STATE OF ILLINOIS
OTTO KERNER, *Governor*
DEPARTMENT OF REGISTRATION AND EDUCATION
WILLIAM SYLVESTER WHITE, *Director*

# GEOLOGY AND PETROLOGY OF THE TRIVOLI SANDSTONE IN THE ILLINOIS BASIN

Marvin J. Andresen



DIVISION OF THE
ILLINOIS STATE GEOLOGICAL SURVEY
JOHN C. FRYE, *Chief* URBANA

CIRCULAR 316 1961

# GEOLOGY AND PETROLOGY OF THE TRIVOLI SANDSTONE IN THE ILLINOIS BASIN

# GEOLOGY AND PETROLOGY OF THE TRIVOLI SANDSTONE IN THE ILLINOIS BASIN

**Marvin J. Andresen**

## ABSTRACT

The Trivoli Sandstone, occurring midway in the Modesto Formation of the McLeansboro Group in the Illinois Basin, was studied as part of an investigation of Pennsylvanian sandstones in the basin and their bearing on exploration for coal, oil, and ground water.

The detritus composing the Trivoli Sandstone was predominantly fluvially deposited in a well integrated, southward-trending, dendritic valley system. The main valley of the system was 2 to 8 miles wide and had a maximum gradient of approximately one foot per mile. Cross-bedding in the Trivoli Sandstone, measured principally in the southern part of the basin, indicates that detritus entered the basin from the east, northeast, north, and northwest and was moved toward the south. Both Paleozoic and Precambrian rocks served as source materials. Regionally, the mineralogy of the sandstone is quite homogeneous, and the sandstone is a quartzose graywacke or a subgraywacke.

The morphologic and petrologic properties of the Trivoli Sandstone are similar to those of other sandstones in the upper part of the Pennsylvanian in the Illinois Basin. All the upper sandstones evidently were deposited in accordance with similar tectonic and environmental controls.

The West Franklin Limestone in eastern Illinois is the only key member affected by Trivoli valley cutting, its lateral continuity from east to west being interrupted by the southwest-trending main Trivoli valley. Recognition of this valley cutting may lead to exact correlation of the West Franklin Limestone with other Pennsylvanian limestones in western Illinois.

## INTRODUCTION

### General

The Trivoli Sandstone Member of the Modesto Formation, McLeansboro Group, is one of the prominent sandstones in the upper part of the Pennsylvanian System in the Illinois Basin. This report on the Trivoli Sandstone is part of a broad study of Pennsylvanian sandstones that is being made by the Illinois State Geological Survey to determine their character, their influence on present structure, and their relation to the stratigraphic sequence, which is important in exploration for coal, oil, ground water, and other mineral resources. Detailed information about the sandstones also is expected to contribute to the understanding of the structural and depositional history of the basin.

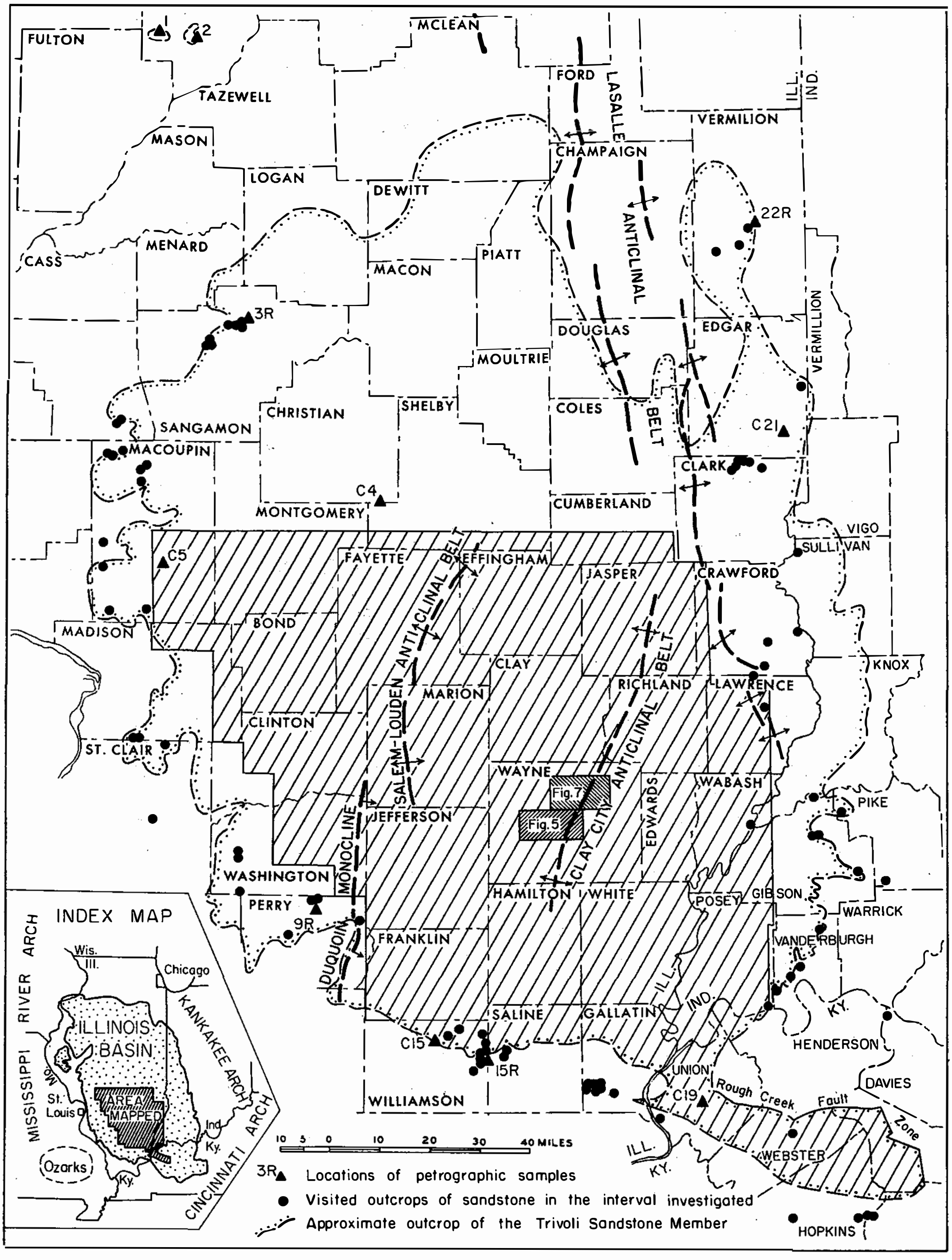


Fig. 1 - Location of area studied and sample localities.

A combination of field and laboratory methods was used to determine the morphology, distribution, petrology, provenance, and environment of deposition of the Trivoli Sandstone and of the interval of Pennsylvanian strata, from the base of the Anvil Rock Sandstone to the top of the Shoal Creek Limestone, which includes the Trivoli. The morphology, petrology, and directions of sediment transport of four sandstones in the interval are compared in order to assess the constancy of the sedimentational and tectonic conditions. Stratigraphy within the interval also is clarified.

The location of the area studied and locations from which samples were taken are shown in figure 1.

## Sedimentational and Tectonic Background

The dominant paleoslope in the Illinois Basin was toward the southwest during all or most of Pennsylvanian time, as is shown by the southwest-trending valley system at the base of the Pennsylvanian System (Siever, 1951), the cross-bedding in basal Pennsylvanian rocks (Potter and Olson, 1954; Potter and Siever, 1956), and the south-southwest trend of the stratigraphically higher Anvil Rock channel system (Hopkins, 1958). According to Potter and Glass (1958, p. 58-59), the southwestward regional slope of the Illinois Basin persisted in southern Illinois from earliest Pennsylvanian time through at least the time of deposition of the Mt. Carmel Sandstone Member of the Bond Formation.

Source areas for basal Pennsylvanian sediments probably were the southeastern Canadian Shield, the northeastern portion of the Appalachian mobile belt east of the Appalachian Basin, and, to a minor extent, older Paleozoic sedimentary areas in the upper Mississippi Valley (Potter and Siever, 1956, p. 317). Hopkins (1958, p. 37) postulated a northeastern source area for Anvil Rock Sandstone detritus, and Siever (1957, p. 247) stated the northeastern areas probably continued as dominant detrital sources through all of Pennsylvanian time.

The northeastern source areas appear to have been of increasingly greater importance as Pennsylvanian sedimentation progressed (Siever, 1957, p. 249). In early Pennsylvanian time, relatively pure quartz sand was carried into the Illinois Basin and deposited. As Pennsylvanian sedimentation in the basin continued, progressively less mature material was deposited, reflecting the slow uplift and erosion of the northeastern source areas and exposure of metamorphic and granitic rocks (Potter and Glass, 1958, p. 52-53).

## Acknowledgments

This report, adapted from a doctoral dissertation completed at the University of Missouri, is based on research done largely at the Illinois State Geological Survey. A. G. Unklesbay, Professor of Geology at the University of Missouri, guided the research project.

Jack A. Simon, Illinois Geological Survey, advised on stratigraphic matters, and Paul Edwin Potter, Illinois Geological Survey, and John F. Hubert, University of Missouri, provided assistance. They and other members of the staff of the Illinois Geological Survey read the manuscript and offered suggestions.

Pope Meagher of the Humble Oil Company and Charles E. Wier of the Indiana Geological Survey provided subsurface records from Indiana and Kentucky.

## STRATIGRAPHY

The interval of Pennsylvanian strata investigated extends upward from the base of the Anvil Rock Sandstone to the top of the Shoal Creek Limestone, and consists of the upper portion of the Carbondale Formation, the entire Modesto Formation, and the basal member of the Bond Formation. This interval ranges in thickness from less than 250 feet in the northern part of the Illinois Basin to more than 500 feet in the southern part. The Trivoli Sandstone is approximately in the middle of the interval studied. The rock-stratigraphic classification of this interval is presented in figure 2.

| Group | Formation | Northern and Western Illinois — Member | Southwestern Illinois — Member | Southeastern Illinois — Member | Eastern Illinois — Member | Indiana — Formation | Indiana | Western Kentucky — Formation | Western Kentucky |
|---|---|---|---|---|---|---|---|---|---|
| Mc Leansboro Group | Bond Fm. | | Mc Wain Ss | Mt. Carmel Ss | Mt. Carmel Ss | | | Lisman Formation | |
| Mc Leansboro Group | Bond Fm. | Hall Ls | Shoal Creek Ls | Shoal Creek Ls | Shoal Creek Ls | | | Lisman Formation | Carthage Ls |
| Mc Leansboro Group | Modesto Formation | | New Haven Coal | New Haven Coal | | | | Lisman Formation | |
| Mc Leansboro Group | Modesto Formation | | Macoupin Ls | | | | Parker Ls | Lisman Formation | |
| Mc Leansboro Group | Modesto Formation | | Womac Coal | | | | Parker Coal | Lisman Formation | |
| Mc Leansboro Group | Modesto Formation | | Burroughs Ls | | | | | Lisman Formation | |
| Mc Leansboro Group | Modesto Formation | | Carlinville Ls | Inglefield Ss | Inglefield Ss | | Inglefield Ss | Lisman Formation | |
| Mc Leansboro Group | Modesto Formation | Cramer Ls | | | | | | Lisman Formation | |
| Mc Leansboro Group | Modesto Formation | Chapel (No. 8) Coal | Chapel (No. 8) Coal | Chapel (No. 8) Coal | Chapel (No. 8) Coal | Ditney Fm. | Ditney Coal | Lisman Formation | |
| Mc Leansboro Group | Modesto Formation | Trivoli Ss | Trivoli Ss | Trivoli Ss | | Ditney Fm. | | Lisman Formation | |
| Mc Leansboro Group | Modesto Formation | Exline Ls | Scottville Ls | | | | | Lisman Formation | |
| Mc Leansboro Group | Modesto Formation | Lonsdale Ls | | West Franklin Ls | West Franklin Ls | W. F. Fm. | West Franklin Ls | Lisman Formation | Madisonville Ls |
| Mc Leansboro Group | Modesto Formation | | Athensville Coal | Lake Creek Coal | | Shelburn Formation | | Lisman Formation | |
| Mc Leansboro Group | Modesto Formation | Gimlet Ss | Rock Branch Coal | Pond Creek Coal | | Shelburn Formation | Busseron Ss | Lisman Formation | |
| Mc Leansboro Group | Modesto Formation | | | DeGraff Coal | | Shelburn Formation | | Lisman Formation | |
| Mc Leansboro Group | Modesto Formation | Farmington Shale | Piasa Ls | Piasa Ls | | Shelburn Formation | | Lisman Formation | |
| Kewanee Group | Carbondale Formation | Danville (No. 7) Coal | Danville (No. 7) Coal | Danville (No. 7) Coal | Danville (No. 7) Coal | Dugger Formation | Coal VII | Lisman Formation | |
| Kewanee Group | Carbondale Formation | | Galum Ls | | | Dugger Formation | | Lisman Formation | |
| Kewanee Group | Carbondale Formation | | | Allenby Coal | | Dugger Formation | | Lisman Formation | No. 14 Coal |
| Kewanee Group | Carbondale Formation | | Bankston Fork Ls | Bankston Fork Ls | | Dugger Formation | Universal Ls | Lisman Formation | Bankston Fork Ls |
| Kewanee Group | Carbondale Formation | Copperas Creek Ss | Anvil Rock Ss | Anvil Rock Ss | | Dugger Formation | | Lisman Formation | Anvil Rock Ss |

Fig. 2 - Rock-stratigraphic classification of the investigated interval (adapted from Kosanke et al., 1960).

### Key Members

At least eight cycles of deposition are represented in the interval from the Anvil Rock Sandstone Member to the Shoal Creek Limestone Member. Consequently, there is a great deal of vertical, as well as horizontal, lithologic variability. Most rock units in the interval have limited areal extent, but a few members are recognizable throughout the area studied and are designated as "key members" — the Danville (No. 7) Coal, Piasa Limestone, West Franklin Limestone, Chapel (No. 8) Coal, Womac Coal, Macoupin Limestone, and Shoal Creek Limestone. The lithologic variability in the interval is generalized in figure 3.

### Stratigraphic Position of the Trivoli Sandstone

The Trivoli Sandstone occurs in the middle of the Modesto Formation (fig. 2) and is the basal member of the Trivoli Cyclothem, which includes the Chapel (No. 8) Coal. The cyclothem was named by Wanless (1931) for exposures

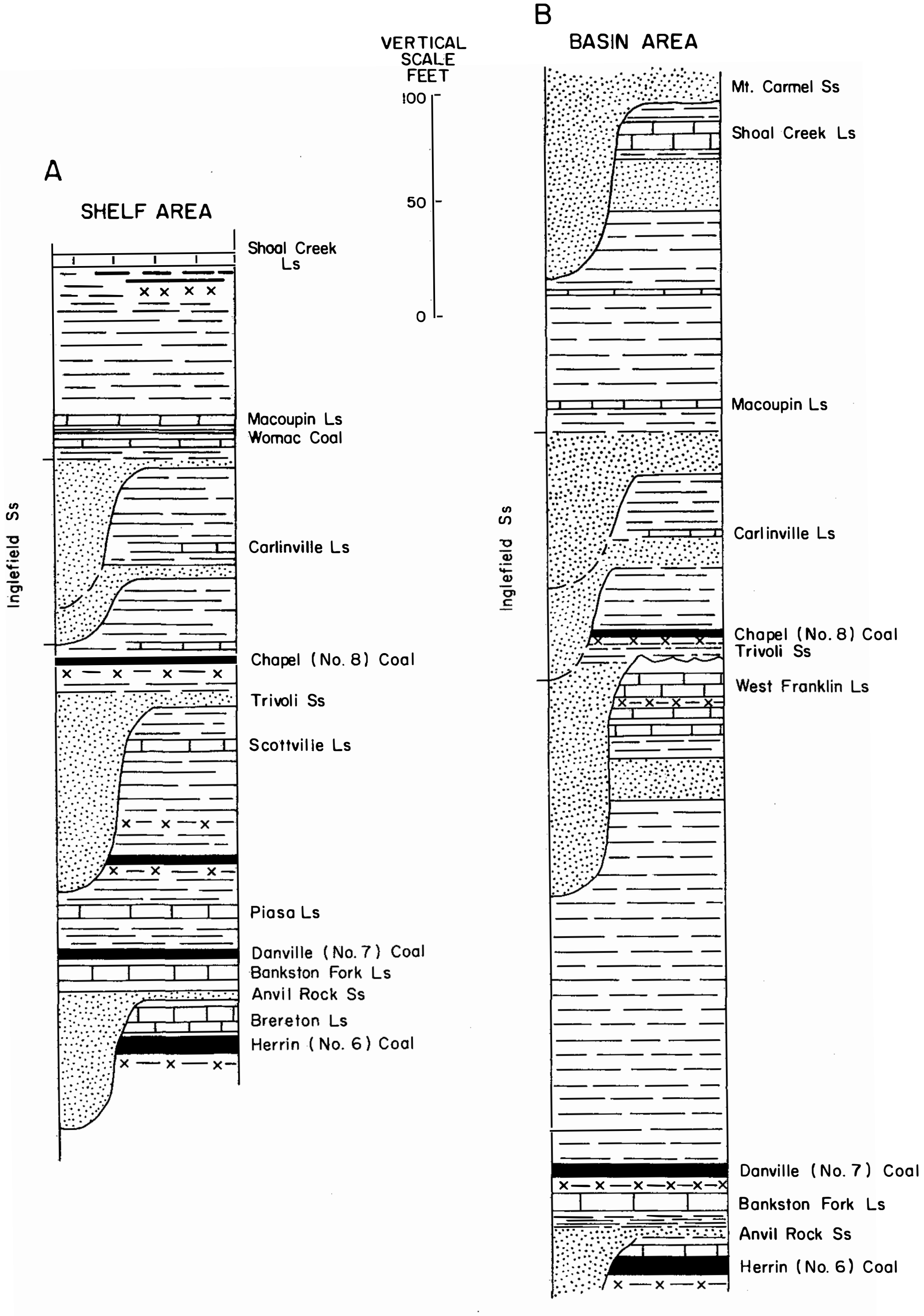


Fig. 3 - Generalized stratigraphic sections of the investigated interval in (A) southwestern and (B) southeastern Illinois.

along a creek in the SW$\frac{1}{4}$ sec. 3, T. 8 N., R. 3 W., Peoria County, Glasford Quadrangle, near the town of Trivoli, Illinois. (See also Wanless, 1957.)

Unfortunately, the type locality of the Trivoli Sandstone is in a stratigraphic outlier some distance from the main body of Trivoli development, and it is not known how the type outcrop is related to the regional distribution of the Trivoli Sandstone.

### Relation to Inglefield Sandstone

The Inglefield Sandstone of southwestern Indiana, originally named by Fuller and Ashley (1902) for exposures in the railroad cut at Inglefield in Vanderburgh County, Indiana, has hitherto not been recognized in Illinois. However, the thick sandstone that lies immediately above the Trivoli Sandstone in the central part of the Illinois Basin is now believed to be the equivalent of the Inglefield, and that name is here accepted for it. This thick sandstone splits into two thinner sandstones toward the west in west-central Illinois. The Carlinville Limestone is present locally above the lower sandstone, and the Womac Coal at some places overlies the upper sandstone. Presumably, the lower sandstone is a member of the Carlinville Cyclothem and the upper a member of the Macoupin Cyclothem (Ball, 1952). In the central part of the basin where the sandstones have merged, valleys appear to have been cut into the lower sandstone, then filled with the upper sandstone.

## TRIVOLI SANDSTONE

### Collection of Data

Subsurface information was collected from about 7500 electric logs of oil test wells and approximately 140 diamond drill core logs. Data were gathered from one well per section. The availability of adequate subsurface data governed the size of the study area,and an area of about 9000 square miles (fig. 1) was mapped. The locations from which subsurface data were obtained are shown on plate 1. The reliability of the maps, made by sampling of one well per section, was tested in certain limited areas by making detailed maps that used all available subsurface data (electric logs). Comparison of the maps showed that the gross sampling plan yielded adequate results.

Elevations were computed and recorded for the tops and bottoms of all sandstones and for the tops of all key members in the stratigraphic interval from Danville (No. 7) Coal to Shoal Creek Limestone. Typical electric logs of this interval are shown in figure 4.

At some places, stratigraphically higher sandstones were deposited in valleys that had been cut into the Trivoli Sandstone, and the result is a multiple sandstone that is difficult to subdivide on the basis of an electric log. A typical development of such a multiple sandstone is shown on the electric log of the Cullum-Nunn No. 3 well (fig. 4). The areas where the stratigraphically higher sandstones have merged with the Trivoli Sandstone are limited, and the components of the multiple sandstone have been differentiated arbitrarily by projecting the position of the No. 8 Coal into the multiple sandstone. The sandstone below the projected position of the No. 8 Coal was designated as the Trivoli Sandstone and that above the coal as the Inglefield Sandstone.

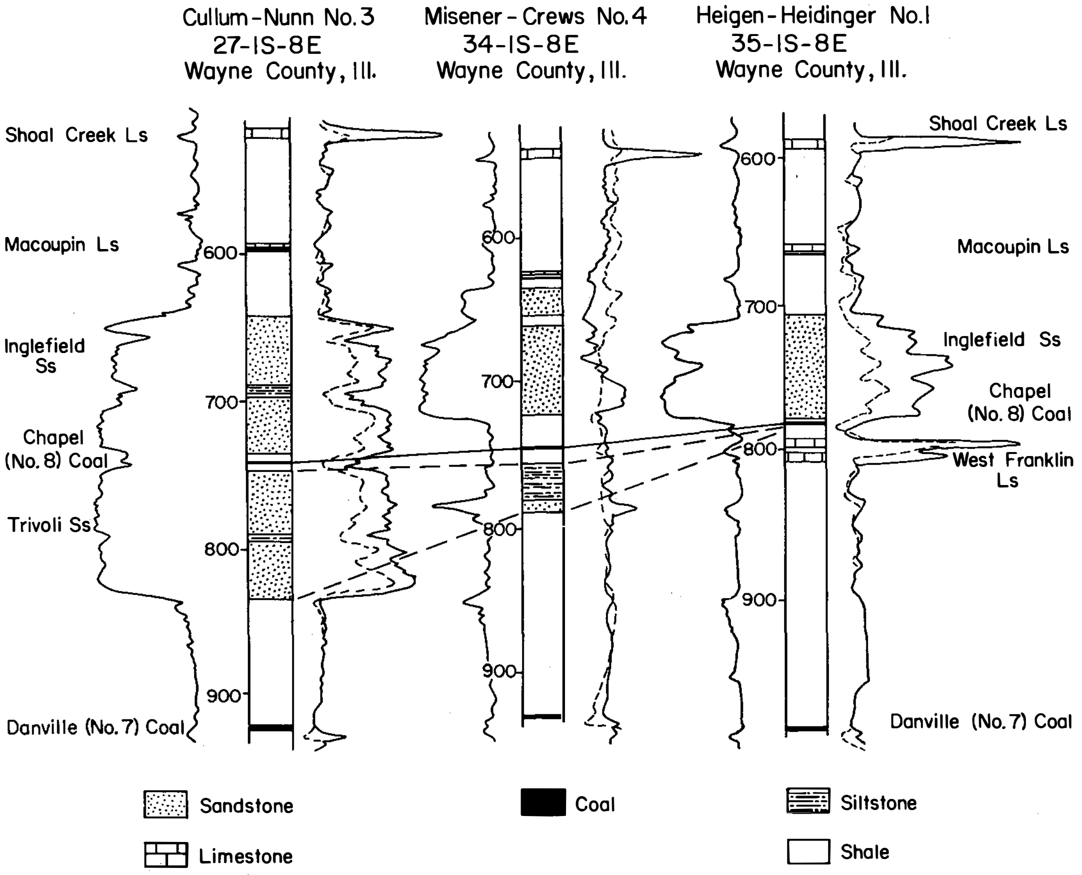


Fig. 4 - Typical electric logs of the interval from the Danville (No. 7) Coal to the Shoal Creek Limestone.

## Areal Distribution

Two phases of Trivoli Sandstone development are recognized on the basis of thickness. The thick phase is the portion of the sandstone more than 40 feet thick, and the thin phase is the portion of the sandstone less than 40 feet thick. The areal distribution of the thick and thin phases of the Trivoli Sandstone is shown in figure 5 and plate 1.

The thick phase of the sandstone is concentrated in two elongate bands that are approximately 2 to 8 miles wide. The first of these trends south-southwest through Jasper, Clay, Wayne, Hamilton, Franklin, and Williamson Counties. The second trends generally east-west through Bond, Fayette, and Effingham Counties, and joins the first in Clay County. The thick phase of the Trivoli Sandstone is generally not more than 100 feet thick along the trends indicated. The thin phase is much more widespread than the thick.

The sandstone is absent in parts of the study area. The largest of such areas is in eastern Illinois and western Indiana, and another is in the vicinity of the Salem-Louden Anticlinal Belt in Marion and Fayette Counties. It appears that positive movement raised the area of the anticlinal belt during or just before the time of Trivoli deposition and precluded sand accumulation.

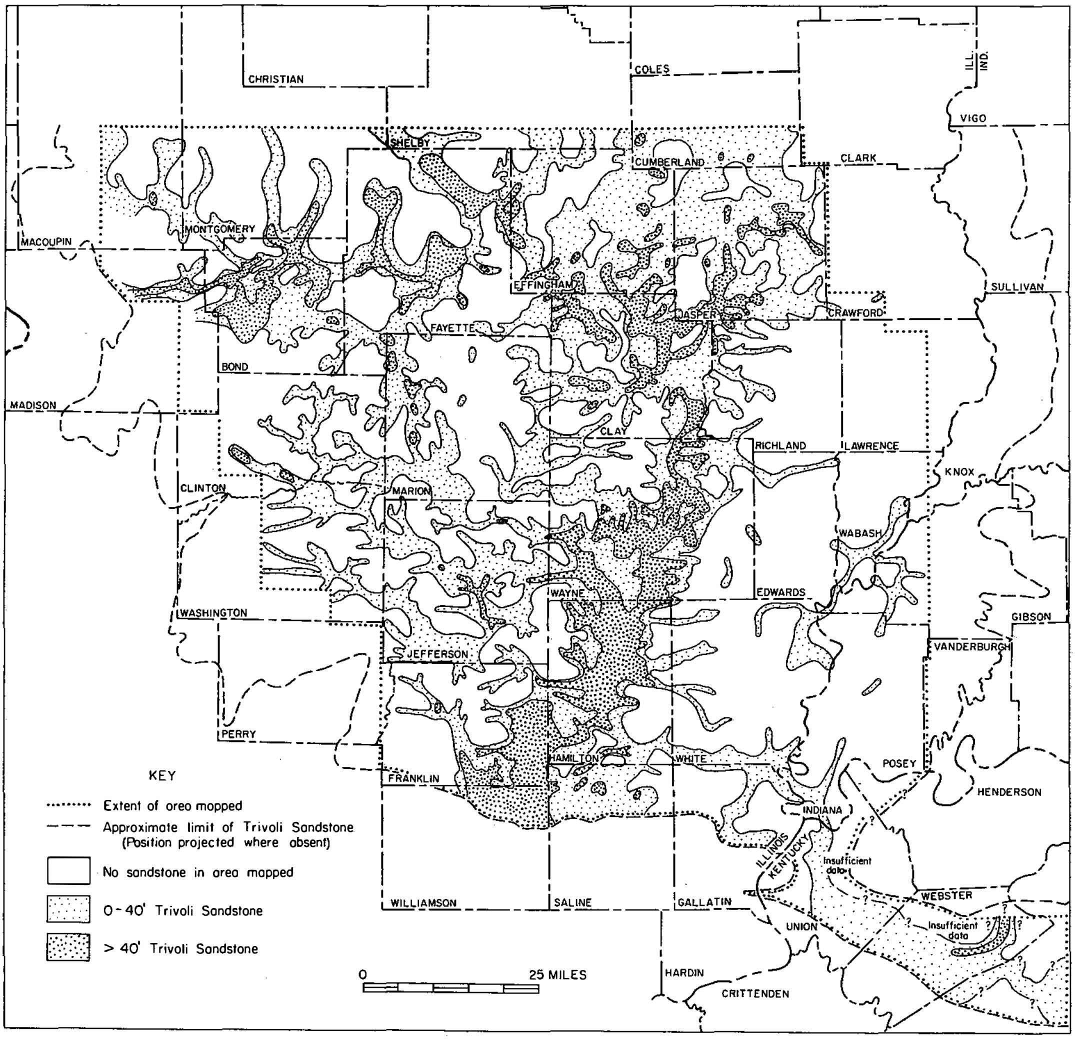


Fig. 5 - Thickness and distribution of the Trivoli Sandstone.

## Trivoli Valleys

A detailed map of the thickness of the Trivoli Sandstone in two townships in central Wayne County (fig. 6A) was compiled from more than 600 datum points. It shows the same trend of sandstone accumulation as that shown on the regional thickness map (fig. 5) and also shows a southward-trending dendritic pattern. Stratigraphic cross sections made in the central Wayne County area (fig. 6B) demonstrate that the Trivoli Sandstone becomes thicker at the expense of stratigraphically lower units, even though key beds above and below the sandstone are essentially parallel. This indicates that the Trivoli Sandstone in part fills depressions in older rocks. These depressions are interpreted as valleys, and cross sections of major and minor valleys are shown in figure 6B. These valleys, called "Trivoli valleys" in this report, were largely eroded prior to deposition of the sandstone now filling them, but undoubtedly valley cutting in some areas was contemporaneous with valley filling elsewhere in the valley system.

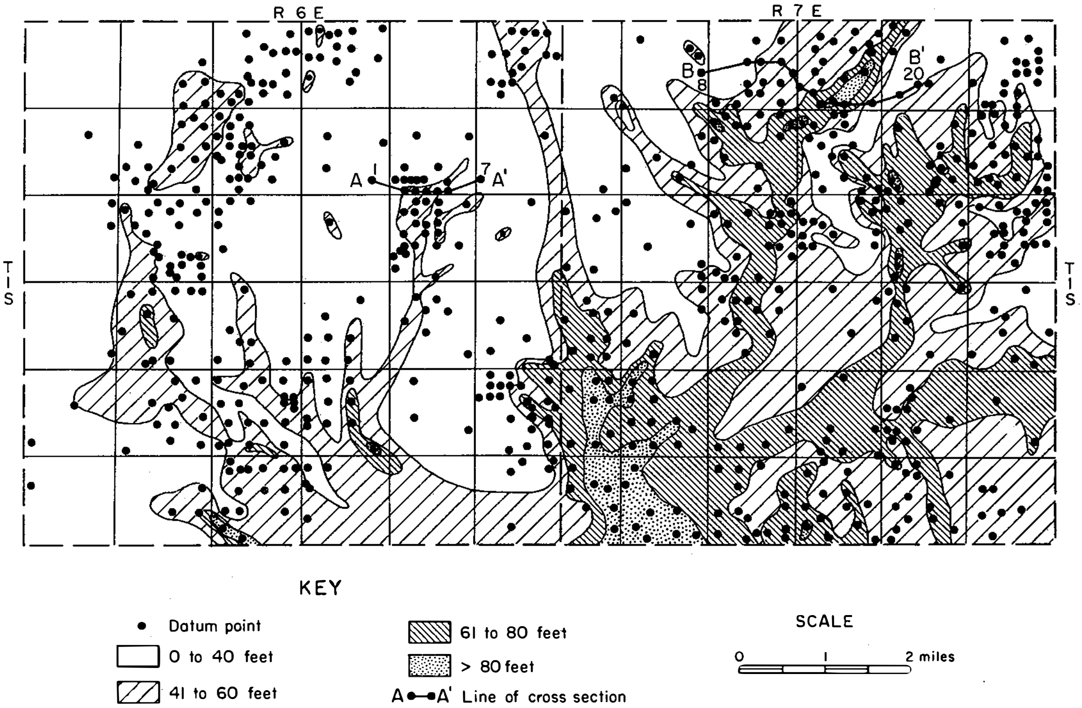


Fig. 6A - Thickness and distribution of the Trivoli Sandstone in Wayne County, Illinois. (See fig. 1 for location.)

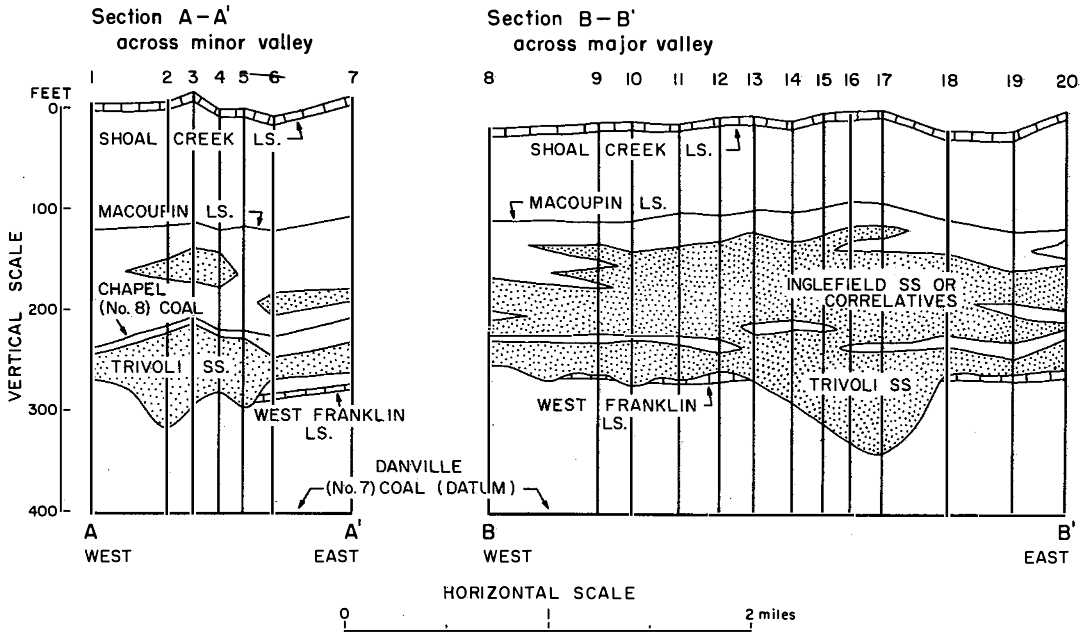


Fig. 6B - Cross sections of minor (section A-A') and major (section B-B') Trivoli valleys.

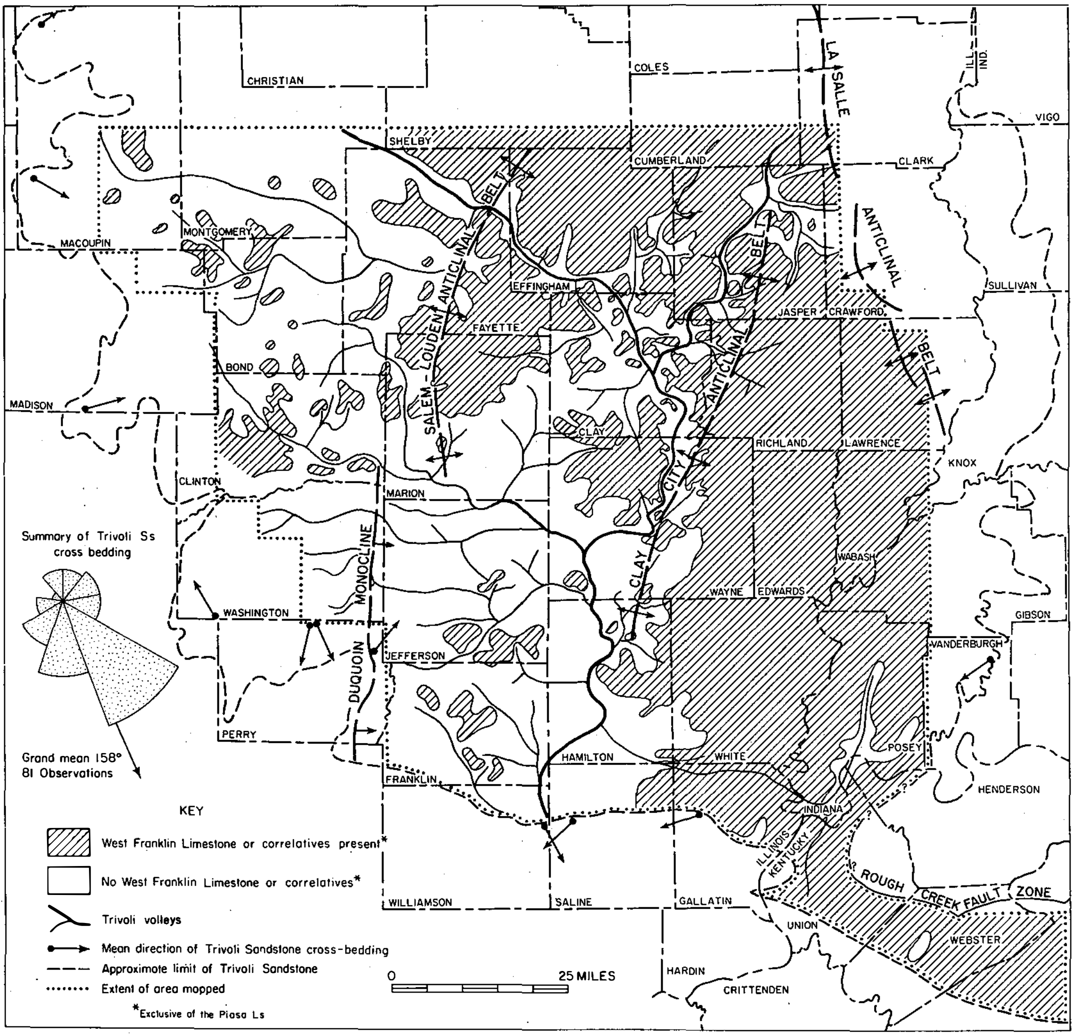


Fig. 7 - Distribution of the Trivoli valley system and the West Franklin Limestone. Also shown are anticlinal axes in the basin area and directions of mean cross-bedding inclination at several Trivoli Sandstone outcrops.

The Trivoli valley system is shown in figure 7, each valley represented by its valley axis. The axis for a major valley is drawn thicker than that for a minor valley. Major valleys are those that have been cut deepest into subjacent strata. The axes lines were constructed from an isopach map of the interval from the base of the Trivoli Sandstone down to the top of the Danville (No. 7) Coal, which was assumed to be a horizontal datum plane (see fig. 6B for a cross section of the interval). The valley axes are indicated by the lines connecting points where the base of the sandstone is closest to the No. 7 Coal datum plane. This map of the valley axes gives the location of the valley system at the time of maximum down-cutting.

The over-all pattern of the Trivoli valleys is that of a southward-flowing dendritic drainage system. The location of the valleys in the system appears to have been controlled by the distribution of the principal anticlines in the basin area (fig. 7), as no major valley crosses any of these anticlinal axes. The main Trivoli valley, which trends south-southwest along the western margin of the Clay City Anticlinal Belt, corresponds in location and trend to the longitudinal axis of subsidence of the Illinois Basin (fig. 13), indicating that the basin subsided rapidly enough to determine the course of the main channel of the Trivoli valley system.

## Trivoli Valleys and the West Franklin Limestone

The West Franklin Limestone consists of two to four limestone benches that are stratigraphically just below the Trivoli Sandstone (fig. 2). The West Franklin Limestone is the only key member affected by the cutting of Trivoli valleys in the study area.

Comparison of the areal distribution of the Trivoli valleys and the distribution of the West Franklin Limestone (fig. 7) reveals that the limestone is absent where Trivoli valleys are well developed, and, conversely, that the limestone is present where there are minor valleys or no valleys at all.

A map of the distribution of the West Franklin Limestone for two townships in northern Wayne County (fig. 8) shows the margins of the main Trivoli valley. In this area, the valley is 2 to 5 miles wide and has very irregular sides. The pronounced indentations in the limestone probably were the places where tributary valleys joined the main valley. The trend of the part of the main Trivoli valley shown on the detailed map is the same as that in the regional map of limestone distribution (fig. 7).

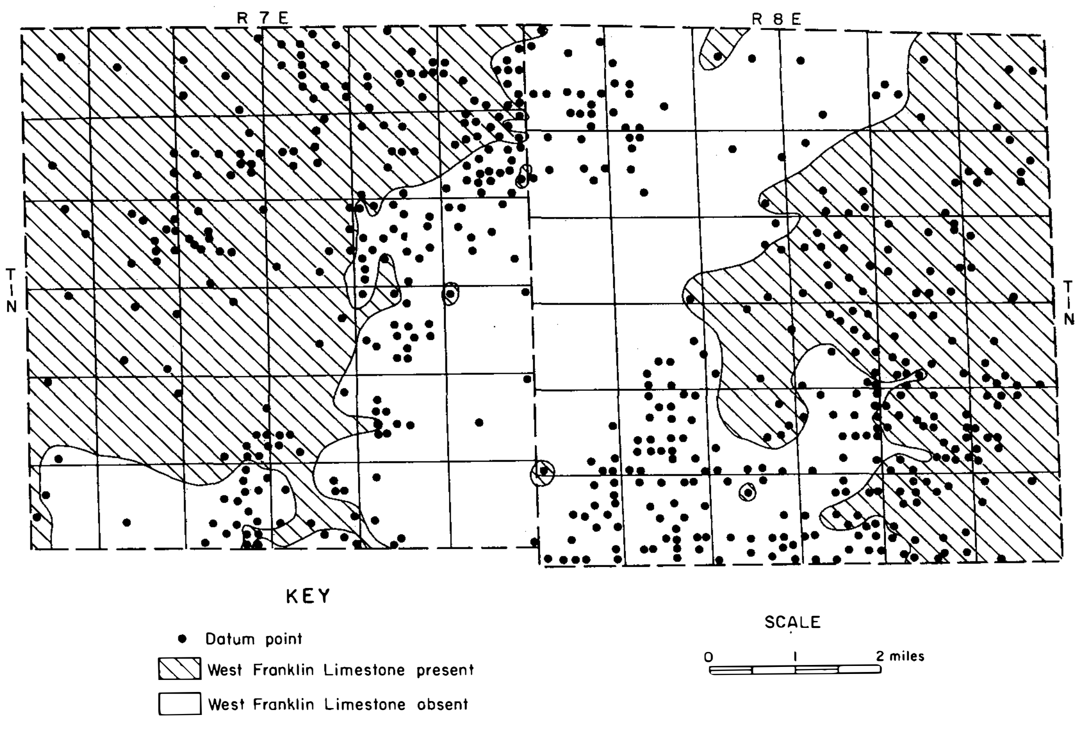


Fig. 8 - Distribution of the West Franklin Limestone in Wayne County, Illinois. (See fig. 1 for location.)

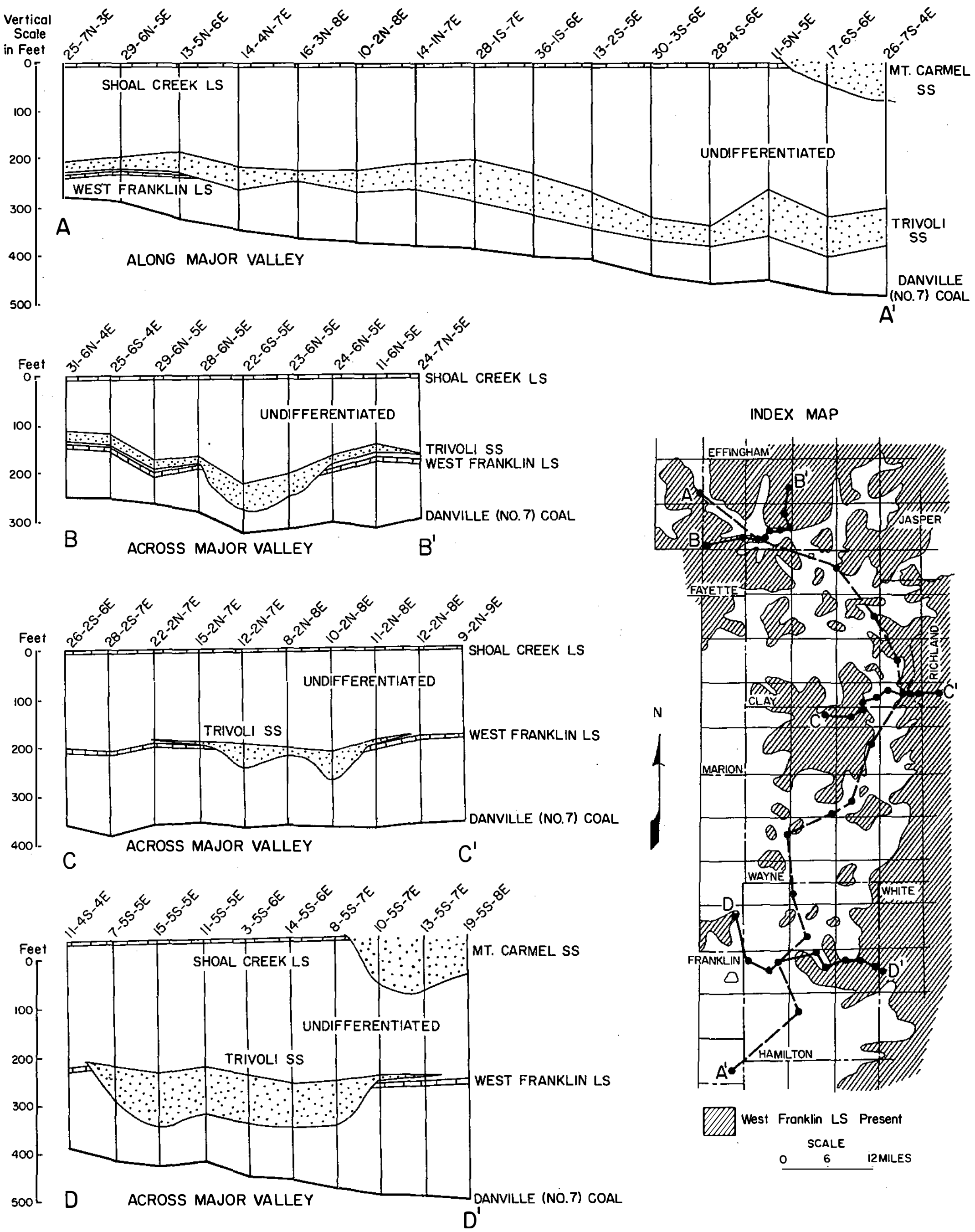


Fig. 9 - Generalized transverse and longitudinal stratigraphic cross sections showing the relationship between the Trivoli Sandstone and West Franklin Limestone.

The relationship between the Trivoli valleys and the West Franklin Limestone is also shown in several stratigraphic cross sections (fig. 9). One cross section approximately parallels the main valley trend and three are transverse to it. The three transverse cross sections give additional information as to the form of the major Trivoli valley, though with not so much detail as the horizontally scaled sections shown in figure 6B.

The base of the main Trivoli valley is progressively lower from north to south compared to the West Franklin Limestone, indicating that valley cutting was greater in the south than in the north. Longitudinal section A-A' of figure 9 shows the West Franklin Limestone present in the north and the base of the Trivoli valley immediately above it. In the south end of the section where the limestone is absent, its position was established by projecting it from adjacent areas where it is present, and the bottom of the sandstone was revealed to be 75 feet below the top of the limestone. In a horizontal distance of about 75 miles, the base of the valley thus appears to have dropped 75 feet. Therefore, if the limestone was originally horizontal, the gradient of the main Trivoli valley probably was about one foot per mile at the time of maximum down-cutting in the valley system.

## Petrography and Petrology

Petrographic investigation of the Trivoli Sandstone consisted of modal analyses of thin sections, heavy mineral determinations, and grain-size analyses. Petrographic samples were collected randomly from outcrops and cores. Sample locations are shown in figure 1 and table 1.

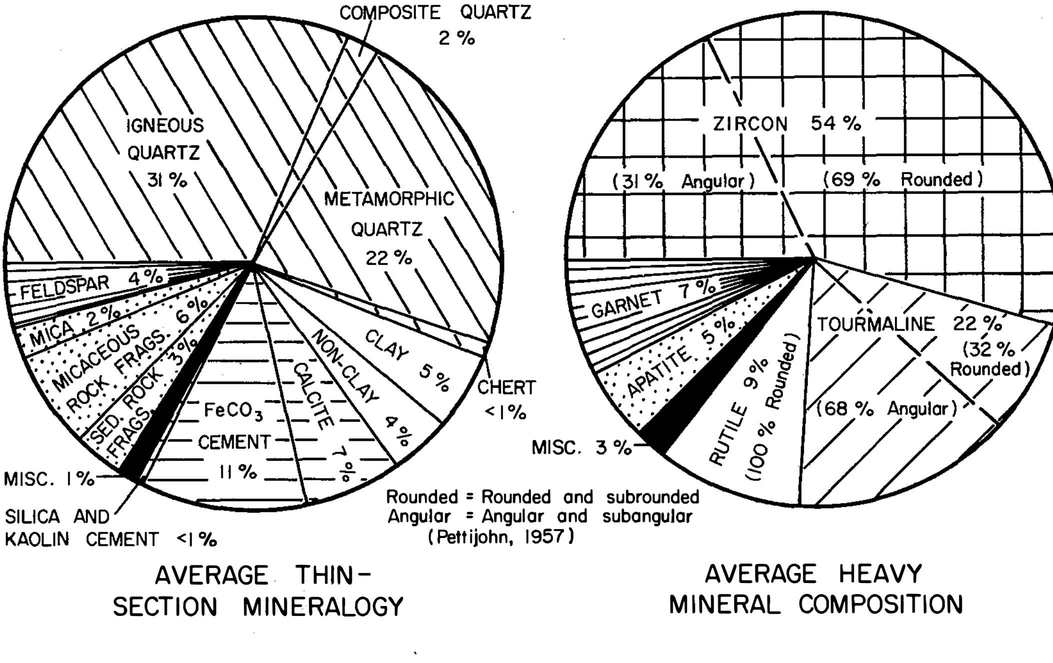


Fig. 10 - Average mineralogy shown in thin sections and average composition of the transparent, nonmicaceous heavy mineral suite of the Trivoli Sandstone.

TABLE 1 - SOURCES OF PETROGRAPHIC SAMPLES

| Sample number | Ft. above base of sandstone | Location (Illinois except as noted) |
|---|---|---|
| 1 | | NW NW SW sec. 3, T. 8 N., R. 5 E., Peoria County |
| 1B | 5 | |
| 1E | 17 | |
| 2 | | NW NE NW sec. 11, T. 8 N., R. 6 E., Peoria County |
| 2D | 6 | |
| 2E | 11 | |
| 3R | | NW NW SE sec. 1, T. 16 N., R. 5 W., Sangamon County |
| 3R-1 | 2 | |
| 3R-2 | 28 | |
| 3R-3 | 17 | |
| 3R-4 | 8 | |
| 3R-5 | 35 | |
| C4 | | NE NE NW sec. 33, T. 11 N., R. 1 E., Christian County |
| C4-A | 545 (depth) | |
| 9R | | SE NW SE sec. 4, T. 4 S., R. 2 W., Perry County |
| 9R-1 | 11 | |
| 9R-7 | 7 | |
| 9R-8 | 4 | |
| C15 | | SE NE SE sec. 17, T. 8 S., R. 3 E., Williamson County |
| C15A | 56 | |
| C15B | 43 | |
| 15R | | SW SE SE sec. 36, T. 8 S., R. 4 E., Williamson County |
| 15R-1 | 0 | |
| 15R-2 | 17 | |
| 15R-3 | 6 | |
| 15R-4 | 4 | |
| 15R-5 | 29 | |
| 15R-6 | 11 | |
| 15R-7 | 7 | |
| 15R-8 | 5 | |
| 15R-9 | 14 | |
| C19 | | 2500 ft E.L., 9400 ft N.L., N-19 (Carter Grid), Union County, Kentucky |
| C19A | 1168 (depth) | |
| C19B | 1152 (depth) | |
| C21 | | NW SE SE sec. 22, T. 13 N., R. 11 W., Edgar County |
| C21A | 170 (depth) | |
| C21B | 164 (depth) | |
| 22R | | SW SW NW sec. 5, T. 19 N., R. 12 W., Vermilion County |
| 22R-1 | 13 | |
| 22R-2 | 25 | |
| 22R-3 | 1 | |
| 22R-4 | 6 | |
| 22R-5 | 20 | |
| 22R-6 | 25 | |
| Ing-1 | | SW SE SE sec. 30, T. 9 N., R. 10 W., Edgar County |
| Ing-2 | | NE SE NW sec. 5, T. 7 S., R. 11 W., Posey County, Indiana |
| Cv-1 | | SW SE NW sec. 10, T. 5 S., R. 3 W., Perry County |

C - denotes core samples; all others are from outcrops.
Ing - denotes Inglefield Sandstone.
Cv - denotes lower part of the Inglefield Sandstone in the western part of Illinois.

## Modal Analyses of Thin Sections

The mineralogy of 19 Trivoli Sandstone thin sections was obtained with a petrographic microscope by the point-counter method (Chayes, 1956) using 400 points per slide (table 2). In addition, 25 to 40 metamorphic rock fragment grains were identified in each thin section (table 3) to evaluate the character of the source area. Table 4 gives the mineral components of the grains, matrix, and cement found in the Trivoli Sandstone.

The average composition of the Trivoli Sandstone (fig. 10) is very similar to that of the Anvil Rock Sandstone (Hopkins, 1958, p. 24-27) and other Pennsylvanian sandstones of the Kewanee and McLeansboro Groups in the Illinois Basin (Siever, 1957, table 1).

## Heavy Mineral Determinations

Heavy mineral separations were made by standard methods (Krumbein and Pettijohn, 1938) using tetrabromethane (specific gravity 2.95). In analyzing the heavy mineral assemblages, only grains completely in the microscope field were counted as they were passed under the vertical cross-hair. Three hundred transparent, nonmicaceous grains were identified in each assemblage. In addition, the relative proportions of opaque, micaceous, and transparent nonmicaceous grains in each assemblage were established on the basis of 100 grains.

The transparent nonmicaceous heavy minerals and varieties of minerals identified and differentiated are listed below. Pettijohn's (1957, p. 59) visual comparison chart was used as a guide in determining the various degrees of grain roundness.

### Heavy Minerals Recognized

Andalusite (?) - rare
Apatite - clear, and with black inclusions; common
Epidote (?) - rare
Garnet - clear, angular, irregular fracture; common
Red rutile - elongate, all grains well rounded; common
Yellow rutile - subequant, well rounded; common
Sillimanite (?) - long, slender prisms; subequant, colorless; rare
Angular zircon - zoning and inclusions are present; most grains are idiomorphic; very common
Rounded zircon - zoning and inclusions are present; most grains are smoothly polished; common
Tourmaline - nine types differentiated on the basis of color and rounding; very common
Miscellaneous grains - anatase, monazite, sphene, zoisite (?); all very rare

The average transparent, nonmicaceous heavy mineral assemblage of the Trivoli Sandstone, which is listed in table 5 and shown graphically in figure 10, contains approximately 85 percent zircon, tourmaline, and rutile, the ultra-stable heavy minerals. Of the less stable heavy minerals, apatite and garnet are the most abundant.

TABLE 2 - MODAL ANALYSES (PERCENT) AND SIZE DATA FOR THIN SECTIONS OF TRIVOLI SANDSTONE

| Sample number*: | 1B | 1E | 2D | 2E | 3R-3 | 3R-4 | C4A | 9R-1 | 9R-8 | C15A | C15B | 15R-3 | 15R-6 | C19A | C19B | C21A | C21B | 22R-3 | 22R-6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Quartz† (Q) | | | | | | | | | | | | | | | | | | | |
| Igneous | 8 | 21 | 21 | 27 | 28 | 43 | 25 | 44 | 39 | 27 | 37 | 45 | 38 | 31 | 40 | 24 | 24 | 28 | 39 |
| Composite | - | 2 | T | 2 | 2 | 4 | 2 | 4 | 4 | 2 | 1 | 5 | 4 | 3 | 2 | - | - | T | 2 |
| Metamorphic | 14 | 28 | 24 | 14 | 31 | 18 | 24 | 21 | 19 | 26 | 23 | 14 | 25 | 30 | 23 | 21 | 27 | 9 | 20 |
| Chert | - | - | T | - | T | T | - | T | - | T | T | T | 1 | 1 | 1 | 3 | T | 1 | 2 |
| Feldspar† (F) | | | | | | | | | | | | | | | | | | | |
| Microcline | - | T | T | T | T | T | - | 1 | 1 | 1 | T | 1 | 2 | 1 | T | T | T | T | 2 |
| Plagioclase | - | - | T | 1 | T | - | T | - | - | 2 | 1 | 2 | T | T | - | T | - | T | T |
| Untwinned | - | 1 | T | 1 | 2 | 1 | 1 | 5 | 7 | 3 | 5 | 8 | 5 | 3 | 2 | 3 | 2 | 3 | 2 |
| Miscellaneous† (M) | | | | | | | | | | | | | | | | | | | |
| Mica | 2 | 3 | 2 | T | T | 2 | 1 | 1 | 2 | 7 | 3 | 2 | 2 | 5 | 2 | 1 | 1 | T | 1 |
| Metamorphic rock fragments | 4 | 4 | 7 | 4 | 9 | 4 | 3 | 6 | 8 | 7 | 7 | 6 | 4 | 8 | 8 | 8 | 8 | 6 | 10 |
| Sedimentary rock fragments | 1 | 4 | 4 | 3 | 5 | 5 | 6 | 3 | 3 | 3 | 2 | 1 | T | 2 | 3 | 4 | 5 | 3 | 5 |
| Miscellaneous grains | - | - | - | - | T | T | T | T | T | - | - | T | - | - | - | 1 | 1 | - | - |
| Clay | 45 | 7 | 7 | 2 | 5 | 3 | 2 | 1 | 9 | 4 | 5 | 9 | 8 | 5 | 7 | 6 | 5 | T | 7 |
| Non-clay | 6 | 6 | 4 | 3 | 4 | 5 | 3 | 2 | 3 | 5 | 3 | 2 | 2 | 7 | 3 | 6 | 4 | 2 | 5 |
| Calcite | - | - | - | 14 | 0 | 4 | 30 | - | - | 7 | T | - | - | 2 | 5 | 16 | 19 | 24 | 1 |
| Iron carbonate | 20 | 23 | 30 | 28 | 13 | 12 | 3 | 10 | 4 | 2 | 13 | 4 | 8 | 1 | 3 | 6 | 2 | 22 | 4 |
| Silica | - | - | - | - | - | - | - | - | - | - | T | - | - | 1 | - | T | T | T | T |
| Kaolinite | - | - | - | T | - | - | - | - | - | - | - | T | - | - | T | - | - | - | - |
| Mean quartz size (mm) | - | .08 | .08 | .11 | .10 | .11 | .10 | .23 | .14 | .17 | .18 | .26 | .25 | .19 | .17 | .12 | .10 | .34 | .21 |
| Texture** (percent) | | | | | | | | | | | | | | | | | | | |
| Grains | 29 | 64 | 59 | 51 | 79 | 76 | 61 | 86 | 84 | 81 | 78 | 85 | 81 | 84 | 82 | 66 | 70 | 51 | 83 |
| Matrix | 51 | 13 | 11 | 5 | 9 | 9 | 5 | 11 | 12 | 8 | 7 | 10 | 11 | 12 | 10 | 12 | 9 | 2 | 12 |
| Cement | 20 | 23 | 30 | 44 | 12 | 15 | 34 | 3 | 4 | 11 | 15 | 5 | 8 | 4 | 8 | 22 | 21 | 47 | 5 |

* Sample locations are given in table 1.
† Source area components.
C Indicates core sample.
T Trace; less than 1 percent.
** See these data plotted in figure 12.

TABLE 3 - PERCENTAGES AND TYPES OF METAMORPHIC ROCK FRAGMENTS IN THE TRIVOLI SANDSTONE

| Sample number | MRF* in sample (%) | Quartz Muscovite Sericite Schist | Muscovite Sericite Schist | Quartz Muscovite Chlorite Schist | Muscovite Chlorite Schist | Quartz Muscovite Sericite Phyllite | Muscovite Sericite Phyllite | Muscovite Phyllite |
|---|---|---|---|---|---|---|---|---|
| 1E | 4 | 45 | 35 | 15 | 5 | - | - | - |
| 2D | 7 | 20 | 20 | 35 | 5 | 10 | 10 | - |
| 2E | 4 | 25 | - | 25 | - | - | 50 | - |
| 3R-3 | 9 | 25 | 5 | 30 | - | 10 | 30 | - |
| 3R-4 | 4 | 30 | 10 | 15 | - | 15 | 15 | 15 |
| C4-A | 3 | - | 40 | 5 | 20 | 10 | 10 | 15 |
| 9R-1 | 6 | 35 | 5 | - | - | 10 | 40 | 10 |
| 9R-8 | 8 | 40 | 10 | 5 | - | - | 35 | 10 |
| C15-A | 7 | 40 | 10 | 15 | - | 10 | 25 | - |
| C25-B | 7 | 30 | 15 | 15 | - | 10 | 30 | - |
| 15R-3 | 6 | 10 | 30 | 45 | 5 | - | 10 | - |
| 15R-6 | 4 | 50 | 15 | 15 | 15 | - | 5 | - |
| C19-A | 8 | 30 | 10 | 10 | 20 | 10 | 10 | 10 |
| C19-B | 8 | 10 | 10 | 20 | 5 | - | 15 | 40 |
| C21-A | 8 | 20 | 30 | 20 | 5 | 5 | 20 | - |
| C21-B | 8 | 5 | 20 | 40 | 5 | 15 | - | 15 |
| 22R-3 | 6 | 10 | 5 | 55 | 20 | 5 | 5 | - |
| 22R-6 | 10 | 35 | 15 | 40 | - | 10 | - | - |

* Metamorphic rock fragments. See table 2.

TABLE 4 - COMPONENTS OF THIN SECTIONS OF TRIVOLI SANDSTONE

| | | | |
|---|---|---|---|
| GRAINS (detrital elements 0.03 mm or larger) | Quartz (Q) components | Igneous quartz | Unit grains with generally sharp extinction |
| | | Composite quartz | Aggregate grains with generally sharp extinction |
| | | Metamorphic quartz | Unit and aggregate grains that do not become extinct within 30 degrees of stage rotation, and aggregate grains with sutured internal boundaries |
| | | Chert | Aggregates of microcrystalline quartz |
| | Feldspar (F) components | Microcline | Grid twin pattern, or subparallel tapering twin lamellae; grains fresh to highly altered |
| | | Plagioclase | Albite or albite-Carlsbad twinning; most unaltered |
| | | Untwinned feldspar | No recognizable twin pattern; most grains probably orthoclase since the refractive indices are lower than balsam and/or quartz |
| | Miscellaneous (M) components | Mica | Predominantly muscovite; limited biotite and chlorite |
| | | Metamorphic rock fragments | Varieties and relative proportions in each thin section are given in table 3 |
| | | Sedimentary rock fragments | Shale, quartzose siltstone, and limestone fragments |
| | | Miscellaneous grains | Accessory heavy minerals and unidentifiable grains |
| MATRIX (detrital material less than 0.03 mm) | Clay | Clay minerals undifferentiated | |
| | Non-clay | Detrital materials, other than clay minerals, less than 0.03 mm; predominantly quartz | |
| CEMENT | Calcite | Mosaics of interlocking crystals; clear and iron-stained | |
| | Iron carbonate | Ankerite and siderite undifferentiated | |
| | Silica | Authigenic overgrowths on quartz grains that show no evidence of subsequent transport | |
| | Kaolinite | Authigenic "books" that do not appear to have been transported | |

TABLE 5 - DETERMINATIONS OF NON-OPAQUE HEAVY MINERALS IN TRIVOLI SANDSTONE

| Sample number*: | | 1E | 2D | 2E | 3R-3 | 3R-4 | C4A | 9R-1 | 9R-8 | C15A | C15B | 15R-3 | 15R-6 | C19A | C19B | C21A | C21B | 22R-6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Relative abundance | Micas | 19 | 12 | 15 | 26 | 13 | 68 | 24 | 14 | 56 | 15 | 15 | 22 | 40 | 42 | 44 | 44 | 11 |
| | Opaques | 55 | 67 | 66 | 42 | 54 | 16 | 55 | 63 | 32 | 66 | 52 | 58 | 46 | 46 | 51 | 52 | 58 |
| | Non-opaques | 26 | 21 | 19 | 32 | 33 | 16 | 21 | 23 | 12 | 19 | 33 | 20 | 14 | 12 | 5 | 4 | 31 |
| Andalusite | | - | - | - | - | - | T | T | - | - | - | - | - | T | - | - | - | - |
| Apatite | | - | 4 | 4 | 2 | 1 | 11 | 9 | 9 | 5 | 3 | - | 1 | 1 | 21 | 3 | 5 | 2 |
| Epidote | | - | T | - | - | - | - | - | - | T | - | - | - | T | T | T | - | T |
| Garnet | | 3 | 1 | 5 | 19 | 17 | 7 | 3 | 16 | 3 | 3 | T | T | T | T | 12 | 7 | 30 |
| Rutile, red | | 3 | 2 | 2 | 2 | 1 | T | 1 | 1 | 2 | 2 | 1 | 3 | - | 4 | 2 | 4 | 2 |
| Rutile, yellow | | 5 | 13 | 8 | 5 | 5 | 5 | 12 | 8 | 7 | 11 | 5 | 11 | 7 | 7 | 7 | 8 | 4 |
| Sillimanite | | 2 | T | T | T | - | T | - | T | 1 | T | T | - | - | T | T | T | T |
| Tourmaline | | | | | | | | | | | | | | | | | | |
| Yellow-brown† | | 5 | 6 | 9 | 11 | 4 | 5 | 8 | 7 | 9 | 5 | 7 | 14 | 20 | 14 | 4 | 13 | 4 |
| Yellow-brown** | | 3 | 1 | 5 | 3 | 1 | 2 | 5 | 5 | 3 | 3 | 5 | 8 | 10 | 4 | 5 | 2 | 2 |
| Brown† | | 3 | 9 | 6 | 2 | 7 | 6 | 6 | 2 | 3 | 3 | 5 | 3 | 2 | 5 | 2 | 4 | T |
| Brown** | | T | - | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | T | 2 | T | 1 | 2 | 2 | T |
| Green† | | 1 | 3 | 2 | - | 2 | - | T | 1 | 1 | 1 | 1 | 1 | 1 | T | 2 | 4 | T |
| Green** | | 1 | 1 | T | T | T | - | T | 2 | - | 1 | T | T | T | T | 1 | - | T |
| Blue | | - | T | - | - | - | T | T | T | T | T | T | - | - | - | - | - | - |
| Black† | | 1 | 3 | 3 | 2 | 2 | T | 2 | 1 | 1 | 1 | T | 1 | 2 | 2 | 2 | - | T |
| Black** | | 2 | T | T | T | 2 | 1 | 1 | 2 | 3 | 1 | 1 | 1 | 2 | - | T | - | - |
| Zircon† | | 30 | 26 | 20 | 18 | 18 | 20 | 14 | 15 | 14 | 16 | 14 | 13 | 16 | 13 | 18 | 18 | 15 |
| Zircon** | | 39 | 30 | 34 | 32 | 37 | 38 | 35 | 29 | 47 | 46 | 50 | 46 | 34 | 26 | 37 | 33 | 30 |
| Miscellaneous | | T | 1 | T | T | - | - | T | T | - | - | T | - | - | - | - | - | 1 |
| Percentage of zircon-tourmaline-rutile (ZTR) in total non-opaque, non-micaceous grains‡ | | 93 | 93 | 90 | 78 | 82 | 80 | 87 | 74 | 91 | 93 | 99 | 98 | 98 | 78 | 84 | 87 | 67 |

* - Sample locations on table 1. C - Indicates core sample. T - Trace; less than 1 percent. † - Angular to subangular.
** - Rounded to subrounded. ‡ Used as an index of compositional maturity (Hubert, 1960).

TABLE 6 - ANALYSES OF GRAIN SIZE (by weight percent)

| Sample number* | Grain Size (mm) .50 | .350-.50 | .250-.350 | .177-.250 | .125-.177 | .088-.125 | .062-.088 | .044-.062 | (PAN) | Inman sorting coefficient ($\sigma_\phi$) | Median grain size (Md $\phi$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TRIVOLI SANDSTONE | | | | | | | | | | | |
| 3R-1 | | | | .2 | 24.9 | 42.4 | 16.1 | 5.1 | 10.1 | .55 | 3.20 |
| 3R-4 | | | | T | 22.9 | 38.7 | 21.1 | 8.5 | 8.5 | .57 | 3.35 |
| 3R-3 | | | | T | 24.4 | 38.1 | 18.1 | 8.0 | 11.3 | .62 | 3.30 |
| 3R-2 | | | | .3 | 27.6 | 31.2 | 19.8 | 8.5 | 12.6 | .73 | 3.37 |
| 3R-5 | | | | T | 23.8 | 38.0 | 16.5 | 6.9 | 14.8 | .77 | 3.35 |
| 9R-7 | .4 | 5.1 | 11.9 | 25.9 | 31.9 | 9.6 | 3.8 | 2.6 | 8.7 | .74 | 2.30 |
| 9R-1 | .2 | 8.0 | 25.9 | 27.1 | 18.2 | 8.6 | 3.2 | 1.7 | 7.0 | .78 | 2.58 |
| 15R-1 | | 1.9 | 25.0 | 33.7 | 16.1 | 6.6 | 3.8 | 4.5 | 8.7 | .90 | 2.30 |
| 15R-4 | .2 | 7.5 | 31.1 | 31.1 | 10.5 | 4.4 | 2.3 | 1.2 | 11.4 | .82 | 2.12 |
| 15R-8 | | .9 | 24.1 | 38.0 | 17.8 | 5.6 | 3.0 | 2.3 | 8.3 | .67 | 2.32 |
| 15R-3 | T | 2.9 | 27.7 | 32.7 | 18.9 | 6.3 | 3.0 | 2.5 | 6.1 | .66 | 2.30 |
| 15R-7 | .4 | 11.5 | 33.2 | 24.3 | 9.3 | 4.3 | 2.4 | 2.2 | 12.3 | 1.03 | 2.05 |
| 15R-6 | T | 4.7 | 33.6 | 17.4 | 8.7 | 4.6 | 2.8 | 2.4 | 5.9 | .81 | 2.08 |
| 15R-9 | .2 | 3.6 | 9.9 | 32.0 | 27.0 | 7.2 | 3.1 | 1.9 | 15.1 | 1.10 | 2.55 |
| 15R-2 | 1.6 | 3.5 | 8.3 | 17.6 | 34.6 | 10.4 | 5.0 | 3.8 | 15.7 | 1.19 | 2.77 |
| 15R-5 | .3 | 6.7 | 12.8 | 27.0 | 32.3 | 6.9 | 3.0 | 2.0 | 9.0 | .70 | 2.53 |
| 22R-3 | .2 | 15.7 | 38.4 | 21.8 | 7.8 | 3.8 | 2.0 | 1.6 | 8.7 | .77 | 1.92 |
| 22R-4 | 10.9 | 22.9 | 35.7 | 10.1 | 4.0 | 2.3 | 1.5 | 1.0 | 11.8 | .96 | 1.67 |
| 22R-1 | .2 | 26.6 | 45.4 | 9.9 | 4.1 | 2.8 | 1.9 | 1.4 | 7.8 | .67 | 1.74 |
| 22R-5 | .3 | 4.3 | 9.0 | 11.1 | 17.0 | 19.3 | 14.3 | 9.0 | 15.5 | 1.14 | 3.19 |
| 22R-2 | .2 | 5.7 | 17.4 | 31.3 | 19.0 | 7.4 | 3.5 | 2.2 | 13.0 | 1.06 | 2.42 |
| INGLEFIELD SANDSTONE AND CORRELATIVE SANDSTONES IN ILLINOIS | | | | | | | | | | | |
| Ing-1 | .1 | 5.3 | 21.4 | 34.6 | 19.1 | 5.6 | 2.6 | 1.7 | 10.4 | .75 | 2.33 |
| Ing-2 | .2 | 12.6 | 42.5 | 21.5 | 7.0 | 3.4 | 2.5 | 2.4 | 8.0 | .75 | 1.92 |
| Cv-1 | .1 | 9.8 | 11.7 | 24.6 | 17.4 | 13.6 | 6.3 | 2.6 | 13.6 | 1.14 | 2.60 |
| ANVIL ROCK SANDSTONE (from Hopkins, 1958) | | | | | | | | | | | |
| Average of 14 nonchannel samples | 3.2 | 6.4 | 12.5 | 15.3 | 15.6 | 14.0 | 10.4 | - | 22.6 | 1.50 | 2.90 |
| Average of 30 channel samples | 6.7 | 22.8 | 30.2 | 16.4 | 7.7 | 3.8 | 2.7 | - | 9.8 | .88 | 1.80 |

* Sample locations are given in table 1. T - Trace.

## Grain Size Analyses

Measurements were made with a micrometer-ocular to estimate the mean grain size of quartz grains in each Trivoli thin section (table 2). These grain-size estimates are supplemented by the results of 21 sieve analyses of Trivoli samples, by the results of grain-size analyses of three samples of the Inglefield Sandstone and its correlatives, and by the average analyses for 30 Anvil Rock "channel phase" samples and 14 Anvil Rock "sheet phase" samples (table 6). The grain-size analysis of each of the above sieved samples was plotted as a cumulative grain-size frequency curve so that the median diameter ($Md_\phi$) and Inman (1952) sorting coefficient ($\sigma_\phi = \phi_{84} - \phi_{16}$) could be calculated. These data also are presented in table 6.

Typical cumulative grain-size frequency curves of the Trivoli Sandstone (fig. 11A) and those of other sandstones in the stratigraphic interval from Anvil Rock Sandstone to Shoal Creek Limestone (fig. 11B) are essentially the same. Their variability in size and sorting (steepness of the curves) is comparable, and the depositing media for the detritus in the various samples probably had approximately the same ranges of current velocity and competence.

The average median grain diameter of the sieved Trivoli samples is 0.17 mm; the range in median diameter is from 0.10 mm to 0.32 mm. The sorting coefficients of the measured samples range from 0.55$\phi$ to 1.19$\phi$, and the average is 0.82$\phi$. These data indicate that the Trivoli Sandstone is a fine- to medium-grained sandstone that is moderately well sorted.

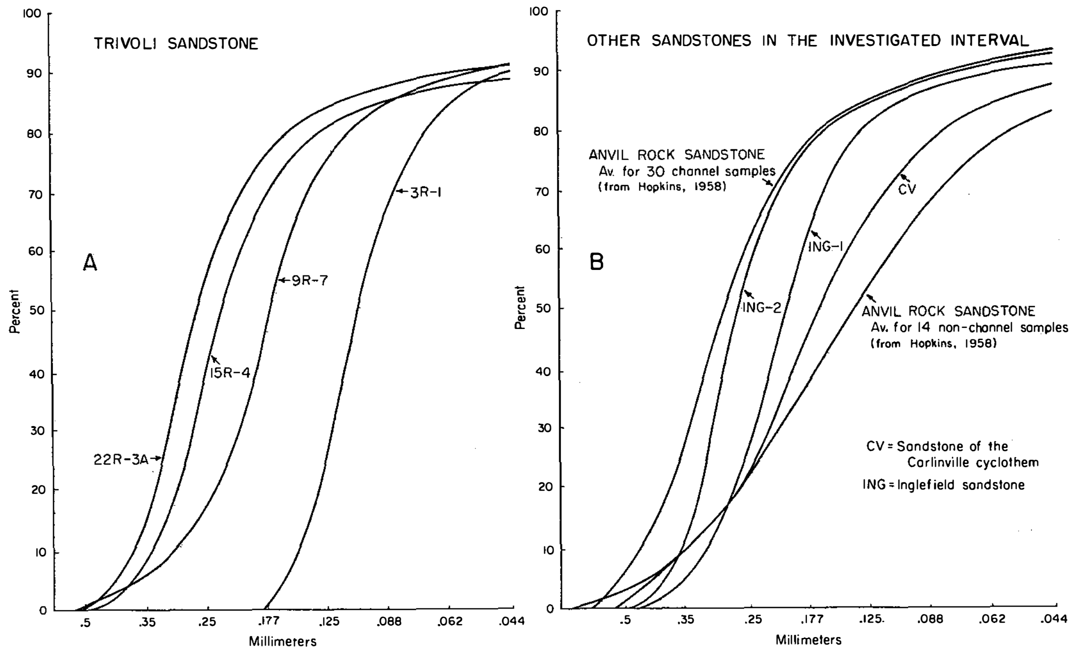


Fig. 11 - Typical cumulative curves showing grain-size frequency of the Trivoli Sandstone (A) and of other sandstones in the interval investigated (B).

Five to eight grain-size samples were collected from each of three widely spaced Trivoli Sandstone outcrops to assess the vertical changes in sorting and grain size. There is a general upward trend toward smaller median diameter and poorer sorting at each of these outcrops. These data demonstrate that the competence of the depositing medium at each place was decreasing as Trivoli deposition continued. Aggradation is indicated.

## Classification of Sandstones

Sandstones of the Kewanee and McLeansboro Groups in the Illinois Basin are classed (Siever, 1957, p. 235; Potter and Glass, 1958, p. 34) as subgraywackes (Pettijohn, 1957). The Trivoli Sandstone conforms to this generalization.

Most present-day mineralogical classifications of sandstone employ both source-area factors (composition of grains) and environmental factors (proportion of matrix) in classifying detritus. The resulting classifications are not entirely adequate because of the interplay between the two types of factors. Hubert (1960, p. 172-174) has proposed a sandstone classification based on the composition of source-area material (grains) only. This classification is useful in making inferences about the composition and tectonic condition of a sandstone's source area and about the compositional maturity of the detritus.

Hubert's (1960, p. 172-179) classification triangle is shown in figure 12A, and the various Trivoli samples are plotted on the basis of the relative proportions of Q (quartz) components, F (feldspar) components, and M (miscellaneous) components (see table 4) in each sample. There is very little dispersion between the Trivoli samples so plotted. All but two samples lie in the quartzose graywacke-micaceous quartzite fields. The relatively small dispersion shown on the sample plots indicates the sandstone is regionally nearly homogeneous in composition.

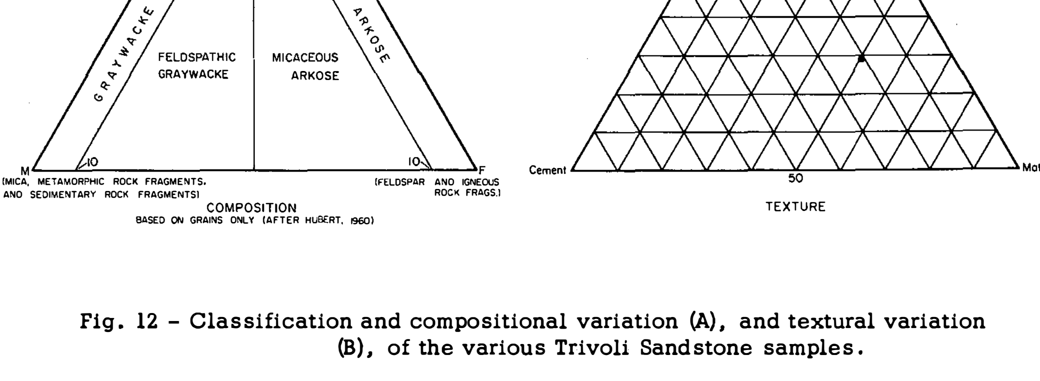


Fig. 12 - Classification and compositional variation (A), and textural variation (B), of the various Trivoli Sandstone samples.

Maturity

Maturity of detritus is discussed on both a compositional and textural basis. The percentage of quartz grains (out of total grains) in a sandstone is widely recognized as a measure of compositional maturity. The percentage of tourmaline, zircon, and rutile (out of the total nonmicaceous, transparent heavy mineral suite) also can be used as an index of compositional maturity (Hubert, 1960). In the Trivoli Sandstone 78 percent of the grains are quartz and 85 percent of the transparent, nonmicaceous heavy mineral suite is zircon, tourmaline, and rutile.

The textural variability within the Trivoli Sandstone was assessed by plotting each sample on a triangle on the basis of the relative proportions of grains, matrix, and cement (fig. 12B). Matrix is concentrated in a relatively narrow range of abundance between 2 and 13 percent, whereas the proportions of grains and cement are much more variable and are shown statistically to be inversely related (correlation coefficient = -0.67; significant at the 0.01 level). It appears that cement is present in the sandstone to a large extent as a replacement of grains; relatively little matrix was replaced by cement. Approximately 40 percent of the grains are subrounded to rounded. The degree of sorting of the Trivoli samples (table 6) and the degree of rounding of the grains indicate the sandstone is texturally semimature. These data show that the proportion of matrix can vary widely in sandstones in the lower and intermediate levels of compositional maturity such as the Trivoli Sandstone.

## Cross-Bedding

The dip direction of 81 Trivoli foreset beds was measured at 20 outcrops. Similarly, 205 cross-bedding directions were obtained from 58 outcrops of other sandstones in the stratigraphic interval from the Anvil Rock Sandstone to the Mt. Carmel Sandstone. The data on the Anvil Rock Sandstone were collected by Hopkins (1958). Locations of the outcrops at which the measurements were made are shown in figure 1.

A mean vectorial cross-bedding direction was calculated for each Trivoli outcrop examined and each mean is indicated by an arrow at the location of the outcrop in figure 7. The cross-bedding data indicate material was moved out of the basin toward the south during the time of Trivoli deposition. These directions of sediment transport corroborate those inferred from the distribution of the Trivoli valleys and from the southward paleogradient determined in the cross section in figure 9.

## Provenance

Provenance is the location, composition, climate, and tectonic condition of a sediment's source area.

Cross-bedding and Trivoli valley patterns (fig. 7) indicate Trivoli detritus entered the Illinois Basin from the east, northeast, north, and northwest. Possible source areas were the Transcontinental Arch to the northwest, and the Canadian Shield and the Appalachian mobile belt to the east and northeast (Potter and Siever, 1956, p. 243; Siever, 1957, p. 247-248). All were relatively far removed from the site of Trivoli deposition. Much of the material constituting the Trivoli Sandstone may be multicycle sedimentary material. Approximately half the quartz grains and ultra-stable heavy minerals are subrounded or rounded. However, the Trivoli Sandstone contains much less multicycle material than do the orthoquartzite and protoquartzite sandstones of the Caseyville Formation.

Although regional petrographic differences in Trivoli Sandstone within the basin do exist, they are minor. Like the other upper Pennsylvanian sandstones of the basin, the Trivoli Sandstone has an impressive petrographic homogeneity, probably resulting from the similarity of petrographic composition of the various source rocks and the mixing of the material in transit to the basin.

The detritus that entered the Illinois Basin to form the Trivoli Sandstone was derived from some relatively mature sediments, some relatively immature sediments, and some metamorphic and igneous rocks. The common association of weathered and fresh feldspars in the Trivoli Sandstone points toward source terranes in which pre-existing sediments and weathered metamorphic and igneous rocks gradually were being cut through to expose fresh rock.

### Aggradation of the Valleys

With the advent of submergence, the dominant process in the valleys changed progressively from erosion to deposition, beginning in the lower part of the main valley. Coarser material was deposited first, and sorting of the sand was relatively good because the competence of the streams was still such that the finer material could be carried away. As this competence gradually decreased, progressively finer and more poorly sorted material was deposited. The valleys were slowly filled by the aggrading streams, the aggradation extending headward. Finally when the valleys were full of sediments, the streams spread material laterally, and the more widespread thin phase of the sandstone was deposited. All but a few areas in the basin were covered with at least some of the sand that became the Trivoli Sandstone.

The above interpretation provides an explanation of all but possibly one phase of Trivoli Sandstone deposition - the source of the sand deposited in the minor tributaries. In part, this sand may have been derived from underlying Pennsylvanian sandstones in the tributary's drainage basin, or at least some of it may have been introduced into the lower reaches of the tributary from the main channel. In his study of the Anvil Rock Sandstone, Hopkins (1958, p. 38-39) considered the sandstones in the minor tributaries to have been derived from an earlier widespread sheet sandstone that preceded the cutting and filling of the main Anvil Rock channels. No fully adequate explanation for the source of the sandstone in the minor channels has yet been offered.

## INTERVAL FROM ANVIL ROCK SANDSTONE TO SHOAL CREEK LIMESTONE

### Isopach Map

An isopach map was made of the interval from the Danville (No. 7) Coal to the Shoal Creek Limestone (fig. 13) instead of the less readily defined interval from the Anvil Rock Sandstone to the Shoal Creek. The interval mapped ranges in thickness from more than 500 feet in the south to less than 250 feet in the north, and thins from south to north at a rate of three feet per mile.

That at least several of the anticlines in the Illinois Basin were active during the deposition of the mapped interval is shown by the thinning of the interval. It is 50 to 75 feet thinner than would be expected in the vicinity of the Salem-Louden Anticlinal Belt, and is approximately 40 feet thinner than might be expected near the axis of the Clay City Anticlinal Belt (fig. 13). The thinning near the anticlinal belts occurs mainly in the stratigraphic interval between the Danville (No. 7) Coal and the West Franklin Limestone, implying activity of these structures after

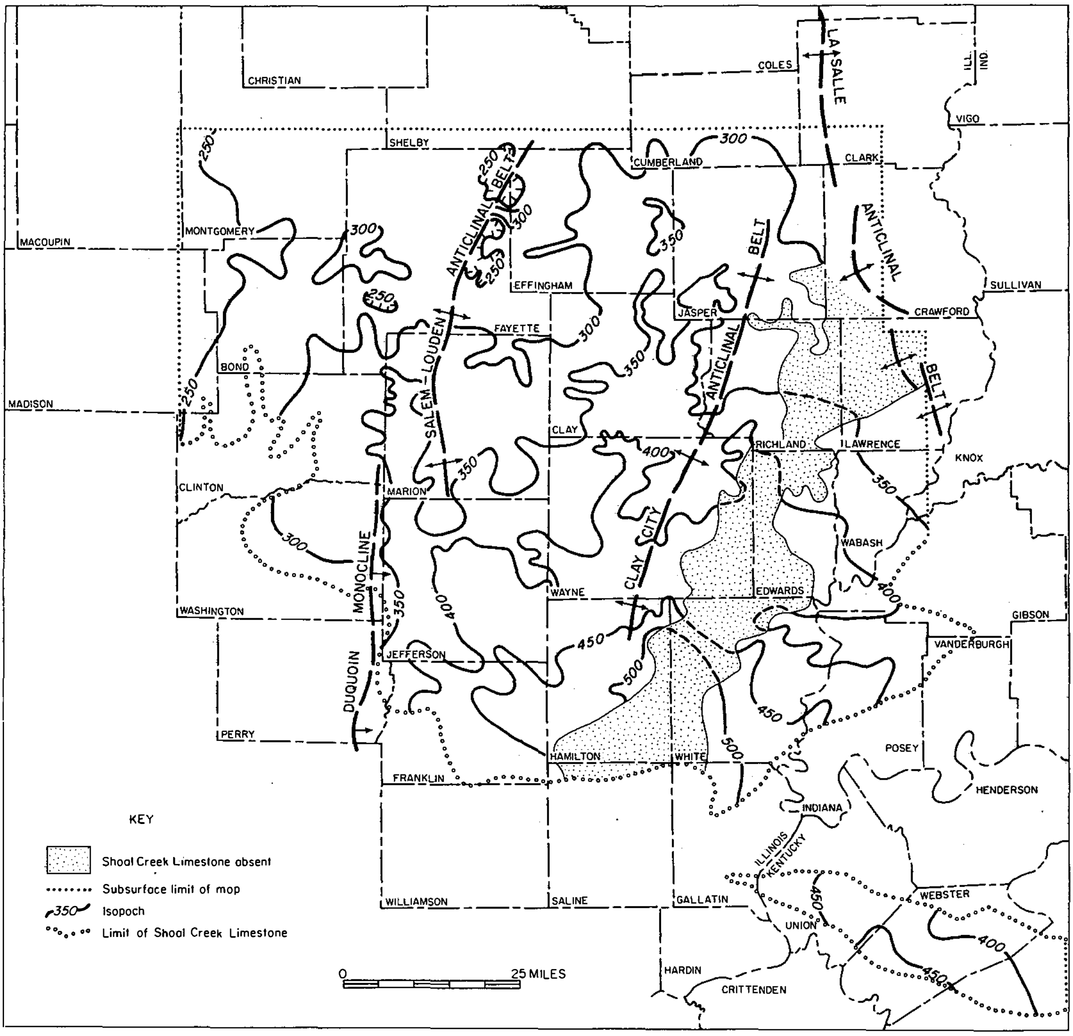


**Fig. 13 - Map showing thickness of the interval from the top of the Danville (No. 7) Coal to the top of the Shoal Creek Limestone.**

deposition of the No. 7 Coal and before deposition of West Franklin Limestone. As noted earlier, absence of Trivoli Sandstone over the Salem-Louden Anticlinal Belt may indicate that this was the approximate time of a movement along this structure.

## Principal Sandstones

Three major sandstones occur within the stratigraphic interval bounded by the Anvil Rock Sandstone and the Shoal Creek Limestone, and the thickness of each has been mapped. Hopkins (1958, fig. 4) and Potter and Simon (1961) mapped the Anvil Rock Sandstone, and maps of the Trivoli Sandstone (fig. 5) and Inglefield

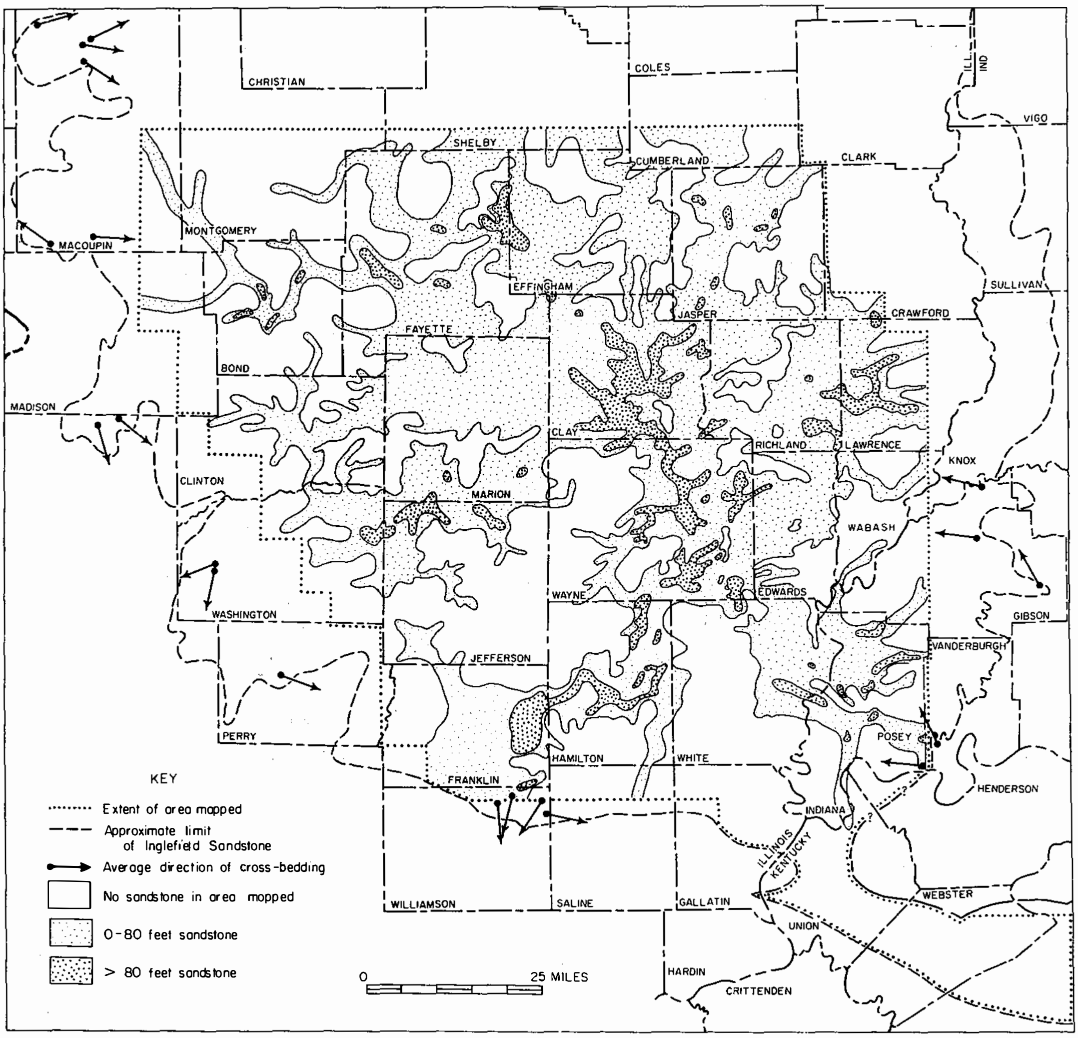


**Fig. 14 - Thickness and distribution of the Inglefield Sandstone and its Illinois correlatives. The average directions of cross-bedding inclination directions at various outcrops of the sandstone also are shown.**

Sandstone (fig. 14) were made for this report. All, or the major portions, of these sandstones were fluvially deposited in integrated valley systems. The patterns of these valley systems are presented in figure 15. The pattern of an additional valley system, that in which the Mt. Carmel Sandstone was deposited, also is shown (fig. 15) and is directly defined by the distribution of the Shoal Creek Limestone, which is absent in areas of maximum development of the Mt. Carmel Sandstone.

All of these sandstones have channel systems oriented to the south and southwest, at approximately right angles to the isopachs of figure 13. The position of the longitudinal axis of the Illinois Basin, located by bisecting the isopachs of figure 13, appears to have exercised a weak but persistent control on the location and orientation of these channel systems. Cross-bedding data support this conclusion.

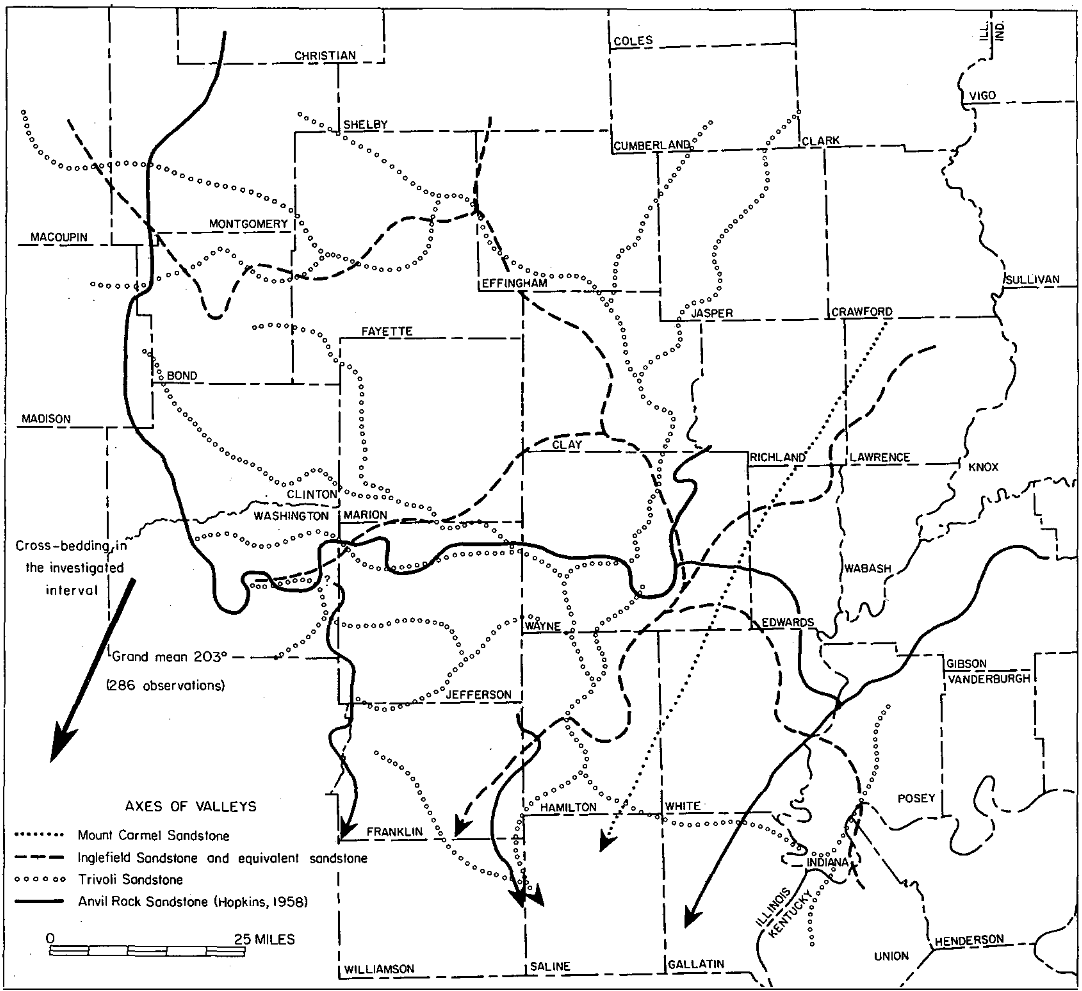


Fig. 15 - Distribution patterns of the various valley systems in the investigated interval.

The direction of sediment transport during the interval of deposition from the Anvil Rock Sandstone through the Shoal Creek Limestone was determined by cross-bedding studies. A grand vectorial mean cross-bedding direction was calculated for the Trivoli Sandstone, the Inglefield Sandstone, and all the sandstones in the interval from the Anvil Rock Sandstone through the Mt. Carmel Sandstone. The vectorial means were calculated by the Tukey Orientation Test (Rusnak, 1957, p. 53-54) and are as follows:

| | Number of observations | Grand vectorial mean cross-bedding direction | |
|---|---|---|---|
| Trivoli Sandstone | 81 | 158 | (S 22 E)* |
| Inglefield Sandstone and correlatives | 108 | 244 | (S 64 W)* |
| All sandstones in the Anvil Rock Sandstone-Mt. Carmel Sandstone stratigraphic interval (includes above) | 286 | 203 | (S 23 W)* |

* Significant at the .01 level.

The above calculations indicate that the average direction of sediment transport in the Illinois Basin during the deposition of the Anvil Rock through Mt. Carmel sediments was in a southerly direction, with but minor variation. Presumably, the same major direction of paleoslope persisted with but slight variation during the deposition of the entire sequence.

## CONCLUSIONS

The sedimentational pattern of the Trivoli Sandstone is comparable to that of the Anvil Rock, Inglefield, and Mt. Carmel Sandstones in the upper part of the Pennsylvanian System in the Illinois Basin. The depositional pattern, cross-bedding, and petrology of the several sandstones are similar, as were the tectonic and environmental conditions prevailing during the deposition of each sandstone.

The lateral continuity of several key members in the interval from the Anvil Rock Sandstone to the Shoal Creek Limestone is disrupted by the occurrence of thick sandstone bodies, although the West Franklin Limestone is the only key member affected by Trivoli valley cutting. The thick sandstone bodies have south-southwest trends, and all are in essentially the same geographic location with but minor east-west variation in position. The thick sandstones were deposited in valleys cut into older rocks, and it was the valley cutting that destroyed the lateral continuity of the various key members. Recognizing that the thick sandstones are valley fillings, and that their basal surfaces are erosional contacts rather than facies changes should help to clarify the stratigraphy of the interval, as well as lead to a better understanding of the influence of the thick sandstones, and Pennsylvanian sandstones in general, on exploration for coal, petroleum, and ground water.

## REFERENCES

Ball, John R., 1952, Geology and mineral resources of the Carlinville Quadrangle: Illinois Geol. Survey Bull. 77, 110 p.

Chayes, Felix, 1956, Petrographic modal analysis: John Wiley and Sons, Inc., New York, 113 p.

Fuller, M. L., and Ashley, George H., 1902, Ditney Folio, United States Geological Survey Folio 84, p. 3.

Hopkins, M. E., 1958, Geology and petrology of the Anvil Rock Sandstone of southern Illinois: Illinois Geol. Survey Circ. 256, 49 p.

Hubert, J. F., 1960, Petrology of the Fountain and Lyons Formations, Front Range, Colorado: Colorado School of Mines Quarterly, v. 55, no. 1, 242 p.

Inman, D. L., 1952, Measures for describing size distributions of sediments: Jour. Sedimentary Petrology, v. 22, no. 3, p. 125-145.

Kosanke, R. M., Simon, J. A., Wanless, H. R., and Willman, H. B., 1960, Classification of the Pennsylvanian strata of Illinois: Illinois Geol. Survey Rept. Inv. 214, 84 p.

Krumbein, W. C., and Pettijohn, F. J., 1938, Manual of sedimentary petrography: Appleton - Century - Crofts, Inc., New York, 549 p.

Pettijohn, F. J., 1957, Sedimentary rocks (2nd ed.): Harper and Bros., New York, 718 p.

Potter, P. E., and Glass, H. D., 1958, Petrology and sedimentation of the Pennsylvanian sediments in southern Illinois. A vertical profile: Illinois Geol. Survey Rept. Inv. 204, 60 p.

Potter, P. E., and Olson, J. S., 1954, Variance components of cross-bedding direction in some basal Pennsylvanian sandstones of the Eastern Interior Basin. Part 2 - Geological application: Jour. Geology, v. 62, no. 1, p. 26-49.

Potter, P. E., and Siever, Raymond, 1956, Sources of basal Pennsylvanian sediments in the Eastern Interior Basin. Part 1 - Cross-bedding: Jour. Geology, v. 64, no. 3, p. 225-244.

Potter, P. E., and Simon, J. A., 1961, Anvil Rock Sandstone and channel cutouts of Herrin (No. 6) Coal in west-central Illinois: Illinois Geol. Survey Circ. 314.

Rusnak, Gene A., 1957, A fabric and petrologic study of the Pleasantville Sandstone: Jour. Sedimentary Petrology, v. 27, no. 1, p. 41-55.

Siever, Raymond, 1951, The Mississippian-Pennsylvanian unconformity in southern Illinois: Am. Assoc. Petroleum Geologists Bull., v. 35, no. 3, p. 542-581.

Siever, Raymond, 1957, Pennsylvanian sandstones of the Eastern Interior Coal Basin: Jour. Sedimentary Petrology, v. 27, no. 3, p. 227-250.

Wanless, H. R., 1931, Pennsylvanian cycles in western Illinois, *in* Papers presented at the quarter centennial celebration of the Illinois State Geological Survey: Illinois Geol. Survey Bull. 60, p. 182.

Wanless, H. R., 1957, Geology and mineral resources of the Beardstown, Glasford, Havana, and Vermont Quadrangles: Illinois Geol. Survey Bull. 82, 233 p.

Illinois State Geological Survey Circular 316
31 p., 1 pl., 15 figs., 1961

ILLINOIS
*Land of Lincoln*

CIRCULAR 316

# ILLINOIS STATE GEOLOGICAL SURVEY

URBANA

370