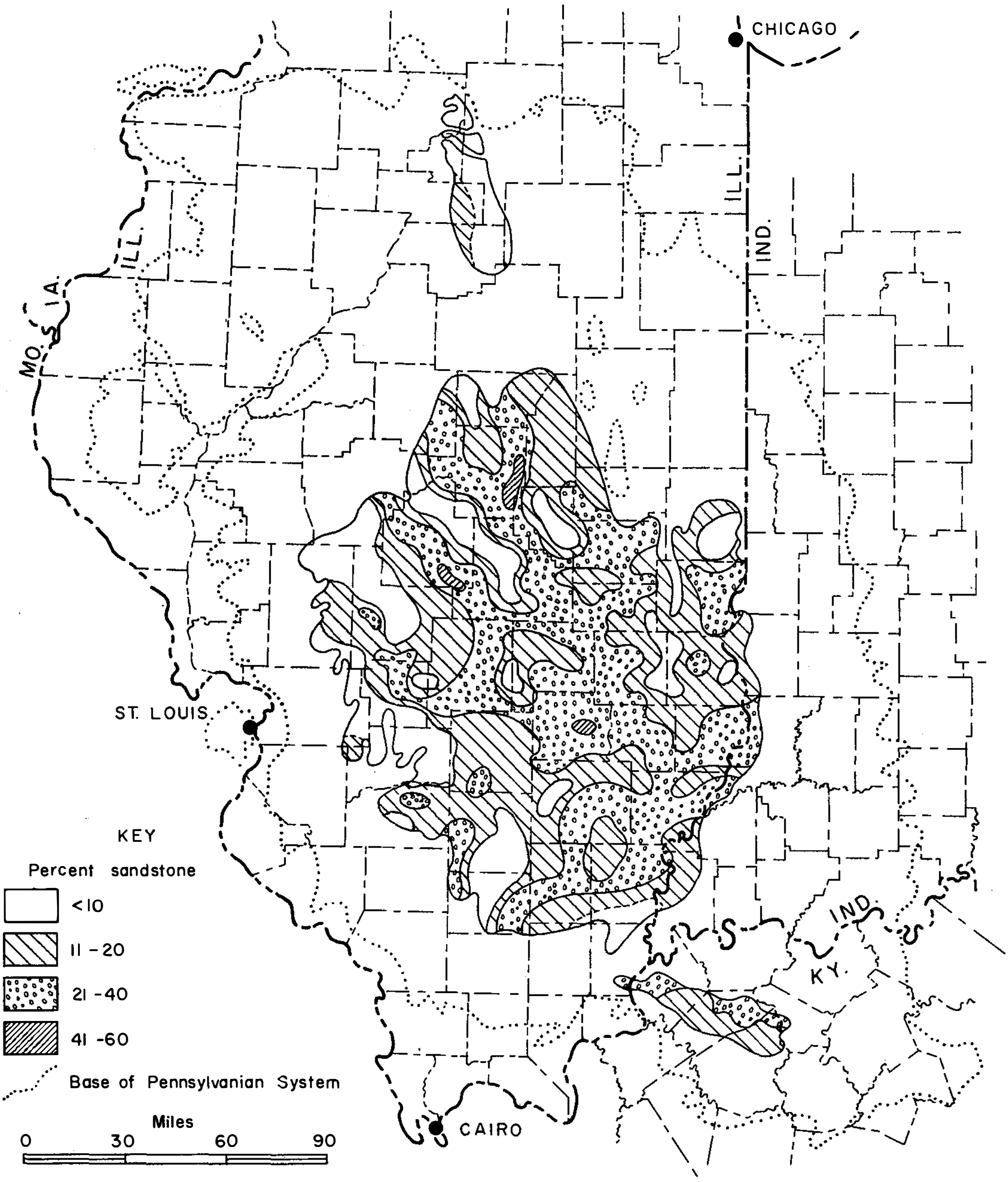

Fig. 15 - Percentage of sandstone in the interval from the Colchester (No. 2) Coal to the Shoal Creek Limestone.

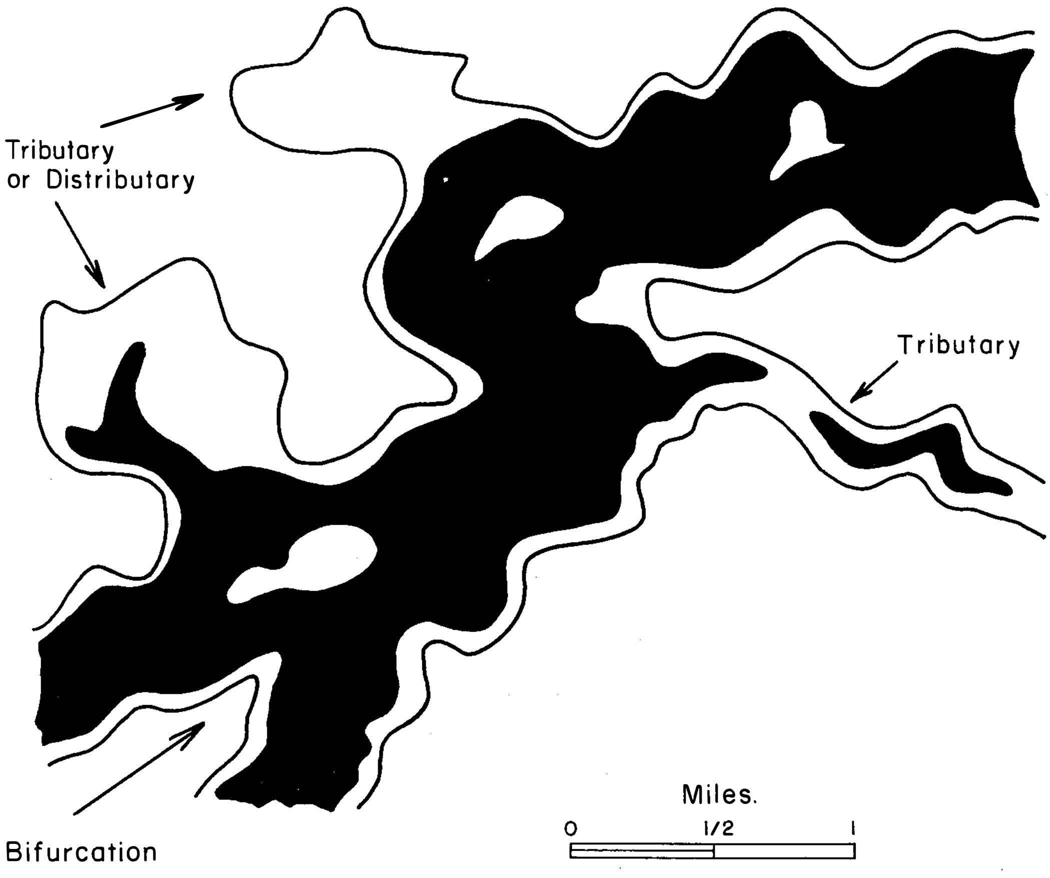

Fig. 16 - Idealized map pattern of typical Pennsylvanian dendroid sand body in Illinois.

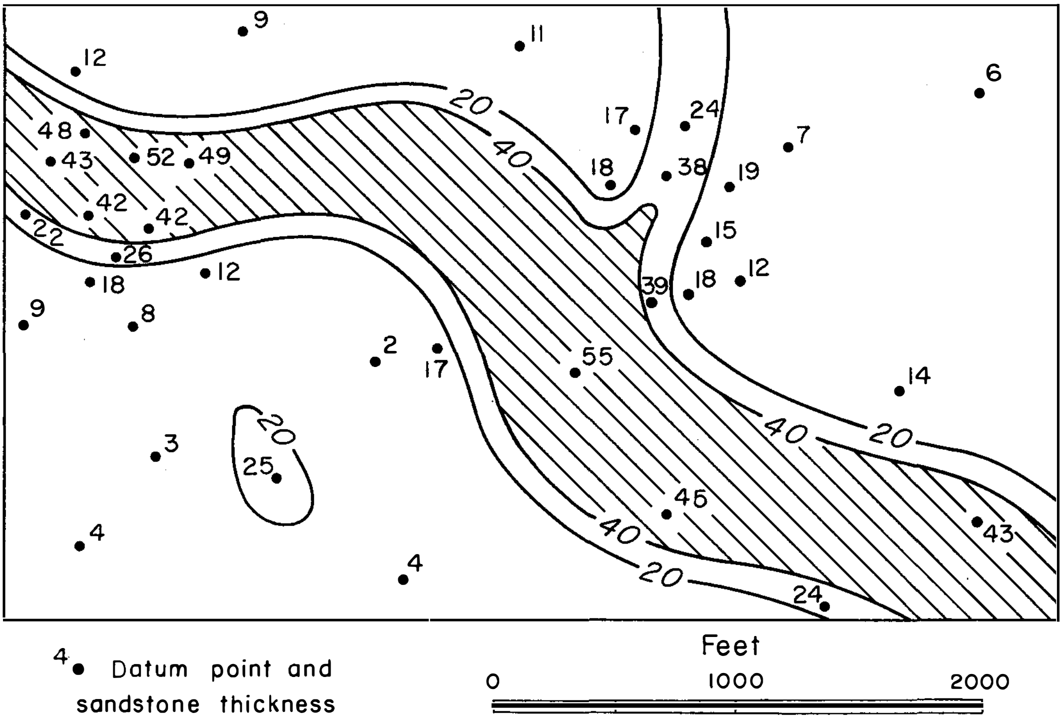

Fig. 17 - Contouring of hypothetical Pennsylvanian dendroid sand body. Width and rate of change of thickness along channel margin are established in areas of dense control and then extrapolated into areas of more open control.

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